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SUMMARY

SOIL SCIENCES

CROP SCIENCES

MISCELLANEOUS

SOIL SCIENCES

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THE ASSESSMENT OF SALINITY-AFFECTED LANDS IN SOUTHERN IRAQ USING SATELLITE IMAGERY

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Abstract

This study aimed to monitor, map and assess the salinity of land in southern Iraq. Where the country suffers greatly from land degradation and desertification problems, especially in the central and southern parts. This study was conducted to monitor the manifestations of salinity in the Najmi area located within the administrative boundaries of the Muthanna Governorate, which has an area of (2066 hectares) and lies between longitudes 44°21'0" to 44°31'0" East and latitude circles 30°11'0" to 32°27'0" North with the help of remote sensing technology through the use of satellite images from the Landsat 8 satellite with field observations. A map of soil units was prepared using Erdas software, Arc GIS for processing, management and analysis of raster and subject data sets. Soil samples were taken from each site for physical and chemical analysis, and the study is summarized as follows: the results indicated when using the spectral index represented by the standard difference index of vegetation cover (NDVI), whose value ranged between (0.47-0.30). It was found that the study area suffers from a lack of vegetation cover by (64%); as for the salinity index values, they ranged between (-0.30-0.49) and therefore the study area suffers from a chemical deterioration represented in the salinity of the soil estimated at (69%); where the values of the dry lands index ranged between (1.37-0.73), and the desertified lands within the study area by (45%); as for the land degradation index, its value ranged from (0.00 to 99.60), and the percentage of degraded lands was estimated at (60%) of the total study lands.

Key words*: salinity, remote sensing, GIS, deterioration index.*

INTRODUCTION

Soil salinization, which is a common form of soil degradation, is one of the world's most widespread environmental problems (Farifteh, 2006). This global problem results in land degradation, especially in irrigated areas in arid and semiarid environments as well as in some subhumid regions. Soil salinization has become increasingly serious in recent decades, with salinization exceeding the average level of soil salinity in the past few years because of unsustainable agricultural practices that lead to the accumulation of soluble salts in soil (Zewdu, 2017). Soil salinization reduces the land value and productivity. By reducing the soil quality, soil salinization limits the suitability of the land for agriculture or reclamation and can increase soil dispersion and erosion.

Soil salinization is a severe environmental hazard that influences almost half of the existing irrigation plans of worldwide soils facing the threat of secondary salinization. General estimates indicate that approximately 1 billion hectares of land are affected by salinization worldwide, constituting 7% of the continental area of the Earth and 58% of the irrigated land (Noroozi et al., 2011). The main causes of soil salinization in dry regions include irrigation (i.e., overpumping), poor water drainage, and climate change (Zewdu et al., 2017). Therefore, areas of agricultural or arable lands will dwindle because of salinization. Additionally, many countries are confronted with varying degrees of soil salinization. The Food and Agriculture Organization has estimated that 397 million hectares of the world's agricultural or nonagricultural lands have been affected by soil salinization. Thus, it is crucial to determine which lands are affected by soil salinization, evaluate soil salinity, and determine the root causes of salinization to help decision makers develop management plans for ensuring the sustainability of agricultural land. This must be prioritized globally because soil salinization has deleterious impacts on the soil quality and productivity and is ubiquitous in the arid and semiarid parts of the world (Shrivastava, 2015). Researchers have recently shown significant interest in evaluating and mapping soil salinity in many regions around the world, especially in arid and semiarid areas that are heavily affected by salinization. For soil salinity evaluation and mapping, data must be collected using traditional soil sampling and laboratory analysis methods. However, these methods are time-consuming and costly, thereby limiting surveys to small areas (Lhissou et al., 2014). To overcome this limitation, several techniques have been developed for evaluating soil salinity. One such technique is based on remote sensing (RS), which has demonstrated considerable success in mapping and assessing soil salinity (Asfaw et al., 2018).

Metternicht and Zinck et al. (2003) observed that meaningful results could be obtained by studying the spectral properties and radar backscatter of saline soils. Some researchers have studied soil salinity based on moisture content using the normalized difference infrared index. Other researchers have assessed the relations between soil salinity and vegetation indices (Iqbal et al., 2011). Other studies have analyzed soil salinity using the thermal and short infrared wavelength bands (Goossens et al., 1998) to examine the relation between soil salinity and the land surface temperature (LST). These studies used satellite imagery containing thermal bands such as a moderate resolution imaging spectroradiometer (MODIS), which provides useful information about the soil properties (Ibrahim et al., 2018). Recently, the multispectral data derived from sources, such as the System Pour I, Observation de la Terre (SPOT), IKONOS, Quick Bird, Indian Remote Sensing, and Landsat satellites, have been used to explore map soil salinity. Several other indices, such as the salinity index and the soil adjusted vegetation index, are also commonly employed to monitor soil salinity. However, Eldeiry and Garcia and Hu et al. recommended the combined use of spectral response index and best band (Abou Samra et al., 2018).

The RS tools and data must be integrated with the field measurements of salinity to achieve soil salinity evaluation and monitoring. RS is an efficient tool for spatial analysis of soil salinity in arid and semiarid areas; therefore, we aimed to estimate the soil salinity using specific spectral indices combined with field measurements. The soil salinity mapping model developed in this study is based on the electrical conductivity (EC) of soil and shows a promising correlation, which can be further improved by considering the soil salinity NDVI relation. This model is helpful to develop effective soil salinity forecasting strategies for sustainable development and land management.

MATERIALS AND METHODS

The study area is located in Al-Muthanna Governorate. It is bounded on the north by the highway, on the west by Al-Najmi, on the south by the Shinafiya district project, and on the east by Diwaniyah Hamza Road. The project lands are confined between longitudes 00-10° 45 = 00-26° 44 and latitudes 40° 31° 00 and 30-30 00. The total area of the project, including residential areas and water bodies, is estimated at 100,000.1 dunums. Figure 1 represents a site map of the study area. Numerous villages are spread throughout the study area, in addition to the center of Al-Najmi district. Climate has an active and influential role in soil formation processes after the occurrence of geological processes responsible for the formation of terrain such as eruptions and folds. Variation differences in temperature and its geographical distribution in the globe. The efficiency of irrigation depends on the climatic conditions. The climate of the study area is considered dry, hot in summer, cold in winter with little rain, i.e. a desert climate.

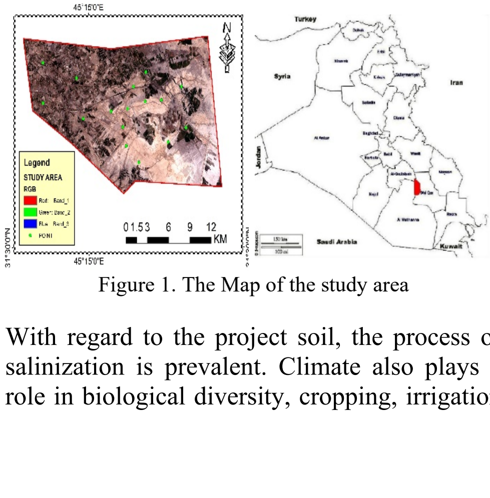

Figure 1. The Map of the study area

With regard to the project soil, the process of salinization is prevalent. Climate also plays a role in biological diversity, cropping, irrigation methods and cultivation pattern, in addition to the effective influence on soil distribution. It was possible to analyze the changes of the important climate elements, temperature, humidity, rain, evaporation, wind, depending on the climatic information available at the weather station in the city of Samawa, which is 3 m above sea level. The study, with a minimum average of 17°C in January and a highest average of 46°C in July (Table 1).

Table 1. Average temperatures, relative humidity and rainfall in Al-Muthanna Governorate

Climate element	J	F	M	A	M	J	T	A	S	O	N	D	Per year
Temperature	17	25	36	42	46	46	44	39	33	26	21	17	**31.9**
Rains	18.8	16.9	4	0.1	0	0	0	4.3	8.2	12.9	16.2	20	**115**
Evaporation	88	138	251	359	467	497	459	371	269	198	118	88	**3300**
Relative humidity	66	57	48	41	30	26	26	28	31	41	56	64	**506**

Laboratory analyzes were carried out on soil samples extracted from the horizons of soil potholes: mechanical analysis to find out the proportion of clay, sand and silt, the percentage of calcium carbonate (calcium) and calcium sulfate (gypsum), the percentage of exchanged sodium (ESP) and percentage of adsorbed sodium (SAR), soil interaction pH and salinity ECe (the electrical conductivity of the saturated extract of the soil solution), the percentage of organic matter and negative and positive ions values (Tables 2, 3).

Table 2. The physical characteristics of the study soil materials

No.	Depth (cm)	pH	O.M.	NO_3^{-1} (ppm)	Partical size analysis			Lab. texture	Gypsum, %	Lime, %
			%		Clay, %	Silt, %	Sand, %			
1	15-0	7.27	0.5	43.5	51	42	7	SiC	2.9	36.4
2	20-0	7.33	0.5	36.5	4.2	50.6	45.2	SiL	13.4	28.6
3	30-0	7.32	0.6	87.5	15	72	13	SiL	7.85	33.2
4	23-0	7.49	0.7	236.5	27.5	49.1	23.4	CL	4.07	31.4
5	25-0	7.1	-	235	-	-	-	0	5.8	26.4
6	30-0	7.68	0.6	16.75	28.1	45.4	26.4	CL	-	25.4
7	26-0	7.07	0.5	208	53	43	4	SiC	4.13	36.8
8	26-0	7.14	0.9	5	25.5	46.5	28	L	6.02	30.4
9	38-0	7.34	1.8	138	37	48	15	SiCL	0.41	36
10	13-0	7.85	-	39	29.8	56.2	14	SiCL	2.35	28.2
11	13-0	7.03	0.6	36.5	28.5	54.1	17.4	SiCL	-	31.8
12	16-0	7.4	1.1	215	-	-	-	-	10.3	27.8
13	35-0	7.18	0.9	32.5	35.5	55.5	9	SiCL	5.04	29.6
14	13-0	7.02	1.2	3.63	12.5	75.1	12.4	SiL	3.63	31.2
15	18-0	7.02	-	174.5	32.3	49.7	18	SiCL	6.7	29
16	17-0	7.07	0.5	5	30.2	60.2	9.6	SiCL	2.9	30

Table 3. The chemical characteristics of the study soil materials

No.	Depth (cm)	ECe ds/m	Cations, meq/L			K^{+1}	Anions, meq/L			
			Ca^{+2}	Mg^{+2}	Na^{+1}	ppm	CL^{-1}	SO_4^{-2}	CO_3^{-2}	HCO_3^{-1}
1	15-0	37	62	171	181	40	345	108	0	3.8
2	20-0	204	300	600	2860	600	3240	360	0	1
3	30-0	165.1	240	700	1870	600	2256	380	0	1.2
4	23-0	89.2	200	580	680	170	490	380	0	1.6
5	25-0	176.9	620	600	1740	400	3000	280	0	1.8
6	30-0	9.43	34	42	41	52.5	40.8	66	0	3
7	26-0	109.6	82	222	1000	850	1302	218	0	1.8
8	26-0	227	280	360	3300	700	3740	260	0	12
9	38-0	29.2	160	260	143	90	270	220	0	2
10	13-0	43.5	104	22	284	80	432	76	2.6	0
11	13-0	4.64	28	14	14.78	32	18	40	0	2
12	16-0	206	400	660	2000	800	3360	300	0	1.2
13	35-0	87.8	60	60	770	90	850	77	0	1.4
14	13-0	96.1	250	540	458	125	1236	342	0	1.2
15	18-0	86.7	68	142	830	155	1000	160	0	1.4
16	17-0	69.3	92	58	694	110	768	116	0	1.4

The study relied on satellite images that provide a lot of information about spatial space, especially multispectral visualizations (MULTISPECTRAL IMAGERY), which include information on the number of beams and are the source of obtaining satellite visuals after processing and extract data from it. It included one scene that covered the study area (2021) for sensor data (ETM) obtained by the American satellite (Landsat and sentinel A2) for the sensor (OLI) and (TIRS). It was obtained from the (USGS) site as a punch in the panels (-) present in the map (1), which was used to classify the land cover of the study area, to determine the most important aspects of desertification to derive the vegetation cover and the locations of the spread of saline soil areas and to determine its areas. Satellite images were obtained, from the website of the University of Maryland, Institute for Advanced Computer Studies, USA, Figure 1 and visual images were mostly corrected and rendered by Universal Transverse Mercator (UTM), all visuals were in the form of files (tiff).

In order to know the saline areas and the deterioration of vegetation cover, two indicators are proposed: the salinity index (SI) and the natural differential salinity index (NDSI) in this study. SI is the ratio of the red band to the infrared band (NIR), while NDSI is the percentage difference between red and NIR divided by the sum of the two. This concept came from Red Edge's concept of mapping the vitality of vegetation. In the red edge concept, the spectral reflectance of the NIR radiates with a red band, which gives very high values of vegetation compared to other land properties. Here, if the opposite is taken into account, then lower values plants are obtained, thereby suppressing vegetation and highlighting the soil. SI and NDSI are calculated as follows (Mekeberiaw, 2009):

NDSI = [(Band 8- Band 4) / (Band 8 + Band 4)]

NDVI= [(Band 4 - Band 8) / (Band 4 + Band 8)]

RESULTS AND DISCUSSIONS

Soil color

The results of the morphological examination of the soil sources indicate that all the headlands of the study area represent the state of the newly formed soils that are not developed, and this was reflected in the absence of distinct horizons such as the subsurface horizons, that the horizons that are dry for part of the year and wet in the other part have two colors or more due to cases oxidation and reduction, and these colors are a medium

between the color of good piercing soil and poor piercing soil.
Soil color is one of the most important and most widely used morphological characteristics to distinguish and determine the horizons of soil conditions, and its importance lies in its direct relationship in the interpretation of some pedological phenomena, especially the evolutionary state of the soil, and the possibility of identifying some of the prevailing pedological processes in the soil. In addition to the ease of sensing the color of the soil using the human eye with some simple auxiliary factors, the color of the soil is a reflection of the mineral and organic compositional nature of the soil and its moisture content, in addition to that it is an helpful guide in determining the types of pedological processes responsible for the formation and development of soil. Soil color has been given special importance and was used as a distinctive characteristic in diagnosing and naming soils, adding the ancient and modern soil classification systems used in different countries. Dark soils have good productivity due to the increase in organic matter and nutrients, while light colored soils have low productivity due to the lack of nutrients in them.
As for the water models, chemical analyzes were conducted on them in the laboratories of the National Center for Water Resources Management, such as the interaction of soil, salinity, positive and negative ions for the purpose of evaluating them and knowing their varieties, their suitability for irrigation operations, the degree of pollution and the effect of their toxicity on the plant.

Soil texture

Tissue is one of the important basic characteristics that directly affect the composition and texture of the soil in addition to its impact on the water content ready for the plant, soil permeability, nutrient retention, soil shrinkage speed, soil drainage, and soil vital activities. The texture is also important in evaluating the suitability of the soil for irrigation and being an important criterion in the process of classifying the soils at the lower levels (series and phase). The texture varies throughout the project from one region to another, especially in the first meter because the soil is sedimentary. The common texture in the soils of the study area is medium fineness (Alluvial clay mixture SICL and clay mixture CL) in the surface layer and becomes soft-textured in the second meter SIC, and according to the quadruple classification of soil texture, it has been classified into four classes (Table 4).

Table 4. Types of tissues according to the Quaternary classification (1982 - SOLR)

Symbol	Texture Class	Soil Texture
1	Fine	Silty Clay, Clay
2	Moderately fine	Silt Clay Loam, Sandy Clay Loam, Clay Loam
3	Medium	Silt Loam, Loam, Sandy loam
4	Coarse	Loamy Sand, Sand

Soil structure

The structure or structure of the soil means the regularity of the primary particles and their aggregates in a particular system. In other words, it is the summation of the elementary particles into groups within geometric shapes.
It can be separated into smaller aggregates at the surfaces of the weakness common to them. Some of the outer surfaces of the aggregates unit have thin sheaths of uniform color. The difference in the regularity of these particles and aggregates between soils and other leads to a difference in the sizes of shapes and the regularity of the pore spaces in the soil, which it is considered.
One of the most important direct effects of soil composition on its other properties. The construction of the soil also leads to changing the effect of the tissue on many properties of the soil, such as water holding capacity, water movement, bulk density, fertility, and the effectiveness of microorganisms (Al-Rawi, 2017).
The degree of cohesion between the granules of these aggregates varies, some of them are weak, which break into smaller parts by hand, and others are strong, which do not disintegrate easily. The construction is important in classifying the soil and its impact on soil productivity.
Through the field work in the study area, it was noticed that the structure of most of the project soils is a weak subangular blocky or massive structure, especially in Typic Aquisalids, because of its high salinity, as the sodium ion

causes dispersion of colloids, which affects the quality of construction and soil permeability.

Salinity

The problem of salinity exists if the salt concentrations of salt rise in the root zone of the crop in proportions that cause a lack or loss of the yield. In irrigated areas, these salts often arise from high and saline ground water or from the salts found in the water used. The decrease in yield occurs when salts accumulate in the root zone to the extent that the crop is not able to extract sufficient water from the soil saline solution. Salinity is widespread in most of the study area and its sources are known, as the soil contains large amounts of dissolved ions such as calcium, sodium, chlorine, sulfates and others, which are derived from the irrigation water that carries these substances as the water evaporates and the salts accumulate. Ground water is another source of salt when it is close to the surface, where the water rises by capillary action, and when the evaporation process occurs, the salts are concentrated at the surface, and the increase in the addition of fertilizers that carry some ions causes an increase in the concentrations of these salts ions.

The field work and the tested results of the salinity of the soil of the area of the study showed that according to the classification of the polluted Muffin Qaffal (Solr, 1982) Table 5, that (6.14%) of the project had low salinity and (70.4%) high salinity and (15%) is highly saline and not suitable for agriculture as in Table 6. According to this classification, a soil salinity map was prepared for the entire project. This map represents the soil salinity rate for a depth of one meter from the surface (Figure 7).

According to Table 5, we note that (85.4%) of the lands of the studied area have high to very severe salinity and are not suitable for cultivation.

Table 5. Classification of soil salinity according to SOLR, 1982

Symol	Salinity classes	Ds / m
S0	Very slightly saline	0-4
S1	Slightly saline	4-8
S2	Moderately saline	8-16
S3	Strongly saline	16-25
S4	Very strongly saline	25-50
S5	Extremely saline	>50

As for the proportion of arable land, it constitutes (14.6 percent) only, and it has low to moderate salinity (Table 6).

Table 6. Distribution of areas for soil salinity classes in the project

Salinity classes	Map symbol	Area Donum	Percentage
Moderately saline	S2	14000	14.6%
Strongly saline	S3	37750	39.2%
Very strongly saline	S4	30000	31.2%
Extremely saline	S5	14350	15%
Total	96.100 Donum		100%
	Conc. + Vill. +Hills		

Soil reaction

Soil interaction is one of the factors affecting the soil's ability to prepare nutrients, as the readiness of nutrients is affected by the degree of soil interaction (Figure 2).

The process of absorption of nutrients and minerals by the plant through direct competition between the hydrogen ion and other ions in the soil when the process of absorption by the plant, especially the calcium, potassium and magnesium ions necessary for plant growth, where many nutrients and their readiness are directly affected by the value of the interaction of the soil, such as phosphorous and trace elements, which are considered the elements most affected by the value of the soil reaction, especially when the reaction is basic to slightly basic. As for the rest of the other microelements such as iron, manganese, zinc, and boron, their validity for absorption decreases by increasing the acidity to a certain extent. The growth of each plant requires a certain degree of interaction, for example, that the jet plant grows well at pH (6.8-7.2). The importance of soil interaction is not limited to plant growth, but has to do with weathering processes, biological activity, and the effectiveness of hydrogen ions in the solution, where bacteria predominate in soils that are neutral or less basic. It is generally preferable that the pH of the soil does not exceed 8.5 so that the plant can obtain the elements more easily. The pH in the project ranged between (7-7.8) meaning that the soil of the project is neutral.

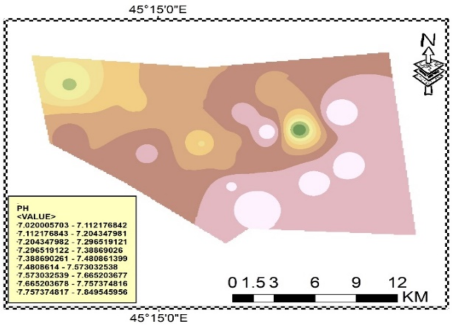

Figure 2. Soil reaction in the study area

Calcium Carbonate $CaCO_3$

This salt is formed by the union of carbonate with calcium ion to form calcium bicarbonate (Figure 3). Salt loses to heat and dehydration part of the carbon dioxide in the form of gas forming calcium carbonate. Calcium carbonate is one of the most important carbonate salts and is common in most arid and semi-arid regions. It is very slightly soluble, as its solubility does not exceed 0.031 g/liter.

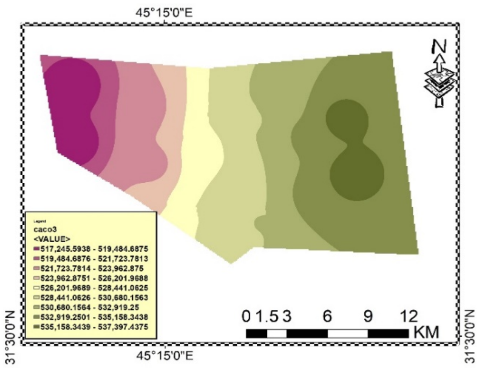

Figure 3. Calcium carbonate content in the study area

Also, the solubility of this salt is related to the degree of reaction of the solution, which increases as the pH value decreases and vice versa. The calcium carbonate solution is characterized by the degree of basic reaction, when there is no amount of carbon dioxide, the calcium carbonate is subjected to hydrolysis, forming an alkaline solution. Irrigation water and groundwater are the main source of lime formation in the soil, because they contain a quantity of bicarbonate and calcium, where carbonates are deposited when the solution reaches the state of saturation, when this water is exposed to drought, which leads to the volatilization of part of the carbon dioxide.

Most of the calcium carbonate in Iraqi soils (Katea, 2007) was transported with the waters of the Tigris and Euphrates its tributaries are in the form of fine particles from the upper north and were deposited and combined with other soil particles in the alluvial plain.

The laboratory results showed that the percentage of calcium carbonate was high, ranging between 20.6-46%.

Soils that contain a percentage of this salt in excess of (45.5%) need frequent and varying irrigations because calcium carbonate reduces the ability of the soil to retain water. It is known that the lack of nutrients such as phosphorous, manganese and zinc is caused by fixation by calcium carbonate. Also, the low ratios of these Carbonates help stabilize soil aggregates and improve the physical properties of soils.

Organic Matter

Soil productivity is affected by the quantity and quality of organic matter because it contains nutrients and elements essential for plant growth and improving its productivity (Figure 4). Soils in dry areas have a low content of organic matter because of their easy decomposition due to high temperatures. Organic matter is necessary for soil fertility and improving its physical, chemical, and biological properties such as soil construction and permeability. It is considered as an effective factor in evaluating and defining the diagnostic horizons that are used in soil classification.

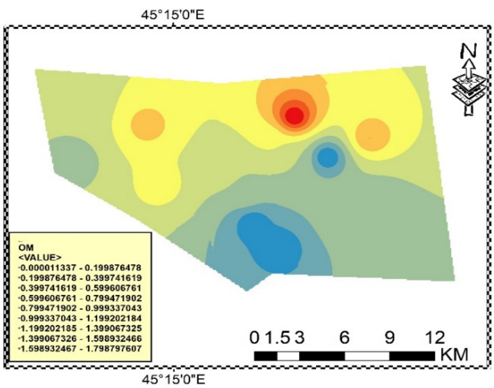

Figure 4. The organic matter content of the soil in the researched area

Through laboratory analysis, it was found that the percentage of organic matter ranged between 0.3%-1.4% in the surface layers and it is less in the subsurface layers, as it ranged between 0.1%-0.2%, and in general the percentage is less than 1% is low (SOLR, 1982), so the project soil needs to be fertilized when carrying out its agricultural exploitation.

Cation Exchange Capacity (CEC)

The exchange capacity is one of the important chemical properties of the soil in relation to plant nutrition, and through it we can know the main components of the clay particles, 52 me/100 g.

The high values of the exchange capacity of the soil of the region is closely related to the high proportions of clay and organic matter (Figure 5). Since the values specified as a minimum exchange capacity in the soil are me 100 g soil/24, and therefore there is no problem of in terms of the exchange capacity of the project soil in terms of soil fertility.

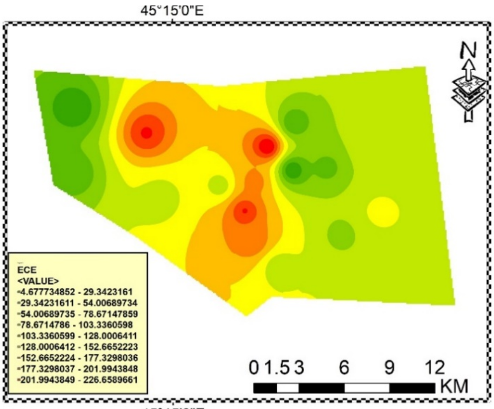

Figure 5. Cation exchange capacity of the soils in the studied area

Normalized Difference Vegetation Index (NDVI)

The results indicated that the values of the Normalized Difference Vegetation Index (NDVI) ranged between 0.47 to -0.30 (Figure 6, Table 6). The reason is due to the existence of a clear variation in the distribution of the type of land cover prevailing in the study area and in a disparate manner spread between agricultural lands and natural plants and plants growing in the marsh areas (Shallal et al., 2007).

The variety, which represents the absence of vegetation cover, occupied an area of about 13,684 hectares of the total the study area, at a rate of 15% due to the presence of barren lands affected by salinity, while the variety with poor vegetation cover an area estimated at about 1132368 hectares and a rate of 39% due to the high rate of salinity and the impact of difficult climatic conditions, which include the lack of rain and high temperatures, which affected the growth of plants, which in its turn led to reduction of the vegetation cover area. As a result, most of the lands of the studied area are not agricultural use.

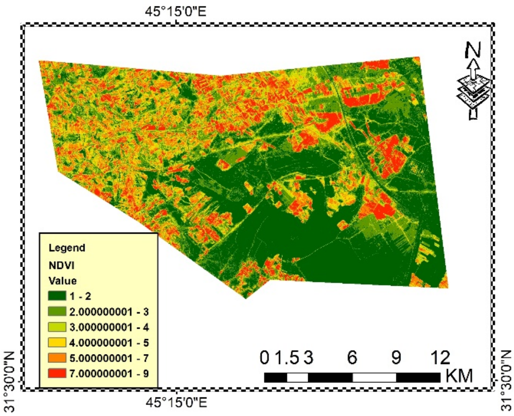

Figure 6. The Natural Vegetation Index (NDVI)

Table 6. Ranges of land degradation and its relationship to Normalized Difference Vegetation Index (NDVI) and natural cover of the study total area (Zaiboon et al., 2015)

NDVI Range	Area, km	Veg. Cover ratio	Land salinity
Non Veg	29114.45	82%	High salinity
Moderate veg	6850.026	14%	Low salinity
Very veg	14000	4%	Not salinity

As for the medium vegetation type, it occupied an area estimated at 591996 hectares, at a rate of 27%. The reason for this may be due to the growth of some plants that coexist with difficult environmental conditions, such as high salinity in the soil, high temperatures and low amounts of rain. As for the cultivar dense vegetation and very dense, it is estimated at 326098 and 109,146 hectares, at a rate of 14%

and 4%, respectively, and the reason is due to the fact that these lands fall into the banks of the rivers, or that they are agricultural use of economic crops or plantations (Ibrahim, 2008).

Salinity Index (NDSI)

The results showed that the salinity index values ranged between -0.49 to - 0.30, as the results shown in Table 7 and Figure 7, indicates that there are 7 categories that represent salinity index values in the study area NDSI.

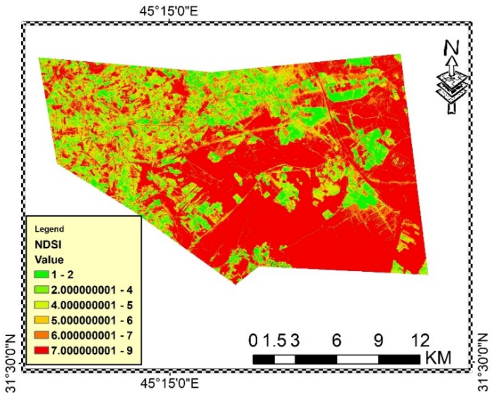

Figure 7. Map that shows the salinity index

Table 7. Ranges of the salinity index values

NDSI range	Area of salinity, Ha	Salinity cover ratio
Not salinity	14000	15%
Low salinity	37750	39%
High salinity	30000	31%
Very high salinity	14350	15%

As the non-salinity category occupied an area estimated at about 1561671 hectares of the study total area with rate of 15% as it is cultivated land or it is located in the banks of rivers, and this in turn is a natural drainage, as for the low-salinity variety, it occupied an area of 4659021 hectares, at a rate of 39%, this reflects the bad category of water and its scarcity, rather than reduction of the ratio of cultivated lands. While the medium salinity variety occupied an estimated area of 4787938 hectares, this is due to the fluctuation of ground water levels and the high percentage of salts in it. It has effectively contributed to the emergence of salinization processes in the soils, which negatively affected the growth and development of vegetation cover and the deterioration of the physical and chemical properties of the soil, while the highly saline and very salty variety occupied an area estimated at 5717664 and 2830104 hectares, with ratios of 15% and 31% respectively, and this indicates the presence of marshland soils (Al Zabidy, Metternicht and Zinck, 2003).

CONCLUSIONS

The study showed the ability of remote sensing and geographic information systems to survey, monitor, identify, analyze and classify aspects of land salinization in the study area and to discover spatio-temporal changes that may occur.

Satellite images are used for regional studies that are performed over a relatively large area due to the relatively low spatial resolution, ranging from 6-10 m, and the accuracy of their results is increased by spectral and spatial improvements and matching processes with reference information, be it maps or images.

The digital indicators (INDEX) contributed to highlighting the features of the land very effectively in clarifying the picture of the spatial distribution and the quantitative and qualitative assessment of the types of manifestations of land degradation in the study area, such as the visuals resulting from the index of natural differences of vegetation cover, salinity guide.

It highlighted the need to develop plans in short and long term to address the situation of land degradation and to combat desertification and loss of water bodies in most of the studied counties of the study area. The efforts should be directed to the improved irrigation situation would enhance farmland productivity, and hence reduce over-cultivation and grazing. If the reasonably water resource in the area could be adequately utilized through agricultural projects, it would be feasible to gradually re-vegetate the degraded lands. Briefly, no single means can work effectively in isolation without the support. Coordinated efforts aimed to reducing and reversing desertification must given to the study area. Rehabilitation endeavors should be directed to both areas of severely degraded and also to the area that are not at high risk to lessen the overall of desertification.

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RESEARCH THE VARIATION OF EXCHANGE CALCIUM ALONG THE DEPTH OF THE SOIL PROFILE AFTER THE APPLICATION OF AMELIORANTS

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Abstract

The effectiveness of ameliorants applied into acidic soils depends on their neutralizing power, which is determined by the calcium carbonate content and their fineness. The choice of ameliorant is a complex task, because it must be found this one which has a high neutralizing effect on easily mobile exchange aluminium, as in parallel to penetrate deeper in the soil. The use of a precipitate, as both a slow-release phosphorus fertilizer and a chemical ameliorant to neutralize acidity was theoretically and practically justified in soils with slightly to moderately acidic reaction and temperate deficiency in terms of easily mobile exchange bases in the soil. The use of hydrated lime as a chemical ameliorant in acid soils led to a relatively fast, long lasting and effective neutralization of exchange acid positions in the soil.

Key words*: acid soils, calcium, hydrated lime, precipitate.*

INTRODUCTION

The effectiveness of ameliorants applied into acidic soils depends on their neutralizing power, which is determined by the calcium carbonate content and their fineness (Edmeades & Ridley, 2003; Álvarez et al., 2009). However, the soil has a huge buffering capacity, which is able to reduce the effects of all kinds of changes and the process of soil acidification is accelerated by other factors such as acid rain and excessive application of ammonium nitrate (Zheng, 2010).

As a way to improve soil acidity can be the replacement of liming by surface application of more soluble materials (Castro & Crusciol, 2013), which requires the application of a limited amount of ameliorant, at a relatively shallow depth in the soil.

Chemical interventions are usually performed with prior consideration of pH values and cation exchange capacity (Joris et al., 2012). The choice of ameliorant is a complex task, because it must be found this one which has a high neutralizing effect on easily mobile exchange aluminium, as in parallel to penetrate deeper in the soil. That is why in practice is increasingly used the liming - application of calcium-containing ameliorants as hydrated lime, roasted lime, saturic lime, etc. However, very often these ameliorants lose their effectiveness in acidic soils, on which there are already perennials, due to the low solubility and low mobility of carbonates along the depth of the soil profile (Soratto & Crusciol, 2008). One of the ways used to improve soil acidity may be to replace liming by surface application of more soluble materials (Castro & Crusciol, 2013), which requires the application of a limited amount of ameliorant, at a relatively shallow depth in the soil. This changes the main goals of the amelioration as the aim is not to neutralize the acidity, but to partially convert the exchangeable Al^{3+} and increase the levels of exchangeable Ca^{2+} in the soil.

The aim of the present study was to research the dynamics of calcium penetration along the depth of the soil profile on soils characterized by high exchange acidity by introducing calcium-containing ameliorants with different neutralizing capacity.

MATERIALS AND METHODS

The study was performed on highly eroded Chromic luvisols with differentiated profile, characterized by the presence of high exchange acidity. The experiment was set up and carried out for two years, as hydrated lime and precipitates were used as main chemical ameliorants. Hydrated lime is dried by a special technology $Ca(OH)_2$. It is a more active chemical ameliorant compared to traditionally use and relatively cheap chemical ameliorants containing $CaCO_3$. Due to its high cost, this material is relatively rarely used for amelioration of acid soils, but it is a soluble compound with a higher neutralizing capacity compared to $CaCO_3$. The precipitate has a weak chemical-ameliorative effect and is used primarily as a mineral citrate-soluble phosphorus fertilizer. Usually the rates in which it is applied to cover the needs of plants as fertilizer are not sufficient to neutralize the harmful acidity in the soil, but its ameliorative effect when applied in acid soils is based on its neutralizing activity. Its interaction with the soil is associated with the release of Ca^{2+}, which is due to its prophylactic chemical-ameliorative effect in acidic soils. In high Ca^{2+} deficiency, it leads to the formation of free phosphoric acid, which depending on the balance between acids and bases, dissociates into H_2PO^{4-}; HPO_4^{2-} and PO_4^{3-}, as usually the products of the three degrees of dissociation are in dynamic equilibrium with each other and reflect the momentary acid- alkaline balance and the equilibrium in the ion concentrations at the boundary between the liquid and colloidal phases. The salts of H_2PO^{4-} and HPO_4^{2-} dissociate easier than hydrolyze, so the equilibrium H_3PO_4-↔ H++HPO_4^{2-} is pulled to the right - a trend that is reinforced by both Ca^{2+} deficiency and phosphorus uptake in the rhizosphere. Thus, from the point of view of its influence on the acid-alkaline balance in the soil, the precipitate on the one side leads to strengthening of the weak acid positions and on the other side releases Ca^{2+} in the system of easily mobile ions (Trendafilov, 2011).

Both ameliorants were applied under the same conditions, in the same way and in the same rates. The experiment was based on the method of long plots (Shanin, 1965), as the distribution of variants were included control and three increasing rates of treatment with hydrated lime and precipitate - 100, 250 and 500 kg/ha. Each of the variants was performed in three repetitions.

After application, the ameliorants were incorporated at a depth of 18-20 cm in the soil, as before that they were homogenized by surface treatment with a top soil layer with a depth of 10-12 cm. Soil samples were taken twice, as the first sampling was 14 months after the application of the ameliorant, and the next one 12 months later. Soil samples were taken from three layers with a depth of 0-25; 25-50 and 50-75 cm, using a soil probe, as the volume of each soil sample was composed of 3 single takes with the probe within the area of each replication. Soil samples were analyzed to establish easily mobile exchange Ca^{2+}, complexometric, by the method of Mazaeva, Neugodova and Khovanskaya (Palaveev and Totev, 1970), (BDS 17.4.4.07-97, 1997).

RESULTS AND DISCUSSIONS

Prior to field experiment, pH content potentiometric in aqueous and salt extract, easily mobile exchange Al^{3+} and H^+ and easily mobile exchange calcium was determined in order to establish the initial state of the soil. The results of the analyzes for determination the harmful acidity of the soil showed that in the terrains there was an acid reaction, relatively high content of easily mobile exchange Al^{3+}, H^+ and too high variation of easily mobile exchange Ca^{2+} and Mg^{2+} content in areas and depths. Based on the obtained results for a relatively short period of time, the degree of neutralizing effect of hydrated lime and precipitates was monitored in terms of the content of easily mobile exchange calcium. There was a necessary to develop a model by which the liming of soils contained harmful acidity and characterized by a strong deficiency of basic elements in the composition of its sorption complex to be partially or completely replaced by mineral fertilization with neutralizing fertilizers to achieve a sufficient degree of ameliorative impact in order to stabilize the acid-alkaline balance of the soil buffer systems (Valcheva, 2020).

Figure 1 shows the change in the content of exchange calcium in three depths of the study, during the two years as a response to the applied ameliorants. The average content of exchange calcium was about 8 meq per 100g/soil and as a result of the application of precipitate increased by about 1-2 meq per 100g/soil. This was an unproven but clearly manifested tendency with a high dispersion around the average values of the indicator,

which was normal in the heterogeneous environment in which it was analyzed.
In practice, the acid-alkaline balance was buffered in relatively close parameters, but in clay and therefore higher absorbing soil horizons it was determined by higher ionic concentrations. The application of the ameliorant reverses the trend.
This was established only in the top soil horizon in the first year and in all studied depths in the second one.

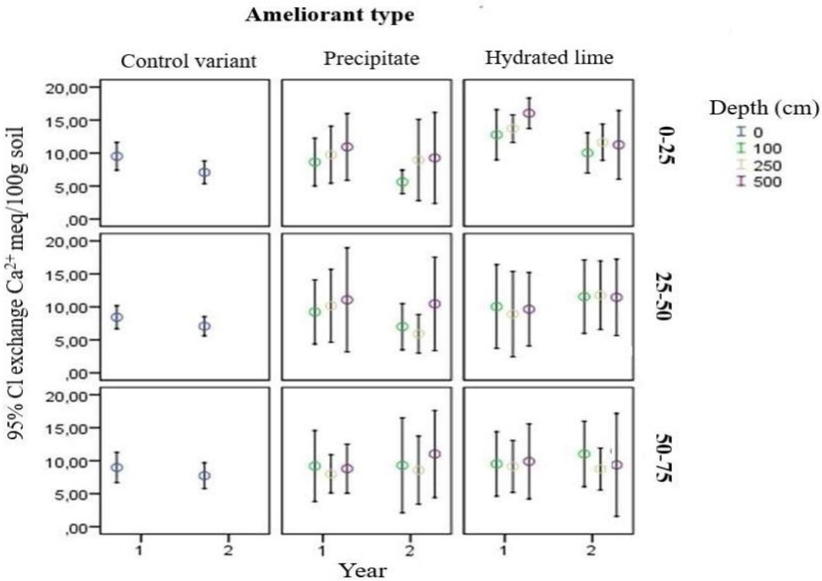

Figure 1. Distribution of calcium along the depth of the soil profile

In the second year, Ca^{2+} content decreased. Probably after the peak increase of its concentrations, established in the year of its application, part of the easily mobile calcium fills its own deficit in the more difficult to access exchange positions, thus stabilized. Part of it was absorbed on more strongly connected exchange positions in the sorption complex, and increased the relatively deeper calcium reserve of the soil, and hence it's buffering against acidification. In practice this did not change the point around which the acid-alkaline balance in the soil was situated. At the same time, the heterogeneity of the element in the soil volume increased. This was explained by the spatial heterogeneity of the environment and by the characteristic for field conditions imperfect homogenization of the ameliorant with the soil.
The application of calcium in the form of calcium precipitate in the doses and rates used for the experimental formulation did not imply a permanent and significant increase in the content of the easily mobile form of the element in the soil, but stabilized the acid-base balance, increased the capacity of the anti-acidification buffer system and improve the conditions for mineral nutrition with this element.
When the hydrated lime was applied, it was found that with the increase of the lime rates the content of the exchange Ca^{2+} also increased, as reach values on average up to about 1,8 times higher than the initial ones. The highest concentration of easily mobile exchange Ca^{2+} was found in the top soil horizon, in the variant limed with a rate of 500 kg/ha hydrated lime. This means that the soil sorption positions had a high buffering capacity until they completely saturated with bases.
In the next experimental year, it was found a steady downward trend of reached high level of exchange Ca^{2+} in the top soil horizons of the plots, limed with rates of 250 and 500 kg/ha and increased its content in the deeper layers. There were two probable possibilities to

observe this secondary movement of Ca^{2+} along the depth of the profile. In the first case, due to the heterogeneity and positional inaccessibility of the applied lime materials with the soil particles, part of Ca^{2+} applied with the ameliorant during the first year of the study did not connect to the sorption positions. It remained in the form of $Ca(OH)_2$ within the layer 0-25 cm, after that intensively leached along the depth of the profile, as saturate more the sorption complex of the deeper soil layers. The second possibility was that the strong deficit of exchange bases and the high solubility of calcium hydroxide have provided exchange connection of all applied and remained Ca^{2+} amount within the top soil layer, in which the sorption positions were saturated to a higher degree than that achieved by liming with low and high rates, but in the deeper horizons. In this case, part of the exchange Ca^{2+} was connected to very labile positions in the complex and was desorbed later, pushed out by the ionic pressure of the acid exchange positions. When applied hydrated lime, it was found that the soil reserved a stable and equilibrium some part of the applied Ca^{2+}, probably in accordance with the capacity of the exchange sorption system. However, the application of a soluble form of lime ameliorant led to a gradual saturation of the soil, as its penetration into the depth took place in a relatively short period. The reason for this assumption was that in the second year of the study, the content of exchange calcium tends to equalize at different depths of the soil profile.

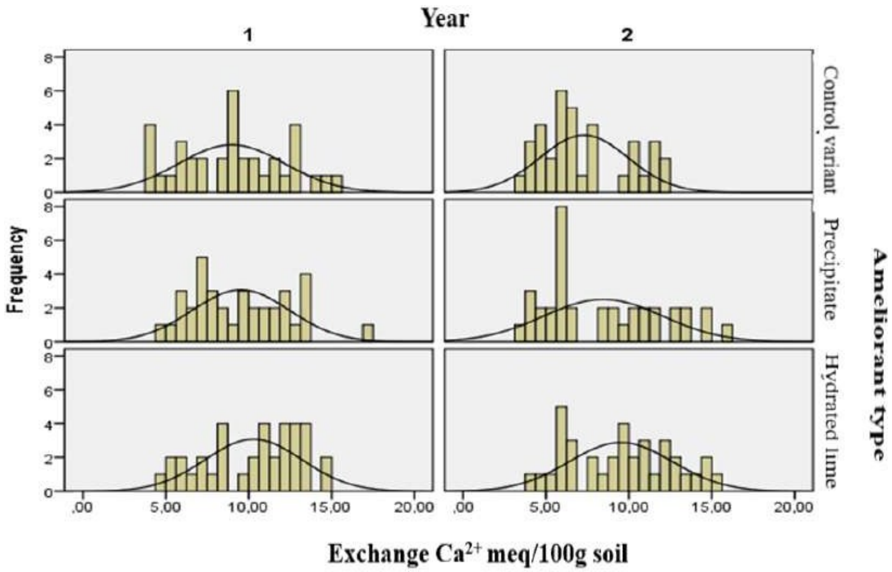

Figure 2. Characteristics of the frequency distribution of the content of exchange Ca^{2+} (meq/100g soil) along the depth of the soil profile

According to the data in Figure 2, the rates of 100 and 250 kg/da for both applied ameliorants, the frequency distribution of calcium along the depth of the soil profile was approximated to a normal level of probability of 95%.

CONCLUSIONS

The use of a precipitate, as both a slow-release phosphorus fertilizer and a chemical ameliorant to neutralize acidity was theoretically and practically justified in soils with slightly to moderately acidic reaction and temperate deficiency in terms of easily mobile exchange bases in the soil.

Its application in the doses and rates described in the present study did not imply a permanent and significant increase of the content of the easily mobile form of the element in the soil, but stabilized the acid-alkaline balance, increased the capacity of the buffer system against acidification and created a prerequisite for improvement the conditions for mineral nutrition with this element.

The use of hydrated lime as a chemical ameliorant in acid soils led to a relatively fast, long lasting and effective neutralization of exchange acid positions in the soil, as retain a stable and balanced some part of the applied Ca^{2+}, in accordance with the capacity of the exchange sorption system. In parallel, its penetration into the depth along the soil profile was carried out for a relatively short period, as proof of this was that in the second year of the observations, the content of exchange calcium tends to equalize at different depths of the soil profile.

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QUALITATIVE EVALUATION OF AGRICULTURAL LAND BY METHODS BASED ON GIS TECHNIQUES. LENAUHEIM CASE STUDY, TIMIS COUNTY, ROMANIA

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Abstract

This study assessed the quality of agricultural land in the area of Lenauheim, Timis County, Romania. Analog maps (1:10,000 scale) processed by GIS techniques (vectorization, digitization) were used. In relation to the 6 indicators taken into account, the studied area was characterized: Indicator 4C - Classes of average annual precipitation corrected in relation to the slope and permeability, 2 classes were found (0575 and 0650); Indicator 14 - Degrees of soil gleic status, 5 classes were found with high value for class 2 - low soil gleic level, 37.52%; Indicator 23A - Soil textural classes, 5 textural classes were found, between sand - clay and clay, with a high share of the medium clay class (42 - clay sand-clay, 92.01%); Indicator 39 - Depth classes of the groundwater level, 5 classes of groundwater were found (class 2 - shallow depth 2.01-3.00 m, 49.54%;); Indicator 44 - Classes of the degree of soil compaction, 4 classes of compaction level were found (class +5 - low compacted (1-10%), 75.51%); Indicator 144 - humus reserve class (in layer 0-50 cm), 6 classes were found (class 225 - very high humus reserve 201-250 t/ha, 81.60%).

Key words*: GIS techniques, quality classes, soil diversity, soil quality indices, spatial variability.*

INTRODUCTION

Agricultural lands show different levels of favorability for agricultural crops depending on the climatic zone (Borrelli et al., 2016; Raza et al., 2019), the physical, chemical, biological properties of the soil (Panday et al., 2019; Tesfahunegn and Gebru, 2020; Alawamy et al., 2021), the presence and degree of manifestation of some limiting factors (Everest et al., 2021).

In order to assess the favorability of agricultural land for different categories of agricultural use, and farm management, it is necessary to analyze and evaluate them based on specific quality indicators (Gelaw et al., 2015; Dai et al., 2018; Pouladi et al., 2020; Mulat et al., 2021).

Remote sensing has been used for a long time, successfully, in various studies and applications for land study, land quality assessment, land use classification, land records by use categories (Govedarica et al., 2015; Herbei and Sala, 2016; Kim, 2016; Popescu et al., 2020; Nedd et al., 2021; Winkler et al., 2021).

The characterization of agricultural land has been done in various studies related to land-use planning and management (Lee et al., 2020; Ippolito et al., 2021; (Ghadami et al., 2022), agricultural systems (Viana et al., 2022), basic soil parameters (Vilček et al., 2020), soil quality indices (Rahmanipour et al., 2014; Gelaw et al., 2015), agricultural technologies (Rocha et al., 2019), the impact of agricultural technologies and land management on the soil (Qi et al., 2011; Salvati, 2013), agricultural production and productivity (Blum, 2013), land use programs, policy and socioeconomic aspects (Rondhi et al., 2018; Spangler et al., 2020; Fei, 2022; Ghadami et al., 2022).

For the qualitative assessment of the land in relation to certain categories of use and agricultural crops, certain indicators of high importance for the soil are taken into account and certain calculation formulas were used, which quantify the participation of each factor in the assessment and classification of land in use categories (Florea et al., 1987a, b).

The present study used GIS techniques to evaluate agricultural land, in accordance with five soil quality indicators, in the area of Lenauheim locality, Timis County, Romania.

MATERIALS AND METHODS

Study area

The study considered for analysis and characterization a territory within the Lenauheim ATU (administrative-territorial unit), Timis County, Romania, Figure 1.

The land area taken in the study by satellite images and soil indices, the area of Lenauheim, was 9800.25 ha.

Soil indicators

For the characterization of the considered agricultural territory, six soil indicators were taken into account: indicator 4C (average annual precipitation classes); indicator 14 (soil gleic level); indicator 23A (soil textural classes); Indicator 39 (depth classes of the groundwater level); Indicator 44 (soil compaction level classes); Indicator 144 (humus reserve classes) (Florea et al., 1987a,b).

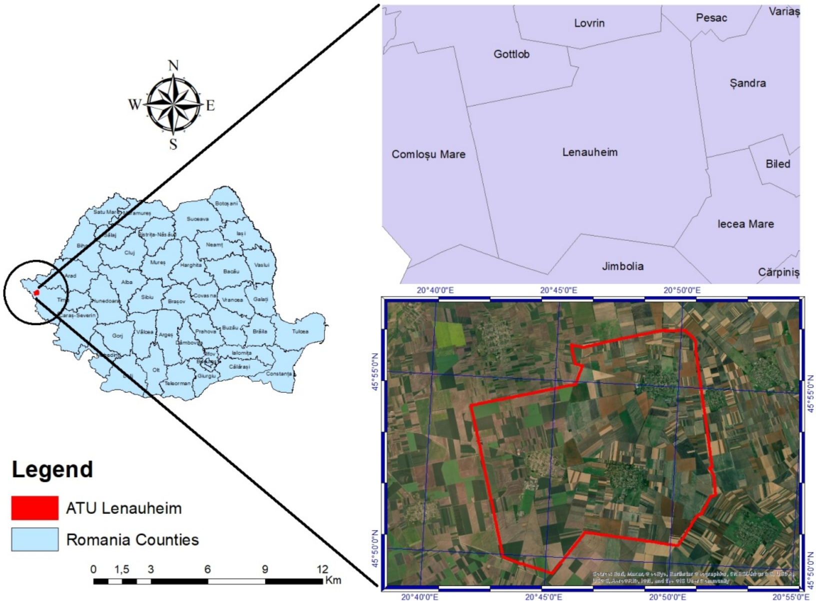

Figure 1. Study area, Lenauheim locality, Timis County, Romania

Indicator 4C expressed average annual rainfall (mm), corrected for terrain slope and soil permeability. Indicator 14 (14) expresses the gleic degree of soil.

Indicator 23A expressed groups of classes, classes and subclasses of soil textures. The granulometry classification was made according to the granulometric components of the soil, clay ($\Phi \leq 0.002$ mm), dust (Φ=0.002-0.02 mm), sand (Φ=2-0.02 mm), and Fs/Cs ratio (Fs – fine sand; Cs – coarse sand).

Indicator 39 (39) expresses depth classes of the groundwater level. Their classification is made according to the depth at which the groundwater is found in the boreholes.

Indicator 44 expresses classes of the degree of soil compaction. The degree of compaction was calculated by formulas, depending on the minimum required porosity (depending on the clay), and the total porosity (depending on the apparent and specific density).

Indicator 144 expresses humus reserve classes (in the 0-50 cm layer). The humus reserve was calculated according to the humus content (%), the thickness of the soil horizon (cm) and the apparent density (g/cm^3).

Use of geomatic technologies in land analysis

In the present study, analog maps (topographic and pedological, at a scale of 1: 10,000) were used, which were processed by GIS techniques (vectorization and digitization). The land area taken into account, Lenauheim ATU, was digitized and classified in relation to the Romanian Soil Taxonomy System and the indicators taken into account based on the land assessment methodology (Florea et al., 1987a, 1987b; Florea and Munteanu, 2012).

Data analysis

The data analysis was done in EXCEL (mathematical and statistical analysis module). PAST software was used for some calculations (Hammer et al., 2001). Within each indicator and classification classes, the corresponding area was calculated in absolute values (ha) and percentages values (%). The percentage share of land per class was calculated in relation to each index considered. The cluster analysis included all indices and classes (with the related surfaces), and the values considered were in the percentage form (%).

RESULTS AND DISCUSSIONS

The results obtained in the study of the agricultural land related to Lenauheim ATU, Timis County, were interpreted in relation to the classification classes of each indicator taken into account.

In relation to the 4C Indicator, within the Lenauheim ATU there are two classes of precipitation. In relation to the average annual precipitation (mm), corrected in relation to the slope of the land and the permeability of the soil, were found class 0575, flat land, and class 0650 land with micro unevenness.

The share of the two classes within the Lenauheim ATU was 73.59% for class 0575, respectively 26.41% for class 0650, Figure 2.

The spatial distribution map of the territory of Lenauheim locality, based on the 4C indicator is shown in Figure 3.

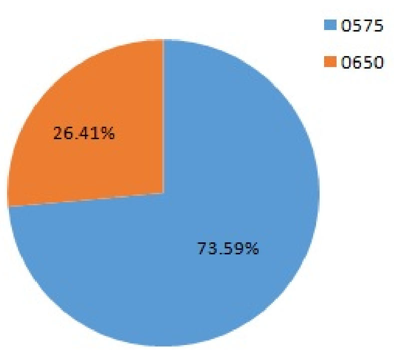

Figure 2. Share of the two classes (0575 and 0650) within the 4C indicator, Lenauheim ATU, Timis County, Romania

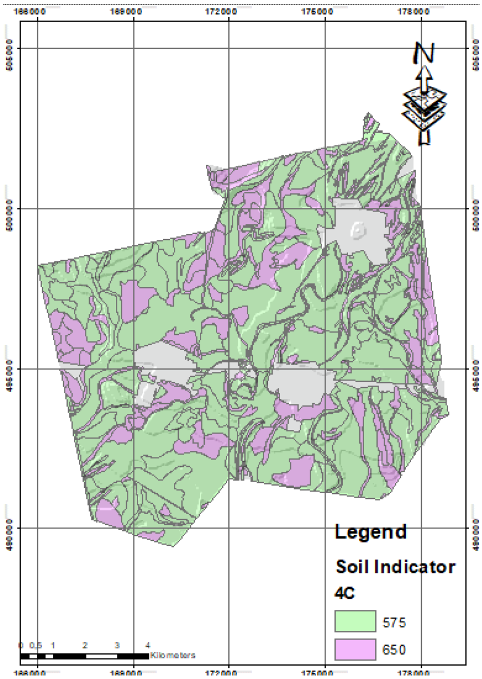

Figure 3. Map of 4C indicator for Lenauheim ATU, Timis County, Romania

In relation to Indicator 14, within the Lenauheim ATU, 5 classes of soil gleic status were identified: 1 - phreatic-wet (with deep gleic level), 33.18%; 2 - low gleic level, 37.52%; 3 - moderate gleic status, 19.14%; 4 - strong gleic level, 5.54%; 5 - very strong gleic level, 4.63%, Figure 4.

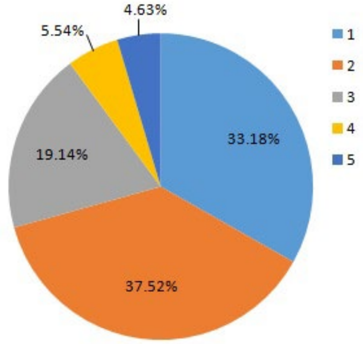

Figure 4. Share of agricultural land in relation to gleic classes, indicator 14, Lenauheim ATU, Timis County, Romania

Classification criteria are expressed in terms of the intensity of the gleic status and the depth on the soil profile at which the gleic phenomenon occurs. The spatial distribution map of the territory of Lenauheim, based on indicator 14 is shown in Figure 5.

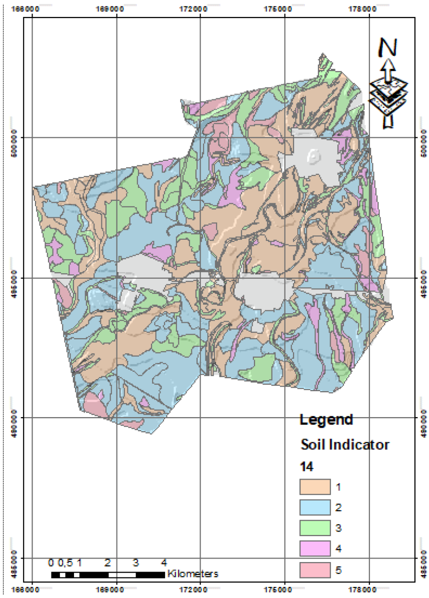

Figure 5. Map of 14 indicator for Lenauheim ATU, Timis County, Romania

In relation to indicator 23A, in the area of Lenauheim locality, 5 textural classes were identified (Figure 6), between sand - clay and clay, with a high weight of class 42, sand-clay; 32 - medium sandy-clay, 0.07%; 42- clay sand-clay, 92.01%; 52 – medium clay, 7.07%; 61 - medium clay-loamy, 0.17%; 62 - loamy-clay, 0.67%.

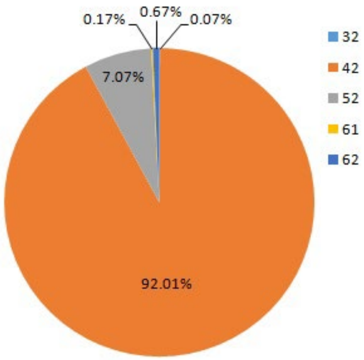

Figure 6. The share of agricultural land in relation to textural classes, indicator 23A, Lenauheim ATU, Timis County, Romania

The spatial distribution map of the territory of Lenauheim, based on indicator 23A is shown in Figure 7.

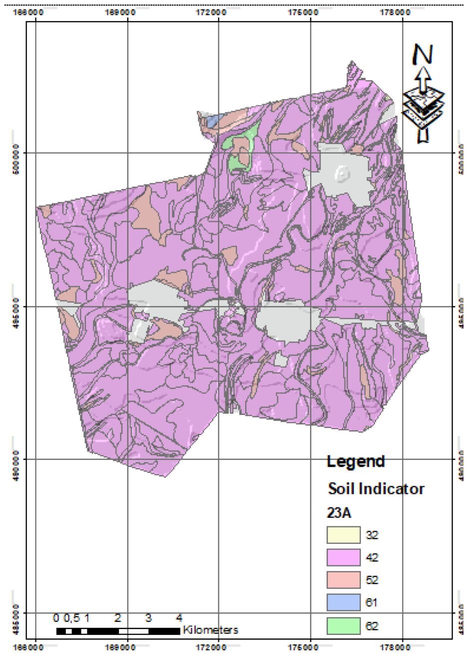

Figure 7. Map of 23A indicator (textural classes) for ATU Lenauheim, Timis County, Romania

In relation to indicator 39, within the Lenauheim ATU, 5 classes of groundwater depth were identified: 0.4 and 0.7 – extremely shallow depth (0.51-1.00 m) 0.12% and 1.12%; 1.4 – very small depth (1.01-2.00 m), 19.02%; 2 – shallow depth (2.01-3.00 m), 49.54%; 3.5 - medium depth (3.01-5.00 m), 30.19%, Figure 8.

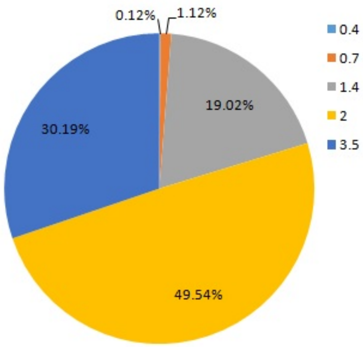

Figure 8. The share of agricultural land in relation to the groundwater depth, indicator 39, Lenauheim ATU, Timis County, Romania

The spatial distribution map of the territory of Lenauheim, based on indicator 39 is shown in Figure 9.

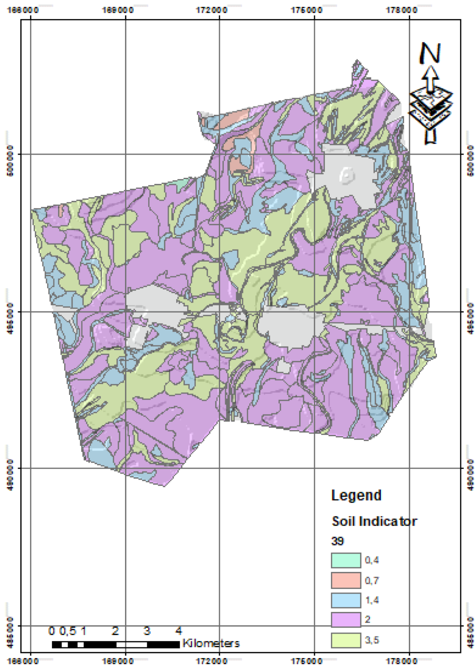

Figure 9. Map of 39 indicator (groundwater depth) for Lenauheim ATU, Timis County, Romania

In relation to indicator 44, 4 soil compaction classes were identified within the Lenauheim ATU: -5 – un-compacted soil (<1%), 11.80%; +5 – low compacted (1-10 %), 75.51%; +15 – moderately compacted (11-18 %), 12.59%; +25 – strongly compacted (≥ 18 %), 0.10%, Figure 10.

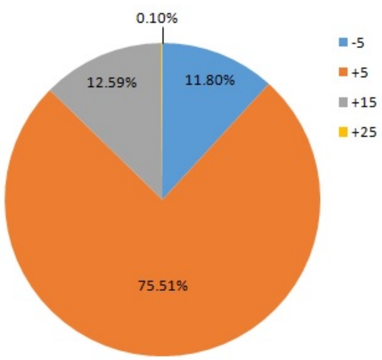

Figure 10. The share of agricultural land in relation to the degree of soil compaction, indicator 44, Lenauheim ATU, Timis County, Romania

The spatial distribution map of the territory of Lenauheim, based on indicator 44 is shown in Figure 11.

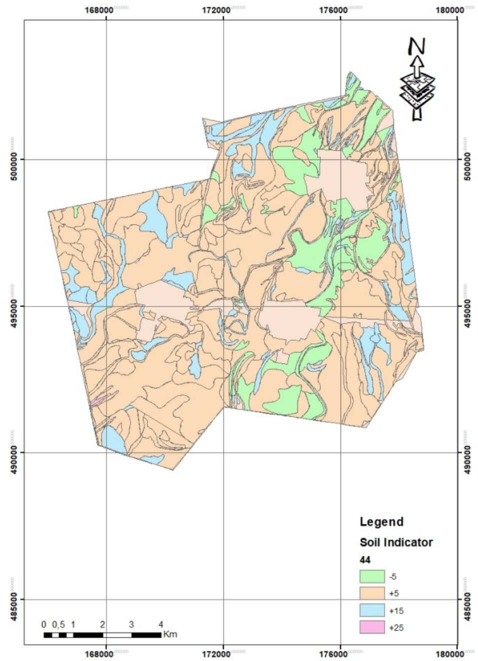

Figure 11. Map of 44 indicator (degree of soil compaction) for Lenauheim ATU, Timis County, Romania

In relation to indicator 144, the humus reserve in the 0-50 cm layer, within the Lenauheim ATU, 6 classes were identified, Figure 12: 090 - low humus reserve (61-120 t/ha), 0.30%; 140 - moderate humus reserve (121-160 t/ha), 0.05%;

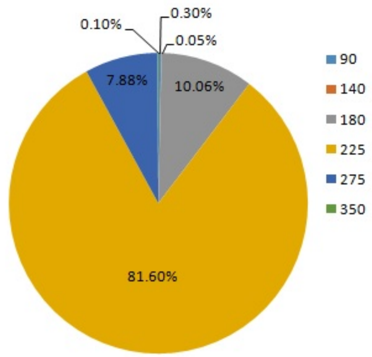

Figure 12. Share of agricultural land in relation to humus reserve (0 - 50 cm depth), indicator 144, Lenauheim ATU, Timis County, Romania

180 - high humus reserve (161-200 t/ha), 10.06%; 225 - very high humus reserve (201-250 t/ha), 81.60%; 275 - very high humus reserve (251-300 t/ha), 7.88%; 350 - extremely high humus reserve (301-400 t/ha), 0.10% (Figure 12).

The spatial distribution map of the territory of Lenauheim, based on indicator 144 is shown in Figure 13.

The overall analysis of the studied territory, in relation to the values on indicators and land classification classes (soil indicators considered) led to the representation in the form of a circular diagram, Figure 14.

The circular diagram in Figure 14 shows the indicators with maximum values (percentage expression of the associated land area) for the characterization of the agricultural territory studied.

Cluster analysis led to the grouping of soil indicators and classes in relation to the percentage value of the associated land area in the characterization of the studied territory, in conditions of statistical safety (Coph. corr. = 0.926).

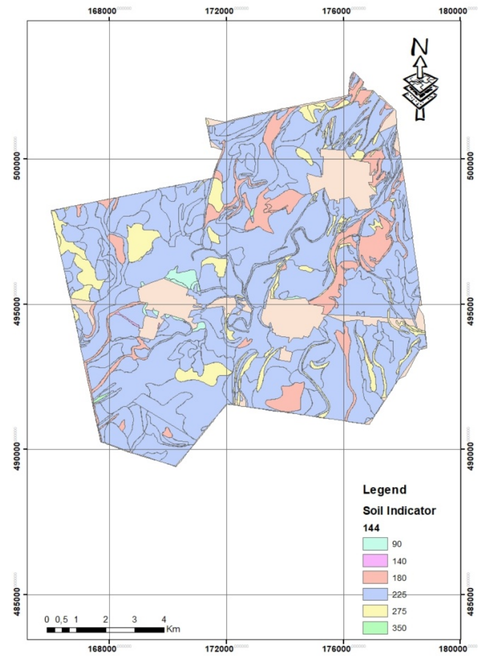

Figure 13. Map of 144 indicator (humus reserve, 0 - 50 cm depth) for Lenauheim ATU, Timis County, Romania

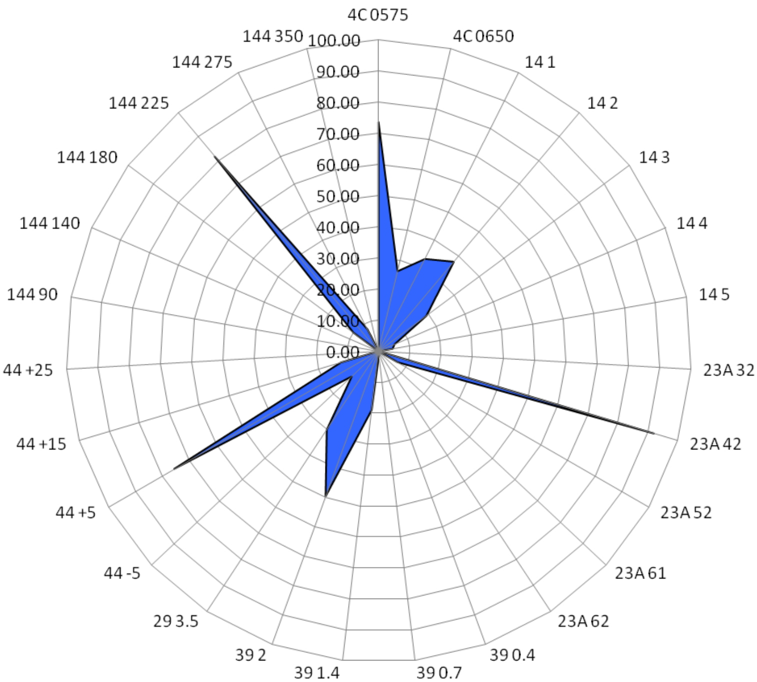

Figure 14. Circular diagram of land characterization indicators and classes, Lenauheim ATU, Timis County, Romania

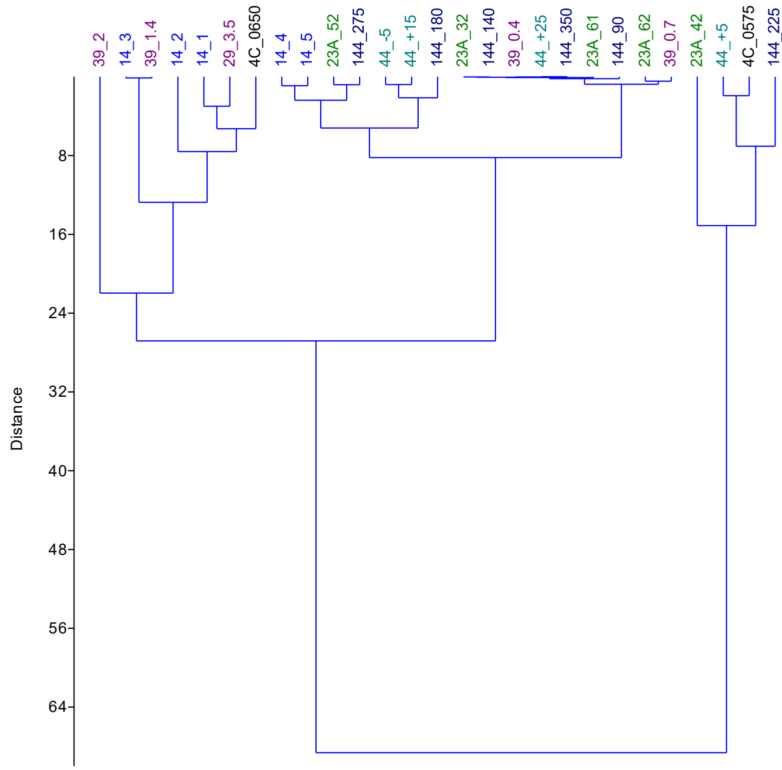

Figure 15. Dendrogram for grouping indices and land characterization classes, expressing the related areas (%), Lenauheim ATU, Timis County, Romania

The grouping of the indices (as a percentage expression of the studied land) was found in two distinct clusters (C1 and C2), with several sub-clusters each. Cluster C1 comprises surfaces associated with 4 indices and classes (maximum values), and cluster C2 comprises the other indices and classes considered, with the surfaces associated with them (Figure 15).

The evaluation of the categories of agricultural land use is important in order to efficiently classify the land in different socio-economic and ecological processes (Mendas and Delali, 2012; Geng et al., 2019; Viana et al., 2022).

Internal and external agricultural markets (Popescu, 2018; Popescu et al., 2018) are based on agricultural products of different categories, and the quantity and quality of agricultural production is consistent with the efficient use of land and agricultural technologies (Sala et al., 2015; King, 2017; Abate et al., 2018; Subramanian, 2021).

Various methods and techniques have been developed and used for the evaluation of agricultural land, due to the importance of framing as efficiently as possible in relation to the potential of each land area (Theobald, 2014; Burian et al., 2018; Herzberg et al., 2019; Mugiyo et al., 2021; Shang et al., 2021).

Agricultural land valuations are useful for decisions and planning support in crop management and resource allocation (Elsheikh et al., 2013; Herzberg et al., 2019; Li et al., 2020).

Techniques that used GIS and relied on multicriteria analysis in land assessment have been reported in some studies regarding the proper use of land in relation to different agricultural crops, and especially to crops of major importance (Ahmed et al., 2016; Yohannes and Soromessa, 2018), as well as for peri-urban agricultural land studied (Ustaoglu et al., 2021).

Given the appropriate classification of land by category of use, in agricultural areas, another stage in increasing productivity aims at issues of adequate biological material and improvement of agricultural technologies by optimizing inputs for quality production (Dobrei et al., 2009, 2016; Rawashdeh and Sala, 2014).

The results of the present study show that the technique based on remote sensing and GIS can be promoted for the study, classification and management of agricultural lands, the results communicated being in the trend registered from the reference studies in the field.

CONCLUSIONS

The soil quality indicators that were considered facilitated the classification of the land under consideration, ATU Lenauheim, in relation to the quality classes included in each indicator.

The technique based on remote sensing and GIS, which took into account the indicators and classes resulting from the classical method of analysis, facilitated their transposition into digitized format, the generation of maps for each indicator, and the safe classification of the studied territory.

The cluster analysis led to the grouping of the indicators, with the associated land surfaces on each class, in conditions of statistical security (Coph.corr = 0.926).

The GIS technique based on remote sensing used can be adapted and extended to other indicators, with applicability for different studies of agricultural land.

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RESEARCH ON THE CHEMICAL PROPERTIES OF THE SOIL ACCORDING TO SOME AGRICULTURAL PRACTICES APPLIED TO THE SORGUM GRAIN CROP

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Abstract

Sorghum, due to its high drought resistance, has become more common in many parts of the world. The article presents the results of the changes generated, by the two factors studied (Factor A - sowing density with three graduations and Factor B - mineral fertilization, with nitrogen and phosphorus with five graduations) and by their interaction, in some soil characteristics from an experimental field organized by A.R.D.S. Secuieni, where grain sorghum was cultivated. In order to assess the influence of fertilization and plant density, 45 soil samples were collected from the experimental field and analyzed. From the analysis of laboratory tests and statistical data processing, results statistically significant changes soil reaction, manganese and mobile iron contents under the influence of the interaction of the two experimental factors studied: sowing density and level of fertilization. The other soil quality indicators have no changed statistically significant under the influence of the tested technological factors however, showing slight increasing trends of the N, P, K contents in soil as a result of the applied fertilization treatments.

Key words*: grain sorghum, soil, plant density, fertilization, chemical characteristics.*

INTRODUCTION

The climate evolution towards heating and aridization for the 2001-2050 period of time in the Balkan area, where Romania is also found, compels to a reconsideration of the sorghum as: alimentary cereal (beads used in the formula for composite flours destined for gluteic and agluteic panification, the sweet juice extracted from the body, used for making syrup, vinegar and other alimentary products) (Revathi et al., 2011), fodder plant (under the shape of green mass, hay, silo), technical plant (stationary and textile celluloses, plastic material), the industry of construction materials and the handicraft industry (brushes of domestic and industrial use, brooms, nettings) (Antohe, 2007; Pochișcanu et al., 2015, 2016, 2017; Oprea et al., 2020).
Sorghum (*Sorghum bicolor* L. Moench) is one of the 5 major cultivated species in the world and can be used as feed, food, sugar or ethanol production (Almodares et al., 2007, 2008, 2011; Buah et al., 2012).
Planting space is closely related to yield density that affects crop production per unit of land area. Sharifi et al. (2009) explain that higher space density promotes competition among plants in absorbing nutrients.
Furthermore, fertilize the soil with compound fertilizer (nitrogen, phosphorus, and potassium), particularly nitrogen is vital for plant growth because it promotes shoot elongation, tillering regeneration, leaf to stem ratio, succulency, and palatability of fodder crop (Choudhary& Phrabu, 2016).
Several works observed improvement of sorghum biomass and protein content by increasing nitrogen (Sher et al., 2012; Cameron et al., 2013; Astuti et al., 2019).

MATERIALS AND METHODS

This paper presents data from the experimental field from Agricultural Research-Development Station (A.R.D.S.) Secuieni, located on the second terrace of Siret, on a typical cambic faeoziom (chernozem) soil type, being characterized by normal supply with mobile phosphorus (P_2O_5 – 39 ppm), and mobile potassium (K_2O – 161 ppm), moderately supplied in nitrogen (soil nitrogen index: 2.1), slightly acidic (pH: 6.29) and slightly fertile (humus content 2.3%).

The experiment was of the two-factor A×B type with: Factor A – sowing density with three gradations: a_1 – 20 grains/m^2, a_2– 25 grains/m^2 and a_3 – 30 grains/m^2 and Factor B – nitrogen and phosphorus fertilization with five gradations: b_1 – unfertilized, b_2 – $N_{75}P_{80}$, b_3 – $N_{75}P_{80}$ + Biostimulatory, b_4 – $N_{150}P_{80}$, and b_5 – $N_{150}P_{80}$ + Biostimulatory and the interaction between these two factors. The analysis of the results of the laboratory tests and the statistical processing of the data, allowed us to highlight the effects of the applied technological factors on the soil quality indicators.

From the experimental field, 45 soil samples were collected, which were conditioned and chemically analyzed.

The determinations carried out on the soil samples concerned:

- Soil reaction (pH);
- Organic carbon content (Corg);
- Nitrogen content ($N_{kjeldahl}$);
- Accessible phosphorus content (P_{AL});
- Accessible potassium content (K_{AL});
- Content of microelements in forms accessible (Cu, Zn, Mn and Fe).

RESULTS AND DISCUSSIONS

In our study, the changes produced by factor A (sowing plant density) with the three gradations and by factor B (nitrogen and phosphorus fertilization) with the five gradations on the main properties of the soil and heavy metals in the soil are presented.

Figure 1 shows that the influence of factor A (sowing plant density) on the soil reaction has no statistical changes, with a slight increase in acidity in variant a_2. The supply of soil with humus, nitrogen, mobile phosphorus and mobile potassium has no significant changes in any of the three variants. The humus content is low (2.16-2.21%), the total nitrogen has low values between 0.130 and 0.144%. The soil supply with mobile P is high in variant a1 and a_3 and very high in a_2 (148 mg·kg^{-1}), and mobile K has average values without statistical changes.

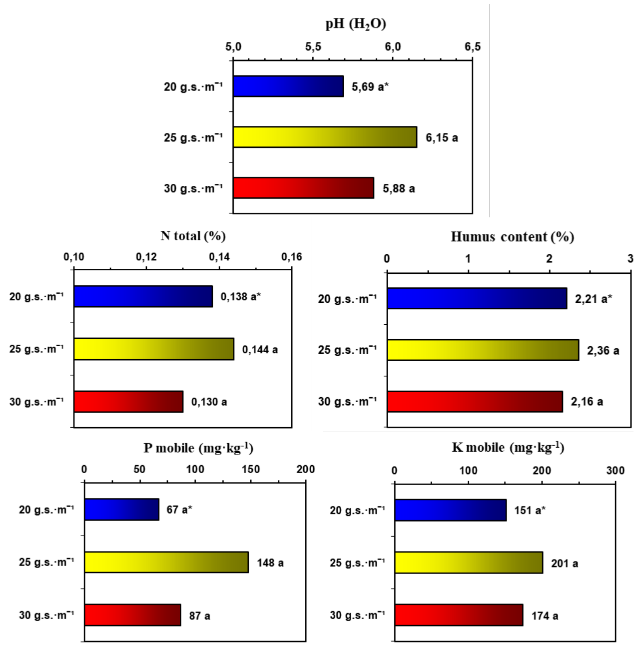
Figure 2 shows the influence of factor B on the chemical properties of the soil, without statistical changes. The soil reaction is slightly acidic between 5.80 to b_2 and 5.99 to b_3, the humus content values are low to medium, and the total nitrogen content is low between 0.137-0.139%. The supply of mobile phosphorus is very high, with lower values in the control variant, and mobile potassium has average values between 164-190 mg·kg^{-1}.

The density of seeds at sowing on the concentration of heavy metals (Cu, Mn and Fe) in the soil extractable form in DTPA did not produce statistical changes. The Zn content, the extractable form in DTPA increases significantly in variant a_2 compared to a_1 (20 grains/m^2) are shown in Figure 3.

Figure 4 shows the influence of factor B (fertilization level) on the concentration of heavy metals in the soil, the extractable form in DTPA (Cu, Zn, Mn and Fe) where no significant changes are observed.

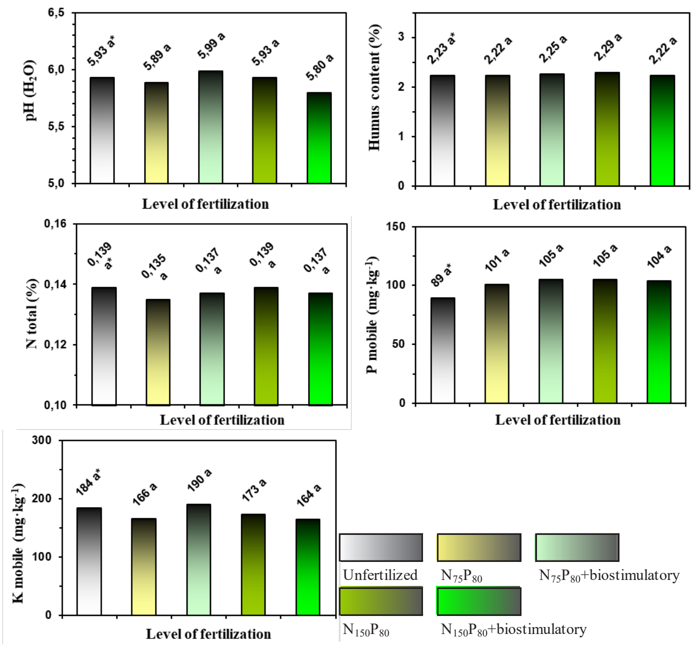
Table 1 shows the statistical significances of the Fisher test established by variant analysis method to highlight the changes produced by the two factors studied and their interaction on soil characteristics from the experience organized to establishing technological parameters with high efficiency on sorghum grains.

It is noted that only the soil reaction, manganese and mobile iron content in the soil underwent statistically assured changes under the influence of the interaction of the two experimental factors studied (sowing density and nitrogen fertilization). Other indicators of soil quality and nutrition of sorghum plants did not change statistically significantly under the influence of applied technological links.



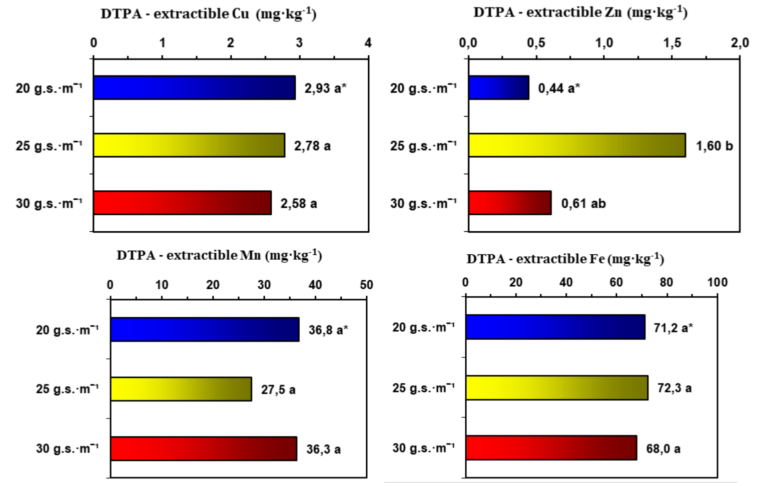
*Values followed by the same letter (a, b, c) are not significantly different at the 5% level according to the Tukey's honestly significant differences (HSD) test.

Figure 1. The effects of factor A (plant density) on the pH value and the contents of humus, nitrogen, mobile phosphorus and mobile potassium in soil, in the experience field cultivated with sorghum grains (0-20 cm, A.R.D.S. Secuieni, 2019)



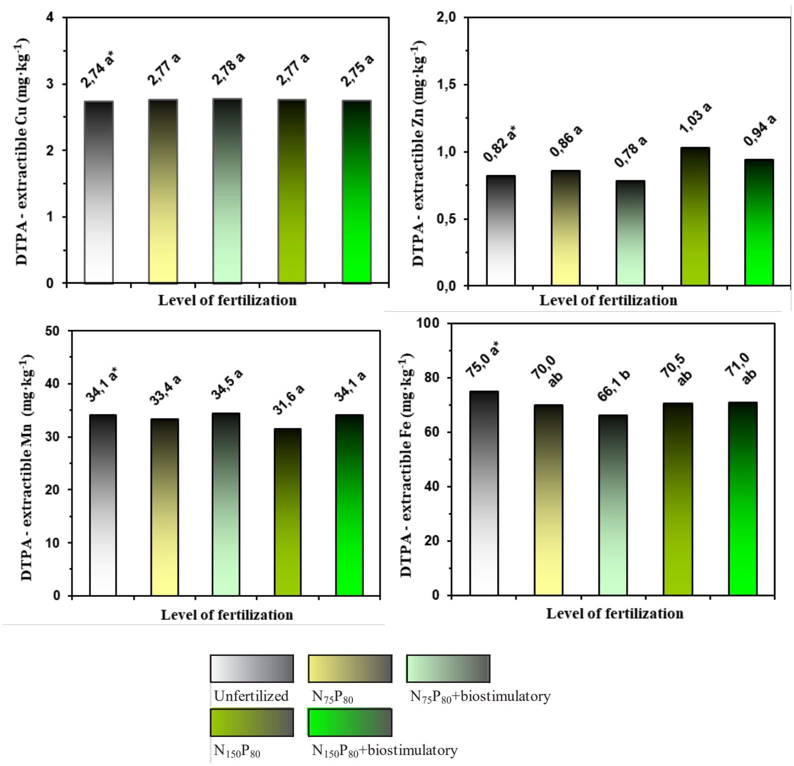
*Values followed by the same letter (a, b, c) are not significantly different at the 5% level according to the Tukey's honestly significant differences (HSD) test.

Figure 2. The effects of factor B (fertilization level) on the pH value and the contents of humus, nitrogen, mobile phosphorus and mobile potassium in soil, in the experience field cultivated with sorghum grains (0-20 cm, A.R.D.S. Secuieni, 2019)



*Values followed by the same letter (a, b, c) are not significantly different at the 5% level according to the Tukey's honestly significant differences (HSD) test.

Figure 3. The effects of factor A (plant density) on the contents of copper, zinc, manganese and iron in soil - extractible forms in DTPA, in the experience field cultivated with sorghum grains (0-20 cm, A.R.D.S. Secuieni, 2019)



*Values followed by the same letter (a, b, c) are not significantly different at the 5% level according to the Tukey's honestly significant differences (HSD) test.

Figure 4. The effects of factor B (fertilization level) on the contents of copper, zinc, manganese and iron in soil - extractible forms in DTPA, in the experience field cultivated with sorghum grains (0-20 cm, A.R.D.S. Secuieni, 2019)

Table 1. Statistical significance of the Fisher test established by variant analysis method to highlight the changes produced by two factors studied and thein interaction on some soil characteristics from the experience field organized establishing technological parameters with high efficiency on sorghum grains

Caracteristics in 0-20 cm soil layer	Source of variation		
	Factor A	Factor B	Interaction AxB
pH	NS	NS	★
Humus contents	NS	NS	NS
Nitrogen contents	NS	NS	NS
Phosphorus mobile	NS	NS	NS
Potassium mobile	NS	NS	NS
Cu in soil – extractibile forms in DTPA	NS	NS	NS
Zn in soil – extractibile forms in DTPA	NS	NS	NS
Mn in soil – extractibile forms in DTPA	NS	NS	★★
Fe in soil – extractibile forms in DTPA	NS	NS	★

NS	Non-significant ($p > 0,05$)	★★	Very significant effect ($0,001 < p \le 0,01$)
★	Significant effect ($0,01 < p \le 0,05$)	★★★	Extremely significant effect ($p \le 0,001$)

Factorul A – Plant density *Factorul B – Fertilization level*

CONCLUSIONS

The main findings of this study note are that only the soil reaction, manganese and mobile iron content in the soil underwent statistically assured changes under the influence of the interaction of the two experimental factors studied: sowing density (Factor A) and nitrogen fertilization (Factor B). The other soil quality indicators have no changed statistically significant under the influence of the tested technological factors however, showing slight increasing trends of the N, P, K contents in soil as a result of the applied fertilization treatments.

ACKNOWLEDGEMENTS

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EVALUATION OF THE NITROGEN REGIME OF CHERNOZEM LEACHED UNDER THE ACTION OF DIFFERENT DOSES OF TURKEY WASTE APPLICTION

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Abstract

As a result of field experiments on the experimental field of Penza State Agrarian University (Russia, Penza region, Mokshansky district), it was revealed that with the annual introduction of different doses of litter turkey manure, an increase in the content of alkaline hydrolysable nitrogen in the soil is observed, although by the end of the growing season its content decreases, which associated with the consumption of its mineral compounds by crops. Manure doses from 12 to 36 t/ha increased the content of alkaline hydrolysable nitrogen in the soil from 26.6-29.9 mg/kg at a dose of 12 t/ha to 40.0-53.9 mg/kg of soil at a dose of 36 t/ha. With the annual use of manure, a gradual increase in the content of nitrate nitrogen in the soil is observed. By the end of the growing season, its content in the soil decreased according to the variants, although its content at doses of 24 and 36 t/ha was characterized by high and very high. This indicates that that at high doses of manure, nitrate nitrogen is not completely absorbed by crops and its amount is excessive. With an increase in the dose of semi-rotted manure more than 12 t/ha with a high content of ammonia nitrogen compounds, its increase is observed at the beginning of the growing season, which can affect the formation of the yield of cultivated crops.

Key words*: leached chernozem, turkey manure, alkaline hydrolysable nitrogen, ammonia nitrogen, nitrate nitrogen.*

INTRODUCTION

The use of bird droppings in crop production for fertilizing crops will reduce the amount of accumulated waste from poultry farming and, thereby, guarantee the non-waste of technological processes in agro-industrial production (Chekaev et al., 2015; Schmidt A. et al., 2019). Bird droppings are a valuable fertilizer containing all the essential nutrients needed for plant growth and development. According to the assimilation of nutrients by plants, bird droppings are close to mineral fertilizers. However, its storage leads to large losses of valuable fertilizer qualities of the litter (Agadjihouèdé et al., 2011; Chekaev et al., 2020; Popov et al., 2019).

The most important aspect of poultry manure utilization as a fertilizer is the scientific approach to determine the dose that will give the maximum agronomic and economic efficiency (Agadjihouèdé et al., 2011; Schmidt et al., 2019).

In foreign sources, bird droppings are evaluated as a fertilizer with a high content of nutrients that increase the productivity of cultivated crops (Kantikowati et al., 2019; Mutlu et al., 2020; Uchiyama et al., 2014). To increase its effectiveness and reduce risks for the environment and public health, its preliminary biocomposting is proposed to reduce pathogenic microflora (Barnossi et al., 2020; Tagoe et al., 2008; Kantikowati et al., 2019).

The use of bird droppings as a fertilizer is hindered due to insufficient knowledge of the chemical composition of the droppings, there is no sufficiently substantiated technology for its use in crop rotation, and the specifics of its impact on soil fertility have not been identified (Chekaev et al., 2020; Schmidt et al., 2019).

In this regard, it seems relevant to study the chemical composition of litter fertilizer, determine the optimal doses of application for specific crops in different natural and climatic conditions, and assess the effect of litter fertilizers on soil properties in direct action and in after effect.

MATERIALS AND METHODS

In order to study the effect of different doses of turkey manure on the nitrogen regime of leached chernozem during the cultivation of spring wheat, on the experimental field of the training and production center of the Penza State Agrarian University (Russia, Penza region, Mokshansky district), studies were carried out according to the following scheme: 1. Without fertilizers (control); 2. Turkey manure 12 t/ha; 3. Turkey manure 24 t/ha; 4. Turkey manure 36 t/ha.

The experience is laid in 3-fold repetition. The area of one plot is 8 m^2. Sowing of spring wheat (variety Granny) was carried out in the second decade of May. The soil of the experimental plot is represented by leached medium-humus heavy loamy chernozem. The content of humus in a layer of 0-30 cm is 6.11-6.48%, alkaline hydrolysable nitrogen is 98-108, mobile phosphorus is 120-128, mobile potassium is 109-116 mg per kg of soil, the reaction of the soil solution is slightly acidic (5.1-5.3), hydrolytic acidity – 4.85-5.57 mEq per 100 g of soil, the amount of absorbed bases is 34.4-36.2 mEq per 100 g of soil.

Bedding turkey manure on straw bedding was used in the experiments. The quality was characterized as semi-overripe. The share of nitrogen in the dry mass of manure was 2.57-2.77%, phosphorus - 3.86-4.58%, potassium - 2.04-4.41%, humidity 48.2-53.2%, organic matter content 37.3-43.1%, ash content 13.8-27.4%, pH - 7.0- 8.7 units

When conducting soil analyzes, the following research methods were used:

- alkaline hydrolysable nitrogen - according to the Kornfield method (modified);
- ammonium nitrogen in the soil in the modification (GOST 26489): the method is based on obtaining a colored indophenol compound formed in an alkaline environment by the interaction of ammonia with hypochlorite and sodium salicylate.
- nitrate nitrogen in the soil by the potentiometric method: the method is based on determining the concentration of nitrates in the soil using an ion-selective electrode in a salt suspension of a 1% solution of potassium alum at a ratio of sample : solution 1: 2.5.

RESULTS AND DISCUSSIONS

Nitrogen is a typical biophilic element, its behavior in the soil is primarily related to biological factors. The main part of nitrogen is not available to plants, as it is found in the soil in the form of complex organic compounds (94-95%). Only a small amount of nitrogen (about 1%) is contained in mineral forms easily digestible by plants. In this regard, the normal supply of nitrogen to plants depends on the rate of mineralization of nitrogenous organic substances and other factors.

Alkaline hydrolysable nitrogen, determined by the Kornfield method, is a combination of mineral nitrogen, represented by the ammonia and nitrate form, a certain amount of nitrogen of organic substances that are part of amino acids and amides, which can be easily mineralized.

According to the results of studies, doses of turkey manure from 12 to 36 t/ha increased the content of alkaline hydrolysable nitrogen in the arable layer of leached chernozem, already in the first year of action.

The selection of soil samples fifteen days after the introduction showed that in the variants with the introduction of manure, the content of this form of nitrogen increased by 18.7-47.7 mg/kg of soil. In the heading phase of spring wheat, two months after the application, the content of alkaline hydrolysable nitrogen in the soil, depending on the doses of manure application, ranged from 122.3 to 144.6 mg/kg of soil, which was higher than the control variant by 19.4-41.7 mg/kg.

By the end of the growing season, when cultivating spring wheat, a slight decrease in alkaline hydrolysable nitrogen was observed in the experimental variants compared to previous determinations. The decrease in the control variant was 11.2 mg/kg (Figure 1).

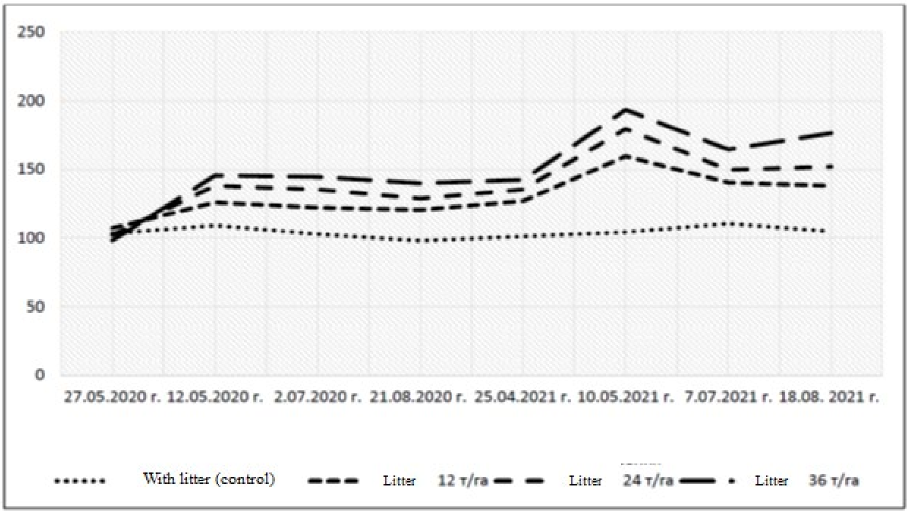

Figure 1. Dynamics of content of alkaline hydrolysable nitrogen in leached chernozem with turkey litter, mg/kg of soil

In 2021, before the introduction of the studied doses of manure, the content of alkaline hydrolysable nitrogen increased compared to the autumn determination in 2020 from 2.4 mg/kg in the variant with a dose of litter of 36 t/ha to 6.6 mg/kg in the variant with a dose of 24 t/ha, which is due to with the processes of mineralization of organic matter of plant residues from the litter.

15 days after the repeated application of the studied doses of manure, an increase in the content of alkaline hydrolysable nitrogen by 32.6-51.0 mg/kg of soil is observed. By the earing phase of spring wheat, with repeated application of the studied doses of manure, a decrease by 19.1-28.9 mg/kg is noted. At the end of the growing season of cultivated crops on plots with different doses of manure, the content of alkaline hydrolysable nitrogen in spring wheat crops ranged from 138.2 to 176.4 mg/kg of soil. On variants with manure doses of 24 and 36 t/ha, the nitrogen content corresponded to the average content.

Thus, with the annual application of doses of manure, an increase in the content of alkaline hydrolysable nitrogen in the soil is observed, although by the end of the growing season its content decreases, which is associated with the consumption of its mineral compounds by crops. Over two years of research, the studied doses of manure increased the content of alkaline hydrolysable nitrogen in the soil from 30.9 mg/kg at a dose of 12 t/ha to 78.2 mg/kg of soil at a dose of 36 t/ha.

The content of ammonia nitrogen in soils depended on the content of these forms of nitrogen in the litter. Before the introduction of the studied doses of manure in 2020, the content of ammonia forms of nitrogen in the soil fluctuated within 4.9-6.3 mg/kg of soil. Fifteen days after the application, the content of ammonia nitrogen in the variants with the studied doses of litter increased from 22.4 mg/kg at a dose of 12 t/ha to 40.9 mg/kg at a dose of 36 t/ha.

On variants with manure doses of 24 t/ha and 36 t/ha, the content of ammonia nitrogen was characterized as very high. In the middle of the growing season of spring wheat, its content decreased and amounted to 19.9 to 23.6 mg/kg of soil in the variants, which was higher than the control variant by 16.7-20.4 mg/kg.

By the end of the growing season, the content of ammonia nitrogen decreased to 5.8-9.2 mg/kg of soil (Figure 2).

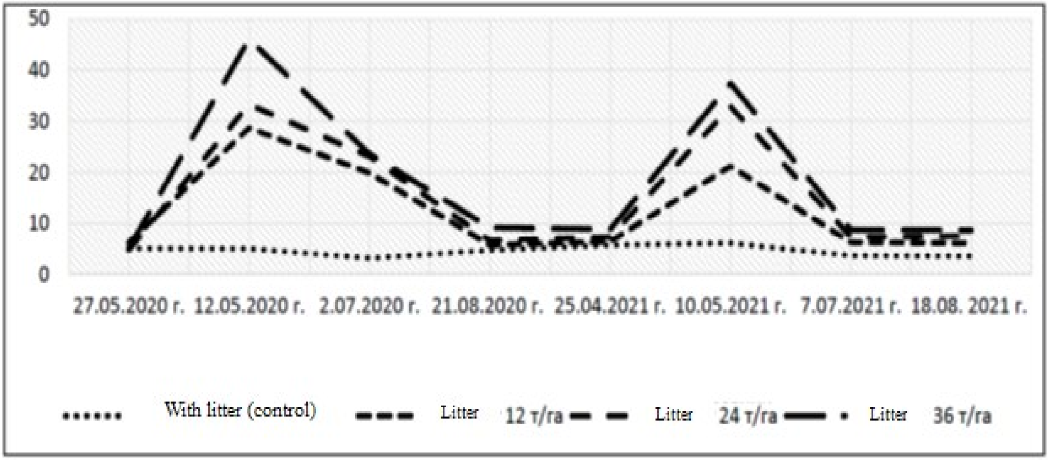

Figure 2. Dynamics of ammonia nitrogen content in leached chernozem with turkey litter, mg/kg of soil

With the repeated introduction of the studied doses of manure in 2021, the content of ammonia nitrogen in the experiments increased by 14.7-28.5 mg/kg compared to the data before the introduction, and in the heading phase its content decreased by 14.7-28.5 mg/kg and was in the range of 6.3-8.8 mg/kg soil.
The maximum values of ammonia nitrogen in the soil are observed within two months after application. By the end of the growing season, its content decreases. During the growing season, the content of ammonia nitrogen decreased and at the end of the growing season, the crops almost leveled off.
With an increase in the dose of litter, the content of ammonia nitrogen increased to a very high content.
The content of nitrate nitrogen in 2020 before the application of manure doses ranged from 12.2 to 15.2 mg/kg of soil (Figure 3).
Fifteen days after application, an increase in the content of this form of nitrogen by 25.9-60.9 mg/kg is noted. In the variant without fertilizers, the content of nitrate nitrogen was characterized as medium, with a dose of manure of 12 and 24 t/ha it was high, and in the variant with a dose of manure of 36 t/ha it was very high.

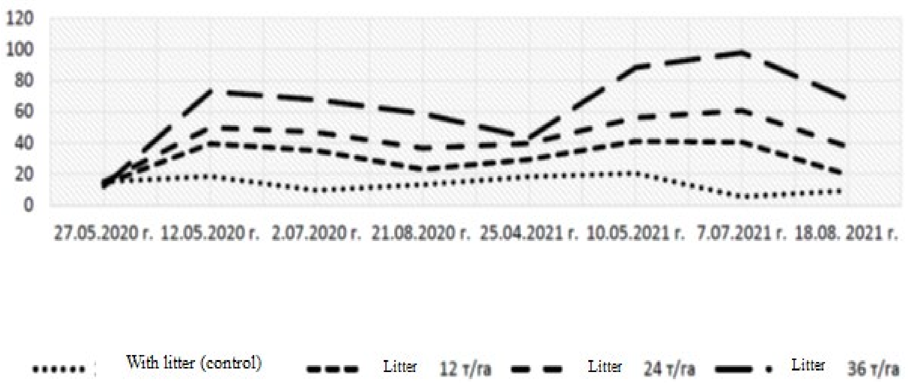

Figure 3. Dynamics of the content of nitrate nitrogen in leached chernozem with turkey litter, mg/kg soil

By the heading phase, the content of nitrate nitrogen decreased by 3.0-5.4 mg/kg, and by harvesting, the content of nitrate nitrogen in the soil ranged from 13.4 mg/kg in the control to 58.8 mg/kg of soil with a manure dose of 36 t/ha.
With a dose of manure of 12 t/ha, its content was characterized as medium, in the variant

with 24 t/ha of manure it was high, and in the variant of 36 t/ha it was very high.

In 2021, before the repeated application of the studied doses, the content of nitrate nitrogen in the soil ranged from 18.4 mg/kg of soil in the control to 43.3 mg/kg at a dose of 36 t/ha. Fifteen days after the second application, the content of nitrate nitrogen in the soil on plots with different doses of manure increased by 11.7-45.0 mg/kg.

By the earing phase of spring wheat, the content of nitrate nitrogen in the soil of the control variant decreased by 15.6 mg/kg, and in the variants with manure doses of 24 and 36 t/ha, an increase by 4.4-9.6 mg/kg was observed.

By harvesting, its content in the variants with manure decreased and ranged from 19.7 to 68.3 mg/kg of soil, while the content of nitrate nitrogen in the control was characterized as low, in the variant with a dose of manure of 12 t/ha - medium, with a dose of manure of 24 t/ha - high, and in the variant with a dose of manure 36 t/ha as very high.

Thus, with the annual use of manure, a gradual increase in the content of nitrate nitrogen in the soil is observed. By the end of the growing season, its content in the soil decreased according to the variants, although its content at doses of 24 and 36 t/ha was characterized by high and very high.

CONCLUSIONS

With the annual application of manure doses from 12 to 36 t/ha, an increase in the content of nitrogen compounds in the leached chernozem is observed. The highest values are observed in the first two months after application, and by the end of the growing season, the content decreases, which is associated with the consumption of its mineral compounds by crops.

The studied doses of manure gradually increase the content of alkaline hydrolysable and nitrate nitrogen in the soil. This indicates that at high doses of manure, nitrogen is not completely absorbed by the crops and its amount is excessive.

The remaining nitrate nitrogen at the end of the growing season would subsequently be lost from the soil due to leaching or denitrification, which leads to unproductive losses.

The content of ammonia nitrogen in the soil increases within two months after application, and by the end of the growing season, its content decreases.

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REVIEW OF METHODS FOR REMEDIATION OF POLLUTED SOILS IN URBAN AREAS

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Abstract

Urban soils are strongly affected by both natural factors: wind, water, freeze-thaw processes, heat, but also by human activity. Soil pollution caused by human activities is often associated with modernization, industrialization, metal extraction activities, oil extraction, inadequate waste storage and pesticide application. Soil pollution is one of the major effects of human technological progress. The impact of soil pollution is not limited to the soil and its organisms, but affects every sector, to humans: human health, plant growth, air pollution, reduced soil fertility, changes in soil structure, impact on ecosystem and biodiversity, contamination of water sources. For this reason, the phenomenon of soil pollution needs to be remedied. This article aims to evaluate the specialized articles and highlight the methods used to remedy polluted soils in urban areas. Remedial methods can be phytoremediation or zooremediation. The remedy can be done ex-situ and in-situ. Soils in urban areas have not received adequate attention and data on this subject are scarce so far, although constraints on soil quality in congested urban areas are acute.

Key words: *methods, pollution, remediation, urban soils.*

INTRODUCTION

Soil is one of the most important resources of the biosphere (Izquierdo et al., 2005). It must be protected because it performs many ecosystem services: it determines the production and productivity of plants, supports the degradation of organic matter and the nutrient circuit (Santorufo, 2012), is a natural buffer for chemicals in the atmosphere (Onete et al., 2009; Ștefănuț et al., 2018), hydrosphere and biota (Onete, 2008; Onete & Paucă-Comănescu, 2008). Soil can be affected by natural factors: wind, water, freeze-thaw processes, heat), but also to a large extent by human activity (Craul, 1985; Hartley et al., 2008). Urban areas are the socio-ecological systems that represent a mix of land uses and comprise the highest percentage of the human population (Li et al., 2018). Recently, the human population has grown exponentially, and for this reason there are needed new living spaces, jobs especially in urban areas (Onete et al., 2010; Agrawal et al., 2020; Manu et al., 2021; O'Riordan et al., 2021). As urbanization is increasing in most of the world, this has implications for the infrastructure needed to support urban growth (McIntyre, 2020; Zissimos et al., 2021). Soils in urban areas called "brown infrastructure" provide multiple ecosystem services (nutrient cycling, carbon sequestration, etc.) (Calzolari et al., 2020), functioning as a source of nutrients for plant growth, called "green infrastructure" important in urban water quantity and quality management ("blue infrastructure") (Trammell et al., 2020). All these components of urban systems are interconnected and influence each other.

As cities become more crowded, pollution in urban areas is an increasing problem (Vara et al., 2012; Ianoș & Jones, 2019; Joyner et al., 2019). The soils undergo physico-chemical changes, through dry and wet depositions (Fowler, 2002) or direct impact (transport, construction, inadequate waste storage (Santorufo, 2012; Kumar et al., 2021), extraction of metals, petroleum substances, application pesticides (Zalesny et al., 2021), excessive use of fertilizers (Muthukumar et al., 2021). Due to the increase of pollutants type (diversity) and intensity, there are also related problems, such as: climate

change, loss of biodiversity (Onete, 2010), acid rain, earthquakes, landslides, floods (Verma, 2021), changes in land use (Petrişor et al., 2020), habitat fragmentation or even loss, changes in plants and invertebrate communities, etc. (Santorufo, 2012; Bielińska, 2013; Manu et al., 2018). The impact of soil pollution results in small concentration of nutrients (Mónok et al., 2021), high degree of compaction, too little differentiated stratification, altered structure of soil invertebrate communities (Jim, 1998; Li & Huang, 2007) from bellow and above ground.
Because of the complex effects of soil pollution, researchers draw attention to the importance of studying soil fauna as indicators of soil quality (Manu et al., 2018). Many studies have been conducted on one of the biggest issues related to urban soil pollution: heavy metal pollution (Pb, Zn, Cu, Cr, Ni) (Damodaran et al., 2011; Manu et al., 2018; Ștefănuț et al., 2017; Damasi et al., 2018). Heavy metals are non-degradable compounds so they remain stored in plant tissue subsequently consumed by animals and humans (Hrynkiewicz & Baum, 2014; Verma, 2021). They are naturally found in the soil due to geological processes (Li & Huang, 2007), but they are largely the result of activities in agriculture and industry (Vara et al., 2012; Cai et al., 2013; Li et al., 2013; Lee et al., 2021). Heavy metal contamination has no color or odor, so it is very difficult to identify them (Su, 2014). Lead, for example, affects many physiological systems, with its action beginning in the womb. Children are most vulnerable because their bodies absorb lead at a much higher rate than an adult's body (Obeng-Gyasi et al., 2021).
Polycyclic aromatic hydrocarbons (PAHs) have also strong impact on the soil (Indelicato, 2014; D'Souza et al., 2015; Alegbeleye et al., 2017). Moreover, it has been shown to have carcinogenic, teratogenic and mutagenic effects on humans (Alegbeleye et al., 2017; Adimalla et al., 2020).
As the soil is affected, the effects cascade along the food web, largely affecting the growth of plants, animals and, finally, human health (Onete et al., 2009; Ștefănuț et al., 2017; Brevik et al., 2020; Verma, 2021). Urban biodiversity is a crucial component of the urban system and have great ecological and cultural importance (Onete, 2008; Onete & Ion, 2008; Onete & Manu, 2013). Currently, nature conservation is not one of the priorities of the urban environment. Many areas that should be preserved are sold to the private sector for the development of residential complexes, hotels and shopping centres (Onete & Paucă-Comănescu, 2011).
The solution for all these problems is called remediation. This term refers to the way in which a problem can be solved, and when it is related to the environment, it is called bioremediation (Lynch & Moffat, 2005; Khan & Desai, 2010; Hussain et al., 2021; Verma, 2021). Researchers are concerned with identifying several bioremediation methods, because there is obviously no generally valid method applicable to any polluted environment (Verma, 2021). Bioremediation is influenced by environmental conditions and has the role of reducing or eliminating contamination (Lynch & Moffat, 2005; George et al., 2017; Verma, 2021). It is efficient and does not require high costs (Dotaniya et al., 2018; Urbaniak & Mierzejewska, 2019; Igun et al., 2019). Moreover, it has a low negative impact on the physical and chemical properties of the soil (Foght et al., 2001; Wolejko et al., 2016; Williams & Amaechi, 2017). The purpose of this paper was to identify the remediation methods (techniques) of polluted urban soil existing so far and what is their specificity.

MATERIALS AND METHODS

Out of the total articles (134), have been chosen for the present paper only those that detailed urban soil remediation methods (96). We used search engines Web of Science and Google Scholar following the keywords: urban soils, remediation methods, pollution, remediation. The information was extracted and introduces in a database for further studies.

RESULTS AND DISCUSSIONS

In the literature, two main approaches have been differentiated in terms of remediation: an approach based on external methods of soil restoration (engineering approach) and one involving the manipulation of processes inside the soil for immobilization, transformation and degradation of pollutants (fertilization with organic amendments, revegetation, etc.) (Haimi, 2000). In order to restore an ecosystem, it must be taken into account that it is characterized by multiple trophic interactions, the properties of the soil, fauna and vegetation being interdependent and closely correlated (Civeira & Lavado, 2008; Manu et al., 2019).

Depending on the organisms or complex substances used in the remedy, the methods may be multiple, as it is specified bellow.

Micro-remediation

Micro-remediation is the phenomenon by which microorganisms that have the ability to degrade pollutants return the soil to the natural circuit (Borozan et al., 2021).

Microorganisms are responsible for the degradation processes of pollutants, a method based on an ecological approach.

Microbial populations are key to maintaining soil quality by mediating the processes of organic matter transformation and nutrient cycle (Izquierdo et al., 2005; Abdulsalam et al., 2012).

According with different types of pollution, researchers used species or groups of species for micro-remediation (Table 1).

Table 1. Species used for micro-remedial remediation

Species used	Type of pollution/ problem	References
Bacteria	Oil contamination	Abdulsalam et al., 2012
Pseudomonas sp., *Arthrobacter* sp., *Alcaligenes* sp., *Corynebacterium* sp.	Polycyclic Aromatic Hydrocarbons	D'Souza et al., 2015
Pseudomonas sp., *Alcanivorax* sp., *Microbulbifer* sp., *Sphingomonas* sp., *Micrococcus* sp., *Cellulomonas* sp., *Dietzia* sp., *Gordonia* sp., *Marinobacter* sp., *Mycobacterium* sp., *Haemophilus* sp., *Rhodococcus* sp., *Paenibacillus* sp., *Bacillus* sp., *Aeromonas* sp., *Burkholderia* sp., *Xanthomonas* sp. *Micrococcus* sp., *Arthrobacter* sp., *Acinetobacter* sp., *Corynebacterium* sp., *Enterobacter* sp.	Polycyclic Aromatic Hydrocarbons	Alegbeleye et al., 2017
Bacillus subtilis, Candida bombicola, Pseudomonas aeruginosa, Arthrobacter sp.	Oil contamination	Zhang et al., 2020
Pseudomonas sp., *Enterobacter* sp., *Streptomyces* sp., *Rhodococcus* sp., *Amycolatopsis* sp., *Escherichia* sp., *Bacillus* sp., *Micrococcus* sp.	Cu, Zn, Fe	Borozan et al., 2021
Pseudomonas fluorescence, Bacillus sublitis (Bacillus licheniformis, Bacillus circulans, Bacillus megaterium)	Oil-Contaminated Soil	Muthukumar et al., 2021

Phytoremediation

This method defines the bioremediation of contaminated air, soil and water using plants (Table 2) (Lee et al., 2021; Zalesny et al., 2021), based on the role of vegetation to take over and degrade contaminants or reduce their movement (phytostabilization) (Lynch & Moffat, 2005). The used plant species must be tolerant to heavy metals in order to be involved in phytostabilization actions, also known as in situ inactivation or phytoimmobilization (Neagoe et al., 2014). Plants are used to immobilize and physically stabilize contaminants in soil and groundwater by absorbtion at the roots and accumulation by the roots or precipitation in the rhizosphere. Reduces the bioavailability of heavy metals in the soil (Dabrowska et al., 2021). Phytoremediation is a promising method: does not harm the environment, is cost-effective and affordable, easy to implement and maintain, does not depend on artificial energy inputs, socially accepted, minimally invasive and sustainable. This is accomplished through several steps: degradation, transformation, extraction, and immobilization (D'Souza et al., 2015; George et al., 2017; Zalesny et al., 2021). It is a complex techniques that comprise several methods: phytoextraction (use plants to extract and remove heavy metals from the soil), phytovolatilization (plants absorb organic and inorganic pollutants from soil or water and volatilize them into the atmosphere in a modified or unchanged form at relatively low concentrations), phytofiltration (hydroponic plant cultures are used to absorb and adsorb heavy metal ions from groundwater), phytodegradation (organic compounds are degraded by the enzymatic activity of plants), rhizofiltration (plants are used to remove contaminants from the solution around the root zone) (Su et al., 2014; Gupta et al., 2016; Wolejko et al., 2016; Damasi et al., 2018; Padoan et al., 2020; Verma, 2021; Zalesny et al., 2021).

Phytoremediation has generated significant variations in soil chemistry. Compounds released by plants dissolve toxic substances (heavy metals) resulting in increased absorption of chemicals from the soil, thus decreasing their concentration in the soil. Different species are used singular or in combination (Table 2).

Table 2. Species used for phytoremediation remediation

Species used	Type of pollution/problem	References
Casuarina equisetifolia, Anacardium occidentale	Heavy metals	Izquierdo et al., 2005
Festuca arundinacea, Lolium perenne	Cd, Cr, Cu, Ni, Pb, Zn	Civeira & Lavado, 2008
Agrostemma githago, Trifolium pratense	Derelict and neglected site conditions (e.g. low fertility)	Hartley et al., 2008
Brassica juncea	Cr, Ni, Pb, U, Zn, Cu	Indelicato, 2014
Brassica napus, Eichhoria crassipes, Hydrilla verticillata	Cr, Pb, Hg	Indelicato, 2014
Cocos nucifera , Zea mays, Helianthus annus	Cs, U	Indelicato, 2014
Salix viminalis, Cynodon dactylon	Polycyclic Aromatic Hydrocarbons	Indelicato, 2014
Cistus salvifolius, Aster sp., *Hypericum perforatum, Achillea millefolium, Allium schoenoprasum*	Pb, Cd, Zn	Indelicato, 2014
Cruciferae, Brassica sp., *Alyssums* sp., *Thlaspi* sp.	Heavy metals	Su et al., 2014
Cymbopogon jwarancusa, Helianthus annuus	Polycyclic Aromatic Hydrocarbons	D'Souza et al., 2015
Hibiscus cannabinus	Heavy metals	Taiwo et al., 2015
Brassica juncea, Helianthus annuus	Co, Cr, Cu, Ni, Pb, Zn	Damasi et al., 2018
three Populus clones, three Salix hybrids, and three Robinia genotypes	Zn	Padoan et al., 2020
Agrostis capillaris	Heavy metals	Neagoe et al., 2014

Phytobial remediation

This method of remediation combines remedial techniques using plants and their associated microorganisms. Cultivated plants are colonized by symbiotic microorganisms that degrade pollutants, helping plants to use them in the photosynthetic process (Lynch & Moffat, 2005).

Zooremediation

This remedial technique uses different animal species to remedy a polluted area (Hankard et al., 2005; Kardousha, 2007; Dada et al., 2015). The direct effect of zooremediation is absorption, accumulation and transformation of pollutants. The main indirect effect of zooremediation is the stimulation of the microbial population due to the release of nutrients, enzymes and some metabolites (Gudimov, 2002). Invertebrate species can be used as indicators of the status of polluted areas both before and after bioremediation (Izquierdo et al., 2005; Manu et al., 2021). Animal species used for this purpose include invertebrates (acarina, collembola, maggots, earthworms) (Hankard et al., 2005; Santorufo et al., 2012; Su et al., 2014), fish, oysters, shells, polychaetes, sponges and earthworms (Dada et al., 2015). They can help to remove a wide range of organic and inorganic contaminants, such as pesticides, polycyclic aromatic hydrocarbons, crude oil, and heavy metals from the soil (Dada et al., 2015; Jóźwiak et al., 2019).

Many methods of assessing the toxicity of an area use only the survival of the species of interest as an indicator, but other parameters are also important, such as: growth, reproduction, structure of the invertebrates communities in that area, etc. (Haimi, 2000). There are multiple methods of zooremediation: zooextraction (species that have the ability to extract and accumulate pollutants in their tissues) (George et al., 2017), zoostabilization (invertebrates in the soil and on its surface can stop the migration of pollutants by accumulating them in their own cells), zoodegradation (toxic substances are degraded by the used species) (Kardousha, 2007; Jóźwiak et al., 2019).

Mycoremediation

This method of bioremediation is performed by fungi by manipulating the rhizosphere (Damodaran et al., 2011; D'Souza et al., 2015) for eliminating contaminants, including heavy metals (Dada et al., 2015) (Table 3).

Contaminated soils which are poor in nutrients can be enriched by inoculating the substrate with mycorrhizal fungi (Constantinescu et al., 2019).

Table 3. Species used for mycoremediation remediation

Species used	**Type of pollution/problem**	**References**
Saccharomyces cerevisiae	Cd, Pb	Damodaran et al., 2011
Arbuscular mycorrhizal fungi (AMF)	Heavy metals	Neagoe et al., 2014
Gomus intraradices	Cr	Su et al., 2014
Aspergillus ochraceus, Cunninghamella elegans, Phanerochaete chrysosporium	Polycyclic Aromatic Hydrocarbons	D'Souza et al., 2015
Arbuscular mycorrhizal fungi	Co, Cr, Cu, Ni, Pb, Zn	Damasi et al., 2018
Trichoderma sp., *Aspergillus* sp., *Mucor* sp., *Rhizopus* sp., *Pleuritus* sp., *Penicillium* sp.	Heavy metals	Borozan et al., 2021

Phycoremediation

Defined as the use of algae for waste or wastewater treatment (Phang et al., 2015; George et al., 2017). To remove heavy metals from the environment, Borozan et al. (2021) used several species (*Asparagopsis* sp., *Codium* sp., *Padina* sp., *Cystoseira* sp.).

Use of compost

Compost is a natural agricultural fertilizer, obtained by the slow fermentation of various plant and animal waste, mixed with some mineral substances (food waste, sawdust, banana peels, rice, coconut); these are also called biostimulators (Nwogu et al., 2015; Taiwo et al., 2015; Obrycki et al., 2017; Williams & Amaechi, 2017). For example, the compost can be obtained by mixing cattle manure with sawdust and some plant species in varying proportions. This mixture is allowed to decompose under aerobic conditions, it is periodically watered until its color is a dark brown, which means that it has turned into humus (Taiwo et al., 2015).

It is a source of nutrients that improve soil aeration and make it more fertile, having the role of biostimulation (Muthukumar et al., 2021). Compost can increase the water retention capacity in the soil, promote aeration and increase soil conservation (Gupta et al., 2016; Taiwo et al., 2016; Verma, 2021). Compost is a method of remedying nutrient-poor urban soil. The concentration of nutrients needed by the plants in the soil can be increased by introducing compost into the soil. The purpose of composting is to increase the activity of microorganisms (providing nutrients) that play a role in degrading contaminants, but also for soil fertilization (Obrycki et al., 2017; Constantinescu et al., 2019; Kranz et al., 2020; Muthukumar et al., 2021).

There are studies using vermicompost. This involves the joint action of earthworms and microorganisms. Vermicompost is a peat-like material with excellent structure, porosity, aeration, drainage and moisture retention capacity. It has special properties for usage in agricultural, pharmaceutical, cosmetic, food and energy industries (Chaudhary et al., 2004; Sanchez-Hernandez and Domínguez, 2017; Mills et al., 2020).

Animal waste

A very common method uses of manure for soil remediation. The manure might be provided by sheep, pigs, cattle, goats, birds and is an important source of nutrients that enriches the soil with organic matter (Arifin et al., 2006; Gupta et al., 2016; Masarirambi et al., 2012).

The method comes from agriculture and uses manure from cattle as a biofertilizer (Gupta et al., 2016). It contains cellulose, protein, hemicellulose and minerals such as nitrogen, potassium, magnesium, calcium, sulphur and also microbial communities, fungi, protozoa, yeast. Goat manure is a stimulant of bacterial activity and helps reduce the amount of hydrocarbons in the soil (Nwogu et al., 2015; Williams & Amaechi, 2017; Muthukumar et al., 2021).

The location of remediation techniques

Depending on the location of the polluted site, remediation techniques can be performed both ex-situ and in-situ (Gillespie & Philp, 2013; Zhang et al., 2020; Verma, 2021). Ex-situ remediation techniques can be: suspension phase (the soil is combined with water in a large reactor and homogenized to make contact between microorganisms and contaminants), solid phase (humidity, temperature, nutrients and oxygen are controlled to increase the rate of degradation), biocells (accumulation of contaminated soil in piles and stimulation of microbial activity by aeration or by the addition of nutrients, minerals or moisture) (Khan & Desai, 2010; Abdulsalam et al., 2012; Indelicato, 2014). In situ remediation is performed at the site of contamination by several methods: bio-venting (it uses microorganisms to degrade the organic constituents adsorbed on the soil), bioslurping (use of improved vacuum dehydration technologies to remedy areas contaminated with hydrocarbons), biosparging (technology that uses native microorganisms to biodegrade saturated organic constituents. Oxygen and nutrients are injected into the saturated zone to increase the biological activity of native microorganisms), bioaugmentation (the practice of adding microorganisms from underground cultivation in order to biodegrade certain soil and groundwater contaminants) (Khan & Desai, 2010; Díaz-Sanz, 2015; Wolejko et al., 2016; Urbaniak & Mierzejewska, 2019; Igun et al., 2019; Muthukumar et al., 2021).

Urban management activities

Soil management in urban areas should aim to reduce the concentration of pollutants and ensure that the physical, chemical and biological properties of the soil allow it to function properly (Obrycki et al., 2017). From a managerial point of view, soil remediation can be done in two ways: natural remediation, when it is taken an action, nothing is added in the soil, and through various monitoring activities, researchers/managers make sure that the disappearance of contaminants is due to present soil organisms and not due to contaminant dilution or migration (Dabrowska et al., 2012; Díaz-Sanz, 2015; Wolejko et al., 2016); remediation throw engineering activities - with different degrees of interventions/effective actions (the soil is excavated, treated directly in containers built in a controlled environment and returned to the polluted area) (Litchfield, 2005).

CONCLUSIONS

At present, there is relatively little information on the impact of human activities on organisms in urban soils. Soil studies, too long neglected in urban planning programs, should be seen as an indispensable part of management. The ecology of communities of microorganisms, algae, fungi, invertebrates in urban systems is not sufficiently studied despite their importance for human health. Soil invertebrates are useful indicators of human activity affecting soil in urban areas.

They have a regulating role on the soil trophic network and have effects on soil pedogenesis.

Remediation of urban soils can sometimes be costly, which is why remediation techniques are adopted that are cost-effective. The city and nature are treated as elements in antithesis. Soil management in urban areas is a foreign concept, which is rarely addressed in cities. Many remediation techniques are expensive and if not properly managed can lead to several disadvantages. The issue of urban soil pollution is of particular importance to cities and to people's health.

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TRENDS OF SIGNIFICANT VARIABILITY OF CLIMATE CHANGE IN THE VILLAGE OF NEGREA IN THE LAST 120 YEARS

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Abstract

Climate change has a profound impact on the availability of resources and agricultural activities. Over the past decade, the country has experienced a number of extreme events, such as droughts and major floods, along with incremental effects caused by rising average temperatures and uneven rainfall throughout the year, which has had a negative impact on the country's economy. Welfare and health of the population. National and international investments in climate observation, research and modelling over the last decades have led to considerable progress in experimental and applied climate predictions and projections. The systematic application of existing climate knowledge in practical solutions requires a review of the way in which climate research is conducted. The main purpose of the investigations carried out in the village of Negrea, is to highlight the climatic oscillations that influence the soil production capacity. The pedological researches in order to assess the change in the characteristics of the arable layer of the researched soil were carried out from 2013 to 2021. Agrometeorological observations from the last 120 offered the possibility to systematize the influence of climate change on the study region. The string of researched data is of particular importance for highlighting and evaluating the real amplification of multiannual climate change. In this regard, improving methods of analysis and forecasting of agroclimatic processes and resources, meteorological parameters and crop yields, taking into account climate change, is currently an urgent scientific issue. In order to adapt agricultural production to climate change, it is necessary to comprehensively study the nature and trends of changes in meteorological parameters, their impact on the growing season and crop yields.

Key words: *agroecosystem function, analyse agrometeorological parameters, inadequate anthropogenic activity, soil.*

INTRODUCTION

The territory of the Republic of Moldova falls within the area with insufficient humidity. The climate is mostly semi-arid, the aridity index being between 0.4-0.5. It is reported that, lately, the frequency of strong and very strong droughts has increased, the consequence of which is the substantial reduction or compromise of agricultural production (Senic et al., 2021).

Although little time has passed since the beginning of the 21st century, average temperatures have risen slightly during this period. The average temperature in Moldova has risen by about 0.6°C in the last 50 years, and by the middle of this century, it will increase by one degree. This will have two important consequences. First - winters will be shorter and probably less severe in all parts of the country, and summers will be very warm and longer. According to the records of the Meteorological Directorate of the Republic of Moldova, 2007 and 2020 was the warmest years in the country's history (with + 2.0-2.5°C above the norm), the temperature reaching on July 21, 2007 and on July 27, 2020 at +41.5-42.8°C in Camenca. The summer was also the warmest, with + 2.5-4.0°C above the norm. In 2007 and 2020 the country faced the worst droughts, when for five days the temperature exceeded +40°C (Agrometeorological Monitoring Direction).

Second - the characteristics of the weather will vary between north and south. The frequency of extremely rainy days has increased in the north and decreased in the south. A clear distinction of about 27% of rainfall between the northern and southern agro-economic zones, or between the northern and southern districts, has existed over the last 8 decades. As the north gets rainier, the south gets drier. Abnormal rainfall was recorded throughout the country and in the period 1940-2011. Although there has been an upward trend of up to 66 mm in the amount of rainfall since the end of the 19th

century and until today, this increase has not been uniform. The number of days with heavy rainfall (> 20 mm of rainfall per day) increased by 23% in the north and decreased by 4.6% in the south. This reveals an intensification of irregular rainfall in the northern regions, with increased chances of flooding and a slow desertification of the southern regions. If we analyse the data on very heavy rainfall (> 50 mm of rainfall per day), the difference becomes more obvious: in the North there was an increase of 42% compared to a decrease of 9% in the South. In other words, the North-South division continues in the case of rainfall. From an economic point of view, economic losses due to drought situations were the worst phenomenon causing more than 65% of total losses caused by disasters (Agrometeorological Monitoring Direction).

The biggest contribution to the increase in the average annual air temperature was introduced by the winter season. According to the secular variation, the average air temperature for the winter season increased by 1.5°C compared to the end of the 19th century. By analogy with the global air temperature, in the Republic of Moldova the average air temperatures for pentad (2016-2020) and decade (2011-2020) were the highest in the entire period of observations. Since 1990, each decade has been warmer than the previous one. Also, the last 60 years of observations indicate an increase in the number of days with heavy rainfall and heavy rainfall. Compared to the mid-1970^{s}, their number increased by 2 to 3 days. In the Republic of Moldova, 2020 was characterized by a high thermal regime and significant insufficient rainfall during the growing season. The average annual air temperature in the territory was +10.7 ... +13.1ºC, exceeding the norm by 2.6-3.7ºC and is reported for the first time in the entire period of observations. According to the Chisinau meteorological station (observation period 126 years) the average annual air temperature was +12.7ºC (3.2°C higher than the norm) and ranked 1st in the number of years with high average annual temperatures (www.meteo.md).

Strong and irregular meteorological phenomena, which will lead to intensified soil erosion, flooding and groundwater depletion (Andries et al., 2004; Constantinov et al., 2003).

A disproportionate reduction in agricultural land (which has fallen by 3% in the last 15 years) and the dependent population (which has fallen by 12% over the same period) is visible as a result of different national policies and geoclimatic factors. The level of stress due to water availability and use problems is expected to increase in the coming decades, especially in the central and southern districts of Moldova (Puthumai, 2017).

Assessment studies of the impacts of climate change on agriculture at farm to regional levels need to analyze complex interactions of climate, agro-ecosystem function, and human management. To this end, researchers typically link climate predictions to crop models and land management decision tools. For instance, Decision Support System for Agrotechnology Transfer (DSSAT), Erosion Product Impact Calculator (EPIC), Terrestrial Ecosystem Model (TEM), and the AEZ model have been used at the global scale (Oprea et al., 2014; Taranu, 2014).

The purpose of this paper is to highlight the most pressing issues for the village of Negrea, related to the ongoing climate change assessment, including inadequate anthropogenic activity, to determine the main directions of climate research in the researched territory needed to be used in preparing regional forecasts and economic and social development programs and proposals for improving soil in the event of climate change.

The analysis of data collected by the Hydrometeorological Service and other departments in the field of climate change study on the territory of the Republic of Moldova, made possible the practical use of climate information from Negrea village, Hincesti district to improve soil quality by properly applying agricultural works.

The way we use the land has a negative impact on the climate. In turn, climate change forces us to think differently about how we use it, making things worse. For example, a decrease in soil fertility forces us to create new fertilizers, new agricultural machinery, which squeezes all the juices from the soil and at the same time increases the volume of harmful emissions. Modern technologies force the soil to degrade a hundred times faster than it is able to regenerate. If humanity does not break this circle, a slip of the road to environmental disaster is inevitable. The price that humanity as a whole and individual countries pay is too high not to act or to take wrong or premature action because of climate change. Given this, we would like to hope that the concrete steps highlighted in the proposed materials will become a reality (Ungureanu et al., 2006).

MATERIALS AND METHODS

In the regions of the Republic of Moldova, agriculture is the most important economic development. The study object was chosen Negrea locality, located in the central physical-geographical province of the Republic of Moldova in the Codri area (Ursu, 2006). It is an ancient locality located in the Lăpușna river valley, a left tributary of the Prut. The main characteristics of climate change in the village of Negrea are presented in the results and discussion section.

The relevance of modern climate change studies is undoubtedly: an increase in the number of natural disasters is observed everywhere, the damage caused by floods, droughts and fires, which are a consequence of ongoing climate change, is increasing. The 2015 World Meteorological Organization (WMO) Statement on Global Climate Status notes that “one of the most effective tools for adapting to the effects of climate change is to strengthen early warning systems for disasters and climate services” (OMO, 2016). In this regard, the study of regional manifestations of climate change in mountainous areas is of particular importance, as it is able to detail the big picture.

To achieve this goal, agrometeorological data were taken and evaluated as a method of analyzing the dynamics of long-term meteorological parameters in the researched area.

The following methods were used: (1) Detailed documentary research of available documents on climate change (both trends and projections) related to Moldova and examination of reports on socio-economic vulnerabilities of the country; (2) Data analysis: included the examination of secondary data, primarily data from the National Bureau of Statistics, Agrometeorological Monitoring Direction and other directions to understand trends and situations of climate change.

The research is based on the materials of long-term meteorological observations for the period 1901-2020 (total precipitation, monthly, annual precipitation, average air temperature, maximum air temperature, minimum soil temperature, average relative humidity, air humidity deficit) according to data from 6 meteorological stations in Central and Southern Moldova. The following research methods were used: statistics, standardized range, deviations from the climate norm and moving averages with a period of N = 120 for the analysis of the dynamics of meteorological parameters.

The information system is the main mechanism by which climate information - past, present or future - is archived, analysed, modelled, shared and processed. It produces and provides authorized climate information products through operational mechanisms, technical standards, communication and authentication. Its responsibilities include analysis and monitoring, evaluation and allocation, climate predictions (monthly, seasonal, decade) and climate projections (centennial scale). Mathematical software was used - MS Excel, Statistics, Matlab and ArcGIS software.

It was found that, in the winter months, the cooling of the air at the surface of the soil in the researched area, is associated with the predominance of anticyclones, the leakage of cold air from the slopes and its stagnation. In the warm period, with the restoration of the western transfer of air masses, a barrier effect appears, and on the slopes under the action of the wind, the clouds are scattered, so little precipitation falls, just like in winter. In the valleys, the air is warming, the clouds are also scattered, and the number of solar hours is increasing (Cojocaru, 2020).

The radiation regime is characterized by significant fluctuations in the duration of insolation and the amount of solar energy that falls on the soil surface. Also, a change in the transit of solar radiation affects the change in air temperature, melting snow, vegetation, soil, seasons of natural phenomena. For each season 1901-2020, the statistics of the surveyed area were estimated on a sample of <90 days (taking into account the gaps that are different for different variables) for each of the 4 variables: T_{med}, T_{min}, T_{max} - average daily temperature, minimum and maximum, ΣP - daily amount of precipitation. The dynamics of climate change have been studied on the basis of long-term meteorological information (120 years: 1901-2020).

For a correct analysis of the temporal distribution of the main meteorological indicators on the territory of Negrea locality, monthly observation data from the operational observation unit of the State Hydrometeorological Service were used, official data from the archive.

The methods of conducting pedological research in the field and analysis used to determine the chemical characteristics of soils are those standardized nationally. The pedological researches in the field were carried out according to the unique system of classification and reclamation of soils, adopted by the Government of the Republic of Moldova by Decision no. 24 of January 11, 1995 as a normative document for the elaboration of the land cadastre and perfected in 1997.

The necessary analyzes for the diagnosis of soil taxonomic units were performed in soil samples collected from all profiles located in the field during the research period: to determine the texture, structure; humus content; carbonate content; pH values; hygroscopicity, density, bulk density, porosity, etc.

The agricultural lands in the Negrea river basin occupy over 600 hectares, of which 90% are located on a slope. As a result of the field monitoring of the leaks following the torrential rains, it was established that the rainwater that did not infiltrate drains on the surface of the sloping agricultural lands and causes soil erosion. As a result of this negative process, on the water concentration lines in micro-depressions, soil washes were formed by streams, directed from the hill to the valley to the foot of the slope. The losses amounted to tens of tons of fertile soil. Deep erosion has led to the formation on the ground of a network of ditches (elongated micro-depressions) with different lengths, from 200-300 m to 600-700 m. The direction of water flow depended on the direction of agricultural works. This fact greatly influenced the intensity of soil erosion on the lands of the Negrea hydrographic basin.

RESULTS AND DISCUSSIONS

The article presents the results of climate monitoring in the village of Negrea, Hincesti district for the period 1901-2020, carried out regularly. The village of Negrea is located in Central Moldova in the middle of the Lăpuşniţa river basin. The approximate distance from the village of Negrea to the main cities is as follows: Hancesti - 23 km, Chisinau - 60 km. The researched fields are located on the territory of two parallel elongated peaks, located northwest of the village. Between the peaks is a valley sloping towards the meadow of the river Lăpuşna, passing towards the river through the southern part of the village. The calculations of the annual air temperature in the calendar frame of the researched area, made it possible to establish a significant positive linear trend (Cojocaru, 2016). Thus, according to the monitoring of the data from the meteorological stations in the Center of Moldova, the increase of the average annual air temperature over a period of 120 years (1901-2020), based on linear trends, was 3°C (Figure 1) at a long-term medium.

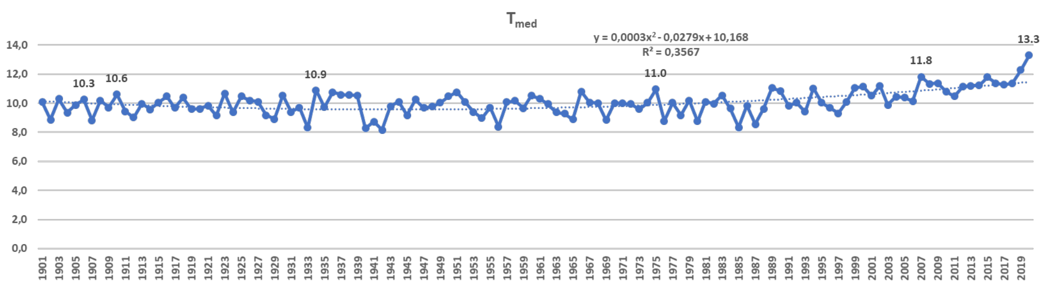

Figure 1. The values of the average annual air temperature (^{0}C) for the years 1901-2020

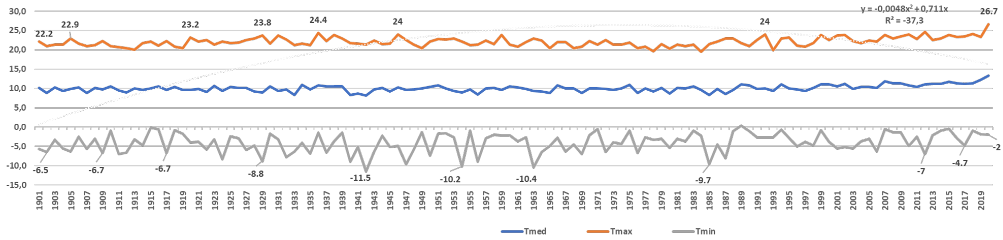

Figure 2. The values of the variation of the average, maximum and minimum air temperatures (^{0}C) during the years 1901-2020

We note that for 120 years the air temperature in the summer season often exceeds 23°C. In winter the snow cover is very thin and usually lasts only two months, the temperature drops below minus 12°C. Substantial temperature deviations occur in both summer and winter, which leads to various natural disasters such as drought and frost, but also to mass illness among the population. Summers are long and hot with average temperatures above 20°C, often tropical air masses bring temperatures of +30 ... + 35°C. Winters are poor in rainfall and in January the average temperature is around -5° C. Absolute minimum: -11.5°C, absolute maximum: 26.7°C (Figure 2).

Since 1938 there has been a "warm-up break". This period is characterized by a relatively stable average temperature, which is occasionally accompanied by sharp explosions of heating. However, deviations from the temperature in the annual average indicators do not reflect the full dynamics of the thermal regime during the annual cycle.

As can be seen from Figure 1, the tendency to change the average annual air temperature before the 90^{s} of the twentieth century was quite small (0.05°C per decade or ~ 0.5°C per century). Since the 90's of the twentieth century this index has a sudden evolution towards growth (approximately 0.63°C per decade or ~ 6.3°C per century).

The average air temperature during the winter is in the territory of Negrea village between 0.9ºC and -3.4ºC. The coldest month of winter is January, the average monthly temperature is 0.1 ... -5.5ºC. The coldest was the winter of 1942 and 1954, when the average air temperature was -7 ... -9.5ºC, being 6-7ºC below the norm. The warmest was the winter of 2019-2020, when the average air temperature was +1.2 … +2.7ºC, exceeding the norm by 4.5-5.5ºC. During the entire period of instrumental observations, the lowest air temperature in the winter season was reported in January 1942 was -11.5ºC (Negrea village), and the highest - in February 1990 was + 23.3ºC. The instability of the thermal regime in the winter season is one of the most specific features of the climate of the Republic of Moldova.

Rainfall is rare, most of it falling during storms accompanied by hail and lightning.

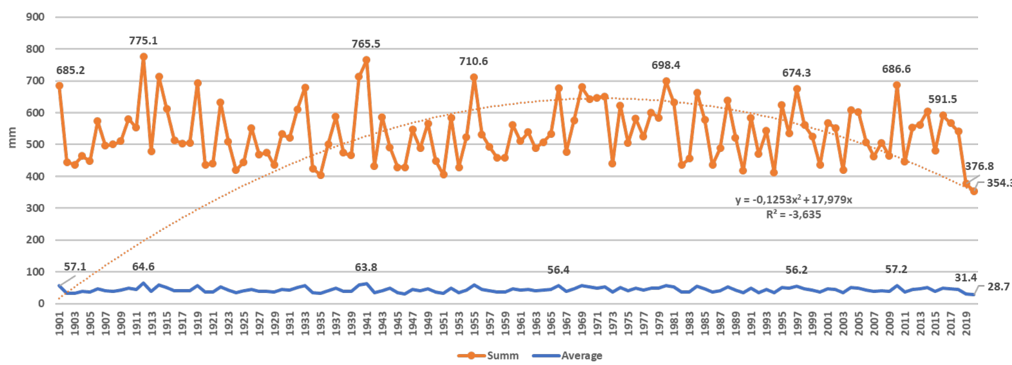

Figure 3. The values of the sum of the amount of annual atmospheric precipitation (mm) for the period 1901-2020

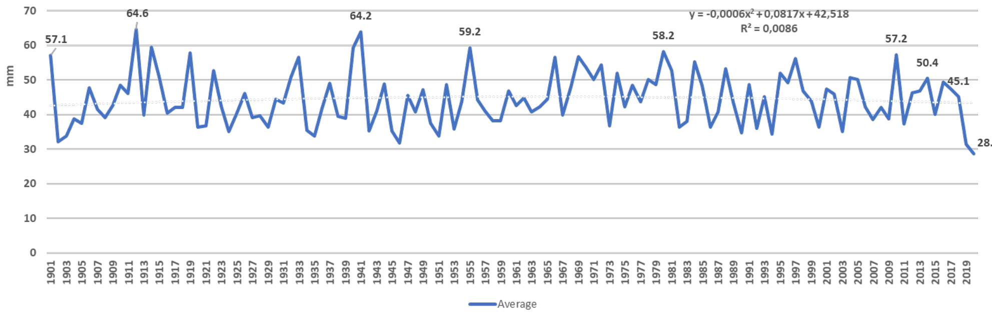

Figure 4. Values of the amount of average monthly atmospheric precipitation (mm) for the period 1901-2020

Droughts are very common. The first part of autumn is similar to summer, in the second part of autumn the temperatures start to decrease and the rains become more frequent.

The area of the village of Negrea is located in the region of interference of the Atlantic, continental air masses from Eastern Europe and the tropical ones from the south. Solar radiation, air mass dynamics and relief form a climate with relatively mild winters and little snow, with long, hot summers and low humidity. In summer, the heat causes the water from the wells to dry up in the high-altitude areas, and in August, torrential rains fall, causing the rivers and streams to overflow. The amount of rainfall varies drastically, droughts are frequent, but the average annual rainfall is around 500 mm. About 2/3 of the rainfall falls between April and September. During the winter season, the precipitation falls mainly in the mixed phase - in the form of rain and snow. The annual amount of their atmospheric precipitation is 350-770 mm or 16-20% of the average annual amount (Figures 3 and 4). At the same time, the variation of the precipitation quantities is observed, which in the last years start to decrease and are rarer having a monthly maximum that reached values of 142 mm (in 1901); 158 mm (in 1948); 185 mm (in 1985); 131 mm (in 2011); 108 mm (in 2018); 63 mm (in 2019) and 37 mm (in 2020).

As a result of the climate change that is generated by the increasing impact of the human activities of the locals, which causes more and more frequent and destructive natural dangers throughout the territory, other disasters can be caused. The full impact of climate change in the village of Negrea is unpredictable, with many long-term variations and fluctuations, including extreme weather in the form of droughts, heavy rainfall, heat waves and rising temperatures.

In this context, it was observed that droughts are becoming more frequent in the village of Negrea. Droughts were recorded in 2007, 2012 and 2020, which caused damage to agriculture, leading to impoverishment. Such a risk was also in the summer of 2013, 2015 and, but which did not have a great destructive impact on agricultural crops. Droughts lead to soil degradation, which poses a major threat to the sustainability of land resources and can reduce the ability of Negrea village agriculture to successfully adapt to climate change.

Floods are also a risk factor for the population of Negrea village. The frequency of heavy rainfall has increased in recent years and floods are a common danger in the locality, leading to soil erosion (essential area research conducted since 2012) and loss of crops in rainy seasons.

The negative aspect of the climate is drought, the frequency of which is 2-3 times in ten years and the torrential nature of precipitation. During the summer, heavy rains of low intensity fall, which moisten the soil well and do not cause appreciable erosion, but predominate torrential rains of high intensity ("erosion"). The latter are usually accompanied by hail storms. Over the course of 24 hours, it can fall over 50-100 mm. These precipitations are particularly dangerous from an erosion point of view. Torrential rains cause considerable water runoff from the slopes, causing surface and deep soil erosion. In order to minimize the erosive effect of runoff, it is necessary, first of all, to strictly observe the whole complex of soil erosion protection measures.

The materials of the periodic pedological researches of the lands with agricultural destination of the republic form the database for the elaboration of the spatial erosion monitoring. Soils are rightly considered the most valuable natural resources, which have always ensured the existence and well-being of our nation. The irrational use of agrotechnical and chemical methods of agricultural land processing in recent times has resulted in massive degradation of these resources. Erosion processes have increased (Cojocaru, 2016), which has considerably reduced the natural fertility of the researched soils. Productivity of eroded soils decreases as follows: poorly eroded - by 20 percent; moderately eroded - by 40 percent; heavily eroded - by 50 percent; very heavily eroded - by 70 percent; completely eroded - by 90 percent. The presence of large areas with poorly eroded soils testifies to the high potential for intensifying the erosion process on agricultural land. The damage done to the national economy by soil erosion is colossal. The weighted average annual crop losses on eroded land are: on arable land - 27 percent; on lands with fruit plantations - 30 percent; on pastures - 37 percent. Ordinary chernozems occupy an area of 548.4 thousand ha of the total area of the Republic of Moldova. This subtype of soil is widespread in most districts of the republic, predominates in the center (high river terraces) and southern Moldova (Southern Moldavian Plain). It is characterized by a lower humus content, often with the presence of carbonates in the arable layer. Slightly alkaline soil reaction. Stability to erosion processes due to the coarser particle size composition (loamy and loamy-sandy soils occupy up to 40% of the surface, and loamy-clayey - almost 60%) is lower than for other chernozem subtypes.

Landslides on the slopes are a source of water pollution in the village. Reducing soil erosion is possible by using the alternative strip farming method for slope-based agrosystems. The massive use of anti-ecological agrotechniques, especially the application of mineral fertilizers and pesticides during the Soviet period, has had a destructive and harmful long-lasting impact on the soils of the village of Negrea. The socio-economic crisis, which marked the last decade of the last century and which still persists today, has spread far and wide over the ecological management of agricultural land. Although the use of chemical fertilizers and pesticides on heavy agricultural machinery has been substantially reduced, the overall impact on agricultural land and soils is very high. Dehumidification processes, cultivation of the same crops for many years in a row, burning of agricultural waste, unsatisfactory sanitary indices have led to soil degradation. The reduction of humus content and the mechanical processing of arable land have contributed to the deterioration of the soil texture, the compaction of the arable land and the reduction of agricultural productivity.

Excessive migration of the able-bodied population, the aging of the commune's population has generated the phenomenon of enlarging the watering areas. The causes of the intensification of soil degradation processes are: fragmentation of agricultural land in the process of peasant ownership, which excluded from the beginning the possibility of sustainable agriculture, based on modern technologies of tillage and conservation, allocation of arable land, perpendicular to level, insufficient information of the beneficiaries about the agrotechnical and hydrotechnical methods of erosion prevention, the massive negligence of the local population; the lack of an economic motivation necessary to prevent and reduce the destructive impact on the soils, the existing contradictions between the provisions of the different normative-legislative acts in the field.

We state that agriculture is the main form of activity in the locality. Here, the agricultural sector has developed unevenly due to several causes: unfavorable weather conditions (drought, frost), agricultural land degraded due to lack of financial resources of the owners or their inability to be processed, difficulties in achieving increased agricultural production.

Most agricultural land is privately owned with an equivalent share of land. The indicators show that most people work the land without being specialists in the field, using various chemicals that do not meet the requirements of tillage. Economic agents in possession of the given lands also work the land, hiring people who do not work conscientiously, do not work the land according to the rules, like real landlords.

In the researched area, agriculture is facing extreme weather events, which have resulted in a high variability of agricultural crops. Both extreme local weather events and climate variability are increasing as a result of global warming. Cereal crops and other crops may decline due to more frequent droughts. Even if the losses could be partially offset by the beneficial effects of carbon dioxide, crops would still continue to be threatened by the need for water, the presence of pests and diseases, and the loss of agricultural land through desertification.

The main anthropogenic factors of soil degradation, in addition to climate change, are the maximum entrainment of the plowed territory, the cutting of forest strips, agricultural work along the slope, incorrect location of the road network, insufficient protection of soils with vegetation, the exaggerated share of weeding crops in crops, compaction of soils with heavy mechanisms, non-compliance with anti-erosion agrotechnics. The agricultural activity, without taking into account the particularities of the soils, the relief, leads to the continuous decrease of the fertility of the lands and their degradation. The intensity of agricultural activities in different periods, for different uses differs in terms of quality and quantity and is very varied (Cojocaru, 2018).

To date, the technology of growing crops on slopes with different inclinations is slightly different from that used on horizontal land with uneroded soils. For example, the cultivation of land along the slope causes the loss, with surface runoff, of 20-30 percent of torrential rainfall. In case of 30 mm of precipitation falling from the slope soils, 90-150 m^3 of water per hectare are lost. The damage to the wheat crop is 1.5-2 q/ha.

The concentrated nature of the leaks also damages the sowing. Stream erosion covers 40-50 percent of the area of the demonstration fields. Leaks formed by heavy rainfall destroy the soil, exposing the root system of plants. The annual loss of fertile soil is tens of tons per hectare. As a result, the annual losses of nitrogen, phosphorus and potassium, caused by erosion, often exceed the amount of fertilizers incorporated. The soil removed from the slopes is deposited at their foot, in valleys, ponds and rivers (Cojocaru, 2018).

The complexity of the structure of the soil cover, the diversity of the destructive influence of the natural factors, the intensity of the anthropic activity determines the wide development of the processes of degradation and destruction of the lands of the fields. The main factors of agricultural land degradation are climate change and soil erosion by surface water and depth.

The eroded soils in the researched area differ from the not eroded ones, by decreasing the thickness of the humus profile and the humus content. According to the data obtained from previous research, soils of varying degrees of erosion on the territory of Negrea village are characterized by the following parameters of the thickness of the humus profile with humus content greater than one percent: not eroded - > 90 cm; poorly eroded - 70-90 cm; moderately eroded - 50-70 cm, strongly eroded - 30-50 cm. The humus content in the soils of different degree of erosion in the researched soils is the following: not eroded - about 3.0-3.3%; poorly eroded - 2.5-3.0% for clay-loam and mainly 2.0-2.5% for clay; moderately eroded - 2.0-2.5 for clay-loam; strongly eroded - 1.3-1.7% (Cojocaru, 2016).

Recommendations. At the level of agricultural holdings, some elements of adaptation to the effects are extremely important climate change: the use of multifunctional agricultural technologies; diversification of agricultural crops resistant to climate change; the correct anti-erosion and hydrological organization of the agricultural territory taking into account the suitability of the lands for different use; crop adaptation through the use of existing genetic diversity and new opportunities offered by bio-technology; better soil management by increasing water retention in order to maintain soil moisture; creation of rainwater catchment basins; the introduction of crop rotation, the reduction of the share of weeding crops; planting herbaceous plant species that prevent soil erosion; afforestation of lands at risk of erosion.

CONCLUSIONS

The unpredictability of meteorological phenomena: the time and place where the phenomena will take place is difficult to predict, because there are many anthropological and ecological factors that determine the extreme meteorological phenomena.

The village of Negrea is characterized by moderately warm conditions and a semi-temperate climate. Average annual temperature 9.0ºC; the sum of temperatures higher than 10º - 150 days; the average temperature of July - + 21.5ºC, of January - minus 6ºC; the average amount of annual precipitation is 472 mm, of which 362 mm fall during the warm period, the hydrothermal coefficient 0.58; duration of vegetation period 176 days.

Changes due to high temperatures could lead to early-onset disasters - such as hailstorms, heavy and uneven rainfall, and landslides on the slopes.

In the agricultural sector in the village of Negrea it is proposed to introduce new varieties of crops, some older ones could adapt to climate change or could disappear altogether. At the same time, the emergence of more agricultural land, due to the food security conditions of the population and the possible water deficit, as well as the temperatures that will continue to remain sometimes lower, sometimes higher on the upper plains of the river basin, could condition a certain level of migration of microorganisms outside the investigated area. Thus, it is possible to reduce the fertility and quality of agricultural land, by obtaining much lower agricultural production.

As a result of the observations for the period of 120 years, it was observed that in the village of Negrea droughts are becoming more frequent. Droughts were recorded in 1902, 1924, 1935, 1946, 1951, 1973, 1994, 2003, 2007, 2012 and 2020 (Figure 4), which caused damage to agriculture, which leads to impoverishment of the population. Such a risk was also in the summer of 2013, 2015 and, but which did not have a great destructive impact on agricultural crops.

The average air temperature during the winter is in the territory of Negrea village between 0.9ºC and -3.4ºC. The coldest month of winter is January, the average monthly temperature is 0.1 ... -5.5ºC. The coldest was the winter of 1942 and 1954, when the average air temperature was -7 ... -9.5ºC, being 6-7ºC below the norm. The warmest was the winter of 2019-2020, when the average air temperature was +1.2 ... +2.7 ºC, exceeding the norm by 4.5-5.5ºC. During the entire period of instrumental observations, the lowest air temperature in the winter season was reported in January 1942 was -11.5ºC, and the highest - in February 1990 was +23.3ºC (Figures 1-2).

For this reason, in order to cope with climate change, we need to use crop varieties that are better adapted and more resistant to high temperatures and drought. To the same end, it is important for farmers to be able to continue their work, by providing services in rural areas and providing assistance so that they can adapt their production methods. Changes in land use are expected, as well as changes in ecosystems and reduced biodiversity, which will affect the balance of the agricultural sector. In addition, climate uncertainty will affect the financial security of farmers and reduce confidence in agricultural activities. Small farmers are the most vulnerable to climate change because they find it more difficult to cope with economic and social difficulties. Moreover, problematic environmental conditions increase their vulnerability and reduce their ability to adapt to the effects of climate change.

It is unlikely that humanity will be able to completely prevent climate change. However, the international community is able to contain the rise in temperature to avoid irreversible consequences. Climate change is one of the main challenges today.

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EXPERIMENTAL ASPECTS REGARDING THE FEEDING BEHAVIOUR OF THE EARTHWORM SPECIES *Eisenia fetida* – QUICK TEST OF FOOD LOCATION AND SELECTION

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Abstract

This research aimed to study in a laboratory experiment some aspects regarding the feeding behaviour of the earthworm Eisenia fetida: food location and selection, time towards food, time to access food. The experiment has been carried out as a quick test: earthworm released and placed at 15 cm distance away from a food source consisting of two adjacent substrates in order to observe the ability to locate food and to select a certain substrate of the food source: soil and respectively, soil mixed with earthworm food commercially purchased. The results of this experiment showed that earthworms Eisenia fetida possess the ability to locate the organic food source used within the experiment. A proportion of 90% of tested earthworms were able to locate the food source, and 70% of earthworms were able to choose a specific food substrate from two available. A proportion of 30% of earthworms reached the food source in the first 1-2 minutes after exposure, 20% during 2-3 minutes, 30% after 4-5 minutes, and 10% after 6-7 minutes of exposure. The statistical interpretations of the achieved results (Chi-square Goodness-of-fit-test) showed that earthworms Eisenia fetida are able to rapidly identify the organic food sources and chose between food sources, and these are not random behaviours.

Key words: *earthworm, food location, food choice, food access, feeding behaviour.*

INTRODUCTION

The question how earthworms are able to locate and select their food in soil and what implications are these abilities was often asked (Bonkowski & Schaefer, 1997; Amoji et al., 1998; Bonkowski et al., 2000; Zaller & Saxler, 2007; Rief et al., 2012; Euteneuer et al., 2020) and it concerns all three ecological groups of earthworms: epigeic, endogeic, anecic. Due to its particularities of feeding, the epigeic group of earthworms has been questioned frequently: are or are not able these earthworms to locate their food in soil using structural features, like, for example, olfactive structures? Or the feeding behaviour is randomly manifested in soils? To find answers is important because the earthworms dominate the invertebrates in soils (Philips et al., 2021) and their role is extremely important in turning the organic matter back to simple inorganic, plant available, chemical elements, which means implications in soil fertility (Curry & Schmidt, 2007). All the major benefits of earthworms in soil fertility are strongly related to their digestive and locomotion behaviours, and this is the reason why this investigation about food location and selection on *Eisenia fetida* has been carried out. But, there are also other important aspects and implications of earthworms’ behaviour of food choice, for example the mechanism of heavy metal resistance which has been demonstrated to be expressed in earthworms through their ability to choose the food (Depta et al., 1999), or the foraging strategies which are based on food choice preferences among others (Zirbes et al., 2011), or ecotoxicological implications both in soil chemistry (Lowe & Butt, 2007; Butt et al., 2020) or in soil biota (Zirbes et al., 2011), and even ecological implications in vegetation distribution (Rajapaksha et al., 2013; Ashwood et al., 2017).
Although the behaviour of earthworms to locate and choose the food and to detect

chemical substances have been demonstrated in various experiments, remain uncertain the structural, physiological and behavioural mechanisms involved in these earthworm actions, and these represent future research directions aiming to detail the feeding ecology of earthworms.

MATERIALS AND METHODS

The experiment has been set up as a laboratory quick test in order to observe if the earthworms *Eisenia fetida* (Savigny, 1826) possess the immediate ability to find the food located at 15 cm distance away. This species has been choose because of its easily purchase and because aspects like food location and choice have been insufficiently studied in this species and generally insufficiently studied in earthworms. The experiment (Figure 1) used ten adult, clitellate earthworms, which were individually tested on a glass plate containing a moisturised (70%) source food made by two components, adjacent, placed together on the glass plate without any space or physical barrier between them: half of the food source was represented by ordinary plant cultivation soil, commercially purchased, and the other half consisted of mixture between this type of soil and specific earthworm food in 3:1 ratio, in order to detect the earthworms ability to find the food measured as time (minutes) spent from the start of the testing until earthworm is reaching the food, and also the earthworms ability to select one of the two adjacent substrates which made up the whole food source.

Figure 1. Aspect during the experimental test

The specific food for earthworms has been commercially purchased and it was based on dried plants of *Aspergillus,* with the following nutritional proportions: 12% proteins, 3% gross fat, 10% fibres, minimum 0,6 - maximum 1,4% calcium, minimum 0,4% phosphorus, minimum 0,1% salt, minimum 0,02 ppm selenium, minimum 25 ppm zinc, minimum 0,9 copper, minimum 9,50 I.U./kg vitamin E, minimum 1,1 I.U./kg vitamin A, minimum 0,11 I.U./kg vitamin D_3. Important to be mentioned is the specific smell of this food as compared with the other half of the food source.

The environmental temperature was 20°C. The moisture of the food substrates was 70%. The level of substrate humidity is an important factor in earthworms' locomotion, which also is strongly related to the nutrition function, both functions being important to be maintained in optimal conditions in our experiment. Based on these arguments, the glass plate was also humidified, to facilitate the earthworm movement according the physiological requirements of the species.

Each earthworm has been individually tested, orientated with the anterior (head) side towards food source. The distance between earthworm and food source was 15 cm. The achieved data has been statistically processed using Chi-square Goodness-of-fit-test, IBM SPSS Statistics 28.0.

The tests have been performed as rapid tests, meaning the release of the earthworm and its positioning on the glass board containing the food source, followed by an waiting time assigned to each worm to locate and reach the food.

RESULTS AND DISCUSSIONS

The main objective of the study was to establish if the earthworms *Eisenia fetida* are able to find a food source located at 15 cm distance away immediately after earthworm release by measuring two parameters: food location expressed as the number of earthworms able to move in the direction of the food source and measured as time (minutes) necessary to reach the food, and respectively the ability of food selection/choice expressed as the number of earthworms choosing one or another of the two available food substrates.

In Table 1 are shown the moving times towards food source of ten earthworms *Eisenia fetida,* individually tested.

A proportion of 90% of tested earthworms was able to identify the food source and 70% of earthworms have chosen the substrate containing special earthworm food. In Table 2 are listed the time measurements of food accession, categorised by time intervals achieved by earthworms starting with the beginning of the test and ending with the reach of the food source.

Regarding the food location ability, there was observed that 30% of earthworms have reached the food source within 1-2 minutes after exposure on the glass board, 20% during 2-3 minutes, 30% during 4-5 minutes, and 10% during 6-7 minutes (Figure 2).

Table 1. The moving times towards food source of earthworms *Eisenia fetida* counted from the test start until the food source is reached by earthworms

Tested earthworms *(Eisenia fetida)*	Moving time (minutes and seconds)	Action type: food source reached/failure		
		Soil with earthworm food	Soil without earthworm food	Failure, movement out of the test board
Eisenia fetida 1	1m15s	x		
Eisenia fetida 2	1m56s	x		
Eisenia fetida 3	2m10s	x		
Eisenia fetida 4	2m0s		x	
Eisenia fetida 5	0			x
Eisenia fetida 6	6m25s		x	
Eisenia fetida 7	2m20s	x		
Eisenia fetida 8	4m18s	x		
Eisenia fetida 9	4m58s	x		
Eisenia fetida 10	4m56s	x		

Table 2. Time intervals achieved by earthworms *Eisenia fetida* in reaching the food source

Tested earthworms *(Eisenia fetida)*	Moving time (minutes andseconds)	Type of the reached food substrate	Time interval
Eisenia fetida 1	1m15s	Soil with earthworm food	1-2 minutes
Eisenia fetida 2	1m56s	Soil with earthworm food	1-2 minutes
Eisenia fetida 3	2m10s	Soil with earthworm food	2-3 minutes
Eisenia fetida 4	2m0s	Soil without earthworm food	1-2 minutes
Eisenia fetida 5	0	Failure, movement out of the test board	0
Eisenia fetida 6	6m25s	Soil without earthworm food	6-7 minutes
Eisenia fetida 7	2m20s	Soil with earthworm food	2-3 minutes
Eisenia fetida 8	4m18s	Soil with earthworm food	4-5 minutes
Eisenia fetida 9	4m58s	Soil with earthworm food	4-5 minutes
Eisenia fetida 10	4m56s	Soil with earthworm food	4-5 minutes

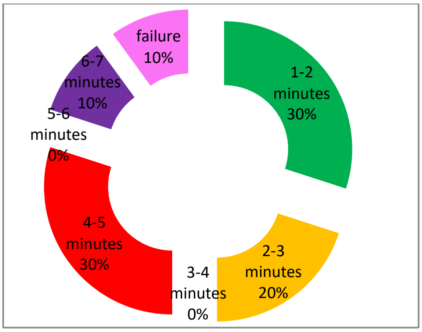

Figure 2. Proportions of earthworms (%) able to locate the food source by time intervals necessary to reach the food source

Regarding the earthworm ability to choose between two types of nutritive substrate (namely ordinary plant cultivation soil and respectively mixture of this type of soil and specific earthworm food in 3:1 ratio), there was found the following results: 20% of earthworms have chose the mixture of soil and special earthworm food in 1-2 minutes after the experiment beginning; 20% of earthworms have chose the mixture of soil and special earthworm food in 2-3 minutes after the experiment beginning; 30% of earthworms have chose the mixture of soil and special earthworm food in 4-5 minutes after the experiment beginning.

The statistical processing of data (Chi-square Goodness-of-fit-test, IBM SPSS Statistics 28.0) showed that earthworms *Eisenia fetida* are able to detect organic food sources, and this is not a random behaviour (Figure 3), the observed results being significantly different from those expected (Chi-square Goodness-of-fit test, $\chi^2(1)=6{,}40$, $p=0{,}011$). Also, the Chi-square Goodness-of-fit-test showed that earthworms significantly preferred the food substrate containing special earthworm food versus the substrate of simple soil (Chi-square Goodness-of-fit test, $\chi^2(1)=6{,}20$, $p=0{,}045$) (Figure 4).

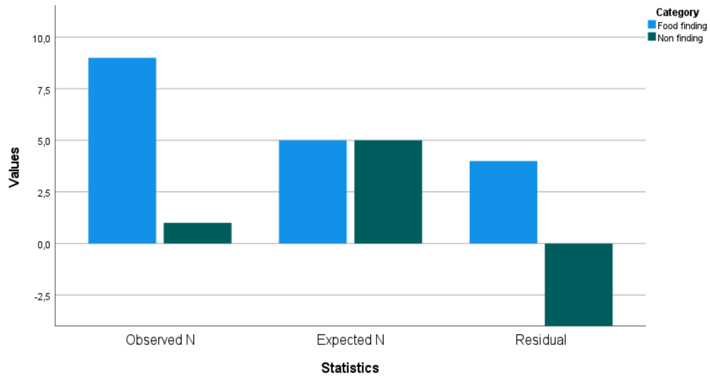

Figure 3. Distribution (earthworm number - N) of the ability of earthworms *Eisenia fetida* to locate the food source: the observed results are significantly higher than those theoretically expected (Chi-square Goodness-of-fit-test: $\chi^2(1)=6{,}40$, $p=0{,}011$)

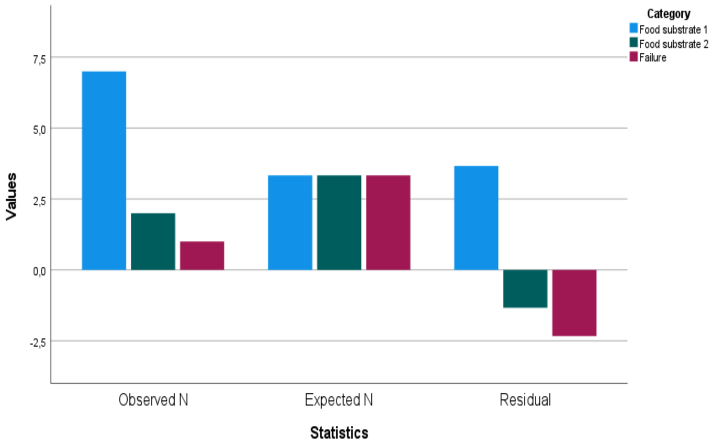

Figure 4. Distribution (earthworm number - N) of the ability of earthworms *Eisenia fetida* to chose a certain food source (Food substrate 1 = food substrate containing special earthworm food; Food substrate 2 = simple soil; Failure = movement out of the test board): the observed results are significantly higher than those theoretically expected (Chi-square Goodness-of-fit-test: $\chi^2(1)=6{,}20$, $p=0{,}045$)

The results achieved through this quick test clearly showed that earthworms *Eisenia fetida* are able to rapidly identify the organic food sources tested within this experiment.

However, although this study represents an initiative in trying to demonstrate the ability of earthworms to locate and choose their foods, it is necessary to extend researches with additional factors to be considered, and moreover to explore research directions able to reveal the structural and physiological implications of this behaviour, which currently still remain mostly unknown.

It is cert however, as possible explanation of the results achieved through this study, the presence of specialized sensitive cells – chemoreceptors located on the prostomium (mouth) and in the buccal epithelium of earthworms (Laverack, 1960), which can detect sucrose, glucose, and quinine and other many chemicals (Laverack, 1960; Satchell, 1983). Other studies emphasize that the volatile emissions emanated by fungi and other microorganisms at soil level are the main substances detected by earthworms using chemoreceptors (Zirbes et al., 2011). There are available also other several researches which demonstrate the obviously orientated movement of earthworms towards organic food sources (Satchell, 1967; Doube et al., 1997; Neilson & Boag, 2003; Curry & Schmidt, 2007), and which support the findings achieved through this study.

CONCLUSIONS

The results of the experiment showed that a large proportion (90%) of earthworms *Eisenia fetida* have located the food source and also 70% of the tested earthworms have chosen a specific food substrate within a time interval no longer than 5 minutes.

The statistical interpretations of the achieved results (Chi-square Goodness-of-fit-test) showed that earthworms *Eisenia fetida* are able to rapidly identify the organic food sources and chose between food sources, and these are not random behaviours.

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METHODS OF CROP ADAPTATION TO UNFAVORABLE AGROPHYSICAL PARAMETERS OF THE ARABLE SOIL LAYER

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Abstract

Under current conditions of climate change and intensive anthropogenic pressure on soils, it is extremely important for the agro-industrial complex of Ukraine to increase the productivity of crops. In recent years, there has been an increase in air temperature, unstable soil moisture in important phases of plant growth, reduced water permeability and moisture availability to plants, compaction, destruction of agronomically valuable structure, which necessitated finding ways aimed at strengthening the biological capabilities of crops and their adaptation to unfavorable soil and physical conditions. The results of laboratory and field research to test different ways of adapting crops to unfavorable agrophysical parameters of the arable soil layer, based on enhancing the growth of the root system and improving its physiological activity through: agrotechnical activities, selection of adaptive varieties of different intensity types and application of mineral fertilizers. It is proved that the use of the developed methods improves the germination, growth and development of crops, increases the productivity of their root system and promotes sustainable yields of crops.

***Key words**: agrophysical parameters, arable layer, crops, methods of adaptation.*

INTRODUCTION

The main issue of the agro-industrial complex of Ukraine is to ensure maximum productivity of crops. This issue becomes especially relevant in the current conditions of climate change and intensive anthropogenic pressure on soils.

Increasing the intensification of production and use of heavy tillage equipment leads to increasing manifestations of physical degradation, which is expressed in the deterioration of physical and physical-mechanical properties of the soil. Scientists emphasize that in Ukraine the area of overcompacted soils is 17 million hectares, disaggregated (with deteriorated structural units) - 14 million hectares (33.7-39 % of the total area of agricultural land), sprayed - 14 million hectares, soils with lump formation - 4 million hectares, soils with crusting and overcrusting - 15.8 million hectares (Baliuk et al., 2017; Kravchenko, 2019; Medvedev et al., 2020; Vakhniak & Kozhevnikova, 2014).

According to expert estimates, the potential annual losses from soil overcompaction in Ukraine could reach about 1.6 billion euros, and potential crop losses will cost about 1 billion euros (Zabrodskyi et al., 2021).

Soil compaction leads to deterioration of soil agrophysical, biological and agrochemical properties, water, air and heat regimes, reduced germination of agricultural seeds, germination and development of their root system and as a result - to a significant (up to 50%) reduction in productivity compared to uncompacted areas. Compacted soil complicates the penetration of roots into the lower horizons and limits the ability of plants to use nutrients from soil and fertilizers (Plisko et al., 2021).

Following the research by Medvedev and co-authors (2004), the movement of moisture inside the soil also depends on the density of its structure. Any changes in the density of the soil profile delay the flow of moisture.

According to the literature, the optimal water regime in the soil is in the range of 65-75% of the lowest moisture content (Medvedev et al., 2011). However, in recent years there has been climate change, manifested in uneven distribution of precipitation over the years, more frequent droughts and sharp fluctuations in air temperature, and as a result we have unstable soil moisture in important phases of plant growth. In accordance with scientific data (Medvedev, 2015; Kornus & Lynok, 2017), over the last decade the annual average air temperature has increased by (2-3)^{o}C, and the amount of precipitation over the past 25 years has decreased by 25%. Weather conditions are changing dynamically, their alternation in some years is becoming less predictable, which leads to an unstable level of crop productivity.

There are many data in the scientific literature on the influence of agrophysical properties on the growth and development of crops (Gangur 2018; Mokrikov, 2019, Medvedev, 2015; Szatanik-Kloca et al., 2018). Ways of regulating agrophysical properties of soil are also widely studied, but the issue of adaptation of crops to negative agrophysical properties of soil due to climate change is insufficiently studied and remains relevant to date.

It is well known that any extreme conditions have a much smaller negative impact on plant productivity if they have a well-developed, deep root system. Plants with a deep root system not only better adapt to lack of moisture, high and low temperatures, but also are able to maximize the use of nutrients from the underarable layer for crop formation (Bondarenko & Tkalich, 1976). The development of the root system of plants, and especially its root hairs, plays an important role in the absorption of nutrients and interaction with microorganisms in the soil (Shibata & Sugimoto, 2019).

Thus, research by Tyutyunnyk and co-authors (2021) found that the use of growth regulator in seed treatment and subsequent foliar fertilization of crops on the background of the main mineral fertilizer $N_{16}P_{66}$ promotes adaptation of winter wheat to autumn moisture deficit and allows obtaining additional yield increase hundreds kg/ha (7%). The use of this stimulant-adaptogen led to a decrease in plant height by 2.5% (2.2 cm), increasing the share of straw in the structure of the crop.

Under modern conditions of deterioration of agrophysical parameters of the arable soil layer, the selection of adaptive varieties of different types of intensity can also be an effective way to influence the level and stability of crop yields (Demidov & Gudzenko, 2016; Molotskyy et al., 2006). Research showed that varietal characteristics of crops play an important role in the choice of technology and soil growing conditions. Selection of varieties with different degrees of intensity can significantly reduce the impact of adverse growing conditions on the level of yield due to the different adaptation of a particular variety to certain soil parameters (Bakhmat et al., 2021; Gudz et al., 2014; Kolesnichenko et al., 2012; Kucherak & Berdnikova, 2021).

Highly adaptive and intensive varieties are able to form fairly high yields under favorable growing conditions, but slightly reduce the yield and its quality in adverse. This is especially true in the context of global climate change and frequent non-compliance by growers with recommended cultivation technologies.

It is known that with increasing intensity of varieties there is a natural decrease in their adaptive potential. The potential of plants of new varieties, even under optimal biotic and abiotic factors, is realized only by 50-60% (Popov & Ermantraut, 2013).

Varieties of semi-intensive type are characterized by increased resistance to both short-term and prolonged droughts or high humidity, which occur during one of the periods of any phenophase. These varieties use natural soil resources and mineral fertilizers in limited doses more efficiently than extensive and intensive varieties. Their disadvantage is the lower level of productivity than the varieties of intensive type, due to the tendency to lodging.

The above highlights the need to develop effective ways to adapt crops to the negative agrophysical parameters of the root layer of the soil, which will achieve maximum productivity and sustainable yields of crops.

Thus, the aim of the research was to investigate the ways of adaptation of agricultural crops to unfavorable agrophysical parameters of the arable soil layer.

MATERIALS AND METHODS

Experimental investigations were carried out in the Soil Geoecophysics Laboratory named after Academician of NAAS V.V. Medvedev of the National Scientific Center "Institute for Soil Science and Agrochemistry Research named after O.N. Sokolovsky" in many factorial laboratory and field experiment.

The study was conducted on typical heavy-loamy chernozem.

A series of laboratory and model experiments were conducted to investigate the methods of adaptation of corn and spring barley to soil overcompaction. The methods of adaptation were the application of growth stimulants, selection of adaptive varieties, soil moisture levels.

The experiments were performed in a light cabinet in vegetation plots with a volume of 1.5 dm^3 in triplicate. The appropriate volume of soil was filled into the plot and an overcompacted subseed layer with a density of > 1.3 g/cm^3 was simulated artificially (with a wooden seal) by pounding. Seeds of the studied crops were sown on this layer and covered with loose soil. Plants were watered through a glass tube so that water came from below. The irrigation rate for the given parameters of soil moisture was calculated according to the method (Agrochemical research in experiments on soil cultivation and fertilization: guidelines, 1977). Duration of experiments - until the appearance of the 4^{th} leaf by plants. The morphological parameters of the root system were determined - diameter and length; the coefficient of root productivity (as the ratio of dry mass of aboveground plant organs on the plot to dry root mass) and biological yield of cultivated crops as the sum of raw biological (aboveground and root) mass of plants was calculated (Stankov, 1964).

In laboratory experiment № 1 the effect of inoculation of corn seeds (variety - hybrid Monolith MV) with growth stimulator "Vympel" on germination, growth and development of plants under the conditions of its cultivation on compacted soils was studied.

Scheme of laboratory experiment №1:

Control: without growth stimulants, soil density > 1.3 g/cm^3;

Variant 1: soil density > 1.3 g/cm^3, Vympel (400 g/t);

Variant 2: soil density > 1.3 g/cm^3, Vympel (500 g/t);

Variant 3: soil density > 1.3 g/cm^3, Vympel (600 g/t).

In the experiment we maintained the optimal level of humidity - at 80% of the field soil water capacity (s.w.c.).

In the laboratory experiment № 2, the influence of levels of soil moisture and variety of spring barley on germination, growth and development of plants under conditions of overcompaction was studied. The studied varieties of spring barley - (intensive variety Vzirets and semi-intensive variety Zdobutok).

The scheme of the laboratory experiment provided the following options:

Control: soil density 1.2 g/cm^3, moisture content 80% of s.w.c.;

Variant 1: soil density > 1.3 g/cm^3, moisture content 60% of s.w.c.;

Variant 2: soil density > 1.3 g/cm^3, moisture content 80% of s.w.c.;

Variant 3: soil density > 1.3 g/cm^3, moisture content 100% of s.w.c.

Under the conditions of temporary field small-scale experiment, adaptive varieties of barley and pre-sowing application of complex mineral fertilizers of spring in the conditions of soil overcompaction were studied. Replication - three times, placement of options - systematic. Area of plots - 1 m^2. Soil overcompaction was simulated in a layer of 0-25 cm before sowing by hand using a metal compactor by pounding.

The scheme of the experiment provided the following options:

Control: without fertilizer, soil density 1.2 g/cm^3;

Variant 1: soil density > 1.3 g/cm^3, without fertilizer;

Variant 2: soil density > 1.3 g/cm^3, 45 kg/ha of active substance (a. s.) NPK;

Variant 3: soil density > 1.3 g/cm^3, 90 kg/ha of a. s. NPK.

Applied mineral fertilizers: ammonium nitrate, simple superphosphate and potassium salt. The studied varieties of spring barley are similar to those used in the laboratory experiment № 2.

In the field experiment, phenological observations of plant growth and development were made: seedling dates were recorded, plant height, number of productive stems (with ears) were determined, and crop accounting was performed. The tillering coefficient was also calculated (as a fraction of the division of the total number of shoots with ears by the total number of plants from one plot).

Mathematical and statistical processing of research results was performed by the method of analysis of variance using software packages Statistica 10.0 and Microsoft Excel.

RESULTS AND DISCUSSIONS

According to experimental studies, the development of plants is directly related to environmental conditions and technology of cultivation. One of the main criteria for studying the technology of growing crops is a detailed analysis of indicators of germination, growth and development of the plant and its root system.

This makes it possible to determine the use of specific technological operations and justify the need and number of agricultural measures that enhance or inhibit the dynamics of plant growth and development. This issue is especially relevant on land plots with unfavorable agrophysical properties of the soil.

As a result of research (laboratory experiment № 1) on studying the effect of growth stimulant "Vympel" on germination, growth and development of corn, it was found that inoculation of seeds before sowing helps to increase plant germination. In the variant with overcompacted soil with the use of growth stimulant even in the minimum dose (400 g/t) there is an increase of 17 % germination energy and complete germination of corn seeds compared to the variant without growth stimulant. The positive effect of inoculation of seeds with biological products is associated with increased sowing properties of plant seeds. First of all, it improves the development of the root system and seedlings in general in the initial stages of ontogenesis. Thus, according to the literature data (Marenych & Yurchenko, 2016), inoculation of corn seeds with growth stimulant "Seed treatment" at a dose of 3 kg/ha increased the weight of seedlings and stem length of corn during seed treatment with growth stimulant compared to the control version by 10% and 20%, respectively.

According to the research results, the application of growth stimulant under conditions of soil overcompaction improves the development of the root system of corn, namely increasing its length, diameter and productivity, as evidenced by the calculation of the coefficient (Figure 1). Root productivity ratio characterizes the productivity of the root system.

The coefficient of determination R^2 indicates the percentage of effective scattering of the variable and is explained by the action of the variable factor. In our case, $R^2 = 0.8088$, ie the coefficient of root productivity by 81 % depends on the dose of inoculation of seeds with a growth stimulant. With increasing dose of growth stimulant, the productivity of the root system increases, which further increases crop yields.

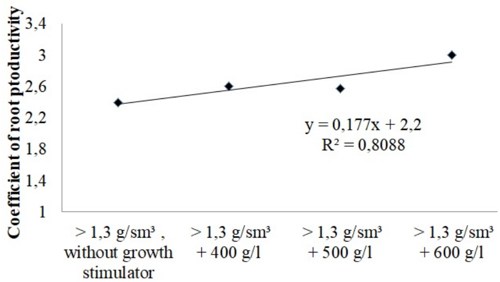


Figure 1. Linear regression model between of the coefficient of productivity of the root system of corn and the dose of growth stimulator under conditions of soil overcompaction

The use of seed inoculation before sowing helps not only to increase crop yields, but also to improve its quality (Căpățână et al., 2018; Oliynyk, 2021). The tendency to increase the biological yield during seed treatment with a growth stimulant is also noted in our studies (Figure 2).

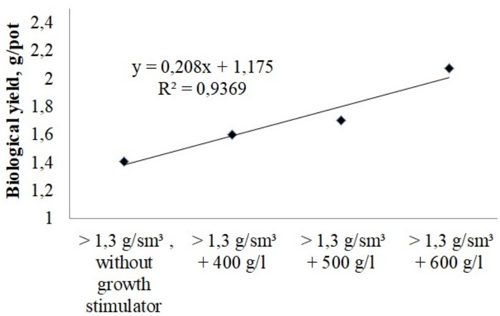


Figure 2. Linear regression model between of the biological yield of corn and the dose of growth stimulator under conditions of soil overcompaction

The dependence of the biological yield of corn on the dose of growth stimulant is statistically significant, 94 % of the variability of this indicator is due to the above model. The increase in biological yield due to inoculation, compared with the non-inoculated variant ranged from 14% to 47% depending on the dose.

Another way to improve the development of crops and their root system on soils with unfavorable agrophysical parameters is to optimize soil moisture and select an adaptive variety.

Thus, according to the results of laboratory-model experiment № 2 it was noted that soil moisture at 80% of s.w.c. helps to increase the diameter of the roots of both studied varieties by 10% compared to low moisture content (60% of s.w.c.) even under soil compaction. Soil moisture at the level of 80 and 100% of s.w.c. helps to increase the productivity of the roots of spring barley plants (Figure 3).

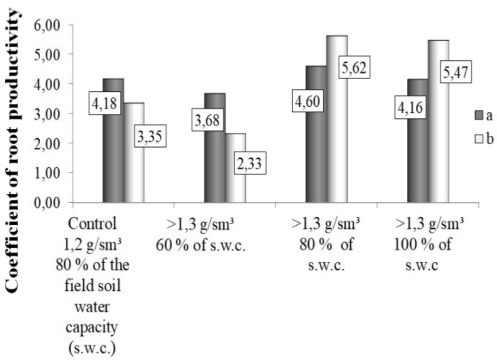


Figure 3. Influence of soil moisture levels on the coefficient of root productivity of spring barleys (a - intensive variety, b - semi-intensive variety) under conditions of soil overcompaction

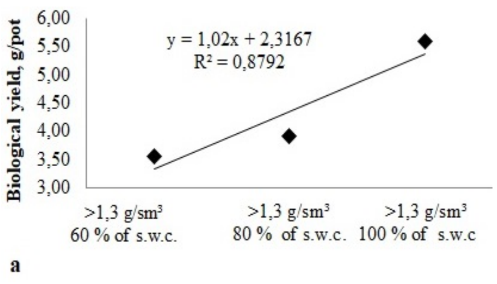
Moreover, the productivity of the roots of semi-intensive varieties is characterized by 18-23% higher compared to plants of intensive varieties, which indicates a better adaptation of the roots of this variety to soil overcompaction.

The correlation between the biological yield of spring barley and the level of soil moisture was established by correlation-regression analysis (Figure 4).

The coefficient of determination is 0.8792 for the intensive variety and 0.8073 for the semi-intensive variety, which indicates that the level of biological yield of spring barley by 87 and 80% depends on soil moisture. In other words, as the soil moisture increases, so does the biological yield of spring barley.

In addition, even with a sufficient level of soil moisture, the yield of an intensive variety is almost 40% lower compared to a semi-intensive variety. And under conditions of moisture lack (60% of s.w.c.) the level of biological yield of intensive varieties is reduced by more than 50% compared to semi-intensive varieties grown in similar conditions.

Under the field conditions, along with the adaptive selection of spring barley varieties, sowing of mineral fertilizers was chosen as another method of adaptation. During the research (field small-scale experiment) it was found that the application of mineral fertilizers contributed to a more even and faster emergence of seedlings. During the growing season, there was a significant increase in the height of semi-intensive varieties compared to the intensive variety by 19% with the application of mineral fertilizers and conditions of soil overcompaction.



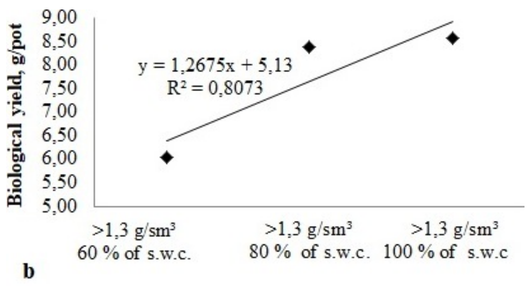


Figure 4. Linear regression model between of the biological yield of spring barley varieties (a - intensive variety, b - semi-intensive variety) and the moisture level under conditions of soil overcompaction

The influence of soil fertilizer on biometric indicators of spring barley varieties was also established (Figure 5).

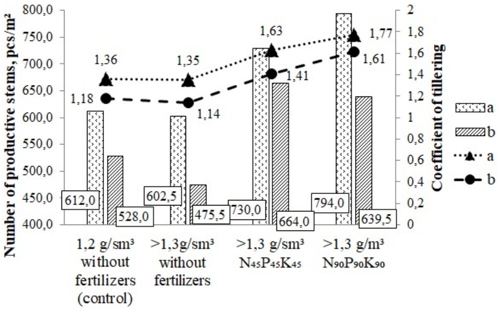


Figure 5. Influence of soil fertilizer on biometric indicators of varieties of spring barley (a - intensive variety, b - semi-intensive variety) under conditions of soil overcompaction

Thus, the number of productive stems of intensive variety under the conditions of soil overcompaction was 602 pcs/m^2, semi-intensive - 475 pcs/m^2. The application of mineral fertilizers increased this inicator by 21 and 39% (with application of $N_{45}P_{45}K_{45}$) and by 31 and 34% (with application of $N_{90}P_{90}K_{90}$), respectively. The coefficient of tillering had the same tendency to increase under the conditions of application of mineral fertilizers.

The dependence of spring barley yield on the dose of mineral fertilizers (Figure 6) is statistically significant - R^2 is 0.8297 and 0.9473, and therefore 82 and 94% of the yield of intensive and semi-intensive varieties is explained by this model.

However, the yield level of the semi-intensive variety was still slightly higher compared to the intensive variety under conditions of soil overcompaction. In the control variant (at the optimal soil density) the yield of the intensive variety was 33 hundreds kg/ha, which was 7 % more than the semi-intensive variety. But even in compacted variants, the intensive variety does not fully realize its biological yield and reduces the yield by 13% compared to the semi-intensive variety.

The advantages of intensive varieties are manifested, as a rule, only under favorable conditions, against the background of high cultivation technology and sufficient moisture. Under conditions of growing them on soils with unfavorable parameters and lack of moisture, intensive varieties not only do not realize their potential, but often form lower productivity than less productive varieties (Adamenko, 2006; Kolupaev & Karpets, 2010), but not demanding to growing conditions.

Therefore, semi-intensive varieties of spring barley should be sown on medium agrobackgrounds, lower soil fertility, after mediocre and satisfactory predecessors, with insufficient agro-technological support.

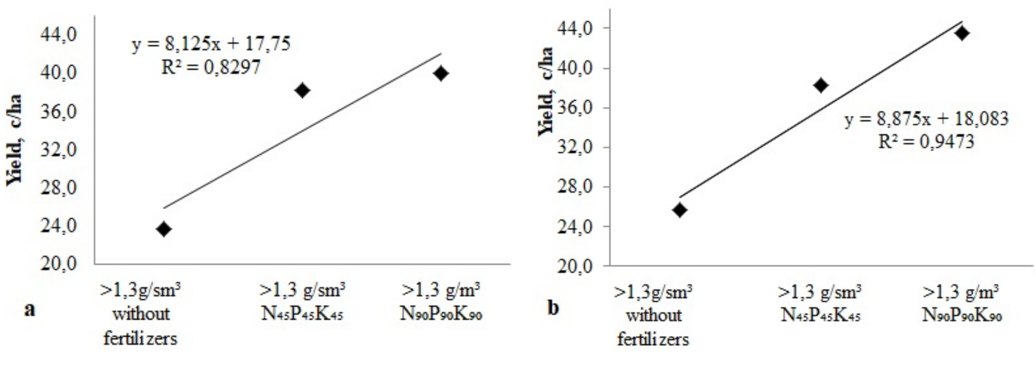


Figure 6. Model of linear regression between of the yield of varieties of spring barley (a - intensive variety, b - semi-intensive variety) and the dose of mineral fertilizers under conditions of soil overcompaction

CONCLUSIONS

The results of research show that the selected methods of adaptation of corn and spring barley to the overcompaction of the subseed sublayer of the soil provide increased germination, growth and development of crops, their root system and contribute to sustainable yields.

Correlations between corn yield and growth stimulant doses were found (r = 0.96); biological yield of barley varieties and moisture (r = 0.93 for intensive and r = 0.89 for semi-intensive varieties); biological yield of barley varieties and doses of mineral fertilizers (r = 0.91 for intensive and r = 0.97 for semi-intensive varieties) under conditions of soil overcompaction.

The best adaptation of semi-intensive varieties of spring barley to unfavorable agrophysical parameters of soil and growing conditions compared to intensive varieties has been established, which indicates the expediency of their cultivation on overcompacted soils.

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NEW WORKING BODIES OF SEEDERS FOR SOWING GRAIN CROPS USING ENVIRONMENTAL FRIENDLY TECHNOLOGIES

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Abstract

An analysis of the works devoted to the theory of the working process of sowing seeds of grain crops shows that the sowing machines are one of the most important working parts of the seeder, which, during their work, must ensure not only a continuous and uniform flow of seeds, but also the necessary stability of the established seeding rate, as well as the possibility of sowing seeds of various crops, the minimum injury of seed. The article is devoted to improving the quality indicators of sowing seeds with seeders for sowing grain crops using environmentally friendly technologies equipped with new coil-screw sowing machines with coils, the grooves of which are turned along a helix at an angle of 20 degrees, as well as a sowing machine with an increased volume of coil grooves, obtained correlations and graphic dependencies between the uneven distribution of seeds along the length of the row, on the forward speed of the sowing units equipped with seeders with the studied sowing machines.

Key words: *seeds, seeder, sowing machine, coil grooves, sowing technology, environmentally friendly.*

INTRODUCTION

For sowing seeds of grain crops using environmentally friendly technologies, the sowing unit remains one of the most important working parts of the seeder (Ovtov et al., 2020; Shumaev et al., 2021; Dorohov et al., 2019; Cheremisinov et al., 2016).

Currently commercially available seeders are equipped with sowing units with straight trough spools. Sowing machines equipped with such coils during operation do not always meet agrotechnical requirements, since they give a pulsating, not constant flow of sown seeds, which increases the uneven distribution of seeds along the length of the furrow (Shumaev et al., 2020; Aksenov et al., 2020; Hevko et al., 2016; Khudoberdiev et al., 2010; Yashin et al., 2021; Shevchenko et al., 2013).

The article describes an experimental coil-screw sowing machine with coils, the grooves of which are turned along a helix at an angle of 20 degrees, as well as a sowing machine with an increased volume of the coil grooves.

MATERIALS AND METHODS

Currently, grain crops are sown with grain seeders (SZ-3.6, SZT-3.6 and SZU-5.4-06, etc.), which do not fully ensure the necessary uniform distribution of seed along the length of the furrow. To solve this problem, Penza State Agrarian University designed, manufactured and tested the design of a coil-screw sowing machine with coils, the grooves of which are turned along a helix at an angle of 20 degrees, as well as a sowing machine with an increased volume of coil grooves.

The design of the coil-screw sowing machine with coils, the grooves of which are turned along a helix at an angle of 20 degrees (Patent for invention No. 2384040) contains a seed box 6 (Figure 1), a socket 2, a coupling 7, a valve 4, a seeding coil with grooves 1 The ribs of the grooved coil 1 are made along a helical line at an angle of 200 to the axial line of the coil. From below, the seed box 6 is closed by a spring-loaded valve 4. The rear end part of the valve 4 of the sowing unit is made of a rectangular shape. The cut line of the back of the valve is below the axis of the grooved spool 1 by 0.6R of the spool. The coil 1 is inserted into the socket 2. The slots of the sockets 2 are made in the form of the ribs of the grooved coil 1 and at an angle of 200 to the axial line of the grooved coil 1. A coupling 7 is put on the shaft of the sowing machine 3. A cylindrical shank 8 is inserted into the coupling 7.

The process of sowing grain crops from a coil-screw sowing machine with coils, the grooves of which are turned along a helix, at an angle of 20 degrees, proceeds as follows. The seeds from the replaceable box flow by gravity into the seed box 6 of the sowing machine and fill the space around the grooved coil 1. Rotating, the grooved coil 1 moves the seeds sunk into the grooves, and part of the seeds of the active layer that do not fall into the grooves, but are located near its edges , into the lower part of the seed box 6 and dumps them at the end of the valve 4 into the funnel of the seed tube, and not in a pulsating batch, but smoothly and continuously due to the fact that the grooves of the grooves of the coil with grooves 1 are made along a helical line, and the rear end part of the valve 4 sowing machine is made of rectangular shape at work, as well as the longitudinal movement of the grooved coil 1 during adjustments, the grain does not spill out of the seed box, due to the socket 2, the slots of which are made in the shape of the ribs of the grooved coil 1. The gap between the valve 4 and the grooved coil 1 is set using the adjusting screw 5 in depending on the size of the seeds sown. When adjusting the seeding rate, the coil with grooves 1 is inserted into the seed box 6 by moving the coil 1 with the shaft 3 in the axial direction while scrolling the shaft 3 along the slope of the ribs.

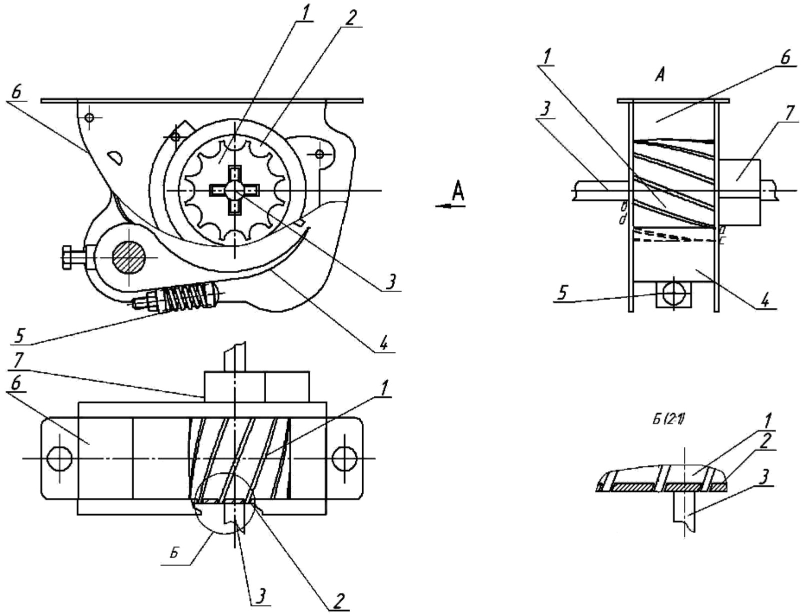

Figure 1 - Scheme of the sowing machine: 1 - coil with helical grooves; 2 - socket; 3 - shaft of the sowing machine; 4 - valve; 5 - adjusting bolt; 6 - seed box; 7 - clutch

The design of the sowing machine with an increased volume of the grooves of the coil (Patent for invention No. 2540547) contains a body 1 (Figure 2), a coil 2 in the form of a cylinder with grooves on its surface, made with an increased volume of the grooves. The coil 2 is made of wear-resistant plastic with anti-friction properties, the valve 3 is made without a seed discharge edge, the bottom 5 is rigidly installed on the valve 3 using supports 4, while the bottom 5 is made in the form of a part of the side surface of the cylinder, with the axis of symmetry coinciding with the axis of symmetry of the coil 2. The bottom 5 has a polished inner surface, front A and rear B edges, while the front edge A of the bottom is located in the third quadrant parallel to the axis of symmetry of the coil 2, the front edge A of the bottom is deflected in the course of rotation of the coil 2 at an angle α equal to 40 ... 45 degrees down from the horizontal plane of symmetry of the coil 2. surface of the bottom 5, more than the radius RK of the coil 2. The rear edge B of the bottom, made with a bevel 6 for dumping seeds, is deflected along the rotation of the coil 2 by an angle β equal to 54 ... 58 degrees to the right of the vertical plane of symmetry of the coil 2. To the front edge A of the bottom, adjoins the shaper-guide 7 rigidly installed in the housing 1 of the sowing machine. The shaper-guide 7 is made in the form of a part of the side surface of the cylinder, with the axis of symmetry coinciding with the axis of symmetry of the coil 2, the shaper-guide 7 has a polished inner surface, The free upper part of the shaper-guide 7 is deflected in the course of rotation of the coil 2 by an angle φ equal to 47...53 degrees to the left of the vertical plane of symmetry of the coil 2. The radius RF of the inner polished surface of the shaper-guide 7 is equal to the radius RD of the inner polished surface of the bottom.

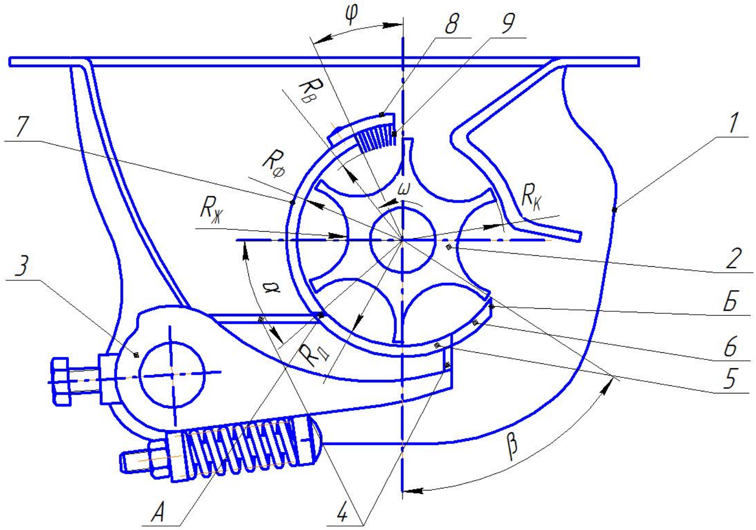

Figure 2 - Scheme of the coil apparatus: 1 - housing; 2 - coil; 3 - valve; 4 - support; 5 - bottom; 6 - bevel; 7 - shaper-director; 8 - brush; 9 - pile; A - the front edge of the bottom; B - rear edge of the bottom

Coil sowing machine works as follows.

During the operation of the sowing machine, the seeds fall into the grooves of the coil 2 in the form of a cylinder with grooves on its surface, made of wear-resistant plastic with antifriction properties, made with an increased volume of grooves in order to leave the process of sowing seeds of various crops without an active layer of seeds, with a smooth flow without pulsation and uniform over the sieving area, at minimum speed and maximum length of the coil 2. Seeds sunk into the grooves of the coil 2 are fed to the shaper-guide 7 rigidly installed in the housing 1. In order to avoid injury to the seeds at the entrance to the free upper part of the shaper-guide 7, the grooves with the seeds of the coil 2 meet with the brush 8 fixed to the free upper part of the shaper-guide 7.

Next, the seeds in the grooves of the coil 2 enter the zone of the shaper-guide 7. In the area of the shaper-guide 7, the formation of an active layer of seeds that is unstable in thickness and volume is excluded, since the seeds during the rotation of the coil 2 are only in the grooves of the coil 2 and are limited by the internal polished surface of the shaper - director 7. After the formation of the seed flow in the shaper-director 7, the seeds in the grooves of the coil 2 are sent to the zone of the bottom 5. At the end of the bottom 5, the seed flow formed in the grooves of the coil 2 of the sowing machine, with the specified parameters and in accordance with agrotechnical requirements, descends from the rear edge of the bottom 5.

RESULTS AND DISCUSSIONS

The studies were carried out using the SZ-5.4-06 seeder (Figure 3) with experimental coil sowing machines.

Figure 3 - General view of the seeder with experimental reel seeders

When determining the effect of the speed of the sowing unit on the uneven distribution of seeds along the length of the row, the speed of seeders with experimental coil-screw sowing machines with coils, the grooves of which are turned along a helix at an angle of 20 degrees, as well as sowing machines with an increased volume of coil grooves, changed within 1.47 ... 3.68 m/s, which meets the agrotechnical requirements.

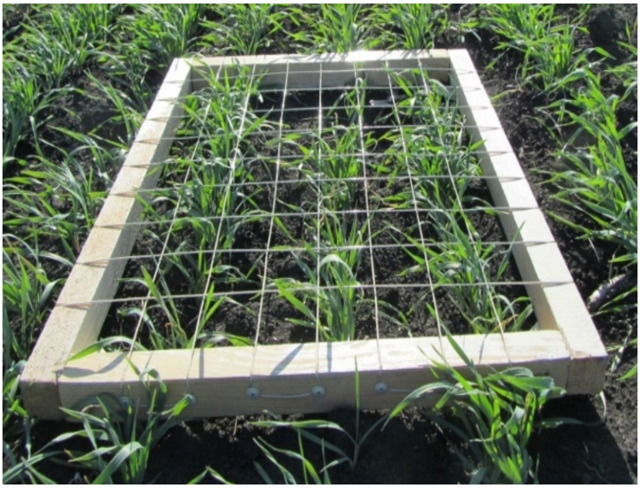

Figure 4 - General view of the frame for determining the uneven distribution of plants along the length of the row

Then they increased (by 25 ... 30%) according to STO AIST 5.6–2010. The operating speed of the unit was determined by the length of the accounting plot, taking into account the time of its passage.
Studies to determine the uneven distribution of seeds along the length of the row were carried out using a frame with squares of 25 x 25 mm (Figure 4).
The frame was superimposed on the seedlings along the diagonal of the site, on three sites, each 30 m^2 in size (repeated three times).
In accordance with the presented method, the optimal parameters of the experimental coil-screw sowing machine with coils, the grooves of which are turned along a helix, at an angle of 20 degrees, were refined. After processing the experimental data, graphs were constructed and

correlations between the speed of the sowing unit and the uneven distribution of seeds along the length of the row were determined (Figures 5, 6).

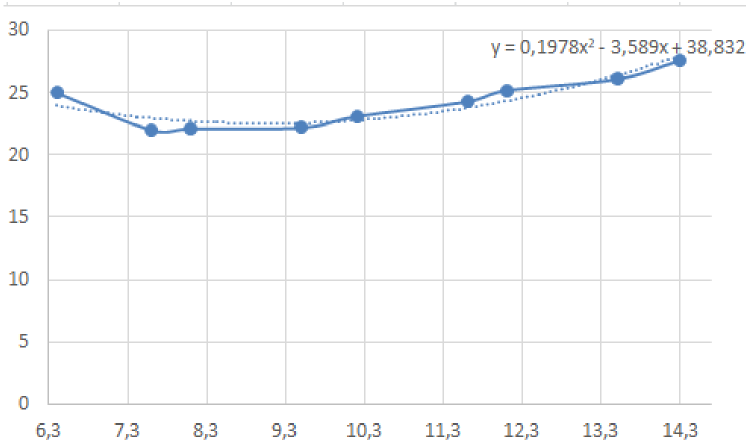

Figure 5 - Graphs of the dependence of the uneven distribution of seeds (ν) grain crops along the length of the row on the speed of the unit (u)

Correlation between the indicator of uneven distribution of seeds of grain crops along the length of the row (ν, %) and the speed of movement of the unit u (km/h) is expressed by the dependence:

$$\nu(u) = 38.832 - 3.589u + 0.1978u2 \quad (1)$$

In accordance with the presented method, the optimal parameters of an experimental coil-screw sowing machine with an increased volume of coil grooves were refined.

After processing the experimental data, graphs were constructed and correlations between the speed of the sowing unit and the uneven distribution of seeds along the length of the row were determined.

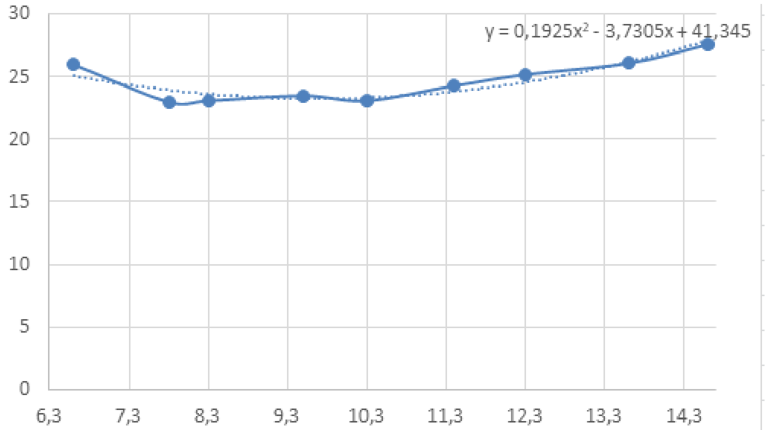

Figure 6 - Graphs of the dependence of the uneven distribution of seeds (ν) grain crops along the length of the row on the speed of the unit (u)

Correlation between the indicator of uneven distribution of seeds of grain crops along the length of the row (ν, %) and the speed of movement of the unit u (km/h) is expressed by the dependence:

$$\nu(u) = 41.345 - 3.7305u + 0.1925u2 \quad (2)$$

CONCLUSIONS

Laboratory and field studies of seeders equipped with experimental sowing machines with coils, the grooves of which are turned along a helix at an angle of 20 degrees, as well as sowing machines with an increased volume of coil grooves for sowing seeds of grain crops, confirmed the reliability of theoretical calculations and laboratory studies. The optimal value of the speed of the unit V can be considered the range of values from 7.8 to 9.7 km/h.

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PEDO-GENETICAL FACTORS IMPLICATED IN SOIL DEGRADATION (LOWER TIMIS RIVER BASIN AREA)

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Abstract

This paper is an overview of pedo-genetical factors implicated in soil degradation from lower Timiş River basin area. The microrelief forms, the groundwater depth in soil profile and the nature of parental rocks is some of the principals factors who dictate the process of soil formation and their direction of development. The analysis of the limiting factors refers to their enumeration by synthesizing the ones the land plots for arable, the study and then the analysis of each one in relation to the manifestation at different points of the studied area, respectively. The purpose of this analysis is to provide the beneficiary with a global picture of the phenomena within the elemental unity of the pedological landscape that would result in the overall strategy on a set of sustainable ameliorative or cultural measures. Among the fundamental features of soil that have a relatively more determinant function are: salinisation, sodisation, acidity, humus reserve, $CaCO_3$ content, properties who influenced the growth and birth of plants in direct relation to the mode of manifestation and the intensity of the phenomena.

***Key words**: fine texture, compactness, excess moisture.*

INTRODUCTION

As part of the vast Tisza Plain, the low plain of the commune's area has a relatively low lithological evolution over the pleistocene sand and pebble formations pushed by Mureş, Timiş and Bega; in the lacustrum phase there are deposited clay and clay, Strong, occur in various situations, generating a variety of soil types.

To make a characterization of the current envelope, it is absolutely necessary to overcome the natural factors that have contributed to the actual materialization of the soil cover. The area studied as a component of the Pannonian depression was constituted by repeated sediments that occurred over the crystalline foundation.

Based on the field study and the study in the office, 7 types of soils were identified as follows: fluvisols on 18.37% of the surface, entiantrosols on 0.14% of the surface, chernozems on 6.13% of the surface, phaeozems on 11.41% of the area, eutric cambisols on 55.15% of the area, pelosols on 2% of the area, solonetz on 0.08% of the surface and associations of soils on 6.72% of the area.

MATERIALS AND METHODS

For achieve our objectives we were used pedological mapping, morphological description, expedited determination in the field, laboratory information processing soil like research pedological methods. (Buta, 2009, Mihalache et al., 2013; Radulov et al., 2011; Rusu et al., 2007)

The soil profiles were located in representative areas of the researched area so that we can be describe the most representative soil types and subtypes of soils. Soil samples was collected from pedogenetical horizons of the soils profile in natural settlement (unchanged) and in amended settlement.

Soil samples in natural settlement (unchanged) it was taken in hydro-cylinder from metal of known volume to characterize certain physical characteristics, the momentary soil moisture and in cardboard boxes for characterize its

micromorphology (Blaga et al., 2008; ICPA., 1987).
Sampling the settlement as to characterize physico-chemical and biological part, was made in bags from each genetic horizon.
Agrochemical samples was taked for the determination of specific chemical indices (processing layer). Research ecopedological conditions and morphological description of soil was studied after "the Romanian system of soil taxonomy (2012), completed and/or modified by "Development methodology of soil studies" (volumes I, II, III) writed by ICPA Bucharest in 1987 (ICPA, 1987; ICPA, 2012).
Other determinations and testing were performed in Pedological and Agrochemical Studies Office from Timisoara, and in the laboratory of Banat's University of Agricultural Sciences and Veterinary Medicine "King Michael I of Romania" from Timișoara, according to the national rules and standards approved by the Standards Association of Romania (ASRO).

RESULTS AND DISCUSSIONS

Limitations due to soil chemical characteristics

Salinization according to the pedological study on the studied area, the intensity of chlorinated salinization exceeds 0.6 me/100 g but it does not exceed 5 me/100 g, respectively sulphatic salinization 1.1 m/100 g but does not exceed 7.2 m.e/100 g, consequently we do not have solonchaks, but other types of soils fluvisols, chernozems, eutric cambisols.
Alkalization (saturation) is present in different subtypes of solonetz and several subtypes of fluvisols, chernozems, eutric cambisols, pelosols; In the first case, it is a sodium saturation more than 15% sodium exchangeable in the clay-humic complex of the cation exchange capacity).
In the studied area salinization and sodification affect 9.46% of the area (Figure1).
Acidity in the perimeter under investigation, the presence of acid reaction creates metabolic defects in most cultures with negative consequences in agricultural production, pH 5.2-5.6 (Dodocioiu et al., 2009; Marin et al., 2016).
Acidity in different degrees affects the area surveyed on 30.95% of the agricultural lands from the studied area (Figure 1).

The humus reserve is a crop food crop and, at the same time, a constituent that, through its influence on the physical, chemical, biological soil properties, determines to a large extent the productive level of the land.
Depending on the criteria specific to indicator 144 (MESP, 1987) within the researched perimeter, we encounter 7383.15 ha, representing 88.03% of the territory (Figure 1).
The CaCO3 content exceeds 12% forming a horizon as it appears in the first 100 cm, which has a negative impact on agricultural output. The content of calcium carbonate affects 11.71 ha, 0.14% of the territory (Figure 1).

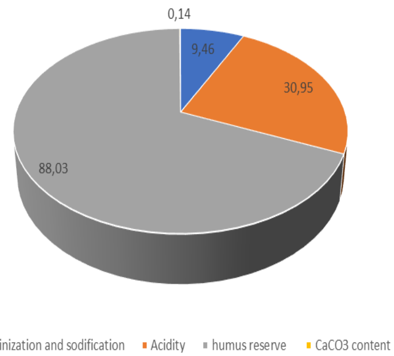

Figure 1. Graphical representation of limitation due to chemical characteristics

Limitations due to physical characteristics of soils

Physical and hydrophysical properties of soils determine the limits in which plants are grown in culture.
Among the physical and hydrophysical features that constitute limiting factors in this area we mention the texture and compactness, the reduced load.
Soil texture or granulometric composition defined by the proportion of particles of different sizes involved in the formation of the general part of the soil and the distribution of different particle sizes in the profile section. It plays an important role in ensuring the necessary conditions for the growth of plants (making different rooting in relation to the texture) as well as other soil characteristics, being correlated with other soil characteristics, enlarging or limiting their production capacity (Mihalache et al., 2013; David et al., 2019; Lațo et al., 2016).

Fine texture - a class group having the following composition: clay <0,002 mm ≥ 33%; Dust 0.002-0.02 mm ≤ 67%; Sand 2-0.02 mm ≤ 67% - affects 1561.84 ha, 18.62% of the area surveyed (Figure 2).
Compactness is the property of the soil to resist forces that tend to mechanically dismantle the particles that make up it. It is related to the granulometric composition, the water content, the humus content and the nature of the adsorbed cations. Tasking through current cultural works occurs when the soils are wet and when the work depth is the same for many years.
Compactness, compaction, total porosity, existing water reserve, microbiological activity and agricultural production are tight links.
Soil compactness is one of the main physico-mechanical properties of greater practical importance in agriculture (besides the other features: consistency, plasticity, compressibility, swelling, contraction, adhesion, cohesion and resistance to soil work).
Compaction is expressed by the degree of compaction as the ratio between apparent soil density at one point (g/cm3) and the maximum apparent density of the soil (g/cm^3). It is expressed as a percentage, establishing the soil compactness classes: very loose, loose, low compact, moderately compact, very compact, characteristics closely related to a complex indicator of compaction - the degree of compaction. In the present paper for each TEO (homogeneous ecological territory) the apparent density, the total porosity and the clay content necessary to determine the degree of compaction were calculated. Compactness is also influenced by the water content, humus and the nature of the cations.
Compactness is a phenomenon that occurs either naturally in the studied area to clay and alluvial soils, or due to anthropogenic causes by carrying out agricultural works at the same depth, leading to worsening of water and air permeability and the resistance that the layer of soil compacted to the penetration of the root system on an area of 8281.61 ha, 98.74% of the arable land (Figure 2).

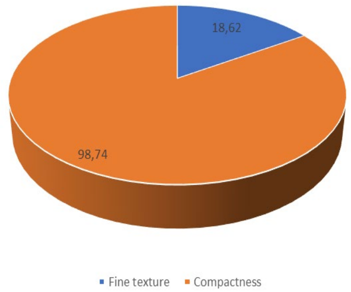

Figure 2. Graphical representation of lands physical limits

Limitations due to moisture excess
Soil moisture excess can be caused by water from rainfall, underground water, or due to poor external and internal drainage.
Water excess is manifested:
- morphologically by the presence of the Gr gley horizon or stagnogley W;
- physically - the water content exceeds the capacity of the field.
Limitations due to groundwater excess
Agricultural crops support the groundwater excess without diminishing production for a short period of time. The expected improvement measures will first aim at removing the causes of excess humidity and then fighting the consequences of water excess on the soil. The excess moisture content of the groundwater affects 34.45% of the area surveyed.

Limitations due to stagnant (surface) humidity excess
Stagnant humidity excess is due to precipitation in years or rainy periods, but also due to a contest of circumstances:
- the presence of a clay soil;
- the existence of micro-depressions;
- the presence of impermeable layers;
- the use of heavy agricultural machinery on poorly landscaped lands.
On an area of 33.36% of the area surveyed.

Limitations due to overflow flooding
The lands with these limitations are situated in the floodable areas of the Timiş River up to the defense and protection dike and cover an area of 4.47% from the surveyed area.

Limitations due to moisture deficiency

Moisture deficiency in the soil is a limiting factor in the normal growth of plants. According to the hydro climatic balance it affects 68.53% of the area surveyed (Figure 3).

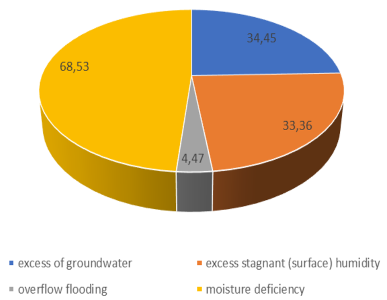

Figure 3. Graphical representation of excess and deficiency of moisture

Limitations due to anthropogenic degradation

The anthropically degraded lands are those limited to the depot (landfills) due to waste deposited and scattered by the wind, in an area of 0.14% from the surveyed area.

Below we present the possible ways to improve the properties of the soils and implicitly the agricultural production and the way of use. From this synthesis also resulted an indicative framework of requirements and improvement measures, the sequence of the approached phenomena is the following:

Salting (salinization and alkalization)

The soil solution becomes harmful to the development of plants from certain limits of soluble salt concentration, as well as to a certain degree of alkalinity. Harmful salts on plants are: $NaCl$, Na_2SO_4, Na_2CO_3, $MgCl_2$, $MgSO_4$, $CaCl_2$; salts are not harmful: $MgCO_3$, $CaSO_4$, $CaCO_3$. Increasing osmotic pressure reduces the accessibility of water to plants and negatively affects the microbiological activity of the soil. In addition to increasing osmotic pressure, salts harm plants through the toxic effect of ions released by dissociation. In this respect, the Cl- ion is more toxic than SO_4^{2-}, and the most toxic of chlorides is $MgCl_2$.

A high sensitivity to chlorine is shown by fruit trees, followed by grasses, legumes and fodder legumes, and sugar beet supports the Cl ion better than the SO_4 ion.

On solonets the plants suffer not because of the excess of salts, but because of the high alkalinity of the soil, determined by the preponderance of Na and Mg cations in the adsorbent complex, as well as by the presence of Na_2CO_3 - so of soda. Soda, among other novice effects, thus manifests a direct caustic action on plants, with the effect of dissolving plant tissues.

Increasing the content of soluble salts in the soil solution has negative effects not only on cultivated or spontaneous plants, but also on the microbiological activity in the soil. The genesis of saline soils is related to the exudative water regime of the soil, to the slightly depressed areas, with faulty drainage, in which the salinization process predominates over the desalination process. Another plausible cause of salinization characteristic of heavily compacted surfaces, with mineralized groundwater without raising their level, is the increase in the height of capillary rise of water in the soil. This phenomenon is possible by accentuated compaction, by destroying the structure and achieving the capillary continuity of the soil on the entire thickness of the profile, especially on the pastures loaded with too many animals during the wet periods of the year.

Improvement of saline and sodium soils involves a series of complex measures, being in possession of all data related to local factors: the degree of uneven terrain, meso and microrelief shape, soil granulometry, the degree and intensity of salinization and soda, the degree of desiccation and dams and a number of other physical and hydrophysical characteristics of the TEOs in question, land use category, genesis of solonet, saline solonet, respectively of other saline soils (components of the soil cover in the perimeter of Şag commune).

The saline and alkaline soils, in the studied area, the salinized, salinized-sodized soils, the salinized solonets are improved by specific measures:

- solonets, can be proposed for pasture use, possibly floristic reservations;
- the saline-sodium soils require the restoration of the drainage and gypsum amendment system, plus agro-amelioration measures from case to case (leveling, mole drainage, scarification - loosening, resistant plants in the assortment of cultivated ones);
- washing is required only on a drained bottom and only where the salinization is strong, being

a subsequent measure to correct the solidification by gypsum.

Acidity

Acid soils were formed by intense leaching of soluble soils and calcium carbonate in some rocks, destruction of silicates and alteration of other primary minerals with the release of bases and oxides-hydroxides of Si, Al, Fe, Mg, perforation of bases and the accumulation of hydroxides in clay minerals; deep migration of newly formed clay "protected" by fulvic acids and formation of the B argiloiluvial horizon.

The improvement of these acid soils can be achieved by: calcium amendment with different doses of $CaCO_3$ t/ha regulation of the aerohydric regime, through agro-ameliorating measures of ameliorating fertilization and land improvement measures.

Humus reserve

The mapped agricultural area with limitations due to the humus reserve has moderate and low limitations, which entitles us to continue to recommend a rational fertilization, balanced with both organic and chemical fertilizers and the application of agrotechnics adapted to local conditions, creating conditions favorable physical - aerohydric, mechanical, hydrophysical and chemical, the humidification process, the main source of increasing the productive potential and preserving the important characteristics of the soils.

The mineral part of the soil is made up of mineral particles of different sizes.

CONCLUSIONS

A plausible cause of salinization characteristic of heavily soiled surfaces, with groundwater mineralized without raising their level, is the increase of the capillary rise of the water in the soil.

Acidic soils were formed by intense leaching of soluble soils and calcium carbonate in some rocks, destruction of silicates and alteration of other primary minerals with the release of bases and oxides of hydroxides of Si, Al, Fe, Mg, perforation of bases and bringing the hydroxyls into clayey minerals; The in-depth migration of newly formed "protected" clay by fulvic acids and the formation of the argiloiluvial B horizon.

The cartographic agricultural of studied area with limitations due to the humus reserve has moderate limits and limited limits, which justifies us to recommend a rational fertilization, balanced with both organic and chemical fertilizers, and the application of an agrotechnics adapted to local conditions, creating conditions favorable physical - aerohydraulic, mechanical, hydrophysical and chemical processes, humification process, the main source for increasing the productive potential and preserving the important soil characteristics.

The degree of compaction is expressed quantitatively by apparent density, through porosity and penetration. We have a natural compaction caused by volume variations, temperature variations, accompanied by so-called "self-sacrifice" at the surface of the ground, and the most widespread anthropogenic compaction dangerous due to the mechanical work at proper humidity, the large number of passes on the ground with heavy machinery and equipment.

Excess wetlands from rainfall are generally depressed, stagno-gleyc formed on fine textured materials.

Grounds with humidity excess from the groundwater are influenced by humidity due to the presence of the groundwater at low depth (critical).

Within the studied territory, soil moisture can decrease in some years to the root casting coefficient for periods that may exceed 5-15 days. In these years, many crops suffer from the lack of water with low crop yields. Irrigation is necessary for very intensive agriculture.

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SOIL BIODIVERSITY MODELLING ITS HABITAT AND CREATING PEDOFEATURES FOR SOIL CLASSIFICATION

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Abstract

Soils "are alive" due to the high activity of their biota. But, when named soils in different classifications the biological activity is more or less ignore. This paper brings biodiversity in the centre of the soil genesis and evolution, and emphasized its activity that modelling the habitat and consequently generating pedofeatures specific to each soil. The researches had been performed on two Greyzemic Phaeozems. Their main morphological characteristic is the presence of the „uncoated silt and sand grains on structural faces in the lower half of a mollic horizon" (WRB-SR-2014). The micromorphological observation located the areas with the uncoated silt and sand grains in the old macrofauna coprolites, integrated into the soil groundmass. The macrofauna also brings from the deeper horizons, soil material (more clayey and less humic) compensating in this way plasma eluviation. On the general background of pedolandscape characteristics (relatively mobile soil plasma containing fulvic acids - in Ame horizon exclusively; clayey loamy texture; and climatic conditions) the soil biodiversity modelling its habitat and created specific pedofeatures helpful for soil classification.

***Key words**: biodiversity habitat, micromorphology, Greyzemic Phaeozem, macrofauna.*

INTRODUCTION

Soil is the critical and dynamic regulatory centre for the majority of processes occurring in both natural and managed terrestrial ecosystems (Barrios, 2007). At the scale of plant roots and macrofauna (centimeters to millimeters), soil is best described as a highly complex assemblage of pore spaces (more or less water saturated) and soil aggregates (Tecon & Or., 2017).

Many species of invertebrates are important in soil fertility and play a vital role in the production and maintenance of healthy soils (Chiriac & Murariu, 2021).

The variety of aggregate sizes, of pore spaces and of chemical gradients results in highly diversified microhabitats (Tecon & Or., 2017). Soil functions as a favorable habitat for many invertebrate species, and invertebrate communities are involved in geochemical cycles (Lemanceau et al., 2014).

Several biotic and abiotic processes act to redistribute organic C and mineral constituents as bioturbation by soil macrofauna or transport by water flow in soil pores (Lavelle, 2012; Tecon & Or., 2017).

The trophic structure of soil fauna can be influenced by changes in soil properties, therefore, different trophic groups respond in various ways to changes in the plant community and soil properties (Xue et al., 2021).

In what concerning the properties of the Greyzemic Phaeozems, as a result of an irrational land use, the present tendencies in their evolution of highly dispersive silicate part (of the Greyzemic Phaeozems from the Pre-Carpathian region) indicate the degradation of their clay profile and loss of very important ecological functions (Franco, 2018).

The microscopic study of Greyzemic Luvic Phaeozems showed, near the greyzemic features, as uncoated sand and silt grains on pores and ped surfaces, also the presence of abundant clay cutans in the argic horizon, as well as abundant secondary carbonates in the subsoil presented by carbonate impregnation of plasma, pseudomicellia and soft and hard nodules (Puzanova et al., 2017).

Soil is the critical and dynamic regulatory centre for the majority of processes occurring in both natural and managed terrestrial ecosystems (Barrios, 2007).

Land-use intensification strongly influences biodiversity by altering habitat heterogeneity, the distribution of habitat types and their extent (Eggleton et al., 2005).

The soil environment is likely the most complex biological community and soil organisms are extremely diverse and contribute to a wide range of ecosystem services that are essential to the sustainable function of natural and managed ecosystems (Barrios, 2007).

This paper emphasized the biological activity that modelling the soil, its habitat, and generating pedofeatures, specific to each soil type, and used for soils classifications.

MATERIALS AND METHODS

Two Greyzemic Phaeozems (WRB-SR–2014) located in different pedolandscapes and climatic conditions had been studied: P_1 - in upper Jijia Plain, and P_2 - in Western Romanian Plain.

P_1 was formed on a slightly sloping surface to the northeast (2-5%) of interfluves, at the absolute altitude of 265 m, in marly clay parent material. Thus the global natural drainage is good. The soil humidity regime is ustic-udic, whilst the soil temperature regime is mesic. The bioclimatic zone is forest-steppe with *Quercus petraea* forest, *Carpinus betulus*, *Acer campestris, Cornus sanguinea*; the grassy vegetation is dominated by *Poa nemoralis* and *Galium schultesi*.

The climate is temperate continental, with the average annual temperature of 8.3ºC, and the average annual precipitations of 563.3 mm.

The second soil profile, P_2, was formed on flat surface, at an absolute altitude of 86 m. The parent material is composed of loessoid deposits. The global natural drainage is good and the groundwater is at 5-10 m depth. The soil humidity is ustic (humid tempustic), whilst the soil temperature regime is mesic. Bioclimatic zone is of oak forest (*Quercus cerris* and *Quercus frainetto*). In the grassy cover, the main edifying species were: *Lithospermum purpureocoeruleum, Festuca valesiaca, Potentilla recta, Verbascum phoeniceum*, *Lathyrus niger, Crepis praemorsa, Ranunculus polyanthemos*, *Polygonatum latifolium,* and *Euphorbia amygdaloides*.

The climate is temperate continental, with an average annual temperature of 10.7ºC, and the average annual precipitations of 545 mm.

Disturbed (for physical and chemical analysis) and undisturbed (for micromorphological study) soil were sampled from each pedological horizon and determined by the standard methods of ICPA-Bucharest (ICPA Methodology, 1987).

From the undisturbed soil blocks (air dried and impregnated with epoxy-resins), oriented thin sections (of 25-30 μm) have been made for the micromorphological investigation. The thin sections had been studied with Documator (20X) and the optical microscope (50-500 X) in plane polarized (PPL) and crossed polarized (XPL) light. The terminology used for micromorphological description was according to Bullock et al. (1985).

RESULTS AND DISCUSSIONS

The main morphological characteristic of the Greyzemic Phaeozems is the presence of the “uncoated silt and sand grains on structural faces in the lower half of a mollic horizon” (WRB-SR–2014), the Ame horizon respectively. This horizon is defined (according to SRTS - 2012) as an A mollic-greyzemic (Ame) horizon located at the base of the Am horizon and has residual accumulations of quartz or other weather-resistant minerals, stripped of colloidal coatings, as spots frequently enough to give the faces of dry structural elements colors with values of 3 and higher, and chrome below 2. This horizon is between an Am and a Bt horizon. It is also called A hypoluvic and showed a “powdering” with quartz; representing the initial stage of an E horizon formation.

The granulometry data of the two Greyzemic Phaeozems emphasized that clay content (Figure 1) ranging between 32.8% into the Am horizon, and 34.5% into the Ame horizon of the P1, while in P2 the clay content (Figure 2) ranging between 28.0% in Am and 33.5% in Ame.

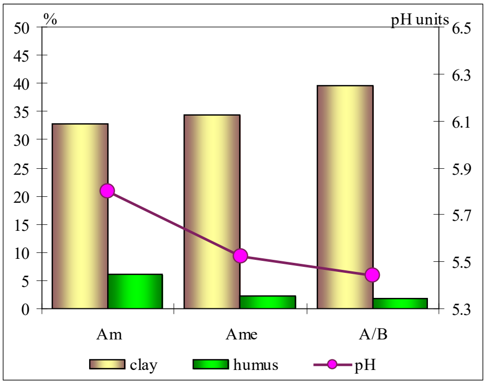

Figure 1. The clay and humus content of P_1 and the soil acidity

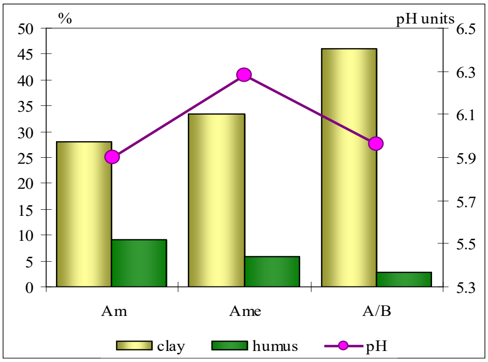

Figure 2. The clay and humus content of P_2 and the soil acidity

Both Greyzemic Phaeozems are moderately acid, the pH values ranging between 5.52-5.90. Into the Ame horizon of P_2, the pH is higher (6.28). According to the values of the base saturation degree (56-68%), the P1 is mezobasic in the mollic epipedon, while Ame horizon is oligo-mezobasic, due to a lower value (42%). The P_2 profile is saturated in bases, the values being very high (92-94%), as well as in Ame horizon (93%).
The analytical data showed high content of humus (Figure 1) both in Am upper horizon (6.12-9.12 %) and in Ame (2.34-5.57%).
In what concerning the analysis of the fractional organic carbon, on the background of a pH 6.1-6.5, the fulvic acids (CAFT) had been detected into the Ame horizon of P_2 (13.1% from the total carbon). Along with this, the presence of the aggressive fractions of the total fulvic acids (CAF_{1a}) had been identified (0.2% from soil).

The mineralogical composition of clay (< 0,002 mm) in both soil profiles showed that illite is dominant (50-53% - Figure 3), while the smectite, the most mobile clay fraction, is lower (42-45%) in Ame.

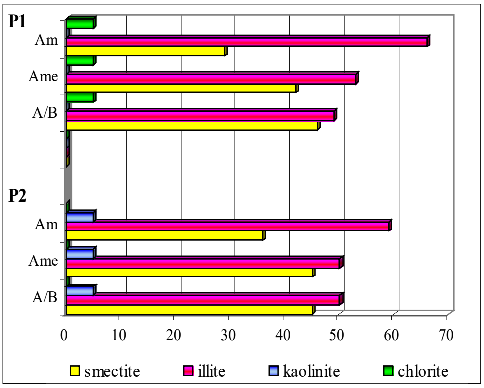

Figure 3. The mineralogical composition of clay (< 0,002 mm) in both soil profiles.

The dominance of the inactive illite clay in the whole humus horizon (0-70 cm) of all Greyzemic Phaeozems (studied by Franco in the Pre-Carpathian region), as well as the high content of kaolinite reduce the role of the clay plasma as the major stabilizer of the organic matter and further of the soil microstructure, along with the accelerated humus mineralization (Franco, 2018).
The exclusive presence of the fulvic acids in Ame horizon and specially their aggressive fraction, showed a great mobility of the organo-mineral plasma at this level and also its local reorganization giving the groundmass an uneven appearance.
What keeps the Ame at the level of an A mollic horizon is the high amount of organic matter (4.38-5.76%) and especially the large amount of stable fractions: humic acids (ranging between 25.8-34.8% from the total C) and humines (varying from 52.0 to 64.8% from the total C). These stable organic components are intimately linked (by means of the binding Ca^{++} and Fe^{++} cations) to the colloidal edaphic substrate which they stabilize, thus, the dominant image of this horizon is that of a mollic one.
At micromorphological level this horizon (Ame - 22-34 cm) appears having a complex structure: subangular blocky and locally

spongy. The porosity is relatively high (20-30%) and is represented by a network of fine cracks, interconnected voids and also biogenic channels (2-6 mm ∅).

The related distribution pattern (the spatial arrangement between the coarse and fine material, skeleton grains and plasma respectively) is complex: chitonic, and locally gefuric (in the areas depleted in plasmic constituents), and monic (in the areas where the skeleton grains appear concentrated and uncoated).

Plasma is clayey-humico-ferric with un-differentiated b-fabric (the spatial arrangement of plasmic, fine material).

The colloidal edaphic substrate is dominated by illite (Figure 3) in the mollic epipedon, and as a result the related distribution pattern is chitonic (*the best type of related distribution pattern, from the agricultural point of view*) in which the shape and size of illite particles make the spatial organization of matrix components more lax.

The soil skeleton is frequent and consisting of quartz, feldspars plagioclase, mica flaks (muscovite), glauconite. Phytolites integrated in the soil groundmass also appear.

Plant debris, still remains numerous at Ame depth (22-34 cm), and are fresh (with birefringent cellulose) located into the bio-channels, and in different degrees of decomposition (located either in the deformed channels or integrated into the soil groundmass).

Particles of charcoal (in longitudinal section) having < 1 mm, appear frequently.

Fungal spores (black, spherical, strongly ornamented and yellowish-brown, ellipsoidal) had been observed on vegetal remains or in their vicinity. Also, brown fragments of mycelium appear sporadically in the voids.

The pedofeatures (generated by different pedo-genetically processes) that appear in this horizon are: textural, depleted and amorphous.

Many type of textural pedofeatures formed into the Ame horizons, as:

- impure clay coatings (illuvial coatings composed of plasmic material identical to that of the horizon groundmass - clay + organic matter ± Fe) without optical orientation, appear located on the surfaces of the structural elements;
- dark brownish yellow coatings (more reddish in N+) with diffuse-sharp extinction; some of them appear integrated in the groundmass and are slightly deformed; also identical material clogs some pores; this type of coatings appears located inside the structural elements, in the intrapedal pores; also the groundmass in their vicinity is very rich in organic matter and Fe;
- yellow to yellowish brown clay coatings free of impurities, with good optical orientation and sharp extinction.

Depleted pedofeatures are groundmass microzones depleted of plasma and residually enriched in skeleton grains.

Amorphous pedofeatures are represented by small blackish-brown nodules.

The micromorphological image of the Ame horizon reveals a mosaic of microzones with different colors, appearance and compositions:

- in some microzones of the groundmass, the constituents are densely packed, which generated chitonic related distribution pattern (Figure 4);

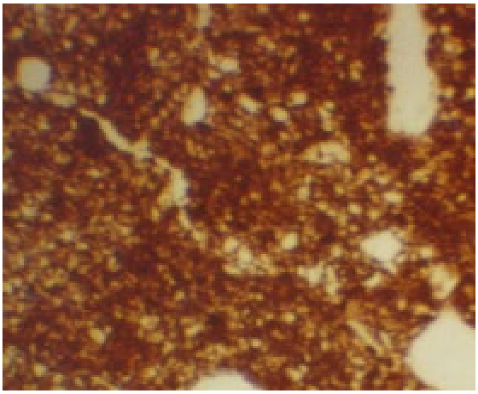

Figure 4. Ame horizon: the horizon groundmass rich in clayey-humico-ferric plasma

- microzones, relatively wide and very frequent, enriched residually in skeleton grains (Figure 5), due to the plasma migration, where the constituents are loosely packed, the related distribution pattern being gefuric; in these areas the clay-humic-ferric plasma remained only as discontinuous coatings or formed locally bridges between the skeleton grains; their presence highlighted a very intense process of plasma leaching;

- microzones with monic related distribution pattern were also observed, in which uncoated skeleton grains appear concentrated (Figure 5).

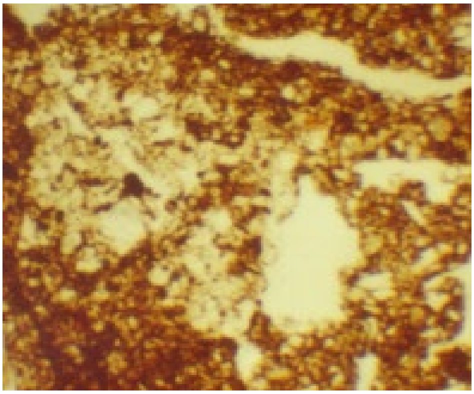

Figure 5. Ame horizon area with uncoated silt and sand grains (depleted in plasmic material and enriched residual in skeleton grains)

The soil macrofauna activity is very high, emphasized by the biological pedofeatures that occupied ≥ 70% of the horizon groundmass. Modelling their habitat, they repeatedly process the soil material. Thus, fresh coprolites (created by the earthworms) appear into the channels and old coprolites and pedotubuls had been integrated in the horizon groundmass.
The microzones with uncoated skeleton grains appear concentrated into the old coprolites, integrated into the groundmass (Figure 6).

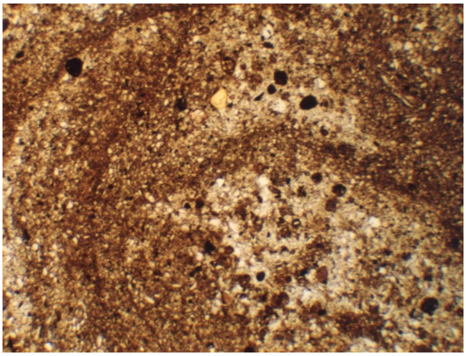

Figure 6. Mezofauna coprolites with bowlike distribution pattern and extended microzones with uncoated skeleton grains.

In these areas the skeleton grains are partially or totally uncoated, and from their more or less lax spatial distribution, results a porous micro-space which further favors the soil solution circulation, and consequently creates furthermore leaching conditions for plasma).
In this respect, it is noteworthy that the main characteristic of the Ame horizon and consequently of the Greyzemic Phaeozems "uncoated silt and sand grains" are located in the old coprolites and pedotubuls created by the earthworms and integrated, in time, into the horizon groundmass. Therefore, the main classifying characteristic of the Greyzemic Phaeozems had been generated by the soil macrofauna.

CONCLUSIONS

The defining feature of the Ame horizon is the presence of areas residual enriched in the skeleton grains due to plasma leaching, consequently a specific spatial redistribution of plasma and skeleton grains (of silt and fine sand sizes) generated during pedogenesis.
The genesis of the Ame horizon cannot be attributed exclusively to plasma leaching, but mainly to biological activity, because these specific areas appear in the old macrofauna coprolites (integrated in the groundmass).
The biological activity also compensates the plasma eluviation by bringing, from the deeper horizons, soil material (more clayey and less humic).
On the general background of the pedolandscape characteristics (relatively mobile soil plasma containing also fulvic acids - in Ame horizon exclusively; a clayey loamy texture and climatic conditions) the soil biodiversity modelling its habitat creates specific pedofeatures helpful for soil classification.

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EVOLUTION OF SOIL PHOSPHORUS CONTENT IN LONG-TERM EXPERIMENTS

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Abstract

Researches carried out in the long-term experimental fields of the agricultural research stations from Valu lui Traian, Turda and Lovrin (experiments started in 1967) and Teleorman and Secuieni (started in 1976 and 1975) highlighted that phosphorus fertilization in doses of 40, 80, 120, and 160 kg/ha led to statistically assured increases for wheat and maize production and to an increase in the level of soil supply with available phosphorus. Currently, in Romania 65.41% of the country's agricultural area are characterised by small, very small and extremely low values of soil available phosphorus content. The trend is worsening due to the low level of using phosphorus fertilizers (on average, between 2012-2019, 13 kg P/ha were applied, the deficit being 26.46 kg/ha). Therefore, it is required a minimum dose of phosphorus of 80 kg/ha, while over 120 kg P/ha are needed to ensure a better level of soil phosphorus content. Higher doses ensure not only higher yields but also better use of nitrogen-based fertilizers or nitrogen and potassium-based fertilizers. In all long-term experiments (39-51 years) high doses of phosphorus (over 120 kg P/ha) led to an increase in soil phosphorus stock at a very high level of supply in all experimental stations. Every 100 kg P/ha increases annually the soil phosphorus content with 0.59-1.90 mg/kg. Long-term (39- 51 years) fertilization with phosphorus, regardless of dose (up to 200 kg P/ha) did not lead to statistically assured increases of heavy metals (Cd, Cu, Pb, Zn, Mn) content in soil.

Key words: *long-term experiences, phosphorus, wheat, maize.*

INTRODUCTION

The continuous growth of the world's population has led to the continuous improvement of agricultural technologies. The fertilization system ensured a production increase of about 40%. In the fertilization system, phosphorus has an important role because: it is found in all plant organs, takes part in building the molecular architecture of various nucleic acids contributing to the formation of genetic code, increases plant resistance to drought, counterbalances the excess of nitrogen, stimulates fruiting and increases fruit resistance to storage conditions, participates in enzymatic processes with a synthetic role, has an essential role in photosynthesis, increases yield quantity and quality (Marin, 2020; Borlan et al., 1994; Dodocioiu et al., 2009; Ștefanic et al., 2006; Lăcătușu, 2006).

FAO (1999) has estimated that fertilizers contribute with 55-57% to the increase in average production per hectare and 30-31% to the total increase of crop production. Lupu (2007) showed that worldwide fertilization contributes with 40% from the total increase in crop production.

Research regarding mineral fertilizers has shown that in short-term experiments, due to soil resilience, the results often do not show statistically significant changes in the physical, chemical or biological characteristics of the soil, excepting the excessive doses of fertilizers and sandy soils. Results had begun to appear highligthing that in the long run mineral fertilizers lead to negative changes in the physical, chemical or biological properties of the soil, with negative effects on crop production. For this reason, Academician Cristian Hera has decided to organize in a unitary network, in different pedoclimatic conditions, long-term experiments with the same doses of fertilizers applied. Between 1967-1975, 16 experimental fields were organized, some of them being still maintained today, but most of them disappeared after 1990 or have undergone changes due to the disorder in the economy and the drastic reduction of funds in agricultural research.

Long-term experiments will still remain, probably for a long time, the best tool for characterizing the soil as an environmental factor and for setting the critical thresholds of different soil properties, as well as for extrapolating experimental data to larger areas, despite the fact that they are not perfect (Dumitru et al., 2008).
The interaction between N and P can be considered the most important interaction between nutrients, having practical significance (Aulach et al., 2007). Research studies had calculated the N/P ratio of cereals (n = 759) and indicated that over 40% of crops reach maximum yield when this ratio is relatively close, ranging from 4 to 6 (Sadras, 2006).
Hera (2010) has shown that the level of soil available phosphorus is strongly affected by the use of mineral fertilizers and organic matter. After 26 years, 126 ppm of available phosphorus was accumulated in the plots fertilized with 160 kg P_2O_5/ha/year, comparing to 3.6 ppm in the control plots. Under the influence of organic fertilization, the available phosphorus content increased from 10.4 ppm in control plots to 25.1 ppm in plots fertilized every 4 years with 60 t manure/ha. The results showed that the annual application of 81 kg P2O5/ha is required for the typical cambic chernozem soil from Fundulea, of which 44 kg P_2O_5/ha re needed to maintain the normal soil content and 37 kg P_2O_5/ha are needed to increase the available phosphorus content with 1 mg/kg.
The researches carried out on the chernozem from Caracal, the luvosol from Oradea, the luvosol from Podul Iloaiei, the eutricambosol from Targu Mures, the cambic chernozem from Perieni, the albic luvosols from Albota and from Livada, and the reddish-molic preluvosol from Simnic, have showed increases in the amounts of soil available with increasing doses of phosphorus based fertilizers, when they were 80-160 kg P_2O_5/ha, both in the case of exclusively mineral fertilization, and especially organic + minera fertilization, while the lack of fertilizers with phosphorus leads to a very sharp decrease in the availability of phosphorus for plants and the achievement of minimum levels that are difficult to change over time, slowing down the plant growth and low yields (Nedelciuc et al., 1989; Mărcuș, 1989; Mocanu et al., 2007; Ciobanu et al., 2003; Vintilă et al., 1989; Rizea et al., 2008; Borza et al., 2001).

MATERIALS AND METHODS

Previous researches concluded that the best crop yields are obtained by fertilizing with nitrogen and phosphorus. Under these conditions, the treatments were established only with these elements, applied in doses of 0, 40, 80, 120, and 160 kg/ha.
In order to highlight the effect of fertilization on the trend of soil phosphorus content, soil samples were collected from experimental fields organized in the agricultural research stations of Valu lui Traian, Turda and Lovrin (experiments starting in 1967), and Teleorman and Secuieni (starting in 1976 and 1975).
Soil samples were collected from the topsoil, at a depth of 0-20 cm, and soil analyzes were performed by the following methods:
- total nitrogen (N%): Kjeldahl method, disintegration with H_2SO_4 at 350°C, potassium sulphate and copper sulphate as catalyst - SR ISO 11261: 2000;
- available phosphorus (mobile): according to the Egner-Riehm-Domingo method and dosed colorimetric with molybdenum blue, according to the Murphy-Riley method (reduction with ascorbic acid);
- total phosphorus, colorimetric method. ICPA Methodology 1986, chap. 8, point 2, PT 2.

RESULTS AND DISCUSSIONS

In Romania, research carried out within the Soil Quality Monitoring System in the grid of 16 x 16 km showed that, on 0-50 cm depth, the soil supply with available phosphorus (P) is extremely low (< 4 mg/kg) on 11.36% from the area (107 sites), very low (4-8 mg/kg) on 21.02% from the area (198 sites), low (9-18 mg/kg) on 33.01% from the area (311 sites), medium (19-36 mg/kg) on 20.70% from cases (195 sites), high (37-72 mg/kg) on 9.45% from cases (89 sites) and very high (> 72 mg/kg) on 4.48% from total area (42 sites). Low, very low, and extremely low values represent 65.41% from the total agricultural area of the country (Dumitru et al., 2000).
The insufficient doses applied in agriculture led to a decrease of soil phosphorus content. Thus,

in 2000 compared with 1990, the areas with low, very low and extremely low P stocks increased with 29%, from 4,473,000 ha to 6,330,000 ha (Dumitru, 2003).

Even in such conditions, organic and mineral phosphorus-based fertilizers are not adequately applied. Data presented in Table 1 showed a continuous increase of soil phosphorus deficit. On average, for 2012-2019 period, 13 kg P/ha were applied, the deficit being of 26.46 kg/ha. Therefore, it was expected to increase the agricultural area affected by phosphorus deficit and to obtain low crop yields. Furthermore, the increase of water deficit leads to a reduced phosphorus uptake in plants. At such high deficit, the recommendations of European Union for reducing with 20% the mineral fertilizers doses could be difficult to apply.

Table 1. The evolution of soil phosphorus consumption, the amount of applied fertilizers and the soil phosphorus deficit

	2012	2013	2014	2015	2016	2017	2018	2019	AVERAGE 2012-2019
Total annual phosphorus consumption by crop (tons)	200121	338045	367566	322356	371221	472728	529144	492980	325148
Total annual phosphorus deficit (tons)	87121	-224045	-248566	-189356	-245221	-327728	-341144	-291980	-244395
Total annual phosphorus deficit /ha (kg/ha)	-9,27	-23,85	-26,46	-20,15	-26,1	-34,88	-36,31	-31,08	-26,01
Quantity of P based fertilizers applied annually (thousands t) / (kg/ha)	113/12	114/12	119/13	133/ 14	126/13	145/15	188/20	201/21	142/15
Organic fertilizers, total (thousands t) / (kg/ha for arable lands)	13293/ 1410	13580/ 1450	16262/ 1730	15212/ 1620	14927/ 1590	12625/ 1340	14717/ 1570	15323/ 1630	14492/ 1543
Organic fertilized area (thousands ha)	443	453	542	507	498	421	490	511	483
Irrigated area (thousands ha)	165.4	180.9	145.4	173.2	152.6	211.6	266.1	-	-

Table 2 shows the effect of long-term phosphorus (superphosphate) fertilization on the level of soil available phosphorus content (mg/kg) in the studied experimental fields.

In all soils, P fractions are adsorbed on the surface of clay particles, especially iron and aluminium hydroxides and complexes of organic matter. At pH values lower than 5.8, the concentration of P in the soil solution is controlled by iron and aluminium phosphates, while below this value, by Ca and Mg phosphates. However, Al, Fe, Ca, and Mg phosphates can coexist in a wide range of soil pH (McDowell et al., 2001). This explains why the highest values of soil available phosphorus content are found in the Phaeozem from Teleorman, with pH values between 5.33 and 5.96, and a high content of clay and humus ranging between 3.72-4.56%.

The very different evolution of the level of available soil phosphorus under the effect of the same doses of superphosphate is due not only to the different soil characteristics analysed and different climatic conditions but also to the disorder that settled in research in the early postrevolutionary years. Experimental treatments in 1990-2000 no longer strictly reflected the experimental plan for different periods of time.

Table 2. Evolution of the level of available soil P under the long-term fertilization with phosphorus (superphosphate)

Dose of P_{AL} (kg/ha)	Valu lui Traian* Calcaric Chernozem	Turda Typical Chernozem	Lovrin Typical Chernozem	Teleorman Cambic Phaeozem	Secuieni Typical Chernozem
0	31	30	45	60	8
40	53^{XXX}	80^{xxx}	41	90^{xxx}	33^{xxx}
80	70^{XXX}	133^{xxx}	59^{xx}	145^{xxx}	75^{xxx}
120	101^{XXX}	145^{xxx}	93^{xxx}	194^{xxx}	97^{xxx}
160	141^{XXX}	156^{xxx}	95^{xxx}	204^{xxx}	114^{xxx}
DL 5%	10	6	10	4	9
DL 1%	14	8	14	6	12
DL 0,1%	21	11	21	10	16

*In the experimental field from Valu lui Traian the applied phosphorus doses were 0, 50, 100, 150, and 200 kg P/ha associated with the same N, and K doses.

The **typical Chernozem from Valu lui Traian** is medium supplied with phosphorus (31 mg P_{AL}/kg). On this soil, the application of 50 kg P/ha doses did not lead to significant increases in wheat yield (the control plot ensured a wheat yield of 4717 kg/ha, while the fertilized variant with 50 kg P/ha ensured a yield of 4907 kg/ha). The highest yield (6388 kg/ha) was obtained with a dose of 100 kg P/ha, and a very significant yield increases of 35%. Doses of 150 and 200 kg P/ha led to productions levels of 5649 and, respectively, 5767 kg/ha of wheat, ensuring distinctly significant yield increases (20 and 22%) compared to the control variant (Lupașcu et al., 2017).

Under irrigation conditions, the highest maize yield was obtained after fertilization with 100 kg P/ha and 150-200 kg N/ha.

Hera and Borlan (1984) showed that in most cases the combined application of nitrogen and phosphorus fertilizers leads to higher yields compared to the separate application of these elements.

After 44 years of application of phosphorus fertilizers, the soil phosphorus level (Chernozem from Valu lui Traian) increased very significantly with the applied dose of superphosphate, the P doses of 150 and 200 kg/ha leading to very high levels of available soil phosphorus content (101 and 141 mg/kg).

Blake et al. (2000) compared the phosphorus content from three long-term experiments (30 years) and showed that soil type significantly affected soil phosphorus dynamics, due to different organic matter contents. The application of phosphorus in both inorganic and organic (manure) fertilizers have an important effect on the soil phosphorus availability, uptake, leaching or fixing, but the rate of soil phosphorus recovering through crop from mineral fertilizers does not exceed 35%, with the lowest recovery (18%) in the soils with the highest clay content in Rothamsted. The most efficient use of phosphorus (on average 47% in Bad Lauchestaedt and 37% in Rothamsted) was in manure-treated soils. The highest amount of leached or fixed phosphorus (8 and 25 kg/ha/year) occurs in superphosphate-treated soils.

When the phosphorus inputs from the fertilizer exceed the P outputs through crop, the accumulation of soil P gradually increases over time (Kuo et al., 2005).

In the long term (44 years) experiments from Valu lui Traian, cadmium values varied between 0.40 and 0.47 mg/kg, not statistically significantly altered by the treatments applied. Copper values varied between 21 and 24 mg/kg, the values not being correlated with the treatments applied. Lead content values have not statistically significantly changed under the applied treatments, ranging from 20 to 21 mg/kg. The treatments applied did not significantly affect the total zinc content in soil, the values maintaining at 83-84 mg/kg.

On the **Phaeozem** from **SCDA Teleorman**, phosphorus fertilization led to a very significant increase of wheat production with the increase of dose, crop yield increases ranging between 15 and 23%. For each kilogram of phosphorus, the wheat production increased with 13.4 kg P/kg in the case of fertilization with 40 kg P/ha, with 9.3 kg/kg at a dose of 80 kg P/ha, with 5.6 kg/kg at a dose of 120 kg P/ha and with 5.0 kg/kg at a dose of 160 kg P/ha.

Davidescu et al. (1974) showed that phosphorus has a slightly higher effect in case of wheat sown after wheat, compared to wheat cultivated in rotation with maize, as is the case of this experiment.

The Phaeozem from SCDA Teleorman has a high content (60 mg/kg) of available phosphorus (P_{AL}). The data presented in table 2 show that after 39 years of superphosphate fertilization the available phosphorus content in soil increased very significantly in all variants (doses of 40, 80, 120 and 160 kg P/ha), the soil becoming very well supplied with phosphorus. In the variant fertilized with the maximum dose of phosphorus (160 kg/ha) the available phosphorus reached 204 mg/kg in soil.

In the same experiment, the total phosphorus content of the soil increased significantly when 40 kg P/ha were applied and very significantly when doses of 80, 120 and 160 kg P/ha were applied. The values of total phosphorus increased from 0.094% in the control variant to 0.146% in case of application the dose of 160 kg P/ha.

The total phosphorus content in the ploughed soil layer is the difference between phosphorus inputs (from fertilizers, root supply from the underlying horizons) and exports (crop export, losses by erosion). The main source for plant nutrition is the non-occluded mineral phosphates existing on soil particles surface. Plant nutrition is determined by the processes of desorption and diffusion of phosphate ions through the soil solution (Borlan et al., 1990).

When higher doses of phosphorus than the crop consumption are applied, the soil available phosphorus content increases significantly.

Tang et al. (2008) showed that for every 100 kg P/ha, the excess of phosphorus increases with 2-6 mg/kg in soil. In our experiments the excess increased with 0.59-2.84 mg/kg. In Teleorman, the accumulation of phosphorus had values of 0.59 mg/kg by applying 40 kg P/ha, 1.10 mg/kg at the dose of 80 kg P/ha, 1.32 mg/kg at a dose of 120 kg P/ha, and 1.56 mg/kg at a dose of 160 kg P/ha.

Doses of phosphorus did not bring significant changes in soil reaction. Superphosphates (simple and concentrated) can cause sporadic temporary effects of soil acidification by the incongruent solubilization of the contained monosubstituted phosphate, which over time results in disubstituted calcium phosphate and phosphoric acid. Thus, the generated acidity is neutralized over time in reactions with the soil hydrated sesquioxide, so that simple (17-20% P_2O_5) and concentrated (34-44% P_2O_5) superphosphates do not change sustainably the soil reaction. Bases (Ca, Mg) and the effect of slightly increase of the soil T value adsorption of phosphoric acid ions on soil particles also contribute to this situation (Borlan, 1998; Vintilă et al., 1984).

The application of phosphorus together with nitrogen in long-term experiments has led to significant increases in soil humus, according to the applied doses.

The content of heavy metals (cadmium, copper, lead, nickel, manganese and zinc) did not change statistically significant under the long-term fertilization with nitrogen and phosphorus of the cambic phaeozem from SCDA Teleorman.

Cadmium values ranged from 0.9 to 1.2 mg/kg and no correlation was found between the applied phosphorus doses over 39 years and the level of cadmium in the soil. The average cadmium level in the variants fertilized only with nitrogen was 0.99 mg/kg, in those fertilized with nitrogen and 40 kg/ha phosphorus the cadmium values were 1.07 mg/kg, in the variants fertilized with nitrogen and 80 kg/ha phosphorus the cadmium values were 1.05 mg/kg, in that's fertilized with nitrogen and 120 kg/ha phosphorus the average cadmium level was 1.00 mg/kg, and in the plots fertilized with nitrogen on a background of 160 kg/ha phosphorus cadmium level was 1.02 mg/kg. The average value of cadmium in plots fertilized only with different doses of phosphorus was 1.03 mg/kg. No cadmium accumulation was observed under the annual application of doses of 40-160 kg/ha P_2O_5 for 39 years. As in all experiments, also at **SCDA Turda**, the highest crop yield increases were ensured by nitrogen fertilization, but phosphorus fertilization ensured very significant additions to the crop yields, the best results were obtained under 80 kg P/ha application. Each kg of phosphorus from supephosphate applied on the chernozem at Turda ensured a crop yield increase of 9.1 kg of maize seeds/kg of P in case of fertilizing with P_{40}, 3.7 kg/kg at P_{80} applied dose, 1.6 kg/kg at

P_{120} applied dose and 1.7 kg/kg at P_{160} applied dose. All the doses of NP ensured very significant additions to the crop yield. The highest crop yield (9632 kg/ha) was obtained in the variants fertilized with $N_{120}P_{120}$. In order to reach the potential of the new varieties, it is required to increase the fertilizers consumption. Within irrigation systems, a proper fertilization is mandatory in order to at least double the crop yield per unit of used water, to prevent the drastic decrease of the soil nutrients level and to avoid nutrients unbalance occurrence. Irrigation without organic and mineral fertilizers lead to an economic inefficiency and decrease of soil fertility on long term. The nitrogen consumption has to increase up to 2040 level up to 1500-20000 thousand tons of N, phosphorus consumption up to 650-980 thousand tons of P_2O_5 and potassium consumption up to 500-700 thousand tons K_2O.The higher doses of phosphorus (120 and 160 kg/ha) improved significantly the soil phosphorus content (of the chernozem from SCDA Turda), 145 and 156 mg/kg P comparing with 30 mg/kg in control. Phosphorus doses up to 80 kg P/ha are maintaining doses which ensure the crop requirements and starting point for accumulation in soil. For higher crop yields and for P accumulating in soil, the applied doses have to be at least 120 kg P/ha.

Phosphorus fertilization ensured significant increases of the maize yield. The dose of P_{40} gave an increase of 5.6%, dose of P_{80} an increase of 8.7%, dose of P_{120} an increase of 9.4%, and the dose of P_{160} an increase of 7.4%.

The level of phosphorus in the Chernozem from Turda increased distinctly significantly after fertilization with P_{80}, and very significantly in the variants fertilized with P_{120} and P_{160}, when the values reached the range of very good phosphorus supply (93 and 95 mg/kg P).

The target for available phosphorus supply in Belgium is between 120 and 180 mg P/kg. This level should be reached in our country as well.

The application of phosphorus fertilizers, natural or industrial products, always positively affects the soil available phosphorus content.

The long-term application (51 years) of phosphorus and nitrogen fertilizers did not lead to a statistically significant increase of the soil heavy metals content (Cd, Cu, Mn, Pb, Zn), the values of these elements being in the normal content class: less than 1 mg/kg Cd, 17 mg/kg Cu, 15 mg/kg Pb, 48 mg/kg Zn and 303 mg/kg Mn.

At SCDA Secuieni, long-term fertilization (42 years) with nitrogen and phosphorus showed a continuous, statistically significant increase in corn grain yield. In the case of phosphorus fertilization, statistically assured increases occurred starting with the dose of 80 kg P/ha, which ensured a significantly distinct increase compared to the unfertilized control of 9%. Doses of 120 and 160 kg P/ha provided very significant crop yield increases (17-18%). At the same doses (0, 40, 80, 120 and 160 kg/ha), nitrogen fertilizers provided double production increases compared to phosphorus fertilizers. The highest production (9805 kg/ha) was obtained in the variants fertilized with $N_{160}P_{160}$. The lowest production (5569 kg/ha) was obtained in non-fertilized variants (Marin et al., 2021).

The data from the Code of Good Agricultural Practice estimate that for one tonne of main production and the corresponding amount of secondary harvest, 27.5 kg N/ha, 12.5 kg P/ha, and 16.6 kg K/ha are up taken from the soil. At the maximum production of 9805 kg/ha, 269.6 kg N/ha, 122.6 kg P/ha and 161.8 kg K/ha were up taken from the soil. We should return at least these amounts of nutrients to the soil. Long-term fertilization (42 years) with doses of 40-160 kg P/ha led to very significant increases in the level of total phosphorus and available phosphorus in soil (chernozem).

The level of available phosphorus in the soil increased from very low (4-8 mg/kg) in the control variants, to medium (19-36 mg/kg) in the fertilized variants with 40 kg P/ha, and to very high (over 72 mg/kg) in variants that received over 80 kg P/ha, but the long-term recommended dose for fertilization with N_{120}-N_{160} is 120 kg P/ha. On the **chernozem from Lovrin** the available phosphorus content did not change statistically significantly in the variants in which the phosphorus doses were of 40 kg P/ha. On a background of 80 kg P/ha, the application of low doses of nitrogen (0, 50, 100 kg/ha) leads to statistically assured increases of the soil available phosphorus, but by increasing the doses of nitrogen to 150 and 200 kg/ha, once as production increases, phosphorus no longer accumulates in soil. The very significant increase of soil available phosphorus content was identified by applying doses of 120-160 kg P/ha. After 51 years, the available phosphorus in soil increased very significantly in the fertilized variants with 120 and 160 kg P/ha, reaching 93 and 95 mg/kg compared to 45 mg/kg in the unfertilized control. On agricultural land in Lovrin, the dose of phosphorus should be increased to 120 kg/ha.

In Belgium, values below 120 mg P/ha are considered low and for this, doses of 115 kg P/ha are recommended for this range of low values of available phosphorus in soil. The targeted level of available phosphorus content in Belgium is between 120 and 180 mg P/ha. We must also go towards this goal.

Long term application of chemical fertilizers with nitrogen and phosphorus did not lead to a statistically increase the heavy metals content (cadmium, copper, manganese, lead and zinc) in soil, the values of these elements being in the normal range: less than 1mg/kg Cd, 17 mg/kg Cu, 15 mg/kg Pb, 48 mg/kg Zn, 303 mg/kg Mn.

CONCLUSIONS

The small, very small and extremely low values of soil available phosphorus contents affect 65.41% of the country's agricultural area, and the trend is worsening.

On average, in the period 2012-2019, 13 kg P/ha were applied and the deficit was 26.46 kg/ha.

Phosphorus (superphosphate) fertilization has led to very significant increases in wheat and maize yields, but their values are also depending on the climate regime.

The dose of 80 kg P/ha can be appreciated as a maintaining dose that always ensures yield increases and a better use of nitrogen fertilizers.

In all long-term experiments (39-51 years) high doses of superphosphate phosphorus (over 120 kg P/ha) led to increased phosphorus stocks in soil at a very high level of supply in all experimental stations.

For every 100 kg P/ha the excess of phosphorus in soil increases annually with 0.59-1.90 mg/kg.

Long-term fertilization (39-51 years) with phosphorus, regardless of dose (up to 200 kg/ha P) did not lead to statistically assured increases in soil heavy metals content (Cd, Cu, Pb, Zn, Mn).

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MITIGATION OF SOIL COMPACTION IN SUGARBEET HARVESTING AND SLURRY APPLICATION BY INCREASING TIRE PRINT AND COVER CROPPING

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Abstract

The paper aimed to present results of two field experiments, where the effect of increased contact area between soil and tire (tire print) and the effect of cover crop on soil compaction was analysed in the Eastern part of Austria. One field experiment investigated the effect of chassis in a six-row sugarbeet harvester (two-axle, three-axle) and soil condition (wet, dry). The second experiment analysed the effect of tire inflation pressure in a slurry tanker (high: 300 kPa, low: 100 kPa) and field coverage (with and without covercrop) on track depth and soil penetration resistance. The results showed, that dry soil conditions in sugarbeet harvesting do not affect the soil penetration resistance and the bulk density negatively. The increase of the tire print area in a three-axle chassis reduced the risk of soil compaction. Lowering of the tire inflation pressure in the slurry tanker increased the tire print and reduced tire track depth in the field and soil penetration resistance. Cover crops created deeper track depths after traffic, which is explained by the loosening of cover crop roots.

***Key words**: sugarbeet tanker harvester, slurry tanker, tire inflation pressure, soil penetration resistance, track depth.*

INTRODUCTION

Agricultural soils can be affected in their ecological functions (biomass production; filter, buffer and transformation processes) through traffic of agricultural machinery. Soil compaction reduces the pore distribution, air permeability, hydraulic conductivity in the soil and root and plant growth. Resulted effects are yield depression, rut formation, soil erosion and increased draft force and fuel consumption in soil tillage. In agriculture, soil compaction as well as soil erosion by wind and water are classified as the most harmful processes which do not only end in a reduction of site-specific productivity but are also responsible for gas emission and a requirement for greater fuel energy in tillage processes (Horn et al., 2003). Subsoil compaction is a major concern in agricultural production, mainly due to its persistence. Effects of topsoil compaction are alleviated in a few years, when the soil is tilled, effects of subsoil compaction persist much longer and may even more or less permanent (Etana and Hakansson, 1994).

High field performance in the field operation can be reached with high working speed ("High speed farming") and/or increased working width. This driving factors are mostly coupled with higher machinery weight. Studies by Keller et al. (2019) stated that future agricultural operations must consider the inherent mechanical limit of soil, because the acceptable loads are exceeded due to upward trends in the average weight of farm machinery.

Shjonning et al. (2016) suggested as a consequence of their study - for highly inflated tires with tractor-trailer an upper threshold for springtime a wheel load of 3,000 kg for avoiding significant subsoil compaction.

In this context, the paper present two conducted field experiments in the eastern Part of Austria, with the aim to analyse technical adaption solutions (increasing the tire print through tire inflation pressure reduction and chassis adaption) and management measures (moisture content of the soil, covercrop integration) on selected physical soil parameters (track depth in the field, soil penetration resistance).

MATERIALS AND METHODS

One field experiment was carried out in 2015 at Hollabrunn (48°34'33.7"N 16°03'34.3"E), Lower Austria with good soil conditions for sugarbeet cropping (silty loam with average contents of 22.3% sand, 52.9% silt and 24.7% clay) to investigate the effect of two chassis (2-axle, 3-axle) of the six-row self-propelled sugarbeet tanker harvester on wet and dry soil conditions on soil physical properties (penetration resistance, dry bulk density, saturated hydraulic conductivity). A detailed description of the sugarbeet harvester and methodology is published in Moitzi et al. (2019). The second experiment was carried out on farm fields (loam soil with 34% clay, 49% silt and 17% sand with an soil organic carbon of 18.6 g/kg) in the northern part of the Austrian province of Burgenland in Krensdorf (47°80'N, 16°41'E, 194 m a.s.l.) in 2018. This study analysed the effect of slurry application in spring with different loads and tire inflation pressures in a field without cover crop and in a field with cover crop on track depth, soil penetration resistance and grain yield of the subsequently grown maize. The used methods for this experiment are detailled described in Moitzi et al., 2021.

RESULTS AND DISCUSSIONS

Sugarbeet harvester experiment

The three-axle harvester reached a total weight of 60.9 mg and was 11.8 mg heavier than the two-axle harvester with total weight of 49.1 mg. The total weight of the three-axle harvester was distributed equally with about 20 Mg each axle. Two-axle harvester distributed the total weight of 49.1 mg to the rear axle with 27.3 mg and to the front axle with 21.8 mg. With the three-axle undercarriage the maximum wheel-load (10.5 mg) was 23.3% (= 3.2 mg) lower than the maximum wheel-load (13.7 mg) of the two-axle harvester.

The bulk densities and the volumetric soil water contents of the two- and three axle harvester wheeled area (Table 1) were associated with total harvester weights of 60 mg and 47 mg, respectively.

The differences in bulk density between treatments were small. Statistically significant differences were found only in the dry treatment in a soil depth of 25-30 cm and 50-50 cm. The two-axle harvester reduced the bulk density in comparison to un-wheeled and three-axle treatment plots under dry conditions. This effect can be explained by the higher wheel-load of the axle in connection with the lower soil water content with higher tendency of deformation. Under wet soil conditions, more pores were filled with water and became rather incompressible (Smith et al., 1997). This could be the possible reason why the high wheel-load of the two-axle harvester did not alter the bulk density statistically significant under wet soil condition. In tendency, the bulk density was smaller after wheeling with the two-axle harvester than three-axle harvester and un-wheeled (Table 1). The effect of higher wheel-loads on bulk density was also found in Arvidsson (2001), where the traffic with the six-row harvester caused greater subsoil compaction than that with the three-row harvester. In our practical experiment, it was difficult to set the moisture content exactly with irrigation especially in the subsoil.

The course of soil penetration resistance differed between dry and wet treatments (Figure 1).

Soil penetration resistance increased with depth in the dry top soil (0-15 cm) and it was in the range of 5 and 7 MPa at the depth of 15-35 cm. Soil penetration resistance was smaller in the wet treatments. The undercarriage effect on the penetration resistance was small in the dry plots. In each treatment, an increased penetration resistance down to 15 cm soil depth was found, which could be explained by the dry hard soil (Figure 1). Some soil penetration measurements had to be rejected in the dry plots because it was impossible to penetrate into the hard soil (reduced n in Figure 1).

The wheeling with two-axle and three-axle harvester on the wet soil resulted in significantly higher soil penetration resistances in comparison to the un-wheeled control treatment, especially in depths of 0-10 cm and 11-20 cm (Table 2). The water content here was the same before and after harvest.

The soil penetration resistance was strongly influenced by the soil water content (Table 2). For wet soil conditions, the cumulated penetration resistance was reduced by 59% (un-wheeled), 44% (two-axle harvester) and 51% (three-axle harvester), respectively.

The multiple wheeling of the soil is caused by the offset track driving using diagonal steer (crab steering). Due to crab steering, the area was differented wheeled. For the 2-axle harvester, un-wheeled area was 6.7%, single-wheeled area was 66.7% and double-wheeled are 26.7%. For the 3-axle harvester, there was no un-wheeled area. 23.3% of the area was single-wheeled, 68.3% was double-wheeled and 8.3% was triple-wheeled. was 6.7%, single-wheeled area was 66.7% and double-wheeled are 26.7%. The wheeling effect on penetration resistance was higher in the wet plot. Single and multiple wheeling showed higher penetration resistance than un-wheeled in the depth 0-10 cm and 11-20 cm. No significant differences were observed in the soil depth 20-30 cm (Moitzi et al. 2019).

Long-term differences in soil penetration of high-axle traffic were found in many studies: Arvidsson (2001) found in his study significant differences in penetration resistance between treatments 2-4 years after traffic.

Slurry tanker experiment

The experiment with three slurry tanker filling levels and two tire inflation pressure of the tanker wheels (Table 3) was carried out on two adjacent fields (à 3 ha).

Regarding all treatments, the tire track depth tended to be deeper in the filled and half-filled slurry tanker setting than in the empty one (Table 4). In the field with cover crop, the average tire track depth was deeper in the field with cover crop than in the field without cover crop (6.88 cm vs. 5.83 cm, p = 0.014). Additionally, high tire inflation pressure of the slurry tanker showed significantly deeper tire tracks in the field than with low inflation pressure (6.68 cm vs 6.03 cm, p = 0.000).

Soil penetration resistance was not significantly affected by the filling level of the the slurry tanker (Table 4), rather. It was only by tendency that the filled tanker tended to resulted in higher top soil penetration resistance than the half-filled and empty tanker. The averaged soil penetration resistance (0-20 cm) was significantly differentiated by the treatment: un-wheeled plot at 0.76 MPa, low inflation pressure at 1.17 MPa, high inflation pressure at 1.31 MPa (p = 0.000). At the soil depth of 21-40 cm, the averaged soil penetration resistance was significantly lower (p = 0.007) in the un-wheeled plot (2.06 MPa) than in the low inflation pressure (2.24 MPa) and high in-flation pressure plots (2.26 MPa).

The effect of ground cover was significant in at athe soil depth of 0-20 cm (+cover crop: 1.01 MPa vs. -cover crop: 1.14 MPa, p=0.008), but not at soil depth of 21-40 cm (+cover crop: 2.15 MPa vs. -cover crop: 2.20 MPa, n.s.).

Compared to un-wheeled, the increase of soil penetration resistance (0-20 cm) was lower with low tire inflation pressure than with high tire inflation pressure: 72% vs 108% (total filled), 54% vs 64% (half-filled) and 50% vs 62% (empty). In the sub-soil (21-40 cm) the effect of tire inflation pressure was much lower: 7% vs 12% (total filled), 15% vs 15% (half-filled) and 7% vs 6%).

Table 1. Mean soil bulk density and mean volumetric water content after passing with the filled sugarbeet harvester

Soil conditions	Depth (cm)	Bulk density ($g\ cm^{-3}$) Un-wheeled	Two-axle	Three-axle	Volumetric water content ($cm^3\ cm^{-3}$) Un-wheeled	Two-axle	Three-axle
Dry[1)]							
	10-15	1.63 (n[3)]=13)	1.57 (n=7)	1.54 (n=7)	0.33	0.31	0.30
	25-30	1.55^{b}[4)] (n=3)	1.48^{a} (n=3)	1.59^{b} (n=3)	0.30	0.27	0.29
	50-55	1.35^{ab} (=3)	1.27^{a} (n=3)	1.44^{b} (n=3)	0.22	0.22	0.24
Wet[2)]							
	10-15	1.60 (n=13)	1.59 (n=7)	1.61 (n=7)	0.48	0.49	0.47
	25-30	1.52 (n=3)	1.42 (n=3)	1.46 (n=3)	0.41^{b}	0.39^{b}	0.31^{a}
	50-55	1.32 (n=3)	1.29 (n=3)	1.31 (n=3)	0.18^{a}	0.26^{b}	0.27^{b}

[1)] gravimetric soil water content 20%, [2)] gravimetric soil water content 30%, [3)] number of score samples is the same for the volumetric water content, [4)] statistically significant differences are shown for the wheeling effect with small letters; Student-Newmann-Keuls ($p<0.05$).

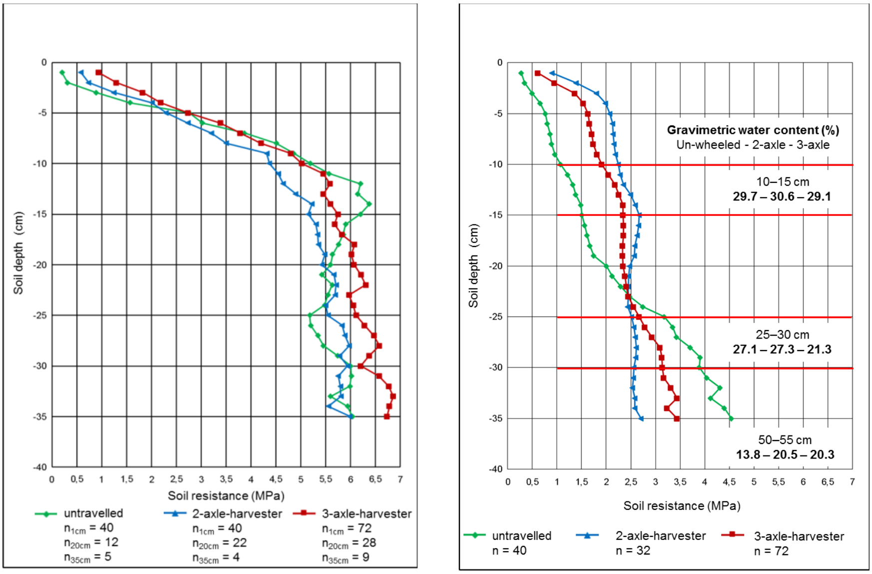

Figure 1. Course of penetration resistance in the dry treatment (left) and wet treatment (right)

Table 2. Mean cumulated penetration resistance (MPa) in different soil depths of dry and wet soil conditions

Soil condition	Depth (cm)	Un-wheeled	Two-axle-harvester	Three-axle-harvester
Dry[1)]				
	0-10	24.8 (n[3)]=40)	24.2 (n=40)	28.3 (n=72)
	11-20	55.3 (n=12)	50.2 (n=22)	52.6 (n=28)
	21-30	53.2 (n=5)	55.0 (n=4)	58.6 (n=9)
	0-30	125.9	124.4	133.5
Wet[2)]		n=40	n=32	n=72
	0-10	7.1^{a}[2)]	19.0^{c}	15.1^{b}
	11-20	15.5^{a}	25.3^{c}	22.8^{b}
	21-30	29.2^{a}	25.2^{a}	27.1^{a}
	0-30	51.8^{a}	69.5^{b}	64,9^{b}

[1)] gravimetric soil water content 20%, [2)] gravimetric soil water content 30%, [3)] number of score samples, [4)] statistically significant differences are shown for the wheeling effect with small letters; Student-Newmann-Keuls ($p<0.05$).

Table 3. Characteristics of the experimental design with technical parameters for the tractor slurry tanker combination

Tanker filling level	**Wheel**	**Wheel load [4] (kN)**	**Tire-soil contact area [5] (cm^2)**		**Mean ground pressure (kPa)**	
			Low inflation pressure [6]	**High inflation pressure [7]**	**Low inflation pressure [6]**	**High inflation pressure [7]**
Filled	Tractor front [1]	11	1,904		57	
	Tractor rear [2]	46	4,840		96	
	Tanker 1st axle [3]	57	7,445	4,152	76	136
	Tanker 2nd axle [3]	56	7,727	4,526	72	123
Half-filled	Tractor front	10	1,926		54	
	Tractor rear	41	4,335		95	
	Tanker 1st axle	39	5,112	3,713	76	105
	Tanker 2nd axle	37	5,584	4,029	66	91
Empty	Tractor front	13	2,348		57	
	Tractor back	31	3,691		83	
	Tanker 1st axle	18	4,060	3,652	45	50
	Tanker 2nd axle	18	4,335	3,607	43	51

[1] 540/65 R30, [2] 650/65 R42, [3] 750/60 R30.5, [4] measured on farm's electronic weighbridge, [5] tire print was chalked and photometrically evaluated, [6] 100 kPa, [7] 300 kPa.

Table 4. Tire track depth (cm) affected by tire inflation pressure, filling level of slurry tanker (filled, half-filled and empty), and ground covering (+cover crop, −cover crop).

Tire Inflation Pressure	Filled Tanker			Half-Filled Tanker			Empty Tanker		
	+Cover Crop	−Cover Crop	Mean	+Cover Crop	−Cover Crop	Mean	+Cover Crop	−Cover Crop	Mean
Low	6.20	5.80	6.00 [a]	6.86	5.83	6.35 [a]	6.61	4.89	5.75 [a]
High	7.49	7.11	7.30 [b]	7.23	5.93	6.58 [b]	6.88	5.41	6.15 [b]
Mean	6.85 [B]	6.46 [A]	6.65	7.05 [B]	5.88 [A]	6.47	6.75 [B]	5.15 [A]	5.95

Statistically significant differences ($p < 0.05$) are shown for the cover crop effect with capital letters and for the tire inflation pressure effect with small letters.

Table 5. Soil penetration resistance (MPa), averaged for the depths (0-20 cm and 21-41 cm) affected by the treatment (un-wheeled, low and high inflation pressure), filling level of slurry tanker (filled, half-filled, empty), and ground covering (+cover crop, −cover crop)

Soil Depth (cm)	Treatment	Filled Tanker			Half-Filled Tanker			Empty Tanker		
		+Cover Crop	−Cover Crop	Mean	+Cover Crop	−Cover Crop	Mean	+Cover Crop	−Cover Crop	Mean
0–20	Un-wheeled	0.74	0.67	0.71 [a]	0.70	0.82	0.76 [a]	0.72	0.81	0.76 [a]
	Low	1.17	1.27	1.22 [b]	1.11	1.23	1.17 [b]	1.06	1.21	1.14 [b]
	High	1.30	1.66	1.48 [c]	1.18	1.32	1.25 [c]	1.16	1.24	1.23 [c]
Mean		1.07 [A]	1.20 [B]	1.14	1.00 [A]	1.12 [B]	1.06	0.98 [A]	1.09 [B]	1.03
21–40	Un-wheeled	2.09	2.06	2.08 [a]	1.88	1.99	1.94 [a]	1.95	2.24	2.10 [a]
	Low	2.25	2.21	2.23 [b]	2.21	2.24	2.23 [b]	2.15	2.34	2.25 [b]
	High	2.33	2.32	2.33 [b]	2.20	2.25	2.23 [b]	2.30	2.15	2.23 [b]
Mean		2.22	2.20	2.21	2.10	2.16	2.13	2.14	2.24	2.19

Statistically significant differences ($p < 0.05$) are shown for the cover crop effect with capital letters and for the inflation pressure effect with small letters.

CONCLUSIONS

The study showed that under rather dry soil conditions, **sugarbeet harvesting** with self-propelled six-row sugarbeet tanker harvesters did not impair the soil physical properties (bulk density, soil penetration resistance).

For wet soil conditions, there were significant differences between the two-axle harvester and three-axle harvester on soil penetration resistance. Single and multiple wheeling in wet soil showed higher soil penetration resistance in the top soil.

Findings under moist soil conditions indicated a higher risk of potential soil compaction. Therefore, soil protecting sugar beet harvesting requires a good load carry capacity of the soil.

The results obtained in this field experiment on passage of a **tractor-slurry tanker** combination with different wheel loads and tire inflation pressure show a soil pro-tecting effect of reduced tire inflation pressure.

Regarding this fact, a slurry tanker should be equipped with an automatic tire pressure controller. This would enable a lower tire inflation pressure in the field and higher tire inflation pressure on the street.

The soil penetration resistance in the subsoil was higher in the wheeled treatments than in the un-wheeled control, but there were no significant effects detected caused by tire inflation pressure (high: 300 kPa, low: 100 kPa) and wheel load (filled, half-filled, empty slurry tanker).

Cover crops created deeper track depths after traffic, which is explained by the loosening of cover crop roots. Cover crops with their positive ecological effects can reduce the risk of potential soil compaction and have ameliorative effects on restoring the soil structure.

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CONSTRUCTION AND THEORETICAL JUSTIFICATION OF THE DRILLING RESISTANCE OF THE CUTTER FOR PRODUCTION OF ECOLOGICAL PRODUCTS OF SMALL SEED CROPS

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Abstract

Modern technologies for the cultivation of small-seed crops impose increased requirements on the sowing operation, the quality of which is largely determined by the design of the coulters used. The developed design of the coulter for sowing small-seed crops, which qualitatively prepares the planting furrow by leveling and compacting the surface of the bottom of the furrow. The stable distribution of small-seeded crops during their sowing significantly affects their productivity, since this forms the feeding area. Compliance with agricultural requirements for the uniform distribution of seed material is a priority task in the design of coulters and closing bodies of seeders. The use of skid coulters makes it possible to use their single-row installation, which, together with protection against damage when leveling and compacting the bottom of the planting furrow in one structural unit, makes it possible to reduce the metal content of the coulter and increase its compactness. When determining the parameters of the coulter, taking into account the condition of stability of its movement when sowing small-seed crops, a theoretical substantiation of its traction resistance was carried out.

Key words*: soil, small-seeded crops, construction, coulter, resistance, speed.*

INTRODUCTION

Commercial production of small-seed oilseeds, such as oilseed flax, mustard, safflower, rapeseed, camelina, is of increasing interest to domestic producers, and compliance with innovative cultivation technologies makes it possible to obtain fairly high yields. The economic component of growing these crops is due to their demand both in the domestic and world markets. First of all, the product of processing these oil crops is oil, which is widely used in the food industry, cosmetology, and the pharmaceutical industry. In connection with the planned trends for green energy, the production of biodiesel and aviation fuel is becoming increasingly important. In addition, rapeseed and camelina processing products, Among the small-seeded crops grown for fodder, the leading place belongs to alfalfa. Alfalfa is one of the most common crops grown for hay, as it has a high productivity, which makes it possible to obtain two cuts in central Russia. In addition, alfalfa is a high-protein component in the diet of cattle, which contributes to its productivity. Due to the development of a powerful root system, penetrating to a depth of 12 m, alfalfa enriches the soil with nitrogen and organic matter, increases soil fertility, which helps to increase the yield of subsequent crops grown. For example, after a three-year growing cycle, alfalfa is able to leave the same amount of organic matter per hectare asin 60...70 tons of manure (Chapaev, 2006). After harvesting with root and crop residues, an average of up to 200 kg of nitrogen per hectare enters the soil, which in turn reduces the application of mineral fertilizers. In addition, alfalfa helps to improve the physical and mechanical properties of the soil, namely, its bulk density decreases, porosity increases and moisture capacity in the arable horizon increases.

However, the cultivation of small-seeded crops requires compliance with the agrotechnical requirements for the quality of their sowing by existing seeders, which do not provide it completely due to their small seed sizes and certain seeding rates. It is known that in modern sowing units, the technological process of sowing seeds is carried out in the following stages: spilling seeds from the hopper through the hole; dosing of seeds by the sowing device; distribution of the received dose in a row; transportation of seeds from the sowing device to the coulter; furrow formation and incorporation of seeds with soil. Differences in the working processes of sowing units are due to the requirements for the quality of sowing small-seed crops. The quality of seeding implies, first of all, uniform distribution of seeds over the sown area while ensuring a given seeding rate. All studies, therefore, are characterized by recommendations on the choice of certain elements of the sowing system and closing bodies.

Analyzing the technological process of sowing existing sowing machines of domestic and foreign production, it should be noted that the quality indicators of sowing are to a certain extent dependent on the structural and technological elements of the seeder. These elements include loading and feeding devices, sowing devices, distributing and transporting devices (seed ducts) and closing devices (coulters, compactors).

The uniformity of distribution of seeds in a row, their placement to the required depth and, finally, ensuring the seeding rate depend on how reliably and accurately the technological operation is performed by each element of the machine.

In the technological process of cultivation of small-seeded crops, an important role in sowing is played by the placement of seeds with coulters at a given depth, since the depth of placement of seeds is small from 1 to 3 cm, the deviation from these values leads to a decrease in the quality of seed germination.

Obtaining high yields requires the use of energy-saving technologies that make it possible to achieve optimal distribution of cultivated small-seed crops over the nutritional area in terms of uniformity. As a result of the uneven distribution of plants over the sown area, their field germination and productivity are reduced. The coulter group of the sowing unit is one of the factors that has a significant impact on the quality of placement in terms of depth and width of placement of seeds of small-seeded crops.

The currently used technologies for the cultivation of small-seed crops impose increased requirements on sowing, the quality of which largely depends on the design of coulters designed to form furrows in the soil and uniform distribution of seeds in the furrow (Petrov et al., 2018; Ovtov et al., 2020; Shumaev et al., 2021; Dorohov et al., 2019; Cheremisinov et al., 2016; Ovtov et al., 2021). In most currently produced seeders, the coulters used only form a sowing furrow for laying seeds, and to ensure contact of the seed after covering with a layer of soil by closing bodies with the lower wetter soil layers, packers are used (Chapaev et al., 2006; Shumaev et al., 2020; Ovtov et al., 2021; Aksenov et al., 2020; Hevko et al., 2016). With high-quality pre-sowing tillage, skid coulters are most acceptable, as they are the simplest in design and reliable in operation, for fixing which it is better to use a parallelogram mechanism that allows you to copy the relief with high accuracy.

Therefore, the improvement of the working bodies of sowing machines, ensuring the implementation of the technological process corresponding to agrotechnical requirements, taking into account climatic conditions when cultivating small-seeded crops, is beyond doubt.

MATERIALS AND METHODS

At present, sowing of small-seeded crops is carried out with grain or grain-grass seeders.(SZ-3.6; SZT-3.6; SLT-3.6; SRN-4.2; SUPN-8; SST-8; SST-12A; SCON-4.2; CO-4.2; SOH -4.2SZU-5.4-06, etc.), which do not fully provide the required seeding rate, their placement in the soil layer at the optimal sowing depth of 2-3 cm. Therefore, pre-sowing rolling is used to evenly place seeds along the sowing depth in the soil horizon. The effectiveness of this technological technique is manifested if the rolling of ripe soil is carried out, then its structure will not be destroyed.

When sowing small-seeded crops, the creation of a dense bed for seeds plays an important role, since in this case, due to the influx of moisture from the lower layers of the soil and the optimum temperature, simultaneous germination of seeds occurs. The most favorable conditions for seed germination are when the seeds lie on a solid bed with a soil density of more than 1.2 g/cm^3, and they are covered with a loose layer of soil from above. In this case, the seeds lying on a hard bed receive moisture from the lower layers of the soil, and the upper, loose soil layer contributes to the penetration of oxygen to the seeds, their rapid germination and the friendly emergence of seedlings. It should be noted that the optimal condition of the soil for sowing small-seeded crops falls on its physical and biological ripeness.

Penza State Agrarian University has designed the design of a skid-shaped coulter with a furrow compactor, the three-dimensional model of which is shown in Figure 1 (RF patent No. 2738273 publ. 12/11/2020, Bull. No. 35), which allows to reduce the traction resistance of the sowing unit when sowing small-seed crops.

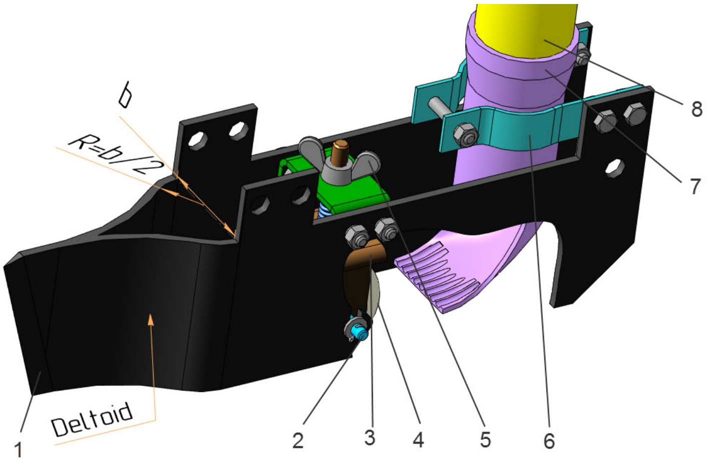


Figure 1. Coulter with furrow bottom compactor

RESULTS AND DISCUSSIONS

In the process of opener operation, in addition to the quality of the preparation of the landing furrow, its traction resistance is of no small importance.

The skid-shaped coulter consists of a cast body with cheeks 1, and the opening angle of the coulter cheeks is formed by flat algebraic curves - deltoids, and at the same time, the radius of deltoid rounding with the coulter cheek is 1/2 of the coulter width b, while the opening angle of the coulter cheeks β4 ... 6 degrees less than the double angle of friction of steel on the soil. On axis 2, installed in the cheeks of the coulter body, a seed bed-former 3 is hinged, with the ability to control the pressure force on the compacted soil with a roller 4 using a lamb nut 5. In the tail part of the coulter, using clamps 6, a receiving funnel 7 is attached, which also performs the function of a distributor seeds and having a curved surface made according to the brachistochrone with guide grooves of a curvilinear shape in cross section connected to the seed duct 8.

The operation of the coulter with the seed furrow compactor is as follows. When the seeder moves, the coulter (Figure 1), fixed on the sowing section, deepens and cuts the soil with a tip knife, simultaneously shifting the dry soil layer in both directions with its cheeks and opening a furrow (bed) in the wet layer. The roller compactor of the seed furrow bed, under the action of the loading spring, evenly compacts the bottom of the planting furrow, which favorably affects the attraction of moisture to the planting material through a network of capillaries formed in the compacted layer of the furrow. Seeds coming through the seed tube are evenly distributed along the grooves in the receiving funnel and sown evenly across the width into the compacted furrow.

During the tests during the movement of the sowing unit, weeds were observed to accumulate in front of the seeder coulter, which affects the quality of sowing. The conducted studies have shown the feasibility of using a skid-shaped coulter with an obtuse angle of entry into the soil.

The traction resistance of the skid coulter Fs will be the sum of its values for a wedge with an obtuse entry angle F_1, coulter jaws F_2, inertia forces of the ejected soil particles Fin and rolling friction force of the compacting roller Ftk (Figure 2) (Khudoberdiev et al., 2010; Shevchenko et al., 2013):

$$F_s = F_1 + F_2 + F_{in} + F_{tk}. \quad (1)$$

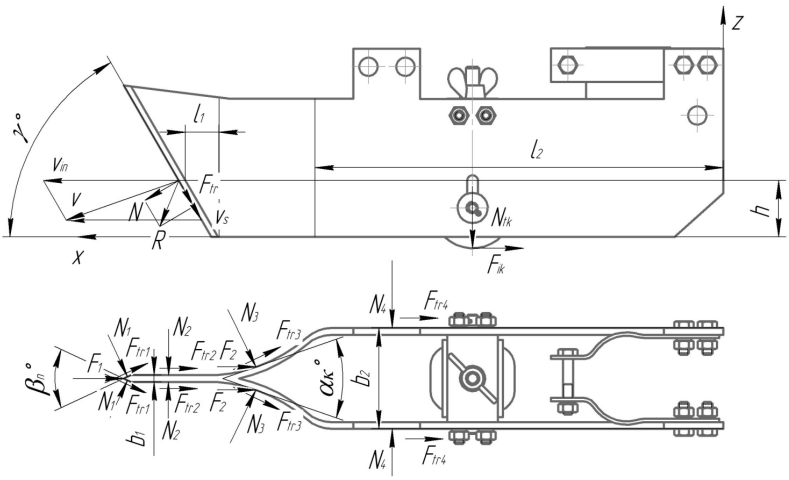


Figure 2 - Scheme acting on the coulter

The traction resistance of the runner coulter with a roller compactor of the bottom of the landing furrow was determined by the expression

$$F_s = q \cdot h \cdot b_1 + 2k\frac{b_1 h}{cos\frac{\beta_n}{2} sin\gamma} \cdot \frac{sin\,(\beta_n/2 + \varphi_{st})}{cos\varphi_{st}} + 2tg\varphi_{st}\frac{k \cdot l_1 \cdot h}{sin\gamma} + 2tg\varphi_{st}k\frac{b_2 h}{cos\frac{\alpha_k}{2}} + 2tg\varphi_{st} \times k \cdot l_2 \cdot h + b_2 \cdot h \cdot \rho \cdot v^2 \, sin\frac{\alpha_k}{2} \cdot tg\varphi_{st} + 2 \cdot N_r\frac{\mu}{D},$$

where q is the specific cutting resistance of the soil, N/m^2; b1 is the thickness of the knife, m, h is the depth of the coulter in the soil, m;β_n - angle of sharpening of the knife blade, degree;φ_{st} - steel friction angle on the soil, degree; k is soil resistivity, N/m^2; l1 is the length of the side surface of the knife, m; b_2 - coulter body width, m; l_2 is the length of the side surface of the jaws of the coulter body, m;γis the specific gravity of the soil, N/m^3;α_k– opening angle of the cheeks of the coulter body, degree; v is the speed of the coulter, m/s; g is the free fall acceleration m/c^2; Nr - compacting capacity of a smooth roller (N/m^2)$\rho$is the volumetric mass of soil, kg/m^3; μ is the coefficient of rolling friction, m/N.

When the coulter moves, it is affected by the force of resistance to the introduction of the knife blade F_l and normal soil pressures on the blade N_1 and on the sidesurface of the coulter knife blade N_2 and side surfaces of the coulter body cheeks N_3 and N_4, soil friction forces on the knife blade fN_1, knife side surface f N_2 and soil friction forces on the coulter body cheek f N3, side surface of the coulter body cheek f N_4 (Figure 2).

Figures 3 and 4 show the theoretical graphical dependences of the traction resistance of the skid coulter depending on the speed of the seeder and the specific resistance of the soil.

The analysis of the presented dependences shows that with an increase in the speed of the sowing unit from 2.5 m/s to 4.72 m/s, the traction resistance of the skid coulter increases by 9.9%, and with an increase in the specific soil resistance from 6000 N/m^2 to 10000 N/m^2 the traction resistance of the skid coulter increases by 35.5% at a machine speed of 4.72 m/s. Thus, the obtained graphic dependences of the traction resistance of the skid coulter show that its traction resistance is more affected by the physical and mechanical characteristics of the soil, and not by the speed of the seeder during sowing.

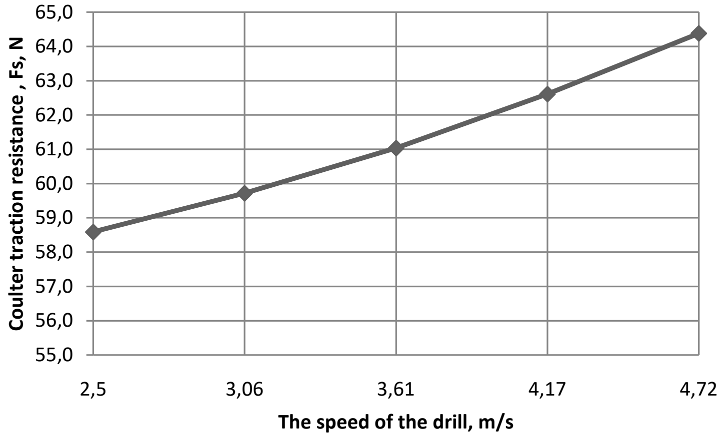
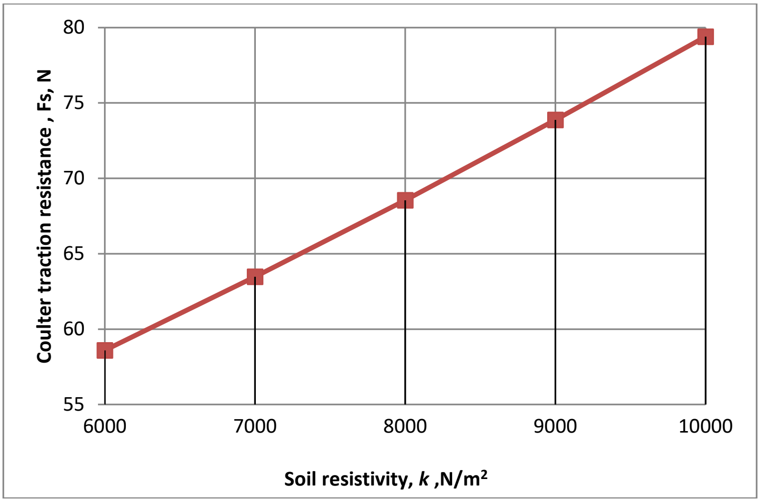


Figure 3 - Coulter traction resistance depending on the speed of the seeder



Picture 4 - Coulter traction resistance depending on soil resistivity

CONCLUSIONS

The design of the developed skid coulter with a roller compactor of the bottom of the seed furrow is proposed, and a theoretical substantiation of its traction resistance is made. The equipment of the seeder with this coulter reduces its traction resistance, which affects the reduction of fuel consumption and the reduction of exhaust gases into the atmosphere, in addition, the quality of the preparation of the seed furrow for sowing small-seeded crops improves, which makes it possible to increase their germination, and consequently the quality and productivity of the cultivated crop.. Also due to the uniform emergence of small-seeded crops, weeds will self-clog with cultivated ones, resulting in a reduced need to use herbicides, which will lead to environmentally safe production of crops.

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RESEARCH ON THE INFLUENCE OF SLAG FROM THE STEEL INDUSTRY ON THE REDDISH PRELUVOSOIL IN WHEAT CULTIVATION

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Abstract

Materials from the steel industry can be successfully used in agriculture, mainly due to their high content in Calcium and other nutrients. In order to follow up on the influence of these materials, an experiment was carried out in 2021, at Moara Domnească, in the Muntenia region, Romania, on a reddish preluvosoil cultivated with wheat. The effects of two types of materials from the steel industry on the acidity of the soil, on the content of heavy metals found in the soil and on their translocation in wheat plants was analyzed. Research has shown that by applying maximum doses of 5 tonnes/ha, these materials increase the soil's pH reaction and the agricultural production, without the risk of heavy metals translocating in wheat plants.

Key words*: amelioration, wheat production, heavy metal, soil fertility, steel slag.*

INTRODUCTION

Mineral lime is normally applied to correct soil acidity, but is impractical in many developing countries due to supply shortages and higher costs (Xu & Coventry, 2003; Li et al., 2010). Additionally, mineral lime cannot effectively increase the contents of K, Mg, and P in acidic soils (Sun et al., 2000). Consequently, some researchers have turned their attention to industrial by-products, with the aim of finding new methods for ameliorating acidic soils (Illera et al., 2004; Li et al., 2010; Shi et al., 2016). Some industrial by-products contain not only alkaline substances but also nutrients such as Ca, Mg, K and P, that are important for plants. Therefore, the incorporation of these industrial by-products into acidic soils can not only neutralize soil acidity but can also increase the contents of nutrients found in the soil. Agricultural use of industrial by-products is also a less expensive disposal method.

With the rapid growth of the world population, similarly to other industries, steel industries are also more concerned about the safe and eco-friendly recycling of their by-products.

In the past, the steel industries were designed to produce iron and steel of a specific quality and quantity (Das et al., 2019). With the rapid growth of industrialization in recent decades, the increased volume of by-products (slag) resulted from iron/steel production has drawn attention to the need for its more effective recycling (Das et al., 2019). Slags are widely used worldwide as a substitute for limestone and offer a cost-effective advantage to farmers. The main aim for researchers and environmentalists is to stop the entry of metals and metalloids into the food chain, for better human health (Kimio, 2015; Brevik et al., 2012), and in this respect, the use of slags in various fields can help cope with this problem (Kimio, 2015).

In the soil medium, the highest concentrations of potentially toxic elements that cause plant toxicity are represented by cadmium (Mehmood et al., 2017), lead (Mehmood et al., 2017), zinc (Hafeez et al., 2013), copper (Bashir et al., 2018), nickel (Tariq et al., 2018), vanadium (Imtiaz et al., 2018) and arsenic (Hettick et al., 2015).

The use of slag as a fertilizer increases phosphorus (Yang et al., 2009), calcium, and magnesium (Castro & Crusciol, 2013) availability for the plants. Calcium and magnesium form inorganic ionic pairs with minerals present on the surface of the slag that is used as a fertilizer (Gonzalo et al., 2013; Wu et al., 2013). It was concluded by Fan et al. (2018) that the use of slag as a fertilizer has the ability to decrease the content of Cr, Cu, Pb and Zn in acidic soils and the authors indicated that slag could be used in PTE pollution control for plants and the environment.

The long-term application of slag on the soil increases the soil's organic carbon contents, due to lower carbon mineralization rates (Wang et al., 2020). Additionally, slag contains ferric oxide on its surface, which could also increase the soil's carbon storage (Ali et al., 2013; Wang et al., 2012). Moreover, other than the improvement of soils, plant growth and yield are high priorities for sustainable agricultural progress (Rai et al., 2019).

MATERIALS AND METHODS

The experiment was carried out in 2021, in the experimental field of the Faculty of Agriculture from Moara Domnească, on reddish preluvosoil.

Reddish preluvosoil is characterized, in the surface horizon (Ao), by the following properties: humus content - 2.4%, clay-loamy texture, soil pH reaction between 5.2 and 5.4, and the degree of base saturation between 65-70% (Mihalache et al., 2014).

In order to follow up on the effect of slag on the soil's chemical properties and on the yield of wheat, the experimental field had nine variants, in three repetitions: V1 (control), V2 (2 tons/ha-$CaCO_3$), V3 (2 tons/ha-$CaMg(CO_3)_2$), V4 (1 ton/ha-furnace slag), V5 (3 tons/ha-furnace slag), V6 (5 tons/ha-furnace slag), V7 (1 ton/ha-converter slag), V8 (3 tons/ha-converter slag) and V9 (5 tons/ha-converter slag).

Figure 1. The experimental field from Moara Domnească, Ilfov County, Muntenia Region, Romania (2021)

Fertilization with 100 kg of nitrogen was also applied, in order to follow up on the combined effect of the amendment and nitrogen fertilizer on the wheat yield. Soil samples were collected in the 0-20 cm and 20-40 cm depth in all experimental variants in order to verify the influence on the soil's pH reaction and to correlate these results with its influence on the wheat yield.

RESULTS AND DISCUSSIONS

It was shown that applying soil amendments improved the chemical properties of the reddish preluvosoil by increasing the soil's pH reaction, in some correlation with the application dosage of the slags and depending on the application of the amendment (Tables 1 and 2).

The application of different quantities of slag in the spring of 2020 led to a change in the soil's pH reaction at a depth of 0-20 cm in all experimental variants.

The most significant increase, compared to the control variant, where the pH had a value of 5.86, was recorded in the V9 variant, where converter slag was applied in a dose of 5 tonnes per hectare, where the pH value increased by more than one unit, respectively up to a pH of 7.29 (Table 1).

Table 1. Variation of the soil's pH reaction on the depth of 0-20 cm (2021)

Variant	Soil's pH		Difference		Significance
		%		%	
V1-control	5.86	100	Mt	-	
V2-$CaCO_3$	6.05	103.29	0.19	3.29	*
V3-$CaMg(CO_3)_2$	6.16	105.11	0.3	5.11	**
V4-LF 1 tonne/ha	6.06	103.35	0.19	3.35	*
V5-LF 3 tons/ha	6.23	106.36	0.37	6.36	***
V6-LF 5 tons/ha	6.22	106.19	0.36	6.19	***
V7-CV 1 ton/ha	6.12	104.49	0.26	4.49	**
V8-CV 3 tons/ha	6.18	105.45	0.32	5.45	**
V9-CV 5 tons/ha	7.29	124.33	1.42	24.33	***
LSD 5% = 0.183 *LSD 1% = 0.252* *LSD 0.1% = 0.346*					

At a depth of 20-40 cm, the soil's pH reaction also increased in all experimental variants, with the pH value increasing from 5.82, in the control variant, to 7.16 in the V9 variant, where converter slag was applied in a dose of 5 tonnes/ha (Table 2).

Table 2. Variation of the soil's pH reaction on the depth 20-40 cm (2021)

Variant	Soil's pH		Difference		Significance
		%		%	
V1-control	5.82	100	Mt	-	
V2-$CaCO_3$	6.07	104.29	0.25	4.29	**
V3-$CaMg(CO_3)_2$	6.14	105.43	0.31	5.43	**
V4-LF 1 ton/ha	5.95	102.11	0.12	2.11	-
V5-LF 3 tons/ha	6.15	105.66	0.33	5.66	***
V6-LF 5 tons/ha	6.11	104.97	0.29	4.97	**
V7-CV 1 ton/ha	6.15	105.54	0.32	5.54	**
V8-CV 3 tonnes/ha	6.25	107.37	0.43	7.37	***
V9-CV 5 tons/ha	7.16	122.88	1.33	22.88	***
LSD 5% = 0.172 *LSD 1% = 0.237* *LSD 0.1% = 0.326*					

Table 3. Biomass production obtained when the wheat samples were harvested

Variant	Production		Difference		Significance
	t/ha	%	t/ha	%	
V1-control	7.07	100	Mt	-	
V2-$CaCO_3$	8.42	119.09	1.35	19.09	**
V3-$CaMg(CO_3)_2$	8.41	118.95	1.34	18.95	**
V4-LF 1 ton/ha	8.58	121.40	1.51	21.40	**
V5-LF 3 tons/ha	9.30	131.54	2.23	31.54	***
V6-LF 5 tons/ha	9.41	133.14	2.34	33.14	***
V7-CV 1 ton/ha	8.36	118.29	1.29	18.29	**
V8-CV 3 tons/ha	9.06	128.24	1.99	28.24	***
V9-CV 5 tons/ha	9.40	132.95	2.33	32.95	***
LSD 5% = 0.684 *LSD 1% = 0.942* *LSD 0.1% = 1.296*					

The above-ground biomass production resulting from the wheat harvest recorded significant increases for the variants where doses of 3 tons/ha and 5 tons/ha were applied, in both the case of LF and CV slag.
Regarding the wheat production obtained in the climatic conditions of 2021, it can be seen that, in the variants where $CaCO_3$ and CaMg $(CO_3)_2$ was applied, in a dose of 2 tons/ha, the production recorded distinctive and significant increases of up to 6.83 tons/ha, in the case of $CaCO_3$ and of 7.06 tonnes/ha, in the case of $CaMg(CO_3)_2$ when compared to the control variant, where the production was of 6.28 tonnes/ha (Table 4).

Table 4. The influence of applied amendments on wheat production

Variant	Production		Difference		Significance
	t/ha	%	t/ha	%	
V1-control	6.28	100	Mt	-	
V2-$CaCO_3$	6.83	108.64	0.54	8.64	**
V3-$CaMg(CO_3)_2$	7.06	112.40	0.78	12.40	**
V4-LF 1 ton/ha	7.13	113.41	0.84	13.41	**
V5-LF 3 tons/ha	7.30	116.11	1.01	16.11	***
V6-LF 5 tons/ha	7.62	121.31	1.34	21.31	***
V7-CV 1 ton/ha	7.12	113.30	0.83	13.30	**
V8-CV 3 tons/ha	7.37	117.33	1.09	17.33	***
V9-CV 5 tons/ha	7.94	126.29	1.65	26.29	***
LSD 5% = 0.468 *LSD 1% = 0.645* *LSD 0.1% = 0.887*					

In the variants where slag from the steel industry was applied, the highest production was recorded for the V9 variant, with a dose of 5 tons/ha of converter slag, respectively a production of 7.94 tons/ha, but very significant increases in the production were also recorded in all other doses applied, when compared to the control variant.
The content of heavy metals (Cu, Zn and Pb) recorded in wheat grains was under the maximum permissible limits.
There were no increases in the quantity of heavy metals found, even with the increase of the doses of slag applied.
The lead content in wheat grains was of 0.5-1.6 mg/kg, the Cu content was of 2.5-5.5 mg/kg and the Zn content was of 18.5-32.7 mg/kg (Figures 2, 3, 4).

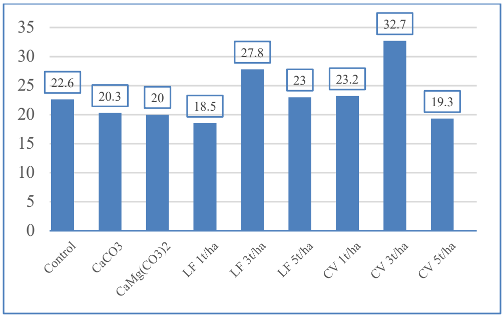

Figure 2. Zinc content in wheat grains (mg/kg)

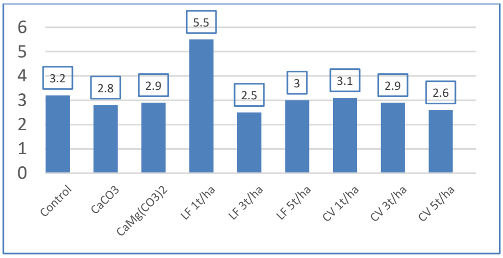

Figure 3. Copper content in wheat grains (mg/kg)

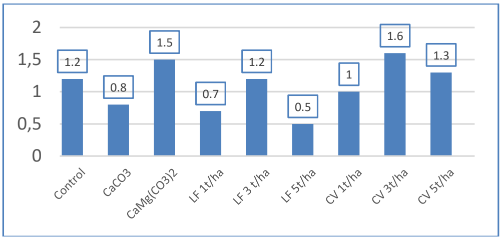

Figure 4. Lead content in wheat grains (mg/kg)

The highest concentrations of heavy metals were recorded at the following doses: Zn - 32.7 mg/kg in the V8 variant, where CV slag was applied at a dose of 3 tonnes/hectare, Cu - 5.5 mg/kg in the V4 variant, where LF slag was applied in a dose of 1 ton/hectare and Pb - 1.6 mg/kg for the V8 variant, where CV slag was applied in a dose of 3 tons/hectare. Cd, Co and Cr were below detection limits.

CONCLUSIONS

Improving the reaction of the soil with by-products from the steel industry improves the conditions for the growth and development of crop plants by neutralizing the soil's acidity, by increasing the nutrient content in the soil and by offering a better nutrient accessibility for crop plants.

Slag from steel factories can be used with good results in agriculture, as it has significant positive influences on both the soil and the plants cultivated - in this case, on wheat cultivation.

Biomass production was higher in all experimental variants, when compared to the control variant.

The research also focused on the behaviour and immobilization in soil and plants of the main heavy metals contained in slag, in order to achieve a more efficient and sustainable use of this by-product in agriculture. The application of slag did not cause the accumulation of heavy metals in wheat grains, recording values below the maximum permissible limits, even at the maximum doses applied.

In order to avoid the accumulation of heavy metals in the soil and in the plants, we recommend not to exceed the dose of 3 tonnes/ha of slag, applied once every 4 years.

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EVALUATION OF BIOCHAR APPLICATION ON SOIL NUTRIENTS

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Abstract

Field experiments with different levels of application of BC and manure were conducted, according to developed methodology based on literature data. Six variants have been developed: 1) V1- control; 2) V2 - with manure (4t/ ha^{-1}); 3) V3 - with biochar (500 kg/ ha^{-1}); 4) V4 - manure (4 t/ ha^{-1}) + biochar (250 kg/ ha^{-1}); 5) V5 - manure (4 t/ ha^{-1}) + biochar (500 kg/ ha^{-1}); 6) V6 - manure (4 t/ ha^{-1}) + biochar (750 kg/ ha^{-1}) under optimum irrigation. For each of the variants were examined the following indicators in dynamics - climate condition, pH, NPK in soil after harvesting of each crops. The dynamics of yields for zucchini, broccoli, broad bean and leek were evaluate, and the biometric data was collected. The aim was to study the effect of imported carbonized plant residues on the content of essential nutrients in the soil.

***Key words**: biochar, manure, soil, nutrition, vegetable.*

INTRODUCTION

Maintaining and increasing soil fertility is a key prerequisite for obtaining high and sustainable yields. Soil fertility is one of the factors that are particularly affected by intensive agriculture. In recent years, in the context of climate change, there is a great interest in studying biochar (BC) use in agriculture (Lehmann, 2007).

As a pyrolysis product containing high organic carbon, biochar is able to improve soil physical, hydraulic and fertility properties, to improve biological activity and reduce pollution (Maftu'ah, 2019).

According to many authors the positive effects of biochar are due to the chemicals and nutrients present that it contains and because of its absorption capacity and the ability to retain nutrients (Hammes and Schmidt, 2009; Lehmann et al., 2011; William & Qureshi, 2015). It also increases the soil organic matter (SOM), which is helpful for the plants (Verheijen et al., 2009). Besides this, it also adjusts the pH of the soil to neutral, which increases the cation exchange capacity level and is beneficial for the growth of the plants. Soil fertility can be improve by amendments applications such as biochar.

Biochar is widely studied in terms of its effect on water-physical properties and soil fertility, but only a small part of the results was obtained from field experiments.

The aim is to study the effect of imported carbonized plant residues on the content of essential nutrients in the soil.

MATERIALS AND METHODS

The experiment was carried out in the experimental field of the University of Forestry Sofia (42° 7′ N, 23° 43′ E). The soil is Fluvisol, slightly stony. This area came under a continental climatic sub region, in a mountain climatic region.

The experiment was set with two amendment - biochar and manure (used as a background). During the spring cultivation, the two ameliorants were incorporated into the soil at 15 cm depth. Six variants were developed:

V1- soil – Control;
V2 - with manure (4 t/ha^{-1});
V3 - with biochar (500 kg/ ha^{-1});
V4 - manure (4 t/ ha^{-1}) + biochar (250 kg/ ha^{-1});
V5 - manure (4 t/ ha^{-1}) + biochar (500 kg/ ha^{-1});
V6 - manure (4 t/ ha^{-1}) + biochar (750 kg/ ha^{-1}).

The experiment was carry out by randomized complete block design with four replicates and protection zones.

During the first year of the experiment, two vegetable crops were selected: zucchini as the first crop cultivation and broccoli as a second one. In the second year, the selected crops were faba beans, first crop, and leeks, the second crop. The selected varieties that were used for

the purpose of the experiment were zucchini, variety Izobilna (as a standard variety for Bulgaria); broccoli is of two varieties: Monty F1, with a 60-day growing season and Corato F1, with a 75-day growing season; broad beans, Super Guadaluche variety, and leek, Starozagorski kamush variety.
Plants were irrigated by a drip irrigation system; the tape drip hose used has the following characteristics: I-Tape 8 mil/distance between drippers 20 cm/5.3 lh. The irrigation rate is 40 mm.
Soil samples for agrochemical analysis were taken by variants at the beginning of vegetation and at the end of the growing season of each crop. Sampling is perform with a soil probe from a depth of 0-30 cm. One medium sample was taken from each section, formed by 10 stitches of the probe diagonally. The soil from all points (from one depth) is mixed in order to homogenize in a larger vessel. An average sample weighing 400-500 g was taken and placed in a packaging bag.
Soil samples is given for laboratory analyses according to approved methods.
Samples of used amendments (biochar and well-decomposed caw manure) have been taken before conducting the experiment.

RESULTS AND DISCUSSIONS

Climatic conditions directly affect the development of plants, and hence the levels of evapotranspiration and nutrient uptake.
Information about the annual amounts of precipitation in the Sofia region, as well as the average monthly temperatures have been collected and analysed. A rainfall security curve has been prepared by year, and the data cover a long period of 31 years (Figure 1). This information is important because rainfall in the autumn - winter period of the previous year is essential for the formation of moisture reserves for the next experimental year.

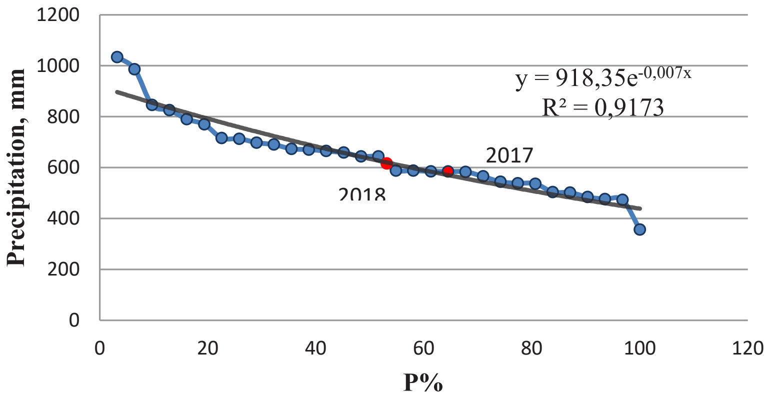

Figure 1. Curve of precipitation for the period 1987-2018

Based on the collected data the extremely wet years with security below 15% are 2013 and 2002, and the dry years with security over 90% are 2000 and 2010.
The experimental year 2017 was characterized by security close to 70%, which defines it as the average year in terms of precipitation.
The second experimental year (2018) was drier, with a security of 53%. The rainfall during the vegetation of the vegetable crops was evenly distributed.
Despite its even distribution, the amount was insufficient to ensure the development of plants, as the necessary water treatment was maintained by a drip irrigation system.
Soil temperature is the function of heat flux in the soil as well as heat exchanges between the soil and atmosphere (Elias et al. 2004). The soil temperature affects pH reaction, cation exchange capacity, and soil mineralization.
The average monthly air temperature over the experimental periods does not exceed 23°C. During the experimental period (April-July, 2017), the weather conditions were favourable for the growth and development of zucchini (Figure 2), with average seasonal temperatures

close to normal. Higher temperature values were observed at the beginning of July during broccoli vegetation, with the maximum reported value was 8.6°C.

The reported temperatures were on average + 1.2°C higher in comparison with the data published by National Institute of Hydrology and Meteorology, compared to the norms for the period 1961-1990. The average daily temperatures during the development of broad beans were permanently above 10°C, reaching 20°C in early May. These temperatures were suitable for the development of broad beans and its timely germination. In period of leek vegetation, the average monthly air temperature does not exceeded 23°C. At the end of September, there was a sharp drop in temperature, which dropped from 16°C to 9°C.

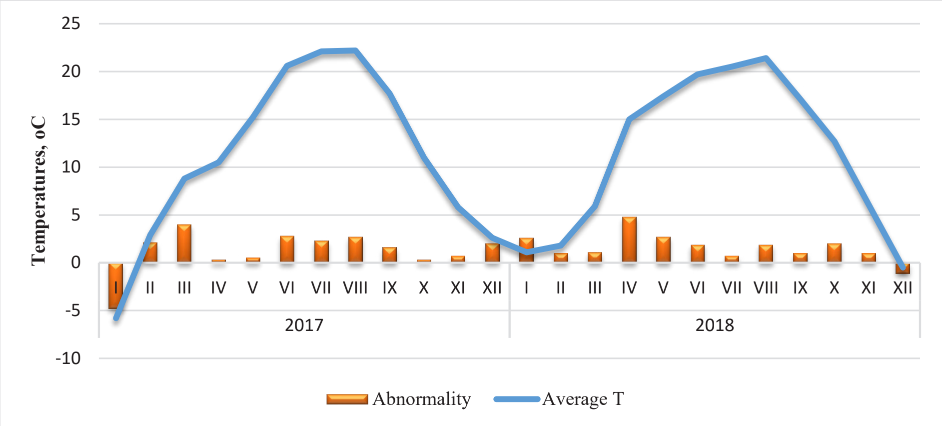

Figure 2. Average monthly temperatures during 2017-2018

The content of basic nutrients, heavy metals and pH was obtained from soil.

The pH reaction was slightly alkaline. The manure contained a high amount of organic carbon, well stored with total N and medium stored with P and K, the values of the mobile forms being approximately equal to the reported total amounts of P-0.89% and K-1.31% (Table 1). The ratio of ammonium to nitrate forms indicates that the mineralization process is not fully complete (NH_4 - 79.9 mg/kg and NO_3-0.9%).

Table 1. Nutrient content of cow manure

Indicator	Unit	Method	Value
pH		BS EN 15933	7.51
Organic C	%	BS EN 13137	16.92
N	%	BS EN 13342	2.06
K	%	BS EN 16170	1.4
P	%	BS EN 16170	1.39
K mobile	%	BS EN 16170	1.31
P mobile	%	BS EN 16170	0.89
NH_3	%	BS EN 16177	0.9
NH_4	mg/kg	BS EN 16177	79.9

The biochar, used to conduct the experiment, was made from wood chips. The pH reaction in the analysed sample from BC was highly alkaline (Table 2).

Table 2. Chemical characteristics of BC obtained from wood chips

pH	EC mS/m	C %	N %	P %	K %	Ca %	Mg %	$CaCo_3$
10.8	45	61.8	0.39	0.22	0.85	2.18	0.23	5.4

It contained a large amount of carbon, which confirms the ability of BC to deposit carbon into the soil, reducing its release into the atmosphere.

The mineral content of NPK was minimal. The presence of $CaCo_3$ was one of the causes of the highly alkaline reaction of the substrate (Table 2).

Soil samples for analysis from the beginning of the experiment and after the end of the vegetation of each crop, showed the influence of ameliorants on the agrochemical composition of the soil.

The sampling depth was consistent with the main root zone of the zucchini.

The soil reaction was slightly alkaline, approaching a depth-neutral layer (Table 3).

Table 3. Agrochemical characteristics of Fluvisol before conducting the experience with zucchini

Depth cm	pH (H_2O)	Humus %	N % Kjeldahle	P_5O mg/100 g	K_2O mg/100 g
0-20	7.3	1.73	0.160	79.2	18.1
20-40	7.2	1.64	0.154	94.81	19.9

Soil data obtained before amendments incorporation, showed a good degree of storage of K_2O, a very high content of P_5O, which increases in depth. The soil was poorly humus with content varying between 1.73% for the arable horizon and 1.64% for the sub arable horizon. The data obtained were characteristic of this soil type.

After the end of zucchini vegetation, the soil samples were taken from a depth of 0-30 cm. It is obvious that the humus content increased in variants with higher BC content in combination with manure (Table 4).

Table 4. Soil analysis after zucchini vegetation end

Variants	pH (H_2O)	Humus (%)	N (%)	P_2O_5 (mg/100 g)	K_2O (mg/100 g)
Var. 1	7.2	1.36	0.165	53.60	10.0
Var. 2	7.3	1.33	0.173	68.45	10.8
Var. 3	7.3	1.30	0.143	51.05	11.0
Var. 4	7.1	1.82	0.189	81.60	14.1
Var. 5	7.3	1.91	0.194	84.32	17.8
Var. 6	7.3	1.90	0.203	81.84	19.3

The reduced content of total N in Var. 3 with biochar, probably was due to the adsorption of NH_3 or organic N onto its surface by cations or anion exchange reactions and the increased immobilization of N, as a consequence of the additional C incorporate in soil with BC. A number of authors investigating BC produced at different pyrolysis temperatures (Yao et al., 2012) reported similar results.

A decrease in P_2O_5 content in variant 3 was observed with BC alone, this is most likely due to the ability of BC to absorb phosphorus and nitrogen anions on its surface. The combined introduction of BC and manure had a positive effect on the potassium content of the soil as the soil storage of K increased from medium to very good. This was probably due to the ability of BC to retain nutrients in the soil directly through the negative charge that develops on its surfaces. "Cations" are positively charged ions, in this case these are nutrients such as calcium (Ca_2+), potassium (K+), magnesium (Mg +) and others. Many authors reported for increasing levels of K in soil after BC application (Cheng et al., 2008; Lentz and Ippolito, 2012). It was considered that plants (Karer et al., 2013) could rapidly absorb available K in the BC composition. However, some researchers have suggested that the high availability of K for plants may not continue beyond the year of application (Steiner et al., 2007).

After harvesting the precursor (zucchini) soil samples were taken for agrochemical analysis, the data are presented in Table 5. These data are the starting point for the broccoli vegetation. To monitor the dynamics of nutrients in the soil, as well as the influence of amendment after the end of the experiment with broccoli, soil samples were taken again. There was an increase in pH by variants, as the medium becomes slightly alkaline. In variant 2, which was only with the application of manure, the pH approached neutral (Table 5).

Table 5. Soil analysis after harvesting the experiment with broccoli 2017

Variants	pH (H_2O)	Hummus (%)	N (%)	P_2O (mg/100 g)	K_2O (mg/100 g)
Var. 1	7.2	1.66	0.174	69.05	10.3
Var. 2	7.1	1.87	0.175	81.68	11.5
Var. 3	7.5	2.02	0.181	86.78	11.9
Var. 4	7.3	1.97	0.189	81.76	14.9
Var. 5	7.4	2.07	0.195	76.87	13.9
Var. 6	7.4	2	0.197	87.12	16.7

The humus content varied between 1.66% for the control variant and 2.7% for variant 5, containing the optimal amount of BC and manure. Over time, mineralization of organic carbon imported with manure occurs, which led to an increase in the humus content compared to the samples after harvesting the precursor. Plant residues after harvesting the previous crop also had an effect.

Total nitrogen increased in variations. In the mobile forms, the ammonia nitrogen is the highest in variant 2, in which only manure is applied in the dose 4 t/da, with the increase of the norm of BC by variants a decrease of the content of NH_4 was observed, which was due to the high porosity of BC which retained positively charged cations on its surface.

In the case of a nitrate form, the opposite trend was observed - the values increased in more variants, ranging from 0.022 to 0.102 mg/kg. The soil was very well stocked with phosphorus, with the highest values reported in variants 6 with an increased rate of BC- 87.12 mg/100 g. Potassium reserves were low to medium, and increased with increasing rates of imported BC.

In the second year of the experiment (2018), broad beans and leeks were grown. The dynamics of the main nutrients in the root layer was monitored. After harvesting the broad bean, the soil reaction was close to neutral, their no significant differences between variants (Table6).

Table 6. Soil analysis after harvesting the experiment with broad beans 2018

Variants	pH (H_2O)	Hummus (%)	N (%)	P_2O (mg/100 g)	K_2O (mg/100 g)
Var. 1	7;1	1.552	0.182	48.4	18.0
Var. 2	7.2	1.690	0.186	58.5	18.4
Var. 3	7.2	1.603	0.188	53.4	16.5
Var. 4	7.2	1.741	0.189	63.6	21.5
Var. 5	7.2	1.845	0.199	76.5	18.7
Var. 6	7.2	1.879	0.210	74.0	19.7

The humus content varied between 1.552% for the control variant and 1.879% for variant 6 containing a larger amount of BC. The carbon content corresponded to that of hummus, ranging from 0.90% to 1.09%. It was noteworthy that the total nitrogen had higher values compared to the samples before planting, which was due to the nitrogen-fixing ability of broad beans. The soil was well stocked with phosphorus, with the highest values reported in variant 5 with increased rate of BC and manure 4 t/da - 76.5 mg/100 g. The phosphorus content decreased after the vegetation of beans, but the trend continued. In variant 6 the K content increased to 19.7 mg/100 g, which was a good reserve for Fluvisol.

Soil samples after the end of the vegetation experiments showed that the soil reaction was kept around neutral to very slightly alkaline (Table. 7).

Table 7. Soil analysis after harvesting the leek experiment 2018

Variants	pH (H_2O)	Hummus (%)	N (%)	P_2O (mg/100g)	K_2O (mg/100g)
Var.1	7.2	1.465	0.176	45.9	16.3
Var.2	7.2	1.345	0.182	58.6	17.2
Var.3	7.2	1.396	0.180	53.4	16.5
Var.4	7.3	1.362	0.185	61.3	18.0
Var.5	7.3	1.500	0.189	58.8	18.6
Var.6	7.2	1.655	0.191	69.3	23.2

After harvesting the experiment, layer-by-layer depletion of phosphorus was observed, however, the storage remained very good. The data showed that leeks exported some of the nutrients, depleting a significant amount of nitrogen fixed by broad beans.

In the variants with a higher BC content combined with manure, the humus content increased. Decreased P_2O content was observed in variant 3 with BC only, most likely due to the ability of BC to absorb phosphorus and nitrogen anions on its surface. Regarding the content of K_2O in the soil, there was a clear tendency to increase with the amount of imported BC. Compared to the initial amount of potassium in the soil before the experiment, variant 6 showed a better supply despite the export of nutrients with plant products.

The production from the selected experimental crops was harvested by variants and replicates. The average yield data show that the tested soil ameliorants have an impact on the yield (Figure 3).

The greatest impact on the yield of zucchini had two options - the self-application of manure and the combination of manure and biochar, with an increased rate of biochar.

The influence of the ameliorants used on the broccoli yield differed between the two varieties. In the variety with short vegetation (Monty F1), the best effect was the option with combined use of the two ameliorants, with a reduced rate of biochar. In the case of the variety with long vegetation (Corato F1), two variants had an impact - with independent use of manure and with combined use of the two ameliorants, with average (standard norm) for the use of biochar.

In the case of beans, the option with self-use of biochar had the best effect on yield.

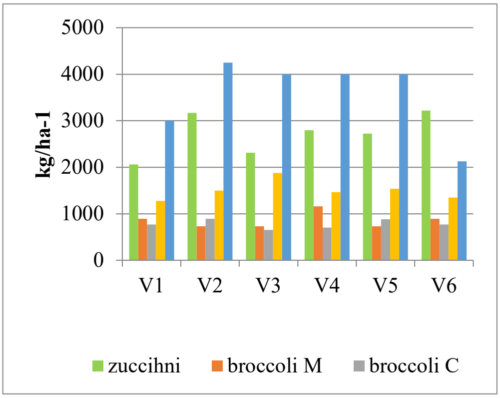

Figure 3. Average yield of experimental crops

Leek yields was best influenced by the option of self-use of manure, followed by the options of self-use of biochar and the combined use of the two ameliorants.

CONCLUSIONS

Based on the experiment the results demonstrate the positive effect of BC on soil organic matter content and water-physical properties.

For variants with higher BC content in combination with manure humus content increases. The reduced content of total N in variant 3 probably is due to the adsorption of NH_3 or organic-N onto its surface by cationic or anion exchange.

The lowest NPK values were reported in variant 1 clear soil and variant 3 with only BC added. In the variants of BC, as the rate of imported carbonated plant residues, the NPK content also increases. The highest N content in the experimental variants is reported in variant 6 (manure 4 t/da + BC 750 kg/da).

It concluded that the addition of carbonized plant residues in combination with organic fertilization could use as a soil improver and as a means of utilization of plant residues in agriculture.

Based on the experiment, the results demonstrate the positive effect of BC on the content of organic matter in the soil and its retention capacity.

In variants with a higher BC content in combination with manure, the humus content increases. The reduced total N content in variant 3 is probably due to the adsorption of NH3 or organic N on its surface by cationic or anionic exchange.

The lowest NPK values were reported in variant 1 non-treated soil and variant 3 with only BC added. In the BC variants, with the increase in the amount of imported carbonized plant residues, the NPK content also increased. The highest N content in the experimental variants wass reported in variant 6 (manure 4 t/da + BC 750 kg/da).

It can be concluded that the addition of carbonized plant residues in combination with organic fertilizers can be used as a soil improver and as a means of utilizing plant residues in agriculture.

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ROLE OF EDTA IN LEAD MOBILIZATION AND ITS UPTAKE BY MAIZE GROWN ON AN ARTIFICIAL Pb-POLLUTED SOIL

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Abstract

Soil pollution with heavy metals is a serious issue worldwide. Metal pollution has serious implications for the human health and environment. Phytoremediation is considered an economical and environmentally friendly method of exploiting plants to extract contaminants from soil. The purpose of this paper is to study the maize seedling, growing and behaviour in a soil polluted with heavy metals. Maize is known from literature as lead accumulators in artificially polluted soil with 1000, 2000 and 3000 mg/kg Pb of soil and in the presence of different treatments with EDTA as the mobilization agent. This means that the treatment for phytoextraction (Pb concentration, EDTA concentration) is expressed in the biomass. From the statistical calculation it results that in the variant with 1000 mg Pb/kg soil + ratio EDTA/Pb = 0.5 have no significant decrease in leaf weight. In conclusion, EDTA application does not influence hyperaccumulation. The toxicity of 3000 mg Pb/kg is too high and the plant does not tolerate this toxicity. Another ligand/lead ratio has to be chosen and other solutions are sought to stimulate plant growth and increase the accumulation of metals in the plant.

Key words: *soil, pollution, lead, maize.*

INTRODUCTION

Soil pollution with heavy-metal is one of the main global environmental problems (Wan et al., 2016).
Regarding their role in biological systems, heavy metals are classified as essential and non-essential. Essential heavy metals are those, which are needed by living organisms in low quantities for vital physiological and biochemical functions. Examples of essential heavy metals are Fe, Mn, Cu, Zn, and Ni (Cempel & Nikel, 2006; Gohre & Paszkowski, 2006). Non-essential heavy metals are those, which are not needed by living organisms for any physiological and biochemical functions. Examples of nonessential heavy metals are Cd, Pb, As, Hg and Cr (Sanchez-Chardi et al., 2009; Dabonne et al., 2010).
Heavy metal concentrations beyond threshold limits have adverse health effects because they interfere with the normal functioning of living systems.
Phytoextraction of heavy metals can be practiced in two ways, natural and induced.
In natural or continuous phytoextraction, plants are used for removal of heavy metals under natural conditions, no soil amendment is made. In induced or chelate assisted phytoextraction, different chelating agents such as EDTA, citric acid, elemental sulfur, and ammonium sulfate are added to soil to increase the bioavailability of heavy metals in soil for uptake by plants (Sun et al., 2011).
Phytoremediation of heavy metals in soils can be categorized into four major routes: uptake of heavy metal, bioaccumulation of heavy metal, *in situ* inactivation or immobilization of heavy metal, minimizing the bioavailability and external transport of heavy metal, and transformation of volatile forms and discharge into the atmosphere (Shah & Daverey, 2020).
Figure 1 presents the traditional concept that have limitations approaches of phytoremediation and to minimize these limitations and to ensure large scale application of phytoremediation, a lot of research was conducted in this field and result in recent advancements in phytoremediation as a modified concept (Sarwar et al., 2017).

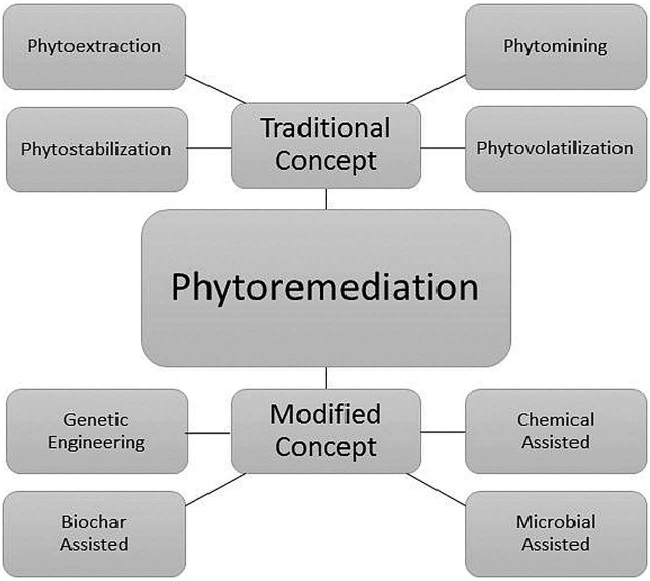

Figure 1. Approaches for heavy metals phytoremediation (Sarwar et al., 2017)

In Figure 2 is illustrated diagram showing the relationship between immobilization, bioavailability and phytoremediation of toxic heavy metals. Both phytoextraction and phytostabilization processes are part of phytoremediation technique employed to manage contaminated soils. The sources of the common heavy metals input to soils, their interactions and bioavailability in soils, and the remediation of metals contaminated soils through manipulating their bioavailability using a range of mobilizing or immobilizing soil amendments is a research challenge (Bolan et al., 2014).

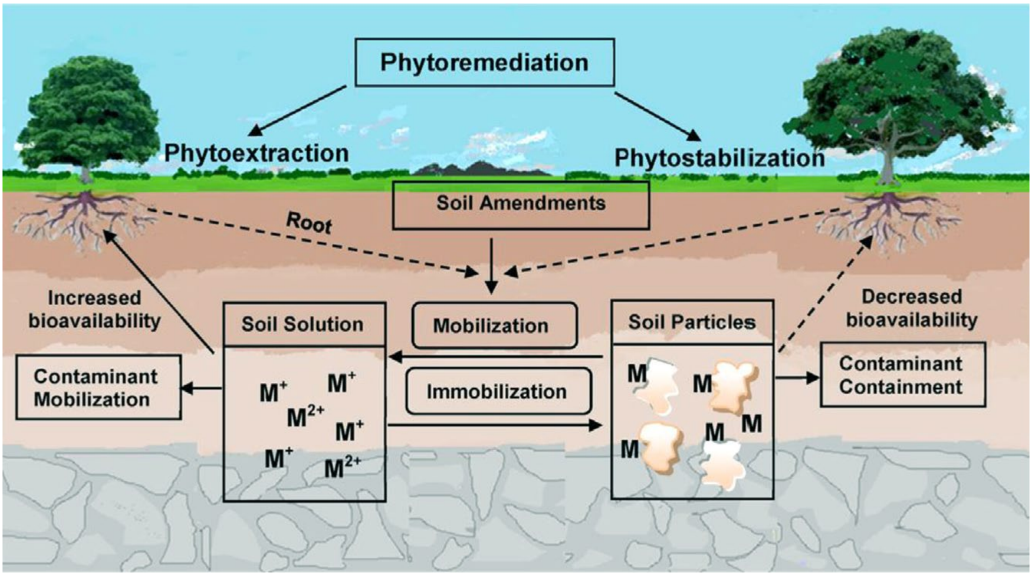

Figure 2. Illustrated diagram showing the relationship between immobilization, bioavailability and phytoremediation of toxic heavy metals (Bolan et al., 2014)

MATERIALS AND METHODS

The purpose of this paper is to study maize seedling, growing and behavior. Maize is known in the literature as being accumulator for lead in the soil polluted artificially with 1000, 2000 and 3000 mg Pb/kg of soil and in the presence of different amounts of EDTA as a mobilization agent. Experiment consists in 8 variants in three repetitions. The test plant chosen is maize. Different variants for maize: V17-V32 variants: 1000-3000 mg Pb/kg soil + EDTA (in different ratios to Pb). The experiment scheme are as follows in Table 1.

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Experiment consists in 8 variants in three repetitions. The test plant chosen is maize. Different variants for maize: V17-V32 variants: 1000-3000 mg Pb/kg soil + EDTA (in different ratios to Pb). The experiment scheme are as follows in Table 1.

Table 1. Experimental scheme

Experimental variant	**Lead concentration (mg/kg)**	**EDTA (Ligand/Lead ratio)**
V17	0	0
V18	1000	0
V19		0.5
V20		1
V21		2
V22		10
V23	2000	0
V24		0.5
V25		1
V26		2
V27		10
V28	3000	0
V29		0.5
V30		1
V31		2
V32		10

The soil used in the experiment is a cambic chernozem from Fundulea area, Călărași County. In Table 2 are presented the physical characteristics of soil.

In table 3 are presented chemical characteristics of cambic chernozem from Fundulea.

Table 2. Physical characteristics of cambic chernozem from Fundulea area, Călărași county (n = 3)

	Particle - size distribution (in mm) (% of the mineral part of the soil)				**Symbol – subclass texture**	Carbonates (%)
	Coarse sand	Sand	Silt	Clay		
	2.0-0.2 mm	0.2-0.02 mm	0.02	< 0.002 mm		
Mean	0.3	33.1	30.7	35.9	LL - Medium Clay (Romanian Soil Taxonomy System, 2003)	-

Table 3. Chemical characteristics of cambic chernozem from Fundulea area, Călărași county (n = 3)

Characteristics	**M.U.**	**Mean value**
pH_{H2O}	-	6.84
Total nitrogen content	%	0.255
Organic carbon content	%	3.98
Mobile phosphorous content	mg kg^{-1}	17
Mobile potassium content	mg kg^{-1}	140

In Table 4 are presented the contents of heavy metals in soil that will be used in the experiment. All the values registered for cadmium, copper, cobalt, nickel, lead, manganese and zinc are beyond the alert threshold.

Table 4. The content of heavy metals in cambic chernozem from Fundulea area (n = 3)

Heavy metals content	M.U.	Mean value
Cadmium	mg kg^{-1}	0.3
Copper	mg kg^{-1}	27
Cobalt	mg kg^{-1}	10
Nickel	mg kg^{-1}	34
Lead	mg kg^{-1}	25
Manganese	mg kg^{-1}	761
Zinc	mg kg^{-1}	83

RESULTS AND DISCUSSIONS

The maize vegetation period was 8 weeks.
The evolution of the plants from sowing, emergence to harvesting was followed. Regarding leaf appearance and emergence, there was a strong influence of Pb treatment with EDTA.
After harvesting maize plants measurements of plant height and weight of the resulting biological material as well as lead dosages were made to determine the amount of lead accumulated in plants (Figures 3-5).
Following the variance analysis (Tukey test, Fisher test), statistical data showed a different evolution of these parameters depending on the treatment applied. There are statistically significant differences both in the weight of the biological material at harvest and at plant height, but also in the lead content of the plants.

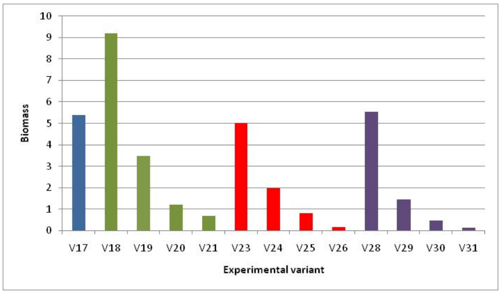

Figure 3. Biomass evolution of maize plants on a soil polluted with 1000, 2000 and 3000 mg Pb/kg and EDTA/Pb ratios by 0, 0.5, 1 and 2

For soil polluted with 1000 mg/kg Pb and treated with increasing amounts of EDTA (ligand) such that the EDTA / Pb ratio reaches 0; 0.5; 1 and 2, leaf weight decreases significantly from the control of each variant in which the ligand (EDTA) was applied in the 0.5, 1 and 2 ratios (Fisher test). At V18 (without EDTA), the increase in leaf weight against the control (V17) is due to the higher nitrogen content of the Pb nitrate that acted as a fertilizer in this case. The significant decrease in leaf weight compared to the V17 control appears only in variants V20 and V21, where the EDTA/Pb ratio is higher: 1 and 2. The decrease is not significant compared to the V17 variant in variant V19: Sol (+ 1000 mg/kg Pb) + EDTA/Pb = 0.5.
There is a distinctly significant decrease in leaf weight with increasing EDTA concentration (increase in EDTA/Pb ratio). At the same time, in these variants, including the V24 EDTA/Pb = 0.5 variant, the biomass decrease is distinctly significant which means that the use of maize as a hyperaccumulative plant on a 2000 mg Pb/kg soil loaded can be tested in EDTA at an EDTA/Pb ratio lower than 0.5, in a variant where the decrease in biomass is not significant. Figure 3 shows the soil treated with a lead content (2000 mg/kg) and different EDTA contents (EDTA/Pb = 0, EDTA/Pb = 0.5, EDTA/Pb = 1, EDTA/Pb = 2 molar ratio).

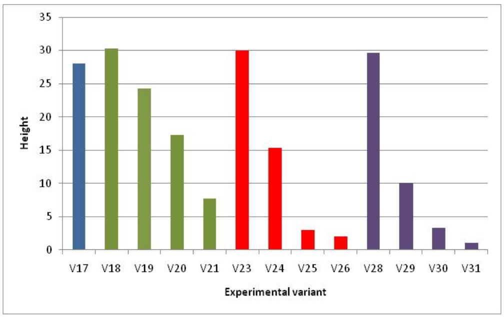

Figure 4. Height of maize plants on a soil polluted with 1000, 2000 and 3000 mg Pb/kg and EDTA/Pb ratios by 0, 0.5, 1 and 2

Plant height decreases significantly from the control. The height evolution is similar to the weight of the leaves. If the treated soil with a lead content (2000 mg/kg) and different contents of EDTA (EDTA/Pb = 0, EDTA/Pb = 0.5, EDTA/Pb = 1; EDTA/Pb = 2 molar ratio), there are differences in the thickness of the leaves. The maize leaf height values also significantly decrease.

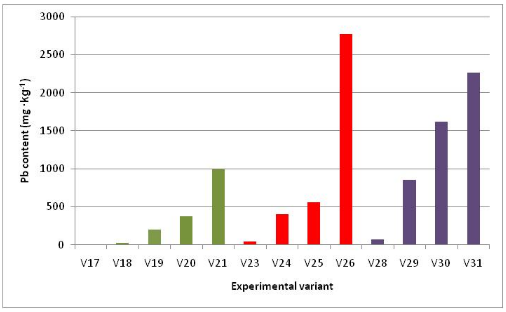

Figure 5. Pb content of maize plants on a soil polluted with 1000, 2000 and 3000 mg Pb/kg and EDTA/Pb ratios by 0, 0.5, 1 and 2

Concerning leaf lead content, there is a distinctly significant increase in each variant compared to the V17 control. Significant increase of Pb relative to the control occurs in variants V19, V20 and V21, where EDTA treatment was performed. The bioavailability of lead increased with increasing EDTA concentration in the soil.

Corroborated, the evolution of the Pb content of leaves with the evolution of biomass weight and plant height, from the test experience, that can be said that only until the EDTA / Pb ratio of 0.5 does not show a significant decrease in biomass, the ligand does not react to this level of negative concentration, although the lead concentration increases.

The content of Pb increases significantly in all leaves, which means that even at concentrations of 2000 mg/kg Pb in soil the bioavailability of lead has increased with the increase in EDTA content. Values higher than 450 mg/kg occur in variants V25 and V26, where the ligand treatment was EDTA/Pb ratio = 1 and EDTA/ Pb ratio = 2.

The lead concentration significantly increases in all variants compared to the control. Values higher than 1053 appear only between V30, EDTA/Pb = 1; V31: EDTA/Pb = 2 and the V17 control on the one hand and between the same variants (V30, V31) and V28 where the soil with the concentration of 3000 mg Pb/kg does not contain EDTA.

Since the decrease of biomass is significant even from V29: EDTA/Pb = 0.5 and the lead concentration increases significantly (> 1053) from V30: EDTA/Pb = 1 the conclusion is that the application of EDTA can not influence the hyperaccumulation; the toxicity of 3000 mg Pb/kg is too high and the plant does not tolerate this toxicity. Thus, another ligand / lead ratio has to be chosen and other solutions are sought to stimulate plant growth and increase the accumulation of metals in the plant.

On the treated soil with different lead concentrations (1000 mg/kg Pb, 2000 mg/kg Pb, 3000 mg/kg Pb) and the same EDTA content (EDTA/Pb = 0.5 molar ratio), the Pb concentration in the leaves increases with soil Pb. Significant increases are at all variants versus control. This means that the choice of the best treatment for phytoextraction (Pb concentration, EDTA concentration) is the amount of biomass. From the statistical calculation it results that in the experimental variant of 1000 mg/kg Pb soil + EDTA/Pb ratio = 0.5 no significant decrease in leaf weight occurs.

In the case of increasing the lead concentration at the same EDTA/Pb ratio of 0.5, the Fisher Test shows a significant decrease in biomass weight and a distinctly significant height of maize plants; phenomena which can also be seen in figure 4.

In the case of the lead concentration increase (1000, 2000 and 3000 mg/kg Pb soil) at the same EDTA/Pb ratio = 1, the Fisher test shows a distinctly significant decrease of both biomass and maize plant height.

This aspect of biomass and plant height development in this type of treatment can be observed in Figures 3 and 4.

A distinctly significant decrease of the two parameters (biomass and height) is observed in the experimental variant of 1000 mg/kg Pb soil; this again excludes the EDTA/Pb = 1 ratio even for this experimental variant of 1000 mg/kg Pb soil.

The increase in the concentration of Pb in the leaf is significant in all variants, but the evolution of biomass is also decisive and how it decreases significantly at all three concentrations compared to the blank, the EDTA/Pb = 1 variant can not be taken into account calculation.

CONCLUSIONS

EDTA application does not influence hyperaccumulation. The toxicity of 3000 mg Pb/kg is too high and the plant does not tolerate this toxicity. Thus, another ligand/lead ratio has to be chosen and other solutions are sought to stimulate plant growth and increase the accumulation of metals in the plant.

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LIMITATION OF THE PRODUCTION CAPACITY OF AGRICULTURAL LAND IN RADUCANENI COMMUNE, IASI COUNTY

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Abstract

The efficient exploitation of agricultural lands and the obtaining of high productions depend on the biological material and the applied technology and, to a large extent, on the factors of environment, soil, climate, relief and hydrology. Soil fertility is affected to a greater or lesser extent by one or more restrictions, caused by natural factors and / or anthropogenic agricultural and industrial actions, which can often act in a negative way in a negative way. Research has shown that soil fertility in the Raducaneni territorial administrative unit is affected by the following limiting factors: surface erosion, deep erosion, landslides, gleyzation, stagnogleyzation, salinization and alkalization. If on the sloping lands the significant restrictive factors are the soil erosion and landslides, on the flat lands, from the River Jijia Meadow, the productive capacity of the agricultural lands is strongly diminished by gleyzation, salinization and alkalization.

Key words: *limiting factors, soil erosion, gleyzation, salinization, arable land.*

INTRODUCTION

The production capacity of agricultural lands is influenced by the complex of environmental conditions (soil, climate, relief, hydrology) and by the anthropic factors that intervene by modifying some natural factors or some properties of the plants.

The evaluation of agricultural lands represents a complex action of research and quantitative appreciation of the main conditions that determine the growth and fruiting of plants, to establish the degree of favorability of these conditions for each agricultural use.

Land valuation is not the same as soil quality assessment. Soil quality assessment is the process of assessing the ability of a soil to function. Due to the different soil functions, simply measuring an individual soil parameter is not enough (De La Rosa D., 2003).

In conditions of intensive land use, maintaining soil and land quality is a major challenge for increasing crop productivity.

Assessment of soil and land quality indicators is necessary to assess the state of degradation and changing trends of different land use and management interventions (Ray SK et al., 2014; Dumanski and Pieri, 2000; Bindraban et al., 2000).

MATERIALS AND METHODS

From a physical-geographical point of view, the administrative territory of Raducaneni is located about 40 km southeast of Iasi municipality (Figure 1), and from a geological point of view it is part of the wide area of the Moldavian Platform, from whose sedimentary cover erosion has uncovered Bessarabian formations (Middle Sarmatian), Chersonian (Upper Sarmatian) and Meotian, which has a slight inclination of approx. 7-8 m/km in the NNV-SSE direction (Ionesi et al., 2005; Jeanrenaud and Saraiman, 1995).

Raducaneni commune has a total area of 8739 ha, of which 6539 ha are agricultural land and 2200 ha are non-agricultural land. The agricultural area represents 75% of the total area of the territorial administrative unit and consists of 3863 ha of arable land, 956 ha of pastures, 840 ha of hayfields, 582 ha of vineyards and 298 ha of orchards. The mapped area is 6624 ha, consisting of 6539 ha of agricultural land and 85 ha of non-productive land.

The peculiarities and geomorphological processes in the territory of Raducaneni commune have been identified both by traditional research methods (field observations and measurements, geomorphological mapping, statistical-mathematical processing, analysis, synthesis), as well as by modern methods based on GIS software.

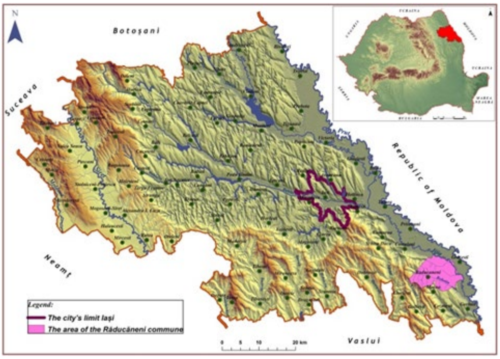

Figure 1. Geographical and administrative location of Raducaneni commune

The cartographic materials were obtained using TNTmips v.6.9 and QGIS, and the statistical processing was performed with Microsoft Office Excel 2007. An important step in spatial modeling was the realization of the Numerical Terrain Model (MNT) by vectorizing contours and elevations on topographic planes at a scale of 1: 5000.
Based on them, thematic maps were prepared regarding geomorphology, hypsometry, terrain slope, surface erosion, etc.
Climate maps were deduced by interpolation based on data covering the period 1950-2000 (Hijmans et al., 2005).

RESULTS AND DISCUSSIONS

Raducaneni commune is located in the eastern part of the Moldavian Plateau, more precisely on the northeastern branch of the Central Moldavian Plateau, in the Comarna-Raducaneni Hills subunit. The altitudes decrease, in general, from SW to NE, being between 414 m in Crasnita Hill and 26 m in Jijiei Plain (Figure 2).
According to the share of areas by hypsometric classes, the area with an altitude of less than 100 m has a share of 40.60%, of the surface of the communal territory of 8739 ha.
This area is located in the Prut-Jijia common meadow, on the middle-lower sections of the bottom of the main local valleys, as well as on the lower slopes of these valleys.

Overall, 54.77% of the surface of Raducaneni commune is at an altitude between 100 m and 300 m, and only 4.63% of the commune surface has altitudes over 300 m.

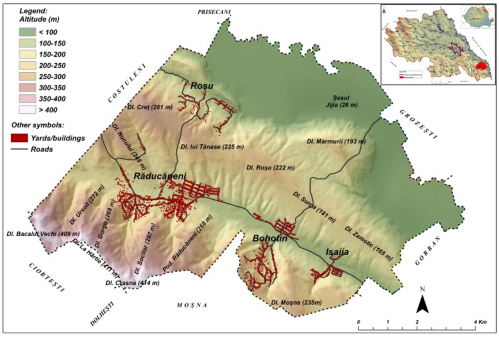

Figure 2. Altitude distribution

The main types of genetic relief in the studied area are those specific to the Central Moldavian Plateau, respectively: the lithological structural relief, the sculptural relief in general monoclinal structure and the river accumulation relief (Figure 3).

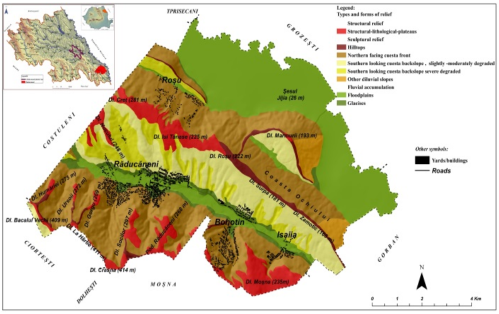

Figure 3. Geomorphological map of Raducaneni territory

The structural relief, restricted on 776 ha (8.88%) occupies the last place, subordinated to the sculptural relief and the fluvial relief of accumulation and is imposed by structural-lithological plateaus.
The sculptural relief (fluvio-denudational topography) in general monoclinal structure is the predominant genetic type as a distribution in the area of Raducaneni commune, because it occupies an area of 5281 ha, which represents 60.43% of the total area.
It is imposed by two specific forms, namely: sculptural interfluvial peaks and deluvial slopes. The interfluvial peaks have a small share, of only 2.31% (202 ha) of the total area.

On the other hand, the deluvial slopes represent the predominant form of local relief extending on 5079 ha, which represents 58.12% of the total surface of the studied administrative territory and plays the role of cuesta fronts (35.47%) and back slopes (20.35%).
The accumulation relief occupies the second place by weight, of 30.69% (2682 ha) and is represented by the common flood-plain Prut-Jijia, the flood-plain meadow of Bohotin and the alluvial-colluvial-proluvial glaciers.
The climate is temperate continental with shades of accentuated excessiveness, characterized by cold winters, relatively high humidity and high frequency of temperature inversions, and in summer the temperatures are high and the humidity low.
The masses of continental polar air are frequent all year round and sometimes there are extreme values of temperature and humidity of the air, caused by the penetration of tropical air from the south and arctic air from the north.
The average multiannual temperatures are between 8.2-10.2°C, increasing from the west of the territory to the east, being in correlation with the distribution of altitudes (Figure 4).

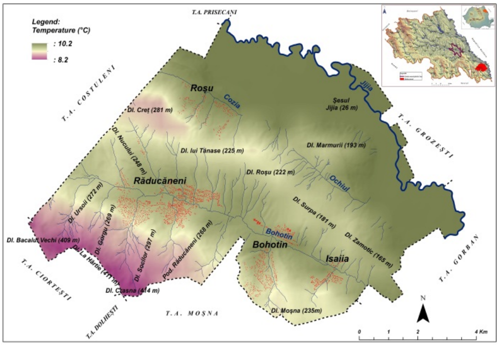

Figure 4. Temperature distribution

Also, the precipitations are correlated with the altitudes, the multiannual average values being between 532-612 mm (Figure 5).
The precipitation regime is uneven, during the year there are periods when the agricultural crops suffer due to the water deficit, as well as periods with excess humidity. The highest amount of precipitation is recorded in June. In the hot season, the precipitations have a pronounced torrential character, when there are showers of a special intensity, which favors the surface erosion of the soil.

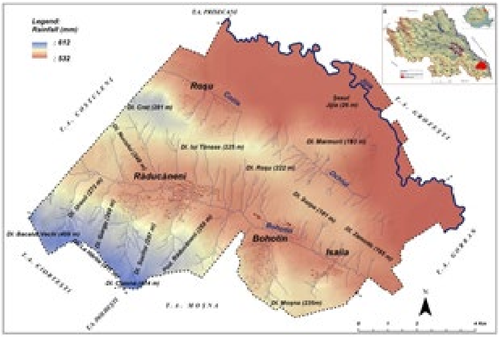

Figure 5. Rainfall distribution

From a hydrographic point of view, the territory of the commune belongs to the middle basin of the Prut, the main rivers being Jijia, Bohotin and Cozia.
The Jijia River drains the eastern extremity of the territory on a length of 19.7 km, with a strongly meandered riverbed due to the small slope, on average 1.4‰.
The Bohotin River drains the central-southern part in the NW-SE direction. Its main tributaries, on the right side, have a torrential character, strongly ravaged in the upper course, with large drainage slopes and a small receiving basin.
Following the mapping of the surface of 6624 ha, according to the Romanian Soil Taxonomy System (SRTS, 2012), 70 simple soil units and 6 complex soil units from the classes Protisols, Cernisols, Luvisols, Hydrisols and Antrisols were identified (Figure 6). These include six soil types and over thirty subtypes, divided into lower level categories based on physico-chemical and agro-productive properties.

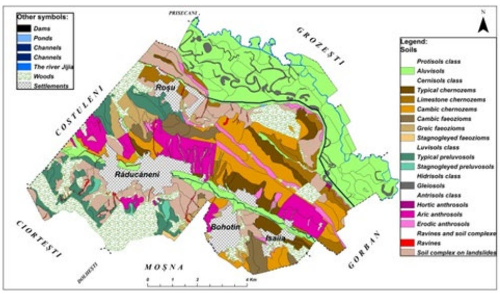

Figure 6. Distribution of soil types

The Cernisols class is the most widespread, comprising 1862 ha of chernozems and 515 ha of phaeozioms, representing 36% of the pedologically studied area. Protisols, represented by aluvisols, are found on 2066 ha (31%). Next, the Antrisols class, with 1359 ha anthroposols, ranks third in weight, 21%, followed by the Luvisols class (677 ha preluvosols) 10% and the Hydrosols class has a weight of 2% (145 ha gleiosols).

The land fund is the expression of the natural conditions of the territory and forms the basis of economic and social activities in agriculture and forestry. It has undergone many changes as a result of socio-economic activities and a change in the legal framework of land.

In general, the distribution of uses is in accordance with the nature of the local pedo-climatic and pedo-geomorphological conditions (meadows, plateaus, interfluvial peaks, slopes, etc.) which allowed the agricultural lands and, within them, the arable lands to have the highest weight (Figure 7).

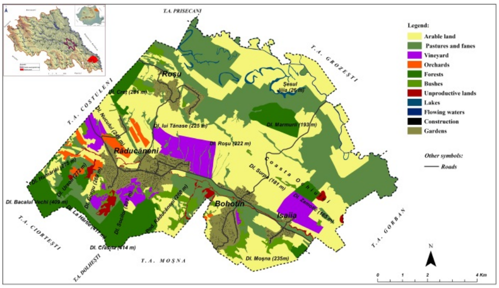

Figure 7. Distribution of use categories

Thus, out of the total area of 8739 ha of Raducaneni commune, 75% represent lands with agricultural use, of which the arable lands have the highest share, respectively 59%, followed by pastures with 15% and at a short distance hayfields with 13%, then vineyards with 9% and lastly orchards with 4%.

From the evaluation of the pedo-geomorphological properties of the lands results a series of limiting factors of the production that determine a series of restrictions in their agricultural use.

The restrictions refer both to the existing conditions, which diminish the harvests, and to the danger of the appearance, through exploittation, of some degradations with the same effects.

The relief by the degree of inclination of the land surface contributes to the differentiation of the surface and depth erosion, the triggering of landslides, the pleasing bottom of the valleys, etc.

The analysis of the slope inclination shows that a large area is relatively flat, spread over the common Prut-Jijia plain, the Bohotin plain, the narrow valleys of Cozia and Ochiului, the plateaus and the slopes on the slopes (Figure 8).

The surface of 2519 ha has slopes less than 5%, 1802 ha slopes between 5-10%, 2166 ha slopes of 10-15%, 1387 ha slopes of 15-20%, 635 ha slopes of 20-25%, and the surface of 230 ha has a slope greater than 25%.

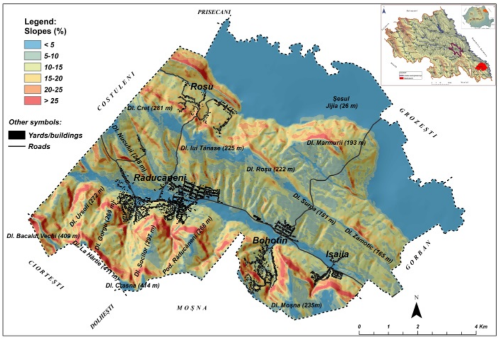

Figure 8. Land slope distribution

As the arable land has a large share in the agricultural area of the commune, 59% (3863 ha), Figure 9 shows its classification by slope classes.

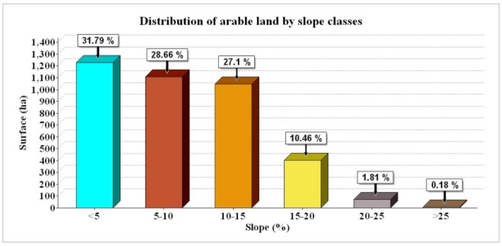

Figure 9. Distribution of arable land by slope classes

The surface of 2335 ha (60.45% of the arable land) has a slope of less than 10% and 1047 ha have a slope between 10-15%. In the slope range of 15-20% there are 404 ha and over 20% are exploited as arable 77 ha.

The intensity of the surface erosion is directly proportional to the degree of inclination and the shape of the slopes, their length and surface, being also influenced by the petrographic composition, the way of using the land, the vegetation cover, etc.

Surface erosion affects 3844 ha, which represents 58% of the pedologically mapped area. 1563 ha is affected by light erosion, 1488 ha by moderate erosion, 136 ha by strong erosion, 579 ha by very strong erosion and 78 ha by excessive erosion (Figure 10).

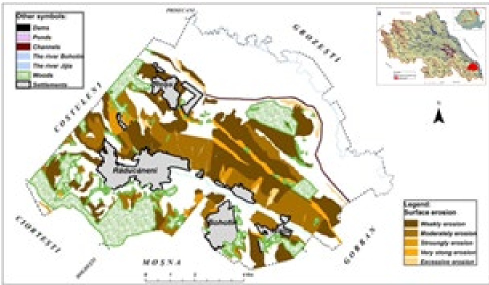

Figure 10. Distribution of surface erosion

Also, the relief, the lithological structure specific to the Central Moldavian Plateau and the anthropic activity led to the manifestation of landslides on 969 ha, of which 447 ha stabilized, 415 semi-active landslides and 107 ha active landslides.

Salinization and alkalization significantly diminish the production capacity of agricultural lands within the Raducaneni commune, being found in the common Prut-Jijia plain and the Bohotin plain.

Salivary fluvial deposits are responsible for the mineralization of groundwater located at shallow depths, which causes salinization and alkalization in the lower soil horizons, more pronounced in the upper horizons during the summer.

Salinization and alkalization affect an area of 1573 ha, which is about 24% of the pedologically mapped area. The surface affected by salinization is 1096 ha, of which 52 ha with poor salinization, 801 ha moderate and 243 ha strongly salinized (Figure 11).

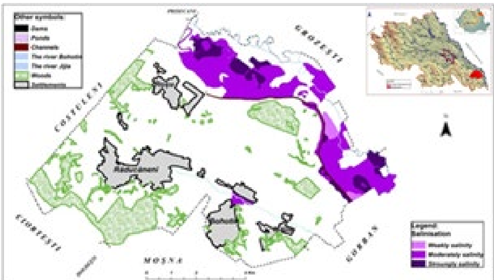

Figure 11. Distribution of soil salinization

The alkalization is manifested on 900 ha of which 771 ha with low intensity, 102 ha moderate and 27 ha strongly alkalized (Figure 12).

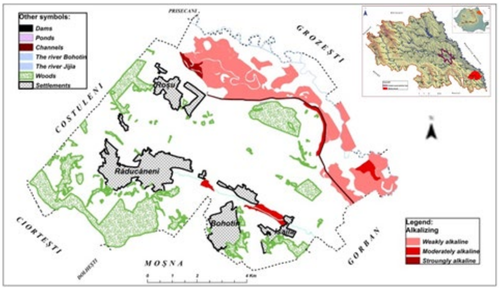

Figure 12. Distribution of soil alkalization

Of the arable land, within the commune, 396 ha are exploited on soils with moderate-strong salinization / alkalization (Figure 13).

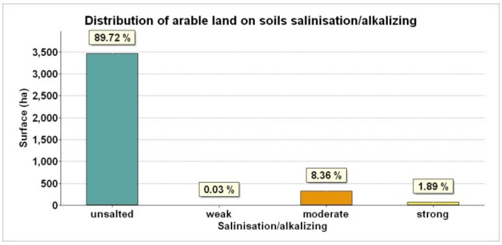

Figure 13. The share of salinization/alkalization on arable land

The presence of the groundwater level at critical depth in the conditions of a weakly deep, strongly meandering minor bed and of a weakly permeable lithological substrate determined that 2133 ha to present excess of phreatic humidity (Figure 14).

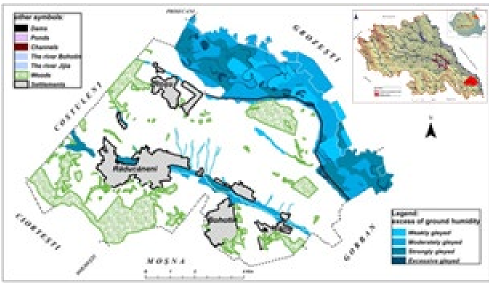

Figure 14. Distribution of gleyzation

Weak gleyed is manifested on 321 ha, moderate on 1019 ha, on 647 ha the soils are strongly gleyzation and 146 ha show excessive gleyzation.

Out of the surface of 3863 ha with arable use, on 240 ha there is weak gleyzation, on 503 ha moderate gleyzation and on 251 ha there is strong and excessive gleyzation (Figure 15).

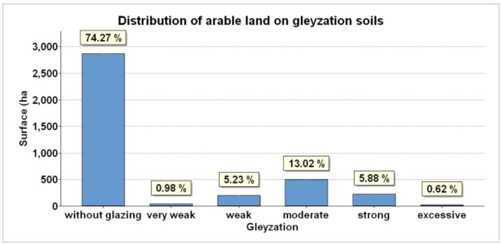

Figure 15. The share of gleyzation on arable land

The influence of the limiting factors on the production capacity of agricultural lands within Raducaneni commune, is highlighted by the low value, 40 rating points out of a maximum of 100, of the weighted average mark obtained for the total mapped area of 6624 ha, for use arable regardless of current use.

CONCLUSIONS

The overall morphography of the territory of Raducaneni commune is typical of the Central Moldavian Plateau, being formed by plateaus, interfluvial peaks and relatively deep, asymmetrical valleys, completed to the east by the Prut meadow.

Of the total surface of the territory, about 49% has a slope of less than 10%, 25% of the surface falls within the slope range 10-15%, 16% within the range 15-20% and 10% of the surface has a slope over 20% . Over 12% of the arable land area has a slope of more than 15%.

Soils of the class Cernisols (36%), Protisols (31%), Antrisols (21%), Luvisols (10%) and Hydrisols (2%) were identified on the mapped surface.

The main limiting factors of the production capacity of the agricultural lands within the Raducaneni commune are: surface erosion, salinization/alkalization and soil gleyzation.

Surface erosion affects 3844 ha of which 136 ha with strong erosion, 579 ha with very strong erosion and 78 ha with excessive erosion.

On the mapped surface, the salinization is manifested on 1096 ha, of which, on 801 ha it has a moderate intensity and on a strong 243 ha. The alkalization is manifested on 900 ha of which, with moderate intensity on 102 ha and on 27 ha strong manifestation.

On arable land, salinization and alkalization are moderate and strong on 396 ha, which represents 10% of the total arable land.

Excessive groundwater affects a total area of 2133 ha, of which 647 ha are heavily gleyzation and 146 ha are excessively gleyed.

On arable lands was identified the gleyzation on about 1000 ha, of which on 503 ha it is manifested moderately and on 251 ha it is manifested strongly and excessively.

In order to limit the production losses within the Raducaneni commune, it is recommended the exploitation on merged surfaces in order to apply the agro-improvement works and the advanced agricultural technologies.

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SOIL OLD AGE

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Abstract

The old and stable landscapes reach a balance with the environmental conditions and have a special beauty, acquired during their long process of formation. Likewise, the very old soils have a special beauty and a unique development of the pedogenetic horizons. This beauty and uniqueness highlighted the paper, by the aim of the researches of an Alosol (SRTS-2012; Alisol - WRB-SR-2014) located on an old and stable terrace relief, researches that starting from the morphological level and reaching the more detailed level of micromorphology. The Alosol had, at least in its upper part, the appearance of a Dystricambosol, due to the high acidity and the destruction processes that penetrated deep into the Bt horizon. The main characteristics that emphasised the oldness of the studied Alosol were the: depleted, textural, and amorphous pedofeatures (whose composition, colour and location reflect their age). The most spectacular was the network (with perfect angles at 90º and greenish-gray reduction colours) expressed more clearly in the Bt_2W horizon. The melioration of such an old soil should be very expensive, the reforestation being the most suitable.

Key words: *soil age, Alisol, Alosol, micromorphology, pedofeatures.*

INTRODUCTION

The soil, as the "epidermis" of our planet, is the major component of the terrestrial biosphere and, in the present age, it is difficult to understand how one could be interested in general ecology without having some knowledge of the soil and further, to study the soil without taking into account its biological components and ecological setting (Lavelle & Spain, 2002).

Soil fauna communities are sensitive to acidity although different groups may react differently, thus, larger invertebrates are more sensitive than smaller ones and, among them, arthropods are more acid tolerant than earthworms (Lavelle et al., 1995).

Such acid environment has Alosols, soils belonging to Luvisol class and defined (according to SRTS-2012) as soils having "eluvial (E) horizon followed by a B argic (Bt) horizon having the cation exchange capacity of clay > 24 me/100 g and base saturation < 53% at least in the upper part of the Bt horizon". While according to WRB-SR-2014, these soils are Alisols and are defined (briefly) as soils having "an argic horizon starting ≤ 100 cm from the soil surface; and a base saturation, calculated on the sum of exchangeable bases plus exchangeable Al of < 50%".

The primary illite is abundant in the Alisol; also the expanding clay minerals have their maximum in this soil (Stahr et al., 2010).

The micromorphological study of a mature profile of Alisol (performed by Krasilnikov et al., 2005), showed few thin clay coatings (occasionally fragmented by biogenic-turbation) in the BW horizon and in the BC and C horizons, the amount of clay coatings and biogenic aggregates decreases.

The acid grassland soils exhibited a faster rate of nutrient turnover than forest climax soils; these differences were emphasised for the N cycle and may be attributable to deposition of dung by grazing cattle, and to the greater rhizospheric activity of the grassland vegetation (Ferreiro et al., 2007).

The old and stable landscapes reach a balance with the environmental conditions and have a special beauty, acquired during their long process of formation. Likewise, the soils, the very old ones have a special beauty and a unique development of the pedogenetic horizons. This beauty and uniqueness wants to highlight the present paper, by the aim of the researches that starting from the morphological level and reaching the more detailed level of micromorphology.

MATERIALS AND METHODS

The researches had been performed on an Alosol Albic Stagnic (according to SRTS-2012; or Albic Stagnic Alisol Hyperdystric, according to WRB-SR-2014) located in Pre-Carpathian Depression of Oltenia, on a terrace, at the absolute altitude of 268 m. The surface is cvasi-horizontal, with < 2% slope (Figure 1).

Figure 1. The landscape of the studied Alosol

The parent material consists of fluvic clayey deposits, while the subjacent rock is represented by the carbonate-free clayey deposits with Holocene substrate of gravels and sands. The groundwater is at 5-10 m depth. The global natural drainage is imperfect. Bioclimatic zone is of oak forest. The vegetation consist of: secondary meadow with *Festuca* sp., *Agrostis stolonifera, Trifolium repens, Trifolium fragiferum, Potentilla recta, Ranunculus cassubicus, Thimus* sp., and *Achillea millefolium*.
The climate is temperate continental, with the average annual temperature of 9.5ºC, and the average annual precipitations of 914.7 mm.
The soil had been sampled in disturbed (for physical and chemical analysis) and undisturbed (for micromorphological study) status, from each pedological horizon. The sample analysis and the data interpretations were performed according to the standard methods of ICPA-Bucharest (ICPA Methodology, 1987).
From the undisturbed soil blocks (air dried and impregnated with epoxy-resins), oriented thin sections (of 25-30 μm) have been made for the micromorphological investigations. The terminology used for micromorphological description was according to Bullock et al. (1985).

RESULTS AND DISCUSSIONS

What does an old soil mean?
Compared to the temporal scale of the human life, all soils can be considered old aged.
In the pedological concept, however, an old soil means an evolved soil, to which the pedogenetic horizons are very well differentiated, and the soil reached a balance with the environment, at a status of „climax“.
Many Luvisols (as Alosols) can be included in the highly evolved soils category.
A representative Stagnic Albic Alosol formed on an old and stable relief of terrace had been studied. The land use was oak forest (the evidence being the fern clumps, reminiscence of the old forest) but in the last 30-40 years the land use has been pasture.
Morphologically (Figure 2) the Alosol had, at least in its upper part, the appearance of a Dystricambisol, being more yellowish (compared to a “classic” Luvisol), and having, in the upper part of the Bt horizon, the specific prismatic structure destroyed.

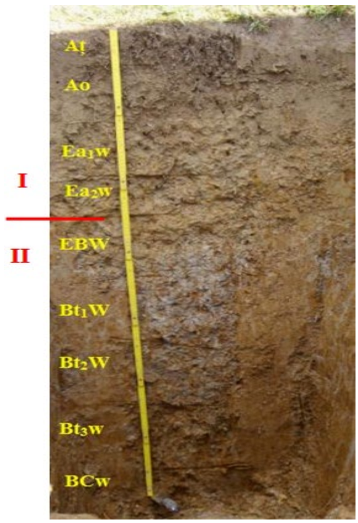

Figure 2. The Alosol profile

This Alosol was formed in stratified parent materials, as a result, the soil is a bisecvum consisting of two sequences of horizons (Figure 2): I) Ao-Eaw and II) EBW-BCw.

The data of the granulometric analysis (Figure 3) also showed this stratification: not only by the clay content differences (which could be mainly pedogenetic) but also by an abrupt decrease of sand (coarse + fine sand) with 10% (from 41.00-43.40% in the upper I sequence to 25.30-34.20% in the second lower one).

As a result, a sharp decreased of the coarse sand appear, from 11.2-13.6% in the upper sequence (corresponding to the depth 0-50 cm) to 5.8-8.1% in the deeper horizons (corresponding to 50-160 cm).

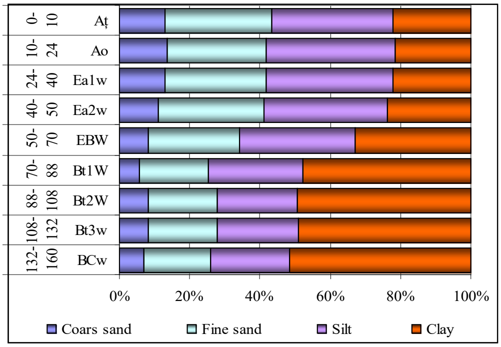

Figure 3. The soil granulometry

The main processes that lead Alosol pedogenesis and further increased, over time, the differences between the two depositional sequences (and which also dominate the pedogenesis nowadays) are: clay illuviation and stagnogleization.

The clay illuviation process was, over time, very intense (both its eluvial and illuvial components) and generated many types of pedofeatures whose composition, colour and location reflected their ages.

The eluviation process was, over time, very hygh, thus, the matrix background of all the pedogenetic horizons became nearly similar to that of the eluvial (Ea) horizon: very poor in plasmic constituents; also emphasised by the pH values and the sum of the exchangeable bases (SB) values (Figure 4).

The destruction processes, lead by the lower values of the soil solution pH, which penetrated deep into the soil profile, throughout the base of the Bt horizon (at 132 cm depth), deeply change the soil physical and chemical characteristics.

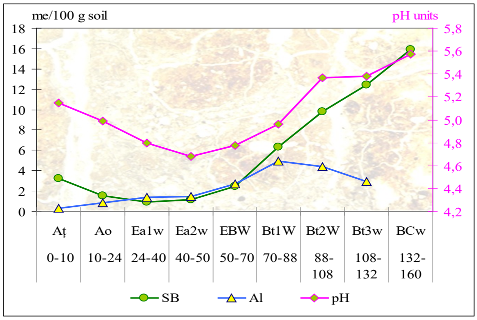

Figure 4. The sum of the exchangeable bases (SB - me/100 g soil), pH and exchangeable Al values

In this respect, only the surface Aţ horizon had a moderate acidity (5.2) as a result of the cation biological accumulation, the SB values reaching 3.23 me/100 g soil (Figure 4). In the major part of the soil profile (10-88 cm) the acidity is strong (pH values ranging from 4.7 to 4.9), while into the BtW horizon, the values increased again to 4.9-5.4, the acidity being moderate.

In this acidic environment, the cation accumulation was hinder, thus the values of the sum of the exchangeable bases (SB) is very low, ranging from 0.94 me/100 g soil (in Eaw horizon) to the higher values of 6.31-15.88 me/100 g soil (into the BtW horizon and BCw respectively).

The soil adsorption complex is dominated by the H^+ cations, followed in the decrease order by Ca^{2+}, Mg^{2+}, Na^+, and K^+. For all these cations, the highest values are reached in the lower horizons (BtW and BCw, respectively).

The exchangeable aluminium content is high, reaching the maximum values (4.91 and 4.39 me/100 g soil) in both Bt_1W and Bt_2W sub-horizons, and decreasing afterwards, in the bottom profile to medium content (2.93 me/ 100 g soil).

Răducu (2019) showed that Al content depends on the amount of colloids (especially clay), thus at very close values of the pH, but different amounts of clay, the content of the (exchangeable) Al is very different (in Alosols).

From the conceptual point of view, Alosol is a Luvisol with high acidity (pH below 5.8) on the

whole profile (holoacid) and, therefore, with very high aluminium content (as its name suggests: "Al-o-sol"). For this reason, to classified this soil, quantitative indices were selected to highlighted the conditions that favour the Al accumulation in soil: the cation exchange capacity of clay (which must be greater than 24 me/100 g clay); and the base saturation (which must be less than 53% - according to SRTS-2012).
Thus the most important chemical parameters used, to separate the Alosols from Luvisols are: base saturation (BS - %) together with the cation exchange capacity of clay (CEC_{clay} - me/100 g clay - Figure 5).

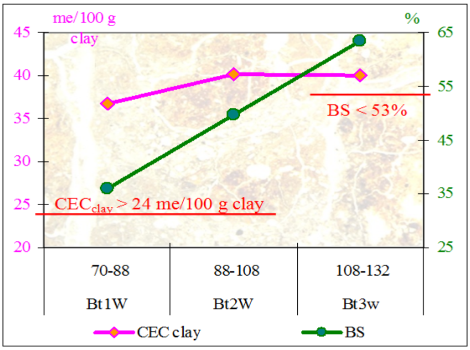

Figure 5. The conditions for the "alic" subtype and "Alosol" type respectively: cation exchange capacity of clay (CEC_{clay}) > 24 me/100 g clay, and the base saturation degree (BS) < 53% (SRTS-2012)

In the studied Alosol, the BS (%) values are low: 34.8% in the surface horizon, decreasing drastically to 15.5-18.4% in Eaw horizon, while in the BtW horizon, the BS values increased again to 63.4-77.5%.
Consequently, the soil is oligomesobazic in both Aț and BtW horizons, and oligobasic in the major part of the soil profile; while in the bottom profile, the soil is mesobasic as a result of the highest BS values.
The Bt horizon of Luvisols is eutric (BS ≥ 53%) by definition, while the Bt of the Alosols is district, at least in its upper part.
In what concerning the eluvial process, it is emphasised, at microscopic level (micro-morphological imagine - Figure 6), by many and relatively extended depleted pedofeatures (depleted in plasmic material) containing greyish clayey-silty matrix and located in the fissure walls (Figure 6a).
The soil matrix appears like scattered islands in the extended depleted pedofeatures.

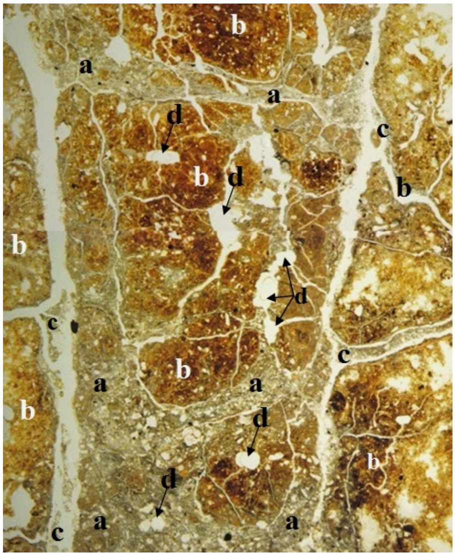

Figure 6. Bt_2W horizon (88-108cm): depleted pedofeatures with grey silty-clayey matrix (a); amorphous pedofeatures inside the structural elements (b); greyish silty-clayey material clogging the (vertical and horizontal) fissures (c); biological porosity (d). PPL

The illuviation process, also very active over time, generated many types of textural pedofeatures in the pedogenetic horizons.
In this general „washed", acid background, the old textural pedofeatures appear inside the structural elements, covered by thin films of Fe oxyhydroxides (Figure 6b).
These Fe films also protect the textural pedofeatures (clay ± Fe coatings) against the aggressive impact of the soil solution.
The intense illuviation process generated coatings and infillings in voids, which had different compositions, colours, and locations, that reveals their ages and depositional conditions (Figure 7).
In the Eaw horizon the sporadic silty coatings had been deposited during the present illuvial process.
In the Bt_2W horizon (88-108 cm), many types of textural pedofeatures deposited during the long period of time and the periodically (annual and/or seasonal) changing climatic conditions.
Clay coatings had been deposited into the intrapedal pores being covered by amorphous

pedofeatures (Figure 7a). Thick micro-laminated infillings of clay ± Fe ± blackish impurities (Figure 7b) were formed at the border between the zones with reductimorphic and oximorphic colours. Old clayey yellowish coatings and infillings with their specific glassy appearance (Figure 7c), cracked and fragmented had been observed. Microlaminated clay ± Fe hypo-coatings (Figure 7 d) had been formed in the walls of the voids, as a result of the soil solution migration from the pores towards inside the aggregates.
Silty-clay coatings (Figure 7e) specific to the depleted pedofeatures matrix, had been deposited in the actual new pores.

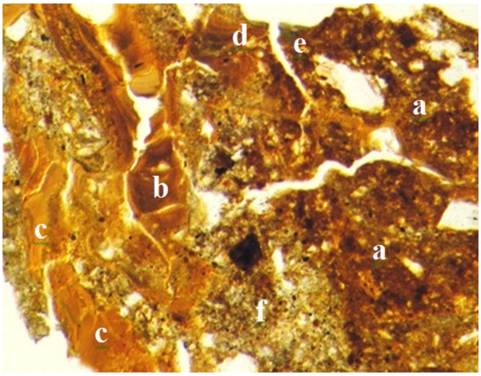

Figure 7. Bt_2W horizon (88-108 cm): clay coatings covered by protected Fe film (a); microlaminated infillings of clay ± Fe ± blackish impurities (b); old glassy-looking infillings (c); microlaminated clay ± Fe hypo-coatings (d); silty-clay coatings (e)

In the bottom horizons (Bt_2W - BCw), the clay±Fe coatings are very old, and had been partially integrated into the soil matrix and had the appearance of mo-unistrial b-fabric.
In the BCw horizon, the presence of the deformed granostriated b-fabric (around some nodules) due to the swelling-shrinking processes had been noticed.
The Alosol being under a permanent seasonal influence of waterlogging, in the soil profile stagnic properties had been developed, under reduction conditions.
The stagnic properties are very old, showed also by the distinct network (Figure 8), with perfect angles at 90° and greenish-gray (5GY 6/1) reductimorphic colours (when wet) formed into the soil profile. This network (more clearly expressed in the Bt_2W horizon) was generated by the preferential and constant circulation of the soil solution along the same voids over a long period of time.

Figure 8. Bt_2W horizon (88-108 cm): at morphological level (in the soil profile) the greenish-gray network is very well expressed (with clear angles of 90°)

This grid delimits perfect prismatic structural elements, inside which the oximorphic colours had been concentrated (Figure 8).
The amorphous pedofeatures generated by the water stagnation are: Fe ± Mn nodules, very common in all pedogenetic horizons; blackish Fe ± Mn concentrations (with nodules and concretions inside them) appear in the Ea_2w horizon; many of them seem to have formed on the account of the coprolite channels, the compacted walls of which appear at the border of these mottles, partly covered by the Fe oxyhydroxides; pseudomorphosis on plant debris, had been observed sporadically in the Eaw and EBW horizons.
Biological activity is very high in the surface horizons. The Ea horizon, although having a strong debazification, is burrowed over 50% by the soil mesofauna, which is why the lamellar structural elements (formed both in the lower part of Ao and in the upper part of Ea horizons) had been partially transformed into coprolites, giving them a highly friability. Black sclerotia sporadically appear in the Eaw horizon, reflecting fungal activity.

The presence of soil mezofauna and roots channels in the Bt_2W horizon (88-108 cm) despite of the stagnic properties (waterlogging) showed an active biodiversity (Figure 6d) which improve and renewed seasonally the soil porosity.

A noteworthy aspect is the fact that bioturbation does not appear in this profile (which showed a very low or even a miss of macrofauna activity); a process that would have renewed (rejuvenated) the upper horizons (Ao-ABw) by plasmic material.

The melioration of such an old age soil would impose a drainage system in order to remove the surface water excess, as well as the acidity correction by liming (which would impede the toxic influence of the mobile Al). To increased soil fertility, mainly organic fertilizers (manure) are recommended. The field being pasture, the occasionally fertilization occur, by grazing animals. Also, to improve pasture, overseeding is necessary. However, the most efficient melioration method (which also involves high costs) would be reforestation (taking into account that the land use, 30-40 years ago was forest).

CONCLUSIONS

The studied Alosol (SRTS-2012; Alisol - WRB-SR-2014) is a spectacular, beautiful old aged soil that developed specific characteristics and pedofeatures which emphasised its long pedogenesis (under the main process: illuviation and stagnogleisation). It is a strong acid soil, the aggressive soil solution penetrated deep into the soil profile (until 132 cm depth) and created many depleted pedofeatures, and consequently the matrix background of all the pedogenetic horizons being nearly similar to that of the Ea horizon.

The clay illuviation process was very high, over time, and generated many types of pedofeatures whose composition, colour and location reflect their ages. The stagnic properties are very old, as a result a distinct network formed (with perfect angles at 90^o and greenish-gray reduction colours ascribed to the preferential and constant circulation of the soil solution along the same voids over a long period of time. The most suitable melioration for such an old soil is the reforestation.

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A REVIEW CONCERNING THE EFFECTS OF CYCLODEXTRINS ON HYDROCARBONS BIODEGRADATION IN SOIL

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Abstract

Organic chemicals as hydrocarbons provided by crude oil represent serious environmental and health risk. For the remediation of contaminated soil different physical, chemical and biological technologies can be applied. The most promising remediation technologies are based on biodegradation. Bioremediation is an inexpensive, safe and environmental friendly technology. The end product of bioremediation is the harmless, decontaminated soil. Bioremediation of hydrocarbon polluted soils can be improved by the increase of hydrocarbon availability. In present review, it is discussed various effects of cyclodextrins on hydrocarbons biodegradation, bioremediation strategies, mechanisms involved in hydrocarbons biodegradation, factors and some technologies in bioremediation approaches.

Key words: *biodegradation, hydrocarbons, cyclodextrins, soil.*

INTRODUCTION

The release of hydrocarbons into the environment, accidental or due to human activities, is a main cause of soil pollution. Many bioremediation technologies have been developed to remove these contaminants, as some biological treatments are cheaper than chemical and physical treatments and sometimes result in complete mineralization (Holliger et al., 1997). One of the most important requirements is certainly the presence of microorganisms with the appropriate metabolic skills, but even the chemical physical characteristics of the oil and the interactions between the oil phase and the aqueous phase (containing the microorganisms) are very important for the success of bioremediation which relies on augmenting the natural biodegradation rate of oil (Ron and Rosenberg, 2014). Several petroleum aliphatic and polycyclic aromatic hydrocarbons can act as source of carbon and energy for the growth of soil microorganisms (Galli, 1998). One main factor that influences the extent of their biodegradation is their bioavailability and this is a priority research objective in the bioremediation field (Brusseau, 1998). Their hydrophobicity and low water solubility mean that hydrocarbons pass very slowly from a non-aqueous to the aqueous phase liquid in which they are metabolised by microorganisms (De Jonge et al., 1997). Moreover, in the soil they are adsorbed to clay or humus fractions (Tabak, 1997).

MATERIALS AND METHODS

Cyclodextrins are natural compounds, non-toxic to soil microorganisms and released enzymes (Szejtli, 1988), with great use in medical applications (Szejtli, 1994). Their involvement in microbial degradation, such as the purification of residual pesticide waters (Olah et al., 1988) or phenols (Banky et al., 1985), has also been investigated. Cyclodextrins absorb little or no soil solids (Brusseau et al., 1994). In unsaturated soils, they increase the desorption of contaminants from solid particles (Olah et al., 1988). The low bioavailability of pollutants is a limiting factor for biodegradation by microorganisms existing in the soil. Cyclodextrins act as a promoter for desorbing non-polar compounds from the surface of solid particles and mobilizing them in the aqueous phase where hydrocarbon-degrading microorganisms (Steffan et al., 2001) are active. Cyclodextrins act as a series of

bacteria such as *Bacillus macerans, B. subtilis, B. coagulans, Flavobacterium*, and soil fungi such as *Trichoderma* sp. (Oros et al., 2001).
Cyclodextrins are non-reducing cyclic oligosaccharides (Figure 1). Of this class, the most important and accessible is β-cyclodextrin. Cyclodextrins can be obtained by a relatively simple technology, following the fermentative prehydrolysis of starch. Synthesis and characterization of new polymeric materials by chemical transformation of cyclodextrin, with the production of polyelectrolyte products being justified for: i) diversification of the range of biodegradable natural polyelectrolytes with biomedical uses; ii) the superior capitalization of polysaccharides as renewable resources; iii) completing the database on chemical modification of polysaccharides and solution behavior of rigid skeletal polyelectrolytes, given that there is little literature data on obtaining soluble polysaccharide derivatives with phosphoric groups (Szejtli, 1982).

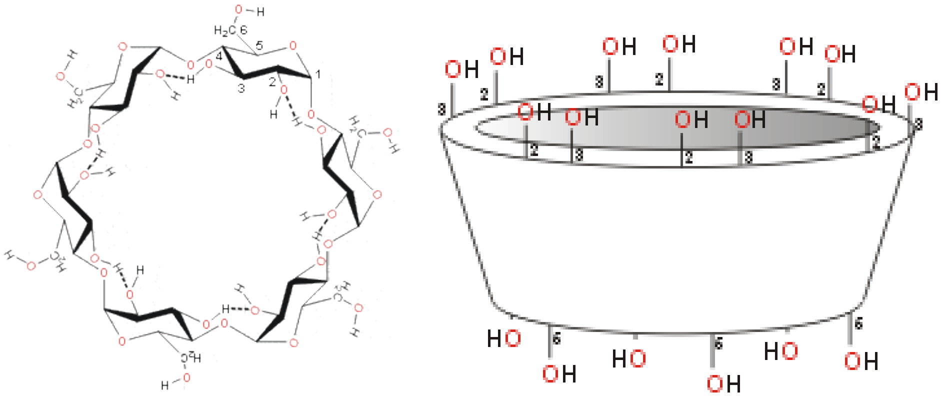

Figure 1. Cyclodextrin structure (Szejtli, 1982)

RESULTS AND DISCUSSIONS

The randomized methylated β-cyclodextrin (RAMEB) is industrially produced and has a high solubility capacity. According to the studies performed by RAMEB, it is capable of enhancing the biodegradability of many organic compounds, such as polynuclear aromatic hydrocarbons (Fenyvesi et al., 1996; Fava et al., 2002). This compound can reduce the toxic effects of contaminants on bacterial microflora, plants and animals (Gruiz et al., 1996). The effects of RAMEB different amounts on the bioremediation of soils polluted with petroleum hydrocarbons have been achieved through a laboratory study. Three types of sandy, clay and loam soil were used which were treated with RAMEB at concentrations of 0-1%. A significant increase in hydrocarbon biodegradability and microbial activity due to the presence of RAMEB (Molnár et al., 2007) was observed in the 4 week study. The RAMEB concentration of soil samples contaminated with petroleum hydrocarbons was determined by the HPLC method. The efficiency of RAMEB extraction from soil samples depended on soil properties. The extraction method had a good recovery rate for sandy and loam soil, and with less efficiency for soil with a higher clay content (Fenyvesi et al., 2002). Steffan et al. (2002) conducted a study on the effects of β-cyclodextrin on dodecane biodegradation. The results obtained showed that β-cyclodextrin significantly influenced the kinetic biodegradation process. A study by Molnár et al. (2005) showed that RAMEB can be applied as an additive in bioremediation of soils polluted with crude oil, and the results were similar to those obtained in the field. These bioremediation technologies based on cyclodextrins have a high potential for enhancing bioremediation compared to convectional biolological technologies in which time is a limiting factor. RAMEB is also a non-toxic and easily degradable product in the soil, does not pose a risk to soil life. The addition of

RAMEB, nutrients and a CO_2 stream has led to very good results in in-situ technologies and seems to be the most effective remediation method (Leitgib et al., 2008).
Bacterial degradation of toluene with an organic solvent and p-methyl benzoic acid, a water-soluble aromatic compound is enhanced by the addition of β-cyclodextrin (Schwartz and Bar, 1995). Also, the phenanthrene biodegradation of a polynuclear aromatic hydrocarbon in the presence of hydroxypropyl-β-cyclodextrin (HPBCD) has been removed (Wang et al., 1998).
Bardi et al. (2000) have conducted a study in which they made research in hydrocarbons degradation by the microbial population using β-cyclodextrin to increase their bioavailability. This work presents ways in which β-cyclodextrin increases the biodegradation of aliphatic hydrocarbons and polynuclear aromatics in high concentrations. Petroleum hydrocarbons having the following meanings were studied: 2 medium-chain (C12-dodecane) and one high chain (C24-tetracosan) and 2 polynuclear aromatic hydrocarbons with 2 benzene rings (naphthalene) and 3 benzene rings (anthracene). A study by Cuypers et al. (2002) demonstrated that hydroxypropyl β-cyclodextrin solutions can accelerate the degradation of polynuclear aromatic hydrocarbons.
The effect of hydroxypropyl β-cyclodextrin (HPBCD) on the biodegradation of polynuclear aromatic hydrocarbons (ΣPAH) in complex matrices was performed by Hickman et al., 2008. According to the results, the method can be applied to soil level.
The extraction capacity of hydroxypropyl-α-cyclodextrin provides information on the bioavailability of aliphatic hydrocarbons in the soil. A study by Stroud et al. (2009) investigated the potential for the extraction of hydroxypropyl-α-cyclodextrin in biodegradation of soil hexadecane. The soil was artificially polluted with 10-100 mg kg^{-1} hexadecane. Following the obtained results, hydroxypropyl-α-cyclodextrin can be used in biodegradation of aliphatic hydrocarbons from polluted soils.
Fenyvesi et al. (2005) conducted a study in which they followed cyclodextrins biodegradation in soil. It have been studied 8 different cyclodextrins on four soil types in a laboratory experiment. According to the results obtained, the cyclodextrins studied are all biodegradable by the microorganisms in the following order α-cyclodextrin ≈ β-cyclodextrin γ-cyclodextrin › acetyl β-cyclodextrin › cellulose › hydroxypropyl β-cyclodextrin (HPBCD) › peracetyl α-cyclodextrin › peracetyl-β-cyclodextrin » methylated β-cyclodextrin (RAMEB). It has been concluded that RAMEB is the least biodegradable. These conclusions confirm that RAMEB is a good solution for enhancing the bioremediation process, reducing it by 40% relative to its initial concentration over two years in a hydrocarbon polluted soil in an experimental field.
To assess the effect over time of the availability of pyrene (polynuclear aromatic hydrocarbon), earthworm accumulation (*Eisenia fetida*) and chemical extraction by unexploited techniques in the soil was artificially contaminated a soil with different pyrene concentrations and were measured at different times. The results showed that the amount of earthquake-rich pyrene did not change over time at high concentrations, but significantly changed at lower concentrations. In addition, the chemical availability of the pyrene has significantly decreased over time. The relationship between the bioaccumulation in the soil of hydroxypropyl-β-cyclodextrin (HPCD) and organic solvent extraction has been investigated to find a suitable and rapid method to increase the pyrene bioavailability. Results showed that at different pyrene concentrations the mean values absorbed by earthworm and HPCD extracts were 10-40% and 10-65%, respectively. The results obtained and their correlation for pyrene removal suggest that HPCD extraction was a better method of increasing bioavailability of pyrene in soil compared to organic solvent extraction (Khan et al., 2011).
According to studies conducted by Viglianti et al. (2006) addition of cyclodextrin (CD) in aqueous wash solutions has been shown to increase the efficiency of hydrocarbons removal from soil, being at the same time a non-toxic agent. In this study, the efficacy of cyclodextrins to remove polynuclear aromatic hydrocarbons (PAHs) occurring in industrial

areas was investigated. The β-cyclodextrin (BCD), hydroxypropyl β-cyclodextrin (HPCD) and methyl β-cyclodextrin (MCD) solutions were used for soil washing by column tests to evaluate certain influential parameters that can significantly increase the hydrocarbon removal efficiency. The process parameters chosen were the CD concentration, the ratio between the volume of the washing solution and the soil mass and the temperature of the washing solution. These parameters proved to be significant and the effect was almost linear on the removal of PAHs from the contaminated soil, except for the temperature at which an insignificant influence on PAH extraction was observed for the temperature range between 5 and 35°C. The removal capacity of HPCD and MCD was higher than BCD.

β-cyclodextrin (β-CD) significantly accelerates the hydrocarbon biodegradation, but its efficacy during the final degradation steps is not yet clear. Moreover, it is not yet known whether the absorption of hydrocarbons by plants is influenced by the presence of cyclodextrins. A field study was conducted by creating two lots (A and B). Crude oil was spread across the surface, and bacterial inoculum and β-CD on B lot. The soybean was sown on both lots. Soil samples were harvested from 10 in 10 cm at a depth of 0 to 60 cm before soil contamination with crude oil, immediately after sowing and after harvesting the plant. Chemical and microbial analyzes were performed throughout the process to characterize soil and determine residual PAH. Soybean seeds were analyzed for PAH content. It was observed that β-CD induced a significant increase in the rate of PAH degradation. Bacterial inoculum did not improve degradation; biodegradation was stronger in superficial layers, and leakage of PAHs was observed that was reduced by this CD. PAH analysis in soybeans showed that there was an absorption of hydrocarbons and that it was more significant in B lot. This suggests that β-CD has accelerated the bioremediation process but can be improved by phytoremediation which could lead to also to obtain an additional profit through the production of biofuels (Bardi et al., 2007).

The research achived by Sivaraman et al. (2010) focuses on studying the degradation of hydrocarbons by *Pseudomonas* isolated from crude oil contaminated soil in the presence of cyclodextrins. Of the three cyclodextrins tested at different concentrations, the 2.5 mM β-cyclodextrin concentration showed the highest biodegradation when n-hexadecane was used as the hydrocarbon test. The percentage of residual hexadecene remaining in the medium in which 2.5 mM β-cyclodextrin solution was added at 120 hours was 15% compared to the biotic environment that was 43%. In the following experiment, degradation of the hydrocarbon mixture (tetradecane, hexadecane and octadecane) by Vid1 (*Pseudomonas* species) was studied at a concentration of 2.5 mM β-cyclodextrin. The residual percent of tetradecane, hexadecane and octadecane at 120 hours was 32, 43 and 61% compared to the biotic environment where biodegradations of 50, 58 and 67%, respectively, were recorded. Studies have shown that in the case of a mixture of hydrocarbons (tetradecane, hexadecane and octadecane) in the presence of β-cyclodextrin, the highest hydrocarbons degradability was registered in tetradecan, then hexadecane and octadecane, respectively.

Ramadass et al. (2015) conducted a study on soils contaminated with petroleum hydrocarbons sampled from an arid Australian region and a significant hydrocarbons biodegradation in three of the five soils by optimizing nutritional status and physical characteristics. The data obtained supported the reduction of THP concentration with increasing bacterial diversity in these soils. Analysis of microbial diversity in soils has demonstrated the existence of bacterial communities of hydrocarbon degradation in these soils. However, bioremediation was not effective in these soils, even after the addition of surfactant (surfactant - Triton) due to high hydrocarbon concentrations (123.757 mg kg^{-1}). Further application of biopile technology to these soils was required. Microbial diversity has been found to depend on the degree of pollution and the solubility (bioavailability) of petroleum hydrocarbons in soils that can be accelerated by HPCD extraction. This study provides an overview of the major parameters to be taken into account when assessing the applicability of remediation technology by using biopiles.

CONCLUSIONS

Research results indicate that cyclodextrins increase hydrocarbons biodegradation significantly. Non-inclusion interactions may play a role in increasing bioavailability. Studies in which hydrocarbon mixtures were used in the presence of cyclodextrins indicate that the reduction in hydrocarbon concentration, both in the presence and absence of cyclodextrins is influenced by chain length. Cyclodextrins are also nontoxic and readily degradable in soil and do not pose any risk to soil life.

Cyclodextrins application has the role of improving the remediation biological method of soils polluted with petroleum hydrocarbons by increasing the efficiency of the biodegradation process. They have the ability to favor the development of existing bacteria in the polluted soil and to increase the rate of biodegradability of petroleum hydrocarbons.

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THE REMANENT EFFECT OF THE AGRICULTURAL USE OF URBAN SLUDGE COMPOST UPON THE SOIL PROPERTIES AND WHEAT CROP

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Abstract

The compost obtained from sludge from wastewater treatment being an important source of macro and micronutrients, can be used in agriculture, because it reduces the production costs and improves the soil quality by providing nutrients and organic matter necessary for modern, ecological agriculture, in the conditions to improve the capacity to retain moisture in the soil, also reducing the pressure on the environment generated by the storage of this waste. The compost used in the experiments is suitable for use in agriculture without risks of environmental and soil pollution, in compliance with the rules in force. The obtained results show that by applying the compost produced at SEAU Mioveni, even in the variants where the highest doses (60 t/ha) were applied, there are no significant changes in the chemical properties of the soil, especially the content of heavy metals. The values determined in the soil after applying the compost to all the experienced variants are far below the maximum allowed values for the concentrations of heavy metals in the soils. Also, analyzing the results regarding the risk of translocation of different chemical elements in the wheat grains, it can be seen that, in general, all indicators register values well below the limits from which zootoxicity phenomena can occur. No increases in heavy metal contents in the wheat grains are observed as the doses of used compost increased.

Key words: *compost, remanence effect, wheat, soil.*

INTRODUCTION

Sewage sludge is regarded as the residue produced by the wastewater treatment process, during which liquids and solids are being separated. Liquids are being discharged to aqueous environment while solids are removed for further treatment and final disposal. The constituents removed during wastewater treatment include grit, screenings and sludge (Metcalf, 1991). Sustainable sludge handling may be defined as a method that meets requirements of efficient recycling of resources without supply of harmful substances to humans or the environment (Council Directive 91/271/EEC).

The positive effect of the organic matters in general, and those from urban activity, in particular, on the physical, chemical and biological properties of the soil is also reflected in plant production, which in most cases is increasing. The organic matter is directly involved in the retention of heavy metals, as being one of the first metals studied in this regard (Kiikkila, 2002) showing that biosolid is an immobilizing agent of this heavy metal.

On the other hand (Moolenaar and Beltrami, 1998) proved that heavy metals can also be complexed by the dissolved organic matter, which influences the ion balance. One of the main factors involved in the absorption of heavy metals is the soil pH, their accessibility being very low in the reaction range of 6.5-7. The presence of competitive metal ions can affect the adsorption of heavy metals in soils. Ca^{2+} ions interfere in the adsorption processes with Zn, Cd, Cu, as a result of the fact that Zn and Cd ions are retained in the soil by cationic exchange reactions, while Cu and Pb form organic complexes with oxides of Fe, Al and Mn (Kiekens, 1983; Pirangeli et al., 2001, 2003).

The adsorption of heavy metals by iron oxides is accompanied by a protonation being dependent on pH, according to research conducted by Cornell and Schwetmann (1996).

The positive effects are due both to the high content of organic matter and nutrients in forms accessible to plants, and to the improvement of the processes of structuring the elementary soil particles in hydrostable aggregates, to the increase of water retention capacity.

The concentration of heavy metals is among the most important factors restricting the use of urban waste products on agricultural land, due to their potentially negative effects on plant biomass and their translocation into food.

The data in the literature contain different ways of interpreting the contents of heavy metals in soils, specifying limit values, but it seems that the closest model of reality is the one that takes into account the content of total forms in the soil (EPA, 1993).

The current acidity of the soil registered a tendency of reduction by biosolid fertilization in the years of application and remanence.

The potential acidity followed the same variation as the current one, so that in the conditions of applying biosolid and in the first year of remanence it had a tendency to decrease as later there was an update in the second year of remanence (Traşcă et al., 2008).

The increased interest in fertilizing the soil with sludge resulting from urban wastewater has been manifested since 1970, when it was established that it can be considered an organic fertilizer (Tomlin, 1993).

The use of sludge resulting from urban wastewater treatment in agriculture is dependent on the properties of the soil, of which pH, organic matter and nutrient content occupy a preferential place, but being restricted by the presence of heavy metals especially Cd, Pb, and Ni, whose concentration in the environment is governed by the nature of the element and the dose applied (Lopez-Mosquera, 2000).

The effect of sludge from urban wastewater treatment on the soil is investigated both in terms of pedo-improvement and in terms of environmental impact. As Beltran (1999) pointed out, knowledge of the chemical composition of sludge is of particular importance when making recommendations on application rates on the agricultural land.

Over time, soluble organic compounds tend to turn into insoluble forms, with the amount of heavy metals settling to low values when the bioavailability decreases (McBride, 1995).

Researches on the effect of sludge application on the soil have not exceeded 30 years, as demonstrated by numerous scientific papers (Kabata-Pendias, 2004).

MATERIALS AND METHODS

In order to study the remanence effect in the 2^{nd} year from the application of a compost resulting from the sewage sludge proceeding from the treatment plant on the agricultural crops and on the soil properties, wheat was used as a test plant, the sown hybrid being Glossa.

The basic soil work was ploughing, carried out at 25 cm. Seedbed preparation was done by two passes with a disc harrow, sowing was done with SUP 29, and the seed rate was 280 kg/ha.

The experience included 5 experimental variants in 3 repetitions, the area of an experimental plot being of 105 m^2.

Fertilization was carried out with moderate doses (360 kg/ha) of complex chemical fertilizers (16-16-16) by uniform spreading and equal in all tested variants. Fertilizers were spread on the ground. Weed control was carried out using the herbicide Granstar.

The experimental variants were: V_1 - Control; V_2 - 10 t/ha; V_3 - 20 t/ha; V_4 - 40 t/ha; V_5 - 60 t/ha.

The researches were performed on a soil of luvosol, podzolite, pseudogley type, as a result of their formation under the vegetation of the quercineae forest, under the conditions of a dominant lithology of fine-textured clays and located on relatively flat-horizontal land (Traşcă et al., 2008).

The quality of the compost used in the experiments

The qualitative parameters of the analyzed compost are within acceptable values for its use in agriculture, including in terms of heavy metal content (Table 1).

The effect of applying compost from sewage sludge as a fertilizer in agriculture is currently focused on cultivated plants and soil.

The samples of compost, soil and plant (leaves, grains) were taken and analyzed according to the methodology in force (pH was determined potentiometrically in aqueous suspension; the organic matter was determined by Walkley-Black-Gogoașă method; mobile phosphorus and potassium by Egner-Riehm-Domingo method; total nitrogen by Kjeldahl method; heavy metal content, in total forms, with dosing by atomic absorption spectrophotometry).

Table 1. The main chemical characteristics of compost

No.	Parameter	Value	Maximum values (Ord. 344/2004)
1	Volatile substances (%)	35.34	-
2	pH	7.09	-
3	$C_{organic}$ (% d.m.)	21.5	-
4	N_{total} (% d.m.)	1.52	-
5	P_2O_5 (% d.m.)	1.38	-
6	K_2O (% d.m.)	0.675	-
7	CaO (% d.m.)	0.35	-
8	Cadmium (mg/kg d.m.)	1.04	10
9	Chromium (mg/kg d.m.)	44.8	500
10	Copper (mg/kg d.m.)	74.3	500
11	Nickel (mg/kg d.m.)	26.5	100
12	Lead (mg/kg d.m.)	46.3	300
13	Zinc (mg/kg d.m.)	612	2000
14	Cobalt (mg/kg d.m.)	6.34	50
15	Arsenic (mg/kg d.m.)	4.09	10
16	Total coliform bacteria (probable no./g d.m.)	1352400	-
17	Fecal coliforms (probable no./g d.m.)	236523	-
18	Enterococci (UFC/g d.m.)	105840	-

RESULTS AND DISCUSSIONS

The influence of compost fertilization on the soil

The obtained results show that by applying the compost produced at SEAU Mioveni, on the agricultural land, even in large quantities (60 t/ha), there are no significant changes in its chemical properties, and especially in the case of potentially polluting heavy metals.

The effect of compost application (remanence in the 2nd year) on the soil is presented in Table 2. The soil sampling was performed in the flowering phenophase of wheat.

From the data presented in Table 2 we can observe that in the 2nd year after the application of increased doses of compost from sewage sludge, the concentrations of heavy metals in the soil are below the maximum allowed values, even at high doses of compost.

Table 2. Soil chemical characteristics after remanence effect of compost

No.	Parameter	V_1	V_2	V_3	V_4	V_5
1	pH	6.37	5.93	5.98	6.08	6.32
2	Organic matter content (%)	3.95	4.25	4.41	4.35	4.06
3	Soluble salts (%)	0.016	0.013	0.015	0.013	0.015
4	Water storage capacity (%)	39	38	38	40	39
5	Bulk density (g/cm^3)	1.47	1.45	1.47	1.46	1.46
6	Total C (% d.m.)	2.45	2.37	2.41	2.48	2.50
7	N_{total} (% d.m.)	0.122	0.128	0.125	0.120	0.122
8	P_2O_5 (% d.m.)	0.121	0.131	0.123	0.127	0.130
9	K_2O (% d.m.)	0.93	1.03	0.99	1.00	1.01
10	CaO (% d.m.)	0.25	0.23	0.25	0.25	0.25
11	Cadmium (mg/kg d.m.)	< 0.3	< 0.3	< 0.3	< 0.3	< 0.3
12	Chromium (mg/kg d.m.)	44.83	46.43	44.75	44.32	44.18
13	Copper (mg/kg d.m.)	17.87	18.12	16.89	17.28	18.23
14	Nickel (mg/kg d.m.)	24.98	24.22	24.38	23.19	24.33
15	Lead (mg/kg d.m.)	16.44	17.20	20.06	20.96	18.41
16	Zinc (mg/kg d.m.)	63.03	66.16	62.48	63.93	65.17
17	Cobalt (mg/kg d.m.)	12.78	11.76	12.04	12.32	12.12
18	Arsenic (mg/kg d.m.)	0.053	0.057	0.043	0.053	0.059
19	Total coliform bacteria (probable no./g d.m.)	11.482	43.952	3.484	2.780	4.102
20	Fecal coliform (probable no./g d.m.)	138	68	44	44	87
21	Enterococci (UFC/g d.m.)	25	51	0	63	236

Practically, there is already a uniformity of these concentrations, in all variants at the level of the non-fertilized variant, which shows that these very low concentrations are not related to the application in the previous year of increasing doses of compost from sewage sludge. Analyzing the data presented in Table 3, it is easy to see that in the 2nd year after the application of the compost from sewage sludge even at high doses, after wheat harvesting the soil remains "clean", the values regarding the concentrations of heavy metals, being much below the maximum allowed limits.

Table 3. Soil characteristics after wheat harvesting

No.	Parameter	V_1	V_2	V_3	V_4	V_5
1	pH	6.37	6.15	6.05	6.04	6.23
2	Organic matter content (%)	3.69	3.79	3.44	3.86	3.90
3	Soluble salts (%)	0.012	0.010	0.011	0.013	0.012
4	Water storage capacity (%)	38	35	38	33	35
5	Bulk density (g/cm^3)	1.38	1.47	1.40	1.50	1.44
6	Total C (% d.m.)	1.10	1.28	1.28	1.37	1.42
7	N_{total} (% d.m.)	0.109	0.116	0.125	0.128	0.132
8	P_2O_5 (% d.m.)	0.116	0.129	0.127	0.137	0.140
9	K_2O (% d.m.)	1.09	1.16	1.16	1.23	1.15
10	CaO (% d.m.)	0.24	0.25	0.24	0.26	0.27
11	Cadmium (mg/kg d.m.)	< 0.3	< 0.3	< 0.3	< 0.3	< 0.3
12	Chromium (mg/kg d.m.)	56.94	57.33	58.63	57.60	54.52
13	Copper (mg/kg d.m.)	18.75	19.74	19.19	19.22	19.12
14	Nickel (mg/kg d.m.)	26.97	28.05	26.58	24.57	23.51
15	Lead (mg/kg d.m.)	19.01	18.81	18.13	20.39	20.29
16	Zinc (mg/kg d.m.)	59.57	61.79	61.78	63.18	60.28
17	Cobalt (mg/kg d.m.)	13.24	13.71	11.18	12.74	11.82
18	Arsenic (mg/kg d.m.)	0.051	0.049	0.049	0.052	0.053
19	Total coliform bacteria (probable no./g d.m.)	112	3519	553	2267	265
20	Fecal coliform (probable no./g d.m.)	36	1112	51	165	0
21	Enterococci (UFC/g d.m.)	0	0	0	0	0

In Romania, the technical norms regarding the protection of the environment, and especially of the soils, when sewage sludge is used in agriculture (even composted) were provided in Order 344/2004, published in the Official Gazette no. 959/October 19th, 2004, an order that is in the process of modification and completion, including through the contribution of the partners of this project. These norms aim at capitalizing the agrochemical potential of the sludge from the treatment plants, preventing all harmful effects on the soils, considered the basic link in the soil - plant - animal (human) food chain. The technical norms of Order 344/2004 have as main provision the content of heavy metals, both from the soils on which the sewage sludge is applied, as well as the content of these metals in the sludge. The references are for the following 7 heavy metals: cadmium, copper, nickel, lead, zinc, mercury and chromium, focused on 3 directions: the maximum allowed values of heavy metals in the soils on which the sewage sludge is applied (Table 4), the maximum allowed values of heavy metals from sewage sludge to be applied to soils (Table 5), limit values for annual quantities of heavy metals accumulated in soils (Table 6).

The new regulations regarding the protection of the environment, and especially of the soils, when sewage sludge is used in agriculture, (even composted), will have in our opinion to distinguish between the application in agriculture of dehydrated and anaerobically stabilized sewage sludge and application in agriculture of compost from sewage sludge. We believe that a special law is required for composts, which regulates the specific rules for their use as fertilizers in agriculture and which also refers to the accepted limits in terms of their microbiological load.

Table 4. The maximum permissible values for the concentrations of heavy metals in soils

The analyzed parameter	The limit value (mg/kg d.m.)
Cadmium	3
Copper	100
Nickel	50
Lead	50
Zinc	300
Mercury	1
Chromium	100

(Source: Order 344/2004)

Table 5. The maximum permissible concentrations of heavy metals in the sewage sludge for use in agriculture

The analyzed parameter	The limit value (mg/kg d.m.)
Cadmium	10
Copper	500
Nickel	100
Lead	300
Zinc	2000
Mercury	5
Chromium	500
Cobalt	50
Arsenic	10

(Source: Order 344/2004)

Table 6. The limit values for the annual quantities of heavy metals that can be introduced into agricultural land based on a 10 year average for use in agriculture

The analyzed parameter	The limit value (kg/ha/year)
Cadmium	0.15
Copper	12
Nickel	3
Lead	15
Zinc	30
Mercury	0.1
Chromium	12

(Source: Order 344/2004)

Analyzing the values of the analyzed indicators (Tables 7 and 8) it can be observed that none of the tested variants show potentially toxic values, these being well below the maximum values allowed and otherwise relatively similar to the values of these indicators in the non-fertilized control with compost from sewage sludge.

Following the translocation of the different chemical elements in the wheat grains and leaves resulting from their analyzes, no potentially dangerous translocations can be found in any experimental variant.

It can therefore be concluded the aspect that in the case of wheat crop cultivated on fertilized land in the previous year, with compost from sewage sludge (remanence effect in the 2nd year), even in large doses, there is no accumulation of potentially hazardous chemicals; the quality of wheat grains was within normal limits and relatively similar to the unfertilized control.

More directly, in the concrete case of using compost from sewage sludge with the specified quality parameters, in the 2nd year of application, wheat can be grown without any restrictions. It can be seen that in general, all the analyzed indicators do not register values that are considered phytotoxic for wheat plants as a result of fertilization in the previous year in the preceding crop (maize) with compost from sewage sludge, in increasing doses.

It is recommended to follow the way in which the translocation of the different chemical elements in the wheat grains took place, by analyzing their content, after harvesting and interpreting these values in correlation with the contents determined in the leaves.

Table 7. Analysis of wheat leaves at the flowering phenophase

No.	Parameter	V_1	V_2	V_3	V_4	V_5
1	Humidity (%)	10.1	9.2	9.8	10.3	10.7
2	Cadmium (mg/kg d.m.)	< 0.3	< 0.3	< 0.3	< 0.3	< 0.3
3	Chromium (mg/kg d.m.)	< 1.5	< 1.5	< 1.5	< 1.5	< 1.5
4	Copper (mg/kg d.m.)	6.63	7.68	7.09	6.89	6.81
5	Nickel (mg/kg d.m.)	< 1.5	< 1,5	< 1.5	< 1.5	< 1.5
6	Lead (mg/kg d.m.)	< 1.5	< 1.5	< 1.5	< 1.5	< 1.5
7	Zinc (mg/kg d.m.)	11.98	13.39	15.21	16.21	16.42
8	Cobalt (mg/kg d.m.)	< 1.5	< 1.5	< 1.5	< 1.5	< 1.5
9	Arsenic (mg/kg d.m.)	<0.03	<0.03	<0.03	<0.03	<0.03

Table 8. Characteristics of wheat grains at harvest

No.	Parameter	V_1	V_2	V_3	V_4	V_5
1	Humidity (%)	9.80	9.51	9.73	9.69	9.82
2	Cadmium (mg/kg d.m.)	< 0.3	< 0.3	<0.3	< 0.3	<0.3
3	Chromium (mg/kg d.m.)	< 1.5	< 1.5	<1.5	< 1.5	< 1.5
4	Copper (mg/kg d.m.)	6.24	6.30	5.78	6.24	5.75
5	Nickel (mg/kg d.m.)	< 1.5	<1.5	<1.5	<1.5	<1.5
6	Lead (mg/kg d.m.)	< 1.5	< 1.5	< 1.5	< 1.5	< 1.5
7	Zinc (mg/kg d.m.)	34.88	32.50	30.62	34.29	34.04
8	Cobalt (mg/kg d.m.)	< 1.5	< 1.5	< 1.5	< 1.5	< 1.5
9	Arsenic (mg/kg d.m.)	<0.03	<0.03	<0.03	<0.03	<0.03

Also, in the wheat crop, determinations were made regarding the influence of compost fertilization on: weeding degree, plant height, grain production, the thousand grain weight, hectoliter mass (Table 9).

Table 9. The influence of remanent effect of compost on wheat crop

The experimental variant	The degree of weeding (pl/m^2)	Plant height (cm)	Production (kg/ha)	The thousand grain weight (g)	Hectoliter mass (kg)
V_1	167	70	4333	44	63.3
V_2	185	72	4670	45	57.1
V_3	192	72	4800	49	64.7
V_4	243	76	6930	45	59.5
V_5	250	78	7200	47	61.4

Determining the degree of weeding is important to see how it is influenced by the compost doses.

For each variant, three determinations were made, for each repetition, the data representing average values. It can be seen that the degree of weeding was influenced by the remanence effect of compost and the size of the doses used according to the experimental variants. Thus, the degree of weeding increased by 11-49% in the variants fertilized with compost compared to the control variant (V_1), which did not received compost, in the preceding crop. The highest increase in weeding, of 49%, is recorded in V_5 (60 t/ha compost). This is explained by the fact that in the process of composting due to the high temperatures achieved in certain phases of composting, although most of the weed seeds are destroyed, weed seeds also get into compost, which germination capacity is maintained in the 2nd year after the application of the compost. It is necessary to carefully direct the humidity and the air inside the compost pile so as to achieve the conditions of raising and maintaining high temperatures, corresponding to the destruction of pathogen agents but also of weed seeds.

The size of the plants was higher by 3 to 11% in the fertilized versions with compost, compared to unfertilized variant (V_1-control), the evolution of the wheat plants height registering the same increasing trend with the size of the compost doses used; thus, the highest size of the wheat plants (78 cm) is in V_5 (60 t compost/ ha). The remanence beneficial effect of compost application on the vegetative growth of wheat plants is very clear.

The use of remanence effect of compost has resulted in extremely high production increases, which reached 66% at V_5 (60 t/ha).

The value of TGW is in all variants within biological limits specific to the cultivated soil (Glossa). There are no significant differences in TGW of wheat grains between the tested variants.

The average values of HLM registered in all variants, relatively low values and which do not correlate with the rather high values of TGW. We mention the fact that the specific value of HLM for the studied wheat variety is over 75. This is explained by the less favorable climatic conditions in the "grain filling" period. There are no systematic differences in HLM of wheat grains between the tested variants.

CONCLUSIONS

For the wheat crop cultivated in fertilized land in the previous year, with compost from sewage sludge (remanence effect in the 2nd year), even in large doses there is no accumulation of potentially dangerous chemical elements, wheat being within normal limits and relatively similar to the unfertilized variant (control).

In the 2nd year after the application of the compost from the sewage sludge even at high doses, after the wheat harvest, the soil remains "clean", the values referring to the concentrations of heavy metals being well below the maximum allowed limits.

It can be said that in the concrete case of using compost from sewage sludge with quality parameters in the 2nd year of application, the wheat crop can be cultivated without any restrictions, both in terms of quality production but also soil quality.

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EDAPHIC FAUNA AS AN INDICATOR OF DEGRADATION PROCESSES IN PODZOLIC CHERNOZEM

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Abstract

The edaphic fauna of the podzolic chernozem in the northern zone of the Republic of Moldova has been investigated. Invertebrates' testing was carried out from semi-profiles around the main profile at a distance of 5-10 m by manual sampling of soil layers to the depth of soil fauna occurrence. The highest values of invertebrates' abundance (84.8 %) were registered in the upper horizon and litter in the natural chernozem. Number of invertebrates constituted 352.0 ex m^{-2} and Lumbricidae family - 277.3 ex m^{-2}, biomass - 89.5 and 68.5 g m^{-2}, respectively. The natural chernozem contained 10 families of invertebrates and its trophic pyramids were stable. Saprophagous of Aporrectodea rosea, Aporrectodea caliginosa and Lumbricus terrestris predominate in the composition of the edaphic fauna. Species of Calosoma inquisitor, Lebia cruxmino, Carabus coriaceus, Lilioceris merdigera, Clubiona stagnatilis, Lucanus cereus, Lithobius forficatus and Melolontha melolontha have also been identified. Degradation of the faunal complex in the arable chernozem has been manifested in a decrease of abundance, biodiversity and disruption of trophic connections.

Key words: *edaphic fauna, biodiversity, podzolic chernozem, degradation, natural and agricultural ecosystem.*

INTRODUCTION

Edaphic fauna meet most of the desired criteria of soil quality indicators (Doran & Zeiss 2000; Schloter, Dilly & Munch, 2003). Soil invertebrates have been positioned as indicators of soil quality in forest and agricultural land use (Eggleton et al., 2005). Their diversity, abundance, biomass, and density have been proven to be suitable as indicators of natural or anthropogenic impacts on terrestrial ecosystems due to their correlation with physicochemical and microbiological properties and ecological changes (Paula et al., 2010). Invertebrates' diversity is one of the most important evaluation criteria of soil ecosystems, its resistance to different forms of degradation (Naeem et al., 2002; Schwartz et al., 2000). Excessive reduction of the soil biodiversity, especially the loss of keystone species and/or species with unique functions may have some cascading ecological effects, which lead to the long-term deterioration of soil fertility and the loss of agricultural productive capacity (Huhta, 2007). There is a growing interest in developing valuable and sensitive faunal indicators of soil quality, which can reflect the effects of land management and ensure a long-term sustainability of soil fertility. In this context, edaphic fauna indices can be used for evaluation of the degradation process and comparison of different land managements.

The purpose of the research was to carry out the monitoring of the edaphic fauna in the podzolic chernozem under the conditions of natural and agricultural ecosystems for assessing the processes of soil degradation, the biodiversity conservation and development of the national soil biota quality standards.

MATERIALS AND METHODS

Experimental site and soil. The experimental site are located in the zone of the hilly wooded steppe of the Northern Plain (1), in the district of wooded steppe of the middle Prut (2) with gray forest soils, podzolic and leached chernozems (Figure 1). The plot with podzolic chernozem (profile 17 under fallow; profile 18 under arable) is situated in the Shaptebani village, Ryshkani region. Invertebrate' state in the podzolic chernozem in the condition of natural ecosystems has been investigated in comparison with the long-term arable podzolic chernozem in conditions of agricultural ecosystems.

Figure 1. Fragments of natural and agricultural landscapes located in the northern zone of the Republic of Moldova

Invertebrates sampling was carried out from 6 soil semi-profiles to a depth of 50 cm in 2021.

Status of invertebrates. Testing of semi-profiles in the amount of 3 units was carried out around the main test cut at a distance of 5-10 m. The state of invertebrates was identified from test cuts by manually sampling the soil layers to the depth of soil fauna occurrence by Gilyarov and Striganova's method (1987). The identification of invertebrate's diversity at the level of families and species, and also their classification according to nutrition type were categorised by standard procedures (Gilyarov & Striganova, 1987; Vsevolodova-Perel, 1997, 2003).

RESULTS AND DISCUSSIONS

The number and biomass of edaphic fauna in the podzolic chernozem of natural ecosystems are characterized by higher values of these indicators in comparison with the arable chernozem (Table 1). The number of invertebrates in the natural podzolic chernozem reaches to 352.0 ex m^{-2}, *Lumbricidae* family – to 277.3 ex m^{-2}, and its biomass – to 89.5 and 68.5 g m^{-2} accordingly. Soil faunal studies of the podzolic chernozem under agricultural conditions have shown and confirmed that the long-term use of arable land leads to significant decreases in the number and biomass of invertebrates and degradation of the faunal complex as a whole. The number and biomass of invertebrates in this chernozem decreased by 66.4 and 111.9 times respectively in comparison with the natural soil, and *Lumbricidae* family reduced to zero values.

Table 1. Number and biomass of invertebrates in podzolic chernozem under fallow and arable land (n = 3 for each profile)

Soil (profile)	Semi-profiles	Number, ex m^{-2}		Biomass, g m^{-2}	
		total	*Lumbricidae* fam.	total	*Lumbricidae* fam.
Natural podzolic chernozem (P17)	69	280.0	192.0	54.4	49.6
	70	328.0	272.0	74.0	59.2
	71	448.0	368.0	140.0	96.8
	Media	**352.0**	**277.3**	**89.5**	**68.5**
Arable podzolic chernozem (P18)	72	16.2	0	2.4	0
	73	0	0	0	0
	74	0	0	0	0
	Media	**5.3**	**0**	**0.8**	**0**

The share of earthworms in the total abundance of invertebrates constitutes of 68.6 %, and their biomass - 91.2% in the podzolic chernozem of natural ecosystem. The weight of the one exemplar of *Lumbricidae* family in chernozems constitutes 0.26 g. The arable podzolic chernozem is characterized by a total lack of earthworms at the time of fauna sampling.

The base mass of edaphic fauna in the natural podzolic chernozem is located in the 0-10 cm layer, in the litter and mixing litter with soil. The number of invertebrates index decreases in the soil profile to a depth of 30 cm (Figure 2). *Lumbricidae* family in the natural podzolic chernozem is located in the 0-10 cm layer (87.5%).

Podzolic chernozems in the natural ecosystem are characterized by a high diversity of invertebrates compared to the arable podzolic chernozem (Table 2). There are 10 families of invertebrates in the natural podzolic chernozem, 2 families - in the arable soil.

In addition to the *Lumbricidae* family the species from the families of *Clubionidae, Hygromiidae, Carabidae, Scarabaeidae, Oniscidae, Geophilidae, Chrysomelidae, Lithobiidae* and *Lucanidae* have been identified in the natural podzolic chernozem. In this soil species from *Lumbricidae* family - *Aporrectodea rosea*, *Aporrectodea caliginosa* and *Lumbricus terrestris* were dominant. *Calosoma inquisitor, Lebia cruxmino* and *Carabus coriaceus* who are representatives of the *Carabidae* family, have been identified. Species *Lilioceris merdigera, Clubiona stagnatilis, Lithobius forficatus, Melolontha melolontha* have also been identified. It should be mentioned that specie of *Lucanus cereus* from the *Lucanidae* family, included in the Red Book of Moldova, was found.

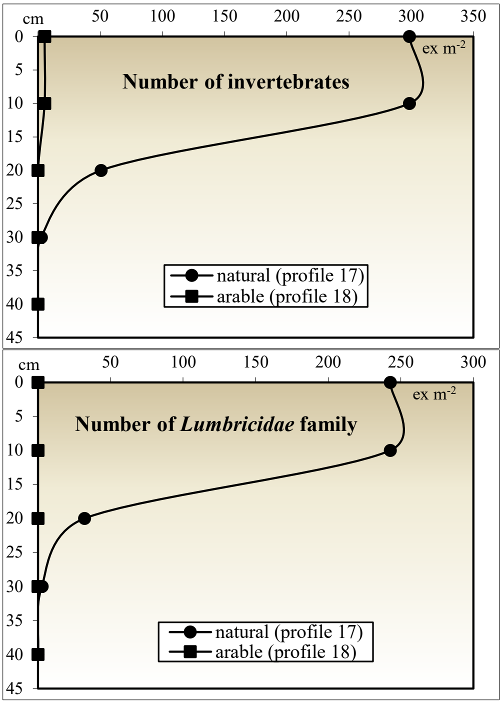

Figure 2. Composition of invertebrates according to the mode of nutrition in podzolic chernozems of natural and agricultural ecosystems (mean values, without *Formicidae* family and unidentified species)

The biodiversity of edaphic fauna in arable podzolic chernozems significantly reduced. This soil contains 2 families of invertebrates (*Clubionidae* and *Noctuidae*).

Saprophagous are present in natural podzolic chernozems (Figure 3). Their amount was quite substantial and constitutes 86.0 % from the total abundance of invertebrates. Saprophagous were absent in arable podzolic chernozems at the time of sampling.

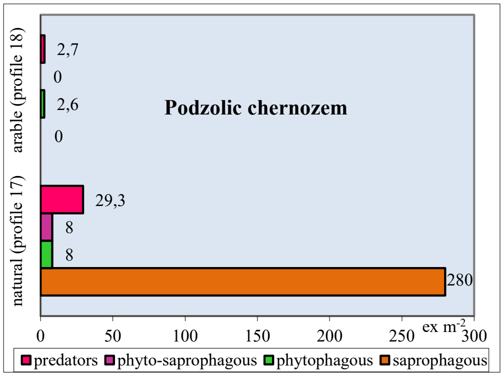

Figure 3. Composition of invertebrates according to the mode of nutrition in the podzolic chernozem in natural and agricultural ecosystems (mean values, without *Formicidae* fam. and unidentified species)

The number of phytophagous and phyto-saprophagous in the chernozem in conditions of natural ecosystems was insignificant and amounts to 2.5% each. The maximum number of phytophagous in percentage expression was recorded in the arable podzolic chernozem and rose to 49.1%.

The abundance of predators in the total number was 9.0% in the natural chernozem and 50.9% in the arable chernozem. Prolonged use of arable podzolic chernozems leads to a sudden decrease in the number of invertebrates, death of saprophagous and destruction of trophic levels and connections (Figure 3, Table 3). Research shows that the balance between invertebrate populations is upset, leading to a decrease in the quality of arable soils.

Table 2. Biodiversity of invertebrates (ex m^{-2}) at the family's level in podzolic chernozem (mean values)

Invertebrates' families	Natural podzolic chernozem (P17)	Arable podzolic chernozem (P18)
Lumbricidae	277.3	0
Scarabaeidae	5.3	0
Carabidae	10.7	0
Geophilidae	8.0	0
Chrysomelidae	2.7	0
Clubionidae	5.3	2.7
Hygromiidae	5.3	0
Noctuidae	0	2.6
Oniscidae	2.7	0
Lucanidae (larve)	2.7	0
Lithobiidae	5.3	0
Unidentified species	26.7	0
Total	**352.0**	**5.3**

Table 3. The ratio of trophic groups of invertebrates in podzolic chernozem

Soil	Profile	Saprophagous /Total	Saprophagous / Phytophagous	Phytophagous /Total
Natural podzolic chernozem	P17	0.86	35.00	0.03
Arable podzolic chernozem	P18	0	0	0.49

Trophic pyramids in podzolic chernozems of natural ecosystems are characterized by higher stability in comparison with arable podzolic chernozems. The quantitative ratio between trophic levels in natural soil is stronger compared to arable soil.

The long-term arable use of podzolic chernozems leads to the significant deterioration of the conditions needed for the vital activity of soil invertebrates, the rupture and the attenuation of relations between the components of the edaphic fauna which, in turn, contributes to the decrease in the natural stability of soils and the strengthening of degradation processes. It should be noted that similar results were obtained during monitoring studies in forest soils (Senicovscaia et al., 2021; 2021a).

CONCLUSIONS

Podzolic chernozems of the natural ecosystems in the central of the Republic of Moldova are the habitat and the source of conservation and restoration of the diversity and abundance of the edaphic fauna. The complex of invertebrates in podzolic chernozems of natural ecosystems is formed at higher level of input and content of organic matter in the soil. 10 families of invertebrates were found in podzolic chernozems. The number, biomass and biota diversity of undisturbed chernozems are considerably wider compared to arable soils. A characteristic feature of natural phytocenoses is the accumulation of basic reserves of the number of invertebrates in the horizons 0-10 cm and in the litter. Saprophagous prevail in the composition of the edaphic fauna in the natural podzolic chernozems, accounting for 86.0 % of the total abundance. The long arable utilization of podzolic chernozems has been rendered disastrous effects on the soil invertebrates. In arable chernozems only species from 2 families of edaphic fauna have been identified. There is a decrease in the number of saprophagous, especially in the *Lumbricidae* family, the destruction of levels and trophic links between invertebrates.

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LONG -TERM NITROGEN AND PHOSPHORUS FERTILIZATION EFFECTS ON SOIL PROPERTIES

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Abstract

More and more attention is being paid to assessing the effect of long-term fertilization considering global warming to ensure sustainable soil fertility management. The aim of this study is to evaluate the soil properties under mineral fertilization in long-term experimental fields. These experiments were carried out in the experimental fields of SCDA Livada. In order to evaluate the effect of fertilization, with progressive doses of nitrogen and phosphorus, with 5 graduations, there were taken and analysed 75 soil samples. Following the statistical processing of the data obtained, it was observed that nitrogen and phosphorus fertilization significantly influenced soil properties. Based on these results it could be established the optimal doses of fertilizers that should be applied on soil in order to improve the quality of soil in terms of environmental protection. Also, these results contribute to contemporary knowledge regarding sustainable land use.

Key words: *fertilization, soil properties, experimental field.*

INTRODUCTION

In recent years people face with finding optimal solutions to problems related to climate change in direct relation to the need to provide optimal yields to crops that provide food for humans and animals. There is also the permanent concern to preserve soil quality and environmental protection. Over time it was demonstrated that long-term fertilization fields experiments provide useful information, particularly how can be quantified soil characteristics changes considering various rates of fertilizer and weather conditions (Korschens, 2006). It is important to avoid excessive doses of chemical fertilizer application which will adversely affect soil chemical properties, resulting in soil hardness and acidification, which eventually lead to a decline in soil organic matter and fertility (Wan et al., 2021).

What is more, excess P or N that are accumulated in soils could be an environmental concern because these can pollute water resources through field runoff and soil leaching (Piotrowska-Długosz et al., 2016). Consequently, a great attention has been focused on the ecological effects of excessive P and N, and on optimizing P and N fertilization. In this context, the paper presents the effect of phosphorus and nitrogen fertilization on soil quality indicators in the long-term experimental fields to Livada, in order to put into evidence, the evolution of soil characteristics with different doses of mineral fertilization with nitrogen and phosphorus.

MATERIALS AND METHODS

Soils were sampled in 2019 from a long-time experimental field, established in 1961 to SCDA Livada - Satu-Mare County, Romania, a unit located in the North West region of Transylvania (23°12' east longitude and 47°86 'north latitude), 132 m above sea level. The soil type was luvosol, characterized by the presence of a horizon B more or less developed, with clay content between 30-35%, a slightly acidic and acidic soil reaction (pH) (the trend being in the direction of acidification), the humus content (which was mainly formed on the basis of fulvic acid) is low and the presence of aluminum ions due to potential acidity. The experiment is of the bifactorial type with five graduates, with progressively increasing doses of phosphorus (0, 40, 80, 120, 160 kg / ha) and nitrogen (0, 40, 80, 120, 160 kg / ha). The soil samples were collected from a 0-20 cm soil depth. The soil samples were air-dried, crushed and passed through a 2 mm sieve.

Soil pH was measured using the potentiometric method (1:2.5 w/v, soil: water). The soil organic carbon content (SOC) was determined on 0.2mm grounded soil samples using dichromate oxidation followed by titration with ferrous ammonium sulphate.

Analysis conducted to determine phosphorus and potassium contents (available forms) were performed by ammonium lactate acetate extraction (at 3.75 pH) followed by a colorimetric determination for phosphorus (P) and by flame atomic emission spectrometry determination for potassium (K) content (Romanian Standard STAS 7184 19-82) based on the Egner Riehm Domingo method.

The base saturation, (V) was calculated, with the formula $V = SB_{Kappen}*100/T$. The sum of the exchange bases (SB) expressed in meq/100g of soil was obtained by summing the individually determined basic exchange cations (SB = Ca + Mg + Na + K). The total cation exchange capacity expressed in meq/100g of soil was obtained by summation (T = SB + SH).

Statistical analysis was performed using analysis of variance (ANOVA), followed by Tukey's range test (honestly significant difference), for multiplecomparison between all pairs of averages.

RESULTS AND DISCUSSIONS

It is observed that, regardless of the applied phosphorus fertilizer dose, there were no statistically assured changes in soil reaction. The lowest average pH value was obtained for non-phosphorus fertilized variants. Instead, nitrogen fertilization causes statistically assured decreases in the pH value, for each graduation, the highest value being obtained in the non-fertilized version and the lowest in the version with the highest dose of nitrogen fertilization (Figure 1).

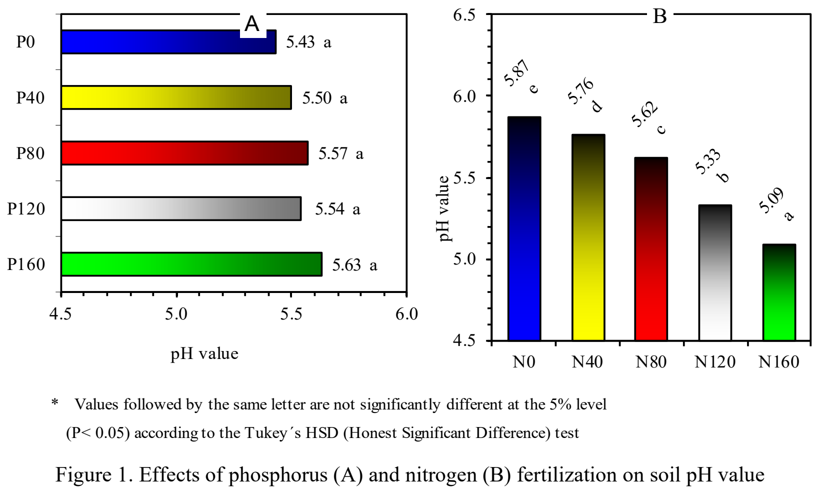


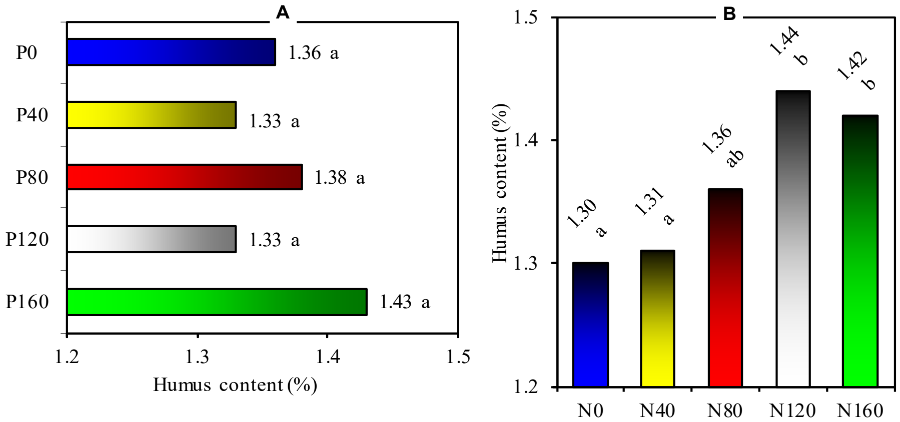
Figure 1. Effects of phosphorus (A) and nitrogen (B) fertilization on soil pH value

It is well known that soil acidification processes lead to increasing of aluminium solubility which can became toxic for agricultural plants or affect establishment and growth of legumes (Whitley et al., 2016). Consequently, in case of samples with a pH value under 5.70, the exchangeable aluminum (Al_{ex}) content was determined. The results obtained showed that exchangeable aluminum content in these soil samples was extremely low (<0.4 meq/100 g soil) and very low (0.44-0.88 meq/100 g soil) (Table 1). Since 1976 Awad observed that the application of nitrogen fertilizers has led to a significant decrease in pH values and raised extractable Al levels Increasing the dose of N in the soil (doses of nitrogen over 80 kg/ha) has led to increasing of exchangeable aluminum content. Concerning the application of high rates of phosphate decreased the concentration of soluble soil-Al (Awad et al., 1976). For the maximum dose of P (160 kg/ha) the lowest values of changeable aluminum were determined under conditions of high doses of N.

Table 1.The values of the exchangeable aluminum content determined in the soil samples

P fertilization	P_0	P_0	P_0	P_{40}	P_{40}	P_{80}	P_{80}	P_{120}	P_{120}	P_{120}	P_{160}	P_{160}
N fertilization	N_{80}	N_{120}	N_{160}	N_{120}	N_{160}	N_{120}	N_{160}	N_{80}	N_{120}	N_{160}	N_{120}	N_{160}
Al_{ex} (meq/100 g)	0.11	0.55	0.88	0.22	0.44	0.22	0.44	0.22	0.33	0.44	0.16	0.27

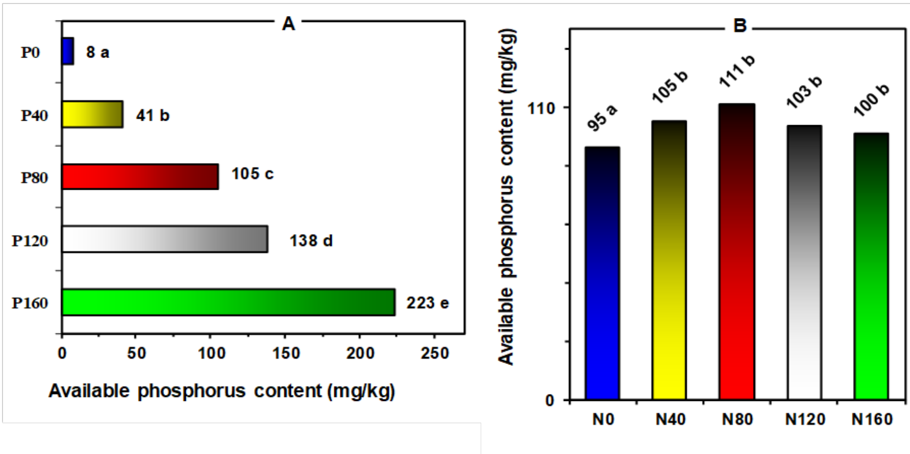
As one of the main indicators for soil fertility is humus content (Zhakashbaeva et al., 2015) it was important to know if the humus content in the soil samples of this research are influenced by different doses of mineral fertilization (Figure 2).



* Values followed by the same letter are not significantly different at the 5% level ($P< 0.05$) according to the Tukey´s HSD (Honest Significant Difference) test

Figure 2. Effects of phosphorus (A) and nitrogen (B) fertilization on humus content in the soil

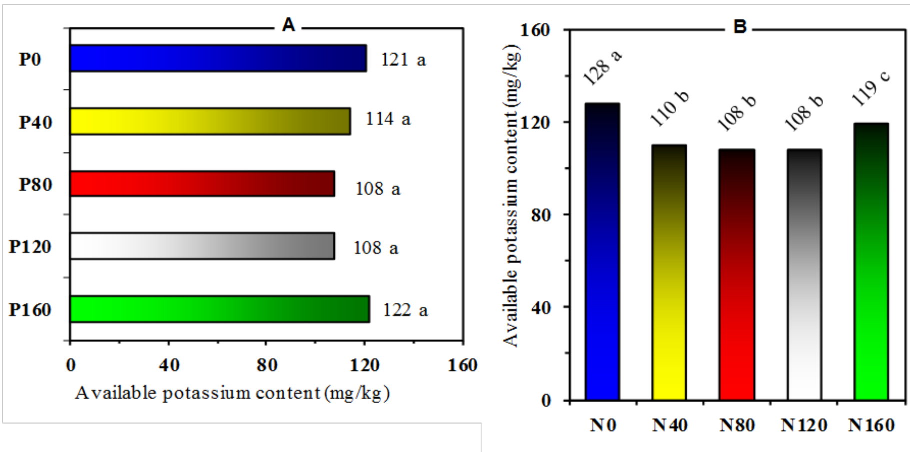
It was noticed that humus content did not change significantly under the influence of different doses of phosphorus applied, the average values ranging between 1.33 and 1.43%. Nitrogen fertilization led to increases in humus content, with the highest average values being obtained on plots where higher doses of nitrogen fertilization were applied (N_{120}, N_{160}) compared to the control and N_{40}, these increases being statistically assured. Regarding soil available phosphorus became a parameter more and more important considering the tendency of applying excess P fertilizer which could cause environmental problems (Cao et al., 2012; Ohm et al., 2017). As expected, in our experiment, fertilization with different increasing doses of phosphorus influenced the available phosphorus content in the soil, causing statistically assured increases. The nitrogen fertilization caused variations in available phosphorus contents ranging between 95 and 111 mg/kg (Figure 3).



* Values followed by the same letter are not significantly different at the 5% level (P< 0.05) according to the Tukey´s HSD (Honest Significant Difference) test

Figure 3. Effects of phosphorus (A) and nitrogen (B) fertilization on available phosphorus content in the soil

Besides phosphorus, another important macronutrient for sustaining plant growth and reproduction, resistance to drought, water excess, high or low temperatures is potassium (Figure 4).

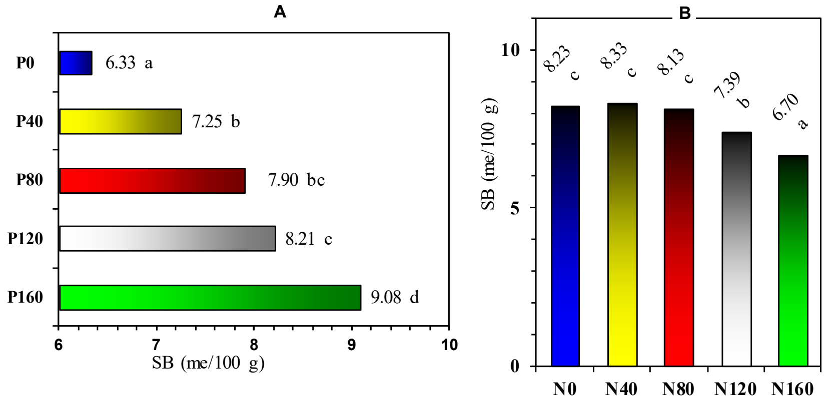


* Values followed by the same letter are not significantly different at the 5% level (P< 0.05) according to the Tukey´s HSD (Honest Significant Difference) test

Figure 4. Effects of phosphorus (A) and nitrogen (B) fertilization on available potassium content in the soil

Phosphorus fertilization did not produce statistically assured changes in the mobile potassium content of the soil and in the case of nitrogen fertilization, the average values of the available potassium content remained in the range of average values in terms of potassium supply status for crops field, values ranging from 108 to 128 mg/kg. ($T = SB_{Kappen} + SH$) and is a fundamental soil property used to predict plant nutrient availability and retention in the soil (Culman et. al., 2019). The SB values increased significantly, the highest value being obtained when fertilizing with P_{160}.

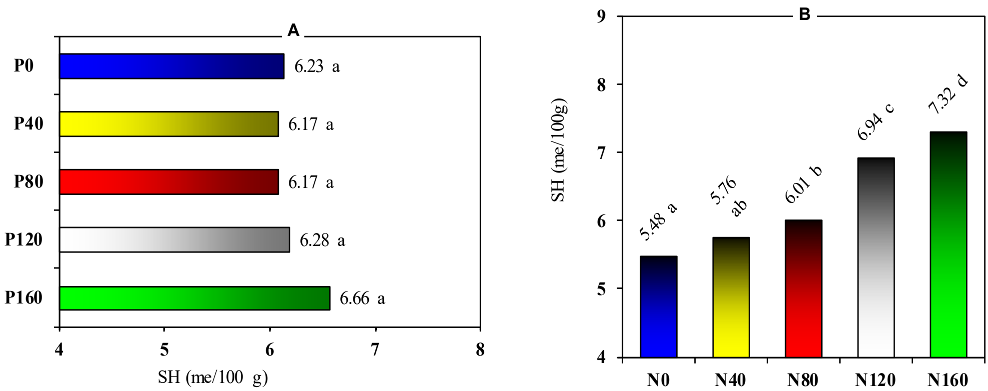
Fertilization with N_{120} and N_{160} led to statistically assured decreases in SB mean values compared to control and the first two doses of fertilizer (Figure 5).



* Values followed by the same letter are not significantly different at the 5% level (P< 0.05) according to the Tukey´s HSD (Honest Significant Difference) test

Figure 5. Effects of phosphorus (A) and nitrogen (B) fertilization on SB content in soil

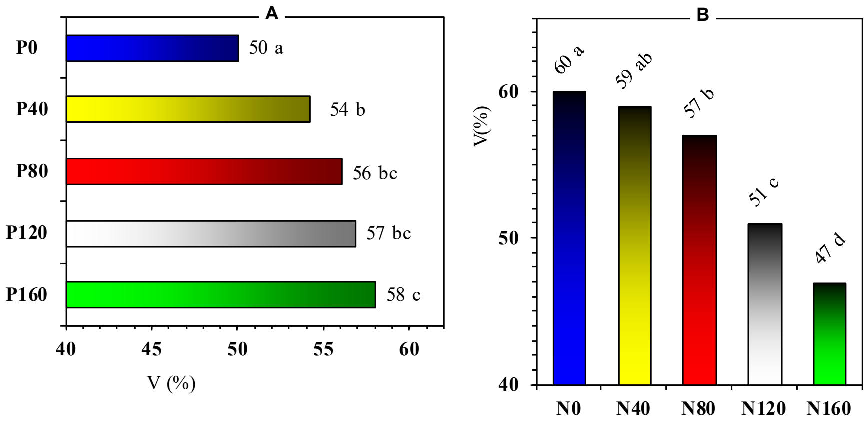
No significant changes in total exchange acidity (SH) were obtained for phosphorus fertilization but nitrogen fertilization led to statistically assured increases, the highest average value being obtained for N_{160} fertilization (Figure 6).



* Values followed by the same letter are not significantly different at the 5% level (P< 0.05) according to the Tukey´s HSD (Honest Significant Difference) test

Figure 6.Effects of phosphorus (A) and nitrogen (B) fertilization on exchange acidity (SH) in soil

Base saturation (V) contents increased with increasing phosphorus dose, the highest value being obtained at the maximum dose of phosphorus, the increase being statistically assured compared to the control and with the plot fertilized with P_{40}. Nitrogen fertilization shows a decreasing trend, a statistically assured decrease for higher doses (Figure 7).



* Values followed by the same letter are not significantly different at the 5% level (P< 0.05) according to the Tukey´s HSD (Honest Significant Difference) test

Figure 7. Effects of phosphorus (A) and nitrogen (B) fertilization on base saturation (V) in soil

CONCLUSIONS

Mineral fertilization with high doses of nitrogen results in soil acidification and increased exchangeable Al content in soil which can induce Al toxicity to plants. Increasing doses of phosphorus influenced the available phosphorus content in the soil, causing statistically assured increases. The continuation of long-term experiments proves to be the best solution for the most accurate assessment of the effects of mineral fertilization on the environment and for the sustainable management of the fertility of acid soils in Livada. This kind of research over a long period of time can provide predictability models in the context of climate change, allowing the optimal application of fertilizer doses according to the trend of evolution over time of various soil quality indicators.

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RESEARCH THE AMELIORATIVE EFFECT OF PRECIPITATE ON pH VALUES ACCORDING TO THE PROFILE OF GENETICALLY ACID SOILS

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Abstract

In the present study, the effect of the precipitate as a chemical ameliorant on the changes of the values of the pH indicator along the depth of the soil profile was studied. Its interaction with the soil was also associated with the release of Ca^{2+}, which was due to its prophylactic chemical-ameliorative effect in acidic soils. The movement of the precipitate along the depth of the soil profile and in general the migration of this compound into the soil volume was very limited, both with respect to the phosphate and the calcium component. Better penetration into the deep soil horizons was observed at constant humidity close to utmost field moisture content and at soils with a high rate of natural water filtration.

Key words: *acid soils, pH, precipitate, soil profile.*

INTRODUCTION

The principle of ameliorative effect of the precipitate applied in acid soils is based on its neutralizing activity. It manifests itself on two levels - direct acid neutralizing action of the accompanying main compound $CaCO_3$ and the neutralizing action of calcium cations contained in the molecule, which after the absorption of phosphorus remain in the soil and are included in the sorbent.

In medium and high absorbing soils the calcium ions released in the process of phosphate absorption charge, neutralize and from the colloid-disperse point of view stabilize the colloidal complex in the soil, causing permanent coagulation of its mineral and organic components.

In conditions of strong calcium deficiency, as a nutrient chemical element, the application of a precipitate solves the problem of mineral nutrition of the plants with calcium even when applied in limited doses. Based on this mechanism, some manufacturers recommend the application of the precipitate off-root (Trendafilov, 2011).

In the present study the effect of precipitate as a chemical ameliorant on the changes of the values of the pH indicator along the depth of the soil profile was studied.

MATERIALS AND METHODS

The experiment was carried out for two years on Chromic luvisols with differentiated profile. A precipitate was used as the main chemical ameliorant. Calcium hydrogen phosphate dihydrate ($CaHPO_4$ x $2H_2O$) is used as a mineral citrate-soluble phosphorus fertilizer in various soils and crops. Contains 25-40% P_2O_5, depending on the quality of the raw material in its production. The advantage of its use is related to its longer-lasting fertilizing effect compared to superphosphates. Its interaction with the soil is also associated with the release of Ca^{2+}, which is due to its prophylactic chemical-ameliorative effect in acidic soils. The rates in which it is applied to cover the needs of annual agricultural plants for phosphorus fertilization have a weak chemical-ameliorative effect and are usually not sufficient to neutralize the harmful acidity in the soil. It can be applied as a phosphorus fertilizer for storage fertilization before deep ploughing the terrains intended for planting perennial crops.

The experiment was based on the method of long plots (Shanin, 1965), and the distribution of variants included control variant and three increasing rates of treatment with precipitate - 100, 250 and 500 kg/ha. Each of the variants is performed in three repetitions.

After application, the ameliorant is incorporated at a depth of 18-20 cm in the soil, and before that with surface treatment it is homogenized with a workable layer with a depth of 10-12 cm. This application model requires no more than routine tillage in perennials and is not associated with additional costs, as with the application of chemical ameliorants in high doses. Soil samples were taken twice, with the first sampling 14 months after the application of the ameliorant, and the next one 12 months later. Soil samples were taken from three layers with a depth of 0-25; 25-50 and 50-75 cm, using a soil probe, as the volume of each soil sample is composed of 3 single receivables with the probe within the area of each replication. Soil samples were analyzed to determine pH, potentiometric in water and in salt extract-1 n KCl (Arinushkina, 1970).

RESULTS AND DISCUSSIONS

Because the pH affects PO_4-P sorption/ desorption to soil components (Haynes, 1982), prediction of the pH effect is important for correct estimates of PO_4-P solubility in a soil subject to pH changes. The processes governing the sorption and desorption of PO_4-P in soils are several. Adsorption to the surfaces of iron(III) and aluminium (hydr)oxides is known to be important. In addition, PO_4-P may be adsorbed also to hydroxy-Al polymers in clay minerals (Karathanasis and Shumaker, 2009) and to carbonate minerals (Yagi and Fukushi, 2011). Because PO_4-P adsorption increases with decreasing pH, these adsorption processes would often be expected to be more influential at low pH (Goldberg and Sposito, 1984), resulting in a "positive" pH dependence (i.e. increased PO_4-P solubility at higher pH), provided that adsorption is fully reversible within the time scale of interest.

Precipitation of PO_4-P with Ca is expected at higher pH. A number of Ca-P minerals may form, such as amorphous calcium phosphate (ACP), octacalcium phosphate (OCP) and apatite (hydroxyapatite, HAp, or fluorapatite, FAp). Precipitation/dissolution of these minerals will cause a "negative" pH dependence (increased PO_4-P solubility at lower pH) (Hesterberg, 2010).

Prior to the application of the ameliorant, pre-sampling was performed in three depths of 0-25, 25-50 and 50-75 cm and the pH values in aqueous and salt extract were determinate. The pH is usually determined potentiometric on pre-dried soil samples. The measurement of pH in a soil suspension is preferred to this in an aqueous extract due to its greater proximity to the conditions in the natural soil (Amelyanchik and Vorobieva, 1991; Vozbutskaya, 1985).

Figure 1 shows that the pH values in both aqueous and salt extract were acidic, as the decrease in depth was insignificant. The soil: water ratio affects pH values not only by affecting the suspension effect, but also by altering the acid-base balance. The suspension effect decreases with increasing amount of the aqueous phase and is the reason for the lower pH values in the soil suspension than in the aqueous extract (Faitondjiev, 2008).

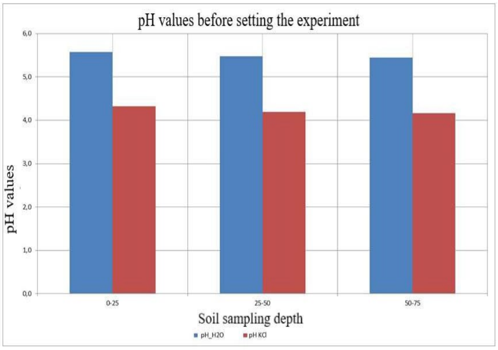

Figure 1. pH values before setting the experiment

After the application of calcium precipitate as an ameliorant, both in the low and in the high doses led to a relatively small change in the pH indicator in both variants of its measurement - in water and in potassium chloride. The values of the change in pH as a result of the application of precipitate did not prove a statistically significant change in the indicator, although there was a tendency that when apply the precipitate as calcium ameliorant the lowest pH values found in the strongly acidic soil area had a tendency for a change towards a medium to slightly acidic reaction. The influence of the precipitates in the top soil horizons was relatively strongest during the first soil sampling.

No influence was established in the deep horizons and this was because of the difficult and slow infiltration of the ameliorant into the depth. The limited doses of the applied ameliorant explained the established decrease in the effect of the calcium precipitate in the second year after its introduction.

The change in pH measured in water (Figure 2) compared to that in the potassium chloride (Figure 3) extract showed that in the salt extract the data had less scattering and were obviously less affected by the impact of the ameliorant.

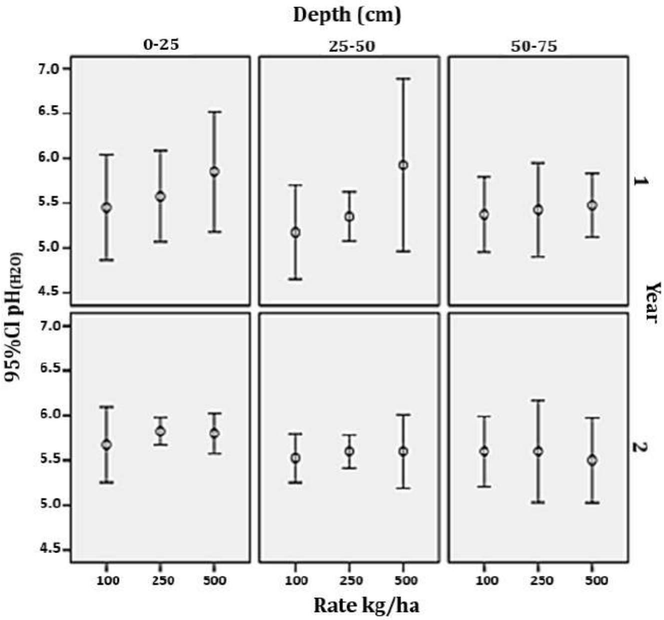

Figure 2. Change in $pH_{(H_2O)}$ at different depths in the soil depending on the amount of the applied precipitate and the measurement time

The pH indicator (KCl) is generally considered to be a more conservative indicator insofar as it characterizes the equilibrium of the constant sorption positions in the soil absorption complex and is less influenced by random factors (Valcheva, 2020).

This is explained by the fact that in the salt extract the balance of the acidic and alkaline component is determined by relatively higher ionic concentrations, and some of the ions that determine it originate from positions in the exchange complex on the easily mobile ions in the sorbent.

The short ameliorative effect is explained by the stability of the acid-alkaline balance in the acidic area and the fact that it was a genetic characteristic based on the high capacity of the buffer system in the soil, representative of the forest soil complex.

Both precipitation and adsorption reactions are involved in the retention mechanism of phosphates. When the orthophosphate concentration is low, the dominant process is the adsorption of phosphate ions onto the surfaces of more crystalline clay compounds, sesquioxide's, or carbonates (Plante, 2007; Gerard, 2016; Whalen and Sampedro, 2010).

On the contrary, when the orthophosphate concentration is high, soluble P precipitates with metal cations to form Fe and Al phosphates in acidic soils, and Ca and Mg phosphates in alkaline soils (Smith, 2003; Plante, 2007; Whalen and Sampedro, 2010). It is believed that the adsorption process is essential in managing the availability of Ca and P over a shorter time frame (Smith, 2003). When soluble Ca is applied to soils in the forms of fertilisers or amendments, a rapid increment of soil solution concentration is noted. Afterwards, these portions undergo precipitation or adsorption processes to decrease their solubility (Power and Prasad, 1997). These chemical reactions are pH dependent. In acidic soils, Al and Fe ions usually form precipitates with approximately all the dissolved $H_2PO_4^-$ ions.

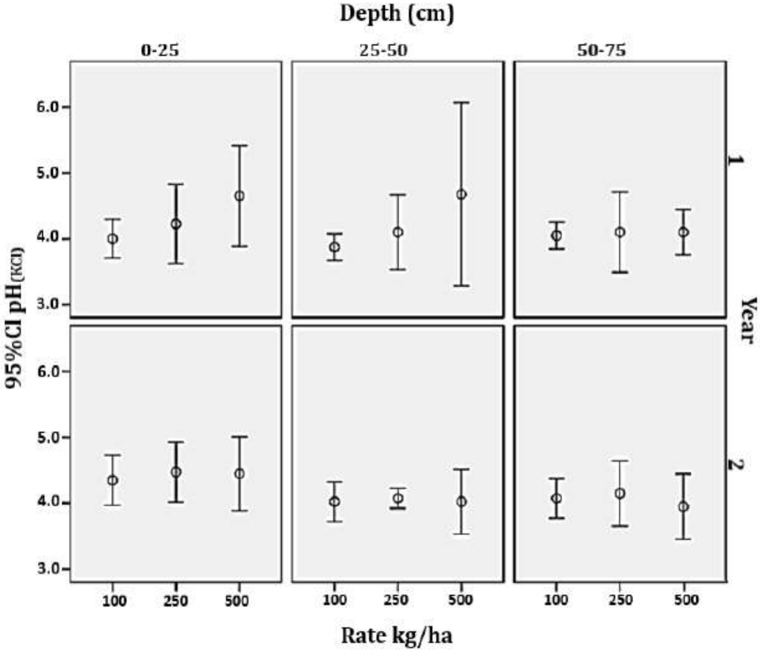

Figure 3. Change in $pH_{(KCl)}$ at different depths in the soil depending on the amount of the applied precipitate and the measurement time

These precipitated hydroxyl phosphates are insoluble, thus, their P content becomes almost unavailable to plants. The pH change data presented as a function of the ameliorative intervention with the precipitate are shown in Figures 4 and 5.

The high pH values found in the first year of measurement were due to the partially undissolved and incompletely interacted with the soil absorption complex Ca^{2+} from the precipitate. The fact that this increase in pH was found along the entire depth of the ameliorated layer showed that the applied at the ameliorative experiment technology of ameliorants application was successful and achieved its penetration into depth. Over time, the applied with the ameliorative materials Ca^{2+} has connected in exchange form, determining a relatively stable acid equilibrium, characterized by pH values in the weakly acidic area.

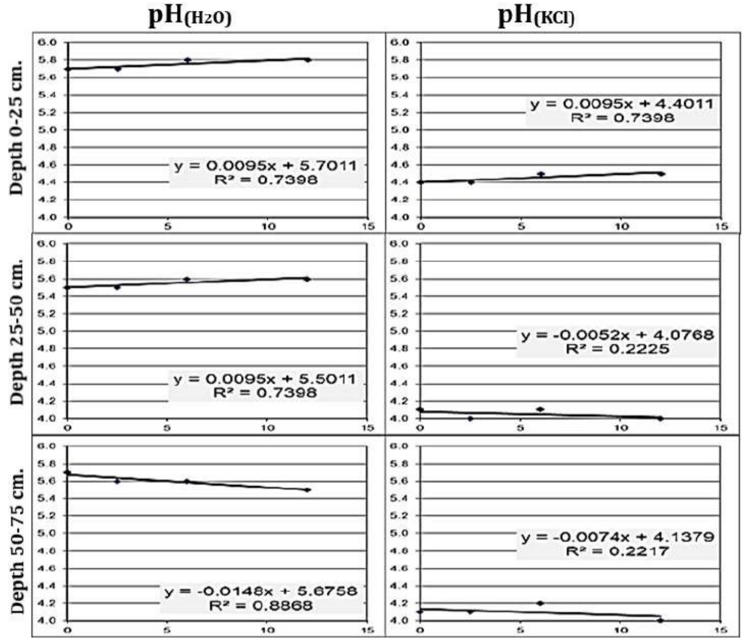

Figure 4. Change in $pH_{(KCl)}$ and $pH_{(H_2O)}$, depending on the amount of the applied precipitate at different depths in the soil in the first year after the application of the ameliorant

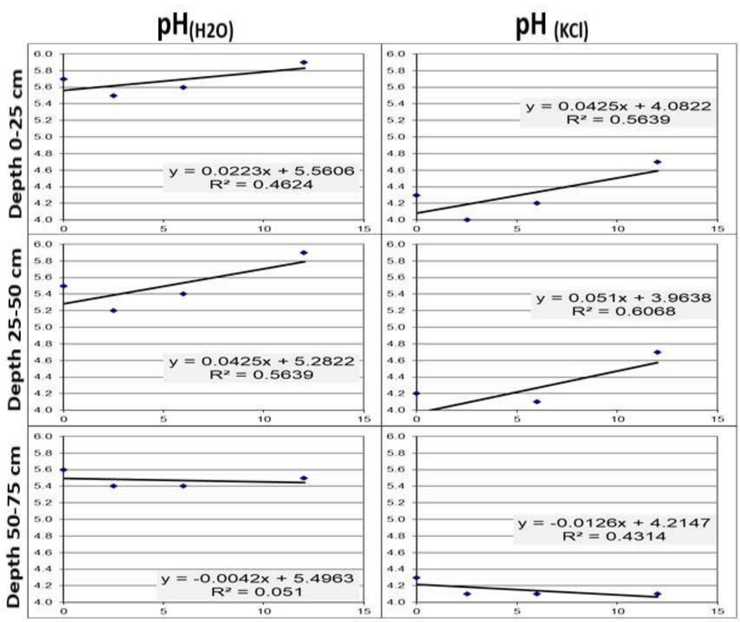

Figure 5. Change in $pH_{(KCl)}$ and $pH_{(H_2O)}$, depending on the amount of the applied precipitate at different depths in the soil in the second year after the application of the ameliorant

CONCLUSIONS

The movement of the precipitate along the depth of the soil profile and in general the migration of this compound into the soil volume was very limited, both with respect to the phosphate and to the calcium component. Better penetration into the deep soil horizons was observed at constant humidity close to utmost field moisture content and at soils with a high rate of natural water filtration.

Its agrochemical effect was comparable with other weakly soluble fertilizers in terms of the mechanism of interaction with soil components and as assimilation. For this reason, the results of its experimental application were extrapolated with those that would be obtained by application of similar chemically phosphorus-containing fertilizers (ameliorants) - phosphorus flours or granules, Thomas flours and others, as long as the ratio of phosphorus to calcium is similar to that of the precipitate.

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MITIGATION OF SOIL COMPACTION BY APPLYING DIFFERENT TILLAGE SYSTEMS

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Abstract

The objective of our work is to present the results of a short-term study in which four different tillage types were tested in order to mitigate soil compaction. The experiment was conducted on a clay-loam soil located in Draganesti-Vlasca Agricultural Research Station in the year of 2018. The tillage variants tested were mouldboard ploughing, subsoiling and chiseling and the control variant was disking. Within each of the tested variants soil physical and chemical properties were determined in laboratory (e.g. saturated hydraulic conductivity, water stable aggregates, bulk density, penetration resistance, soil organic carbon and pH). The obtained results showed that the bulk density values were lower both in topsoil and subsoil in the variant with subsoiling tillage while in the control variant (2 times disking) the bulk density values were higher. The similar tendency was recorded for penetration resistance values. As for the water stable aggregates and saturated hydraulic conductivity, high values were also obtained in the variant where subsoiling was applied, whereas in the variants with mouldboard ploughing and chiseling similar values were obtained. Again, the control variant had the lowest values for both water stable aggregates and saturated hydraulic conductivity. The soil chemical properties did not vary significantly between the tested variants. The soil organic carbon varied between 2.06 and 2.34%, while the soil pH ranged between 5.99 and 6.63. The experimental study showed promising results for mitigating soil compaction by applying subsoiling. The most sensitive soil property to compaction due to tillage was found to be saturatedhydraulic conductivity. Soil chemical properties were not affected by different soil tillages.

Key words: *soil compaction, subsoiling, bulk density, tillage.*

INTRODUCTION

Soil compaction is a worldwide threat for agriculture and a soil physical degradation process which is due to the destruction of soil micro- and macro-aggregates under a certain stress. Soil compaction may affect various ecosystem services such as water retention and movement in soils (Dexter and Zoebisch, 2002), root growth and crop yields (Lipiec et al., 2003).

Soil compaction not only reduces the production of agricultural and forestry crops, but also has negative effects on the environment. For example, the saturated hydraulic conductivity of the soil decreases, and the risk of leakage of water and pollutants to surface waters and the washing of nitrates and pesticides to groundwater increases. It also reduces the volume of soil that can act as a buffer for pollutants and increases the risk of soil erosion due to the presence of excess water over compacted soil layers. Due to the decrease in soil aeration, the production of greenhouse gases by denitrification can take place in the soil due to anaerobic processes.

Taking into account the negative effects of compaction on the soil, the European Commission's proposal for a Framework Directive for the Soil is to say that compaction is one of the major threats to sustainable soil quality in Europe.

Compaction of the subsoil, defined as "soil material below the normal cultivation depth or pedestrian horizon A", is particularly proble-matic because it is difficult and expensive to improve. The risks of underground compaction increase with the increase in farm size, equipment size, and increased mechanization due to the requirements for higher productivity.

When analysing soil compaction, a distinction should be made between the susceptibility of soils to compaction and their vulnerability (Jones et al., 2003). Susceptibility is the likelihood of compaction occurring if a soil is subject to factors that are known to produce compaction of that soil. Susceptibility to compaction depends on intrinsic characteristics, such as texture and carbon content, and in the short term depends on variable properties, such as, for example, soil moisture. It ranges from sandy (non-susceptible) soils - sandy-sandy - sandy-clayey - clayey - clay-clayey - loamy-clayey - clayey. Clay soils with medium and fine texture are resistant to external mechanical stresses at low soil moisture but are highly susceptible to severe compaction at high soil moisture.

The vulnerability of the soil to a particular degradation process is determined taking into account the intrinsic susceptibility of the soil and the estimation of exposure to the degradation process (Borrelli et al., 2016), which is based on the assessment of stresses induced by land management and climate.

The soil's intrinsic susceptibility to compaction is estimated based on soil properties that are relatively stable, such as texture, clay type, bulk density, organic matter content, structure, saturated hydraulic conductivity (Saffit-Hdadi et al., 2009).

In this context, the paper presents the results of a short-term study in which four different tillage types were tested in order to mitigate soil compaction.

MATERIALS AND METHODS

The study is located at Agricultural Research Station from Drăgănești-Vlașca (TR), in an area characterised by natural subsoil compaction. The soil type is CambicChernozem with a clay loam texture. The experiment consisted of a pilot study established in March 2018, and its aim was to mitigate natural soil compaction by tillage. The experimental design was a split plot (36 plots, 6 m × 33 m) with three blocks and involving four treatments: TR1 - mouldboard ploughing with furrow inversion to 25 cm depth, TR2 - subsoiling to 60 cm by ripping and disking to 12 cm depth, TR3 - a control treatment with 2-times disking, and TR4 - chiselling to 25 cm depth with furrow inversion. The testing of tillage treatments also involved three rotations with deep-rooting leguminous crops. Only the main effect of the tillage treatments on the soil physical properties is reported here.

Soil physical and chemical parameters were measured in all plots. For this, disturbed soil samples were collected in autumn of 2018 after crop harvesting for soil water-stable aggregates (WSA, in % g/g) >250 μm, and undisturbed soil cores (100 cm^3 volume) were sampled at 10–20 cm and 40-50 cm depths for soil physical analyses: saturated hydraulic conductivity (Ks, in m s^{-1}) and bulk density (BD, in g cm^{-3}).

The content of water-stable aggregates was measured by the Henin–Feodoroff method based on wet sieving (SR EN ISO 10930:2012). The Ks was determined according to the steady-state falling head method (Romanian standard: STAS 7184/15–91). The BD was gravimetrically determined by weighing the soil core samples before and after drying for 24 h at 105°C (SR EN ISO 11272:2017).

The results obtained for the measured soil properties were then statistically analysed by one-way repeated measure ANOVA considering the soil tillage as the tested factor. Post-hoc pairwise comparisons of the least-squares means were performed using the Tukey method to adjust for multiple comparisons (p< 0.05). All statistical analyses were performed with OriginLab 6.1 software (Origin Lab Corporation, Northampton, MA, USA).

RESULTS AND DISCUSSIONS

The soil from this study was characterized in terms of hydro-physical and chemical properties.

The soil type is a CambicChernozem with clay loam texture, and a clay content varying from 44.2% in topsoil layer to 45.2 % in subsoil layer (Table 1).

Table 1. Physical characterization of the soil profile

Location	Depth (cm)	Clay content (%)	Organic matter (%)	Bulk density (Mg m^{-3})	Texture class
Drăgănești - Vlașca	10-20	44.2	2.25	1.43	clay loam
	40-50	45.2	1.45	1.39	

Soil compaction changes the pore space size, distribution and soil strength. One way to quantify the change is by measuring the bulk density. As the pore space decreases within a soil, the bulk density increases. Such soils with a higher percentage of clay and silt which naturally have more pore space, have a lower bulk density than sandy soils.

For the BD in the topsoil (Table 2), the mean value in the subsoiling treatment (TR2) ranged from 1.27 g cm^{-3} in topsoil to 1.32 g cm^{-3} in subsoil and was always significantly different from the other treatments, which had higher values between 1.44 g cm^{-3} in TR3 to 1.48 g cm^{-3} in TR1 (Figure 1).

For the BD in the subsoil (Table 2), the results follow the same trend as for the topsoil regarding the subsoiling treatment (TR2: 1.27 g cm^{-3}) and had significantly lower values than the other tillage treatments (TR4: 1.39 g cm^{-3}; TR3: 1.51 g cm^{-3}) (Figure 1).

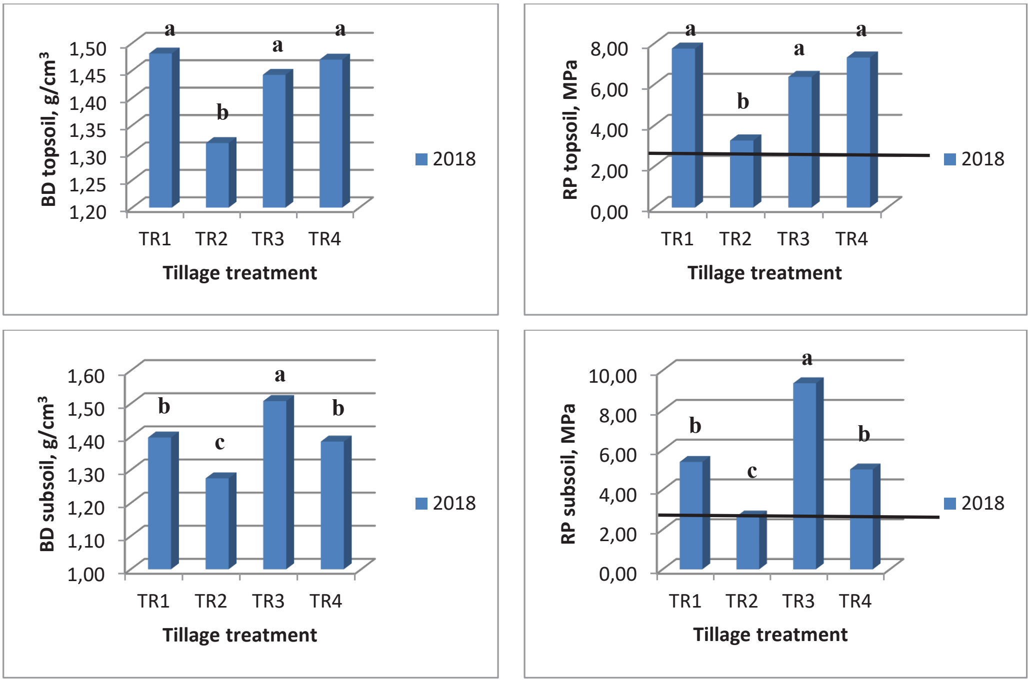

Figure 1. Topsoil (10-20 cm) and subsoil (40-50 cm) bulk density and penetration resistance as affected by different tillages. The black line represents the RP at 2.5 MPa, which is considered as critical limit for root growth

Soil penetration resistance was calculated using a pedotransfer function (Canarache, 1990), its equation being as follows:

$$RPst = 0.55 * 1.047^{C} * BD^{7.53}$$

where: *RPst* is the standard penetration resistance (in Kgfcm^{-2}), *C* the clay content (soil particles <0.002 mm, in %, g/g) and *BD* the bulk density (in g cm^{-3}). Then, the resulted penetration resistance values were converted from Kgfcm^{-2} to MPa by using the following conversion factor:

$$1\, kgf/cm^2 = 9.80665 \cdot 10^{-2} MPa$$

The penetration resistance (RP) was affected by tillages and is correlated with bulk density (Figure 1). For topsoil layer, higher values of BD in TR1, TR3 and TR4 resulted in high values of RP (6.37-7.74 MPa), all of them exceeding the critical limit for root penetration,even in TR2 the RP value exceeded by 0.77 MPa. This can lead to loses of crop yields in time due to formation of a compacted layer below the tillage depth. The tillage variant TR2 (subsoiling) recorded for RP an average value of 3.27 MPa.

Table 2. Bulk density (BD, g cm^{-3}) for different tillage treatments

Soil layer	Treatment	2018	
		Mean	± s.d.
Topsoil	TR1	1.48	0.024
	TR2	1.32	0.039
	TR3	1.44	0.032
	TR4	1.47	0.023
Subsoil	TR1	1.40	0.051
	TR2	1.27	0.035
	TR3	1.51	0.028
	TR4	1.39	0.044

The subsoil layer showed the same tendency of values between the tillage variants. While the RP values in TR1, TR3 and TR4 ranged between 5.02-9.36 MPa, the average RP value in TR 2 was 2.66 MPa.
In case of both topsoil and subsoil RP values, the statistical analysis showed that there are significant differences between tillage variants.
Continuous mouldboard ploughing or disking at the same depth will cause serious tillage pans (compacted layers) just below the depth of tillage in some soils (Parvin et al., 2014). This tillage pan is generally relatively thin (3 to 5 cm thick), may not have a significant effect on crop production, and can be alleviated by varying depth of tillage over time or by special tillage operations, such as subsoiling (Piccoli et al., 2022).
The studied soil is susceptible to degradation by natural subsoil compaction. Compaction is a worldwide problem, and the problems caused by this may be: a decreased root length, retarded root penetration and shallower rooting depth (Nawaz et al., 2013). The soil compaction can result in greater concentration of roots in upper soil layer and reduced root growth in deeper soil layer, mostly due to excessive mechanical impedance such as hard pan which is formed below the tillage depth.
Water stable aggregates (WSA) were significantly affected by soil tillage (Figure 2).

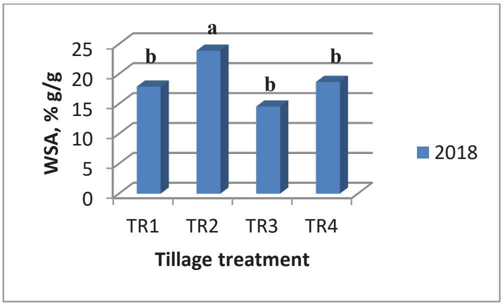

Figure 2. Water stable aggregates in topsoil layer as affected by different tillages

The most pronounced negative effect was observed in the control variant where the soil tillage by disking was two times done (TR3) and the WSA content was the smallest (15% g/g). The less disturbed the soil, as is the case for subsoiling variant (TR2), the higher the content of water stable aggregates (24% g/g).

When statistical analysis was done for comparison of WSA within tillage treatments, the content of water stable aggregates was statistically significantly influenced.
Saturated hydraulic conductivity (Ks) is the soil physical property that was most affected by soil tillage (Figure 3). The more intense the soil is tilled, the more the porous system and its continuity is destroyed and the Ks values are lower. The Ks values in control variant (TR3), when compared with subsoiling variant (TR2), decreased 10 times, while when compared with ploughing (TR1) and chisel tillage (TR4) were only 3 times smaller.

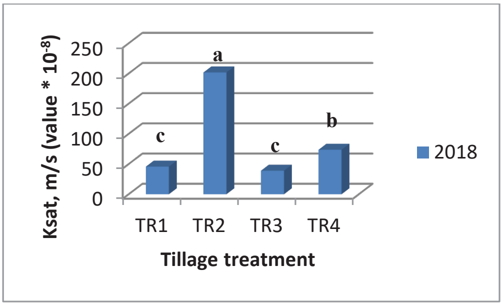

Figure 3. Saturated hydraulic conductivity in topsoil layer as affected by different tillages

The saturated hydraulic conductivity values were highly variable between treatments. The highest values of saturated hydraulic conductivity were determined in variants where subsoiling tillage was done ($202\ x\ 10^{-8}$ m s^{-1}). Moreover in these plots with subsoiling tillage, the high saturated hydraulic conductivity values means that the soil porous system continuity was not further disturbed by tillage and the water pathways in soil were not interrupted.
When statistical analysis was done for comparison of Ks within tillage treatments, the values were statistically significantly influenced.
Soil structure represents one of the major attributes of soil quality and it affects the soil pore system and through it the water movement processes in soil, which is measured by saturated hydraulic conductivity (Dexter, 2004). The saturated hydraulic conductivity of such fine-textured soil shows high variability and records low values, the most significant decrease being encountered in the control variant where disking tillage was done.

Soil porosity plays a significant role in evaluation of the impact of management practices on the quality of soil structure (Pagliai et al., 2004). By adopting alternative tillage systems, such as subsoiling tillage treatment, the soil macro-porosity can increase and is more-homogeneously distributed through the profile when compared with a disking tillage variant, and the resulting soil structure has a better quality, as confirmed by the higher hydraulic conductivity measured in the soil tilled by subsoiling. This is confirmed also by the values measured for water stable aggregates, which were higher in the treatment with subsoiling tillage.

Although subsoiling improved the soil indicators such as infiltration rate and bulk density, by applying subsoiling every year, it is time and energy consuming leading to an The soil organic carbon content did not vary between the applied treatments (2.06-2.34%), the content being moderate between all tillage treatments. The investigated soil was highly supplied with available phosphorus (37-52 ppm), while for the exchangeable potassium content the soil was low to moderately supplied (8-20 ppm).

Soil compaction is one of the most important anthropogenic factors that influence the physical properties of the soil, with immediate effect on the management of agricultural farms and the environment (Nawaz et al., 2013). Soil compaction influences soil water dynamics, erosion, nitrogen and carbon cycle in the soil, agricultural yield, soil biology, and crop productivity (Piccoli et al., 2022).

Compaction affects agricultural and forestry crops and results from the traffic of heavy machinery and equipment on soils susceptible, mainly during the harvesting and harvesting operations (Nawaz et al., 2013). The negative effects of soil compaction on crop production have been shown in many research studies (Shaheb et al., 2021). Compaction causes a decrease in porosity and an increase in soil resistance that can restrict root development and affect the density and diversity of meso-fauna and bacterial communities in the soil (Glab, 2013).

In addition, the exchange of gases slows down in compacted soils, causing an increase in the likelihood of aeration-related problems. increase of workload, and the financial benefits for farmers are not significant. In addition, if the farmers are using high levels of chemical inputs there may increase the health risk due to nutrients leaching and infiltration in groundwater table. For example, in dry years, there is a potential risk of crop failure because of the water stress for crops during the growing season.

Based on these, it is recommended that the subsoiling tillage type should be done periodically at 3-4 years in combination with annually application of mouldboard ploughing.

Regarding the chemical characterization of the studied soil, there were no statistically significant variations between the applied treatments. The soil reaction values in case of all treatments varied between 5.99-6.63, which highlighted a lightly acid soil.

Finally, while soil compaction increases soil strength (the ability of soil to resist being moved by an applied force) a compacted soil also means roots must exert greater force to penetrate the compacted layer.

CONCLUSIONS

Saturated hydraulic conductivity is the soil physical property that was most affected by soil tillage. The highest values were recorded in the subsoiling variant.

The penetration resistance was affected by different tillage treatments and is correlated with bulk density. Significant effects were recorded both in topsoil and subsoil layers.

Soil chemical properties were not significantly affected by different tillage treatments applied to soil. The soil is lightly acid, highly supplied with available phosphorus and low to moderately supply with exchangeable potassium.

In order to mitigate the natural subsoil compaction of the studied soil, the best solution with positive effects on soil quality is to use a combination of the two tillage treatments which were investigated, namely the application of the mouldboardploughing annually and of the subsoiling periodically at 3-4 years. In this way is prevented the formation of the hard pan layer at the base of tillage depth.

The tillage treatment involving subsoiling was found to be efficient for improving soil compaction. However, it was also found that applying subsoiling every year is time and energy consuming, and the financial benefit for farmers is questionable. There is a need for further evaluating if the subsoiling could be done only periodically, once at every 3-4 years.

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PARTIAL RESULTS REGARDING SOME WINTER WHEAT GENOTYPES CREATED AT ARDS TURDA AND TESTED IN THE PEDOCLIMATIC CONDITIONS OF NIRDPSB BRAȘOV

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Abstract

Wheat is not just any plant, it represents the food security of millions of people, being foremost and irreplaceable in many geographical areas. To NIRDPSB Brasov between 2020-2021 was created an experimental field with 25 winter wheat genotypes from ARDS Turda. The culture was randomized with three replicates, totaling 75 experimental variants. The research aimed to study the resistance of genotypes to thermic and hydric stress. Resistance to the attack of pathogens and behavior in terms of production/ha, TKW, hectolitre weight and humidity were also analyzed. Regarding the production on the first place was the line T.51-17 with an average production of 6557 kg/ ha and on the last place was the line T.21-16, with an average production of 3752 kg/ha. The Andrada variety (control) with a productivity of 6003 kg/ha, the lines T.45-18, T.52-18 and the Dumitra variety with yields of 5682 kg/ha, 5590 kg/ha and 5474 kg/ha respectively were also noted.

Key words: *climatic conditions, disease resistance, genotypes, production, winter wheat.*

INTRODUCTION

Wheat (*Triticum aestivum* L.) is an important cereal food crop worldwide and it accounts for 21% of the global food demand with more than 80% of the global population depending on it as a source of protein and calories (Shewry, 2009, Msundi et al., 2021).
One of the decisive factors in achieving the high-performance wheat crop is the variety. Thus, in order to be promoted in production, wheat varieties must possess a series of valuable properties: high productivity, good quality of the grains, high resistance to diseases and to the wintering, to the drought and good stability (Muntean et al., 2008).
Breeding can contribute to the achievement of these goals by focusing its efforts on increasing production potential, reducing the negative correlation between production and quality, increasing water and nutrient efficiency, reducing losses from diseases and pests (Săulescu et al., 2010).
The damage caused by diseases depends on the growth stage of the crop and the severity of the disease, which is a function of environmental conditions, virulence of the physiological race and the susceptibility of the cultivar (Roelfs et al., 1992). Diseases have been shown to reduce test weight, and consequently fungicide application resulted in a 2.5 to 2.8% increase in test weight (Paul et al., 2010; Marinciu et al., 2021).
The continual drive to match yield and quality increases is not without its challenges. Decreasing availability of suitable farm land, climate change and a variety of unpredictable abiotic and biotic stresses continually pose threats to wheat production locally and globally (Figueroa et al., 2018). Thus, the cultivation of varieties with wide adaptability to contrasting environmental conditions can reduce the risks of declining production in unfavorable years (Mustatea et al., 2008).
Increasing the stability of wheat production from one year to another is possible by creating and introducing into the field varieties that combine a high production potential and a good resistance to biotic and abiotic stress conditions (Săulescu et al., 2007; Moldovan et al., 2012).

Increasing the stability of wheat production from one year to another is possible by creating and introducing new varieties that combine a high production potential and a good resistance to biotic and abiotic stress conditions (Săulescu et al., 2006).

Major diseases of wheat in Romania are powdery mildew (*Blumeria graminis* f.sp. *tritici*), brown rust (*Puccinia recondita* f.sp. *tritici*) and the leaf spot complex, which includes brown spot (*Bipolaris sorokiniana*), yellow spot (*Drechslera tritici-repentis*) and glume spot (*Stagonospora nodorum*).

MATERIALS AND METHODS

The study was conducted to the NIRDPSB Brasov field in autumn of 2020 year, on a cambic chernozem soil, using 25 winter wheat genotypes created by ARDS Turda.

A randomized blocks design with three replications was used for all lines which totaled 75 experimental plots.

Fertilization was carried out with NPK complex (64 kg/ha a.s.) on October 1, 2020, on the field ready for sowing. Subsequently, the plants benefited from two more fractions of ammonium nitrate (NH_4NO_3): the first on 30.03.2021, representing a quantity of 52.5 kg/ha a.s., and the second on 17.05.2021, in a quantity of 33.5 kg/ha a.s.

Were made observations regarding: resistance to winter hardiness, growth rate, phenological data (heading, physiological maturity), fall resistance and sterility.

During the vegetation period, the following pathogens were detected: powdery mildew (*Blumeria graminis*), septoria (*Septoria* sp.), fusarium ear blight (*Fusarium graminearum*), brown rust (*Puccinia recondita*) and yellow rust (*Puccinia striiformis*).

During the research, no treatments were performed to control the diseases, thus offering the possibility of the appearance and development of pathogens. In this way the studied genotypes could be evaluated in terms of resistance/tolerance, obtaining an identification of valuable genotypes for this area.

At harvest, the production/plot and the humidity were determined (standard humidity 14%/production per hectare).

After the harvesting, samples were taken to determine other elements of productivity: thousand kernel weight (TKW), test weight, and to determine the quality of the grain, samples were sent to ARDS Turda.

RESULTS AND DISCUSSIONS

The climatic regime in 2020-2021, indicates a warm year with an uneven distribution of rainfalls. The amount of rainfalls summed between August 1 and December 31, 2020, is shown in Table 1. The precipitation that fell in August shows a negative deviation from MAA accentuating the pedological drought, but in September the deviation was positive. In October, the rains favored the germination and emergence of seedlings and the improvement of the soil's water supply. The average air temperature in August was higher than MAA and in September the deviation of the average temperature was positive compared to the multiannual average (2.7°C), as well as that of October (2.1°C).

The weather favored sowing in good conditions, good germination of the grains and a uniform emergence of the plants. A good evolution of the growth and development was also due to the fact that the sowing took place on October 13, 2020, a date that allowed the good evolution of the culture.

Table 1. Air temperature and rainfalls in 2020 - NIRDPSB Brasov

	Month/ Period	Average air temperature °C			Total rainfall (mm)		
		Accomplished	MAA	Deviations	Accomplished	MAA	Deviations
	January	-3,6	-5,0	1,4	4,0	25,5	-21,5
Y	February	2,2	-2,5	0,3	42,0	23,9	18,1
e	March	5,6	2,6	3,0	30,4	28,9	1,5
a	April	8,6	8,5	0,1	12,7	50,0	-37,3
r	May	12,8	13,6	-0,8	98,0	82,0	16,0
	June	17,8	16,5	1,3	120,1	96,7	23,0
2	July	19,2	18,1	1,1	104,1	99,8	4,3
0	August	19,7	17,5	2,2	53,4	76,4	-23,0
2	September	16,3	13.6	2,7	75,5	52,5	23,0
0	October	10,4	8,3	2,1	76,9	38,9	38,0
	November	2,2	3,1	-0,9	21,8	32,8	-11,0
	December	2,9	-2,2	5,1	33,8	27,0	6,8
	Average/total annual	**9,5**	**7,7**	**17,6**	**672,7**	**634,4**	**37,9**

During January-February 2021, the temperatures were higher, showing positive deviations of 4.01°C, respectively 0.1°C, and in March there was a decrease in temperature compared to the multiannual average, showing a negative deviation (-0.9°C) (Table 2). The rainfalls showed a negative deviation of -2.4 mm and -16.7 mm, in the same period and in March, the month in which the tested genotypes were sown, the precipitations showed a positive deviation of +10.3 mm.

In April, the rainfall deficit of -10.8 mm was maintained. The average temperature this month was 6.9°C and showed a negative deviation of -1.6°C. It should be mentioned that the ground was not covered with snow, except in limited areas, only between February 12-21, the snow layer was 2 cm thick.

Table 2. Air temperature and rainfalls in 2021 - NIRDPSB Brasov

	Month/ Period	Average air temperature °C			Total rainfall (mm)		
		Accomplished	MAA	Deviations	Accomplished	MAA	Deviations
Year 2021	January	-1,0	-5,0	4,0	23,1	25,5	-2,4
	February	-2,4	-2,5	0,1	7,2	23,9	-16,7
	March	1,7	2,6	-0,9	39,2	28,9	10,3
	April	6,9	8,5	-1,6	39,2	50,0	-10,8
	May	13,8	13,6	0,2	77,5	82,0	-4,5
	June	19,3	16,5	2,8	109,0	96,7	12,3
	July	21,0	18,1	2,9	71,1	99,8	-28,7
	August	19,3	17,5	1,8	100,8	76,4	24,4
	September	12,8	13.6	-0,8	32,0	52,5	-20.5
	October	7,2	8,3	-1.1	30,0	38,9	-8.9
	November	4,6	3,1	1,5	27,5	32,8	-5.3
	December	1,3	-2,2	3,5	45,5	27,0	18,5
	Average/total annual	**8,7**	**7,7**	**1,0**	**602,1**	**634,4**	**-32.3**

The winter hardiness of wheat genotypes sown in autumn 2020 was generally good, the plants entered in winter mostly tillering. This biological process continued in the spring, highlighting variants with a good tillering capacity and increased winter hardiness.

The growth rate (14.04.2021) was evaluated as good and very good (on a scale from 1 to 9; where 1 represents - very resistant and 9 - very sensitive), the values being between 1.5 and 4.

The height of the plants by genotype, started from 82.3 cm to line T.38-16 reaching up to 105 cm to T.7-18 line.

Depending on the degree of precocity, the genotypes heading between May 26 and June 5, 2021.

The number of fertile ears/sqm exceeded 587 ears/sqm toT.53-18 line, reaching up to 685 ears/sqm to T.21-18 line.

The uniformity of the plants indicated very uniform genotypes, rated with note 2 or less uniform, rated with note 5. In general, the uniformity of the field went to notes 2-3 (note 1 representing a very uniform chain and note 9 a very irregular field).

Full maturity, recorded in the first and second decades of July, was influenced by either variety, either by forced maturity due to the heat wave, or delayed due to falling rainfall and high atmospheric humidity, which encouraged certain genotypes in the development of late tillers.

The resistance of plants to falling was high (note 1-2). However, some genotypes showed a slight drop (note 2.5, average value/3 repetitions) due to the high height of the plants or the rains accompanied by strong storms.

The thousand kernel weight (TKW) and the test weight differ from genotype to genotype, being influenced by both climatic factors and variety characteristics.

TKW was between 36 grams and 50 grams (Figure 1), and the test weight was between 58.3 kg/hl - 78.5 kg/hl (Figure 2).

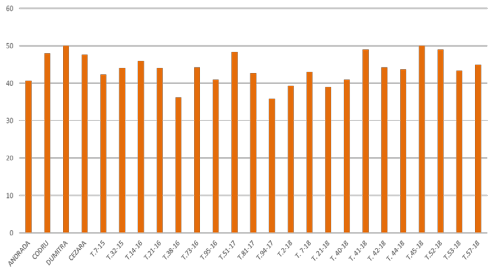

Figure 1. TKW (g) of winter wheat varieties/lines

Many genotypes showed lower values of this index, by not adapting to the unfavorable climatic conditions of the season - maturity milk - soft dough, with periods of rain, alternating with periods of drought and heat, which caused leaf loss and poor grain filling.

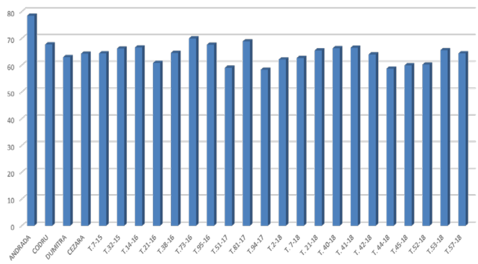

Figure 2. Test weight (kg/hl) of winter wheat varieties/lines

The evaluation of the resistance of the tested plants to the attack of different pathogens, had as starting point the assessments presented by Saulescu et al. (1990): resistance to powdery mildew, in which 1 = resistant and 9 = sensitive; resistant to *Septoria tritici* (scale 1-9); resistant to brown rust (scale 1-9); resistant to yellow rust (scale 1-9).

The climatic year 2020-2021 favored the extension of the **septoria** attack (Figures 3 and 4), which prevented the maintenance of the leaf until physiological maturity and therefore led in most cases to the decrease of the real production capacity of the experienced genotypes, the resistance to attack being between 2.5 and 8.

Figure 3. *Septoria tritici*

Figure 4. *Septoria nodorum*

The resistance to the attack of **powdery mildew** (Figure 5) was low to medium, showing a lower aggressiveness in the genotypes T.41-18, T.45-18 and higher in the variety Andrada.

Figure 5. *Erysiphe graminis*

To the NIRDPSB Brasov in 2021, the attack of the pathogen ***Puccinia striiformis*** (Figure 6), was present at different levels, differentiating the genotypes in terms of resistance, this being between 1 in the genotype T.57-18 and 5 in the genotype T.7- 18.

The resistance to the attack of **brown rust** was also evaluated (Figure 7) demonstrating the medium to high sensitivity of the genotypes. It is noteworthy that this attack occurred in all variants in the last period of vegetation, on the parts of the leaf left green after the attack of other diseases (yellow rust, powdery mildew, septoria) or on areas left green after the leaf drying due to drought.

Figure 6. *Puccinia striiformis*

Figure 7. *Puccinia recondite*

The attack of *Fusarium* ssp., expressed in % of the number of ears analyzed, was evaluated as low to medium (5-11) or high (20), due to the favorable climatic conditions for the installation of this disease during flowering (Figure 8). The periods with long rains negatively influenced the quality of the grains, the attack being found in all genotypes experienced.

and 5474 kg/ha, respectively, were also noted. (Figure 11).

Figure 8. *Fusarium graminearum*

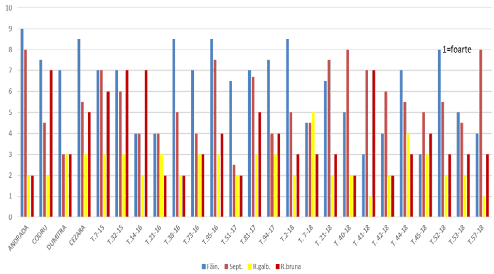

Figure 9. Resistance of autumn wheat varieties/lines to *Blumeria graminis, Septoria nodorum, Septoria tritici, Puccinia recondite* and *Puccinia striiformis attack*

The phenomenon of ear sterility was generally present at a medium level (5-9%). The Dumitra variety and the T.45-18 line with the lowest level of sterility were highlighted (Figure 10).

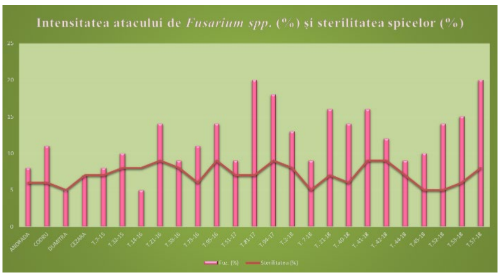

Figure 10. *Fusarium* spp. attack intensity (%) and ear sterility (%)

Yield results were different. On the first place was line T.51-17 with an average yield of 6557 kg/ha, line and on the last place was the line T.21-16 with an average production of 3752 kg/ha. Andrada variety with a yield of 6003 kg/ha, lines T.45-18, T.52-18 and Dumitra variety with yields of 5682 kg/ha, 5590 kg/ha and 5474 kg/ha, respectively, were also noted. (Figure 11).

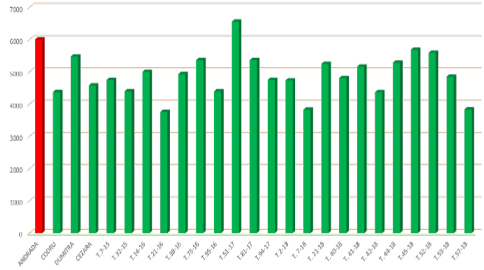

Figure 11. Grain yields (kg/ha) obtained from winter wheat varieties/lines

It can be stated that in the specific conditions of 2020-2021, with a deficit of precipitation in the autumn-winter months, and a thermal regime with differences from the multiannual average, in certain intervals, the tested variants showed a high level of production.

With alfalfa as a precursor plant and a high intake of nitrogen fertilizer, very large yields can be obtained in the area.

In the specific conditions of 2021, the studied varieties/lines gave good results, proving that, due to the increased resistance to wintering and to certain pathogens, we can speak of competitive genotypes at national and international level.

Genotypes have been highlighted that are valuable material, of perspective in the process of creating new varieties with high ecological plasticity, but also with superior quality indices, important in the milling and bakery industry.

CONCLUSIONS

Yield and quality are strongly influenced by the limiting abiotic factors (thermic and hydric stress) manifested during the experimentation period. In the conditions of 2020-2021, with periods of drought accompanied by heat, alternating with periods of low temperatures, excess humidity, the following genotypes were highlighted in winter wheat: line T.51-17 with an average production of 6557 kg/ha, the Andrada variety with an average production of 6003 kg/ha and the T.45-18 line with a production of 5682 kg/ha.

The tested genotypes had a good resistance to wintering, an intense growth rate during spring and different levels of resistance to the attack of foliar and spike diseases, being also present the phenomenon of sterility.

Productivity elements: the number of spike/m^2, the number of grains in the spike, thousand kernel weight (TKW), the test weight, led to the identification of some genotypes of winter wheat with high yield capacity, nationally and internationally competitive. The genotype T.73-16 and the Andrada variety recorded values of 70 kg/hl, respectively 78.5 kg/hl in terms of test weight and the Dumitra variety and the T.45-18 line stood out in terms of TKW (+50 g).

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EFFECTS OF APPLICATION OF VERMICOMPOST AND EXTRACT OF VERMICOMPOST IN MAIZE CULTURE IN THE EARLY STAGES OF DEVELOPMENT

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Abstract

Romania is one of the largest maize producers in the European Union. It is a crop that can be very profitable if certain requirements related to the cultivation and care of the crop. The aim of the present study was to evaluate the effect of vermicompost and vermicompost extract, on seed germination and root development of maize seedlings. Effective concentration range and the degree of stimulation varied significantly between the treatments. The obtained results show that the dose of 1 litter of vermicompost extract at 20 l/water positively influences the seed germination. Regarding the development of the roots, the dose of 1l extract of vermicompost at 5l/water recorded the best results. Regarding the use of vermicompost, the best results in terms of seed germination were the best for the incorporation into the soil of doses of 10 and 20 t/ha. The best results were obtained using the amount of 20 tons of vermicompost/ha, the corn roots having a much stronger and more developed root system compared to the other variants.

Key words: *vermicompost, extract of vermicompost, biofertilizer.*

INTRODUCTION

Traditional agriculture today is characterized by excessive inputs of chemical fertilizers, pesticides and herbicides, while the application of organic fertilizers is insufficient. Excessive use of chemical pesticides and pesticide fertilization and loss determine negative effects on the environment, soil and food pollution with waste, degradation of soil quality (Ju et al., 2009) and agricultural biodiversity (Minuto et al., 2006; Gill and Garg., 2014). According to Fred (1991), agriculture has had both positive and negative effects, and the use of synthetic fertilizers leads to the loss of the soil's natural nutrients when used on its surface. According to Katsunori (2003), inorganic fertilizers that are applied to the soil are more resistant to the environment than natural fertilizers, because they are mixed with chemicals and therefore harmful and also pose a threat to the environment, and the effects are felt on soil fertility. With the current price of chemical fertilizers and declining production of organic fertilizers due to changes in the number of animals, it is necessary to pay attention to other suitable alternatives to create this situation.

Corn can be defined as the "grain god" because of its productivity potential when compared to other grains (Umesha et al., 2014). Romania is one of the largest corn producers in the European Union. It is a crop that can be very profitable if certain requirements related to the cultivation and care of the corn crop are met. Maize is in fact a crop that requires high nutrition and also its productivity depends on proper nutrient management. Nutrient management is a vital factor affecting corn yield, as reported by Verma (2011).

Vermicompost is an organic fertilizer that can be obtained from the recovery of decomposed household waste with the help of earthworms. The process of recycling food waste ensures a natural, black, strong-smelling fertilizer, which has an extremely beneficial effect on the process of growing plants.

Vermicompost extract or aerated compost tea is considered a very good option for conventional and organic growers (Kim et al., 2015), because it increases crop productivity by introducing microorganisms from the extract into the soil and the plant that helps maintain moisture in the plant as well as in the soil, the assimilation of nutrients from the soil, as well as the population of the soil with microorganisms.

MATERIALS AND METHODS

Preparation of plant material

The potted maize experiment was carried out in the greenhouse at the Research and Development Institute for Plant Protection Bucharest (RDIPP). The experiment took place in July 2021. 20 pots 38 cm long and 15 cm wide were used and a total of 160 kg of soil (8 kg/pot) was added to the pots. Fourteen Furti CS (360 FAO) corn seeds from 2020 were added to each pot.

For RDIPP maize experiment on the effect of applying vermicompost extract on seed germination and root length, 25 corn seeds were added to each petri dish. Maize seeds were weighed both before application of the extract and 3 days after seed germination. They stood at 23 degrees in the dark. Blue laboratory paper was used to soak them in different doses of extract.

Preparation of vermicompost and vermicompost extract

The vermicompost was obtained in 2020. Sheep, goat and horse manure one year old was used, to which were added in 2019 the worms of the species *Eisenia fetida*. After an interval of 12 months, the separation between the worms was made and vermicompost obtained by ingesting manure and excreting it by earthworms. The method of separation was through sieving.

The vermicompost extract was obtained in May 2021. The same vermicompost was used in 2020. At 10 litters of distilled water, 1 kg of vermicompost was used, to which was added an aquarium pump to aerate the extract for a period of 24 hours. Subsequently, the extract was strained through a fine sieve and used in the laboratory experiment.

RESULTS AND DISCUSSIONS

Effects of vermicompost extract on maize germination and root development

The experience consists of 6 variants with 8 repetitions each. 25 maize seeds were used for each replicates (Tables 1, 2).

Table 1. Agrochemical characteristics of vermicompost extract

Material	pH	N mg/l	P mg/l	K mg/l	Ca mg/l	Mg mg/l	Zn mg/l
Vermicompost extract	7	2023.05	60	792	70	42	87

Table 2. Vermicompost extract doses used in each variant

V1	Control – distilled water – 0%
V2	1L to 40l distilled water - 5ml to 200 ml water 2.5%
V3	1L to 30l distilled water – 6.67ml to 200 ml a water – 3.3%
V4	1L to 20l distilled water - 10ml to 200 ml water – 5%
V5	1L to 10l distilled water - 20ml to 200 ml a water – 8.3%
V6	1L la 5l distilled water - 40ml to 200 ml water– 20%

The seeds mass was determined for each variant and repetition, the results being the Table 3.

Table 3. Biomass of seeds after treatment

Biomass of seeds after treatment	V1 - 0%	V2 - 2.5%	V3 - 3.3%	V4 - 5%	V5 - 8.3%	V6 - 20%
R1	7.92	7.81	7.6	7.84	8.13	7.97
R2	7.9	7.8	7.67	7.9	7.96	7.87
R3	7.91	7.93	7.76	7.89	7.62	7.93
R4	7.82	7.75	7.73	7.66	7.72	7.86
R5	7.7	7.53	7.33	7.69	7.82	7.85
R6	8.02	7.76	7.81	7.77	7.68	7.77
R7	7.45	7.83	7.87	7.93	7.86	7.84
R8	7.92	7.43	7.74	7.76	7.97	8.07
Average - Seed Mass/g	7.83	7.73	7.68	7.80	7.84	7.89

After determining the mass of the seeds, the doses of the extract were prepared, for each petri dish 3 disks of blue laboratory paper were used which was soaked in the mixture of water and vermicompost extract which was distributed according to alternative. The seeds were kept at 23 degrees Celsius in the dark. The germination of the germs was done after 3 days, as well as the germination of the seeds and the measurement of the roots.

In Table 4 we notice that the vermicompost extract has no effect on the seed biomass, the control, respectively, variant 1 registering the highest average of 12.18 g, and variant 3 where the dose of 1L extract at 30 l water respectively was used, 6.67 ml of vermicompost extract recorded the lowest average, respectively 11.61 grams.

The low percentage can be clearly seen compared to the control (Table 5). Variant 2 with a weight 3% lower than the control, variant 3 with a percentage of 4.73% less than the control, variant 4 with a percentage with 2.43% less than the control, variant 5 with a percentage of 3.12% lower than the control and variant 6 registering the closest percentage to the control by 0.19% less.

Table 4. Germinated seed biomass

Biomass of germinated seeds	V1 - 0%	V2 - 2.5%	V3 - 3.3%	V4 - 5%	V5 - 8.3%	V6 - 20%
R1	11.79	11.6	11.37	12.27	12.5	11.92
R2	12.25	12.26	12.29	12.32	11.33	11.78
R3	12.79	12.19	11.39	11.49	11.47	12.36
R4	12.6	11.62	12.26	11.2	12.06	12.46
R5	11.57	12.34	11.03	11.4	11.3	12.54
R6	12.4	11.71	11.48	12.29	11.38	11.93
R7	11.69	11.63	11.7	12.23	11.96	12
R8	12.4	11.13	11.36	11.92	12.45	12.31
Biomass of germinated seeds/g	12.18	11.81	11.61	11.89	11.81	12.16

Table 5. Seed germination - percentage

Germination percentage	V1 - 0%	V2 - 2.5%	V3 - 3.3%	V4 - 5%	V5 - 8.3%	V6 - 20%
R1	88	96	84	76	80	92
R2	88	100	92	92	76	92
R3	84	100	88	88	84	100
R4	96	68	92	92	100	84
R5	88	96	96	96	88	88
R6	88	84	88	100	92	100
R7	88	88	100	92	96	84
R8	100	84	92	100	96	88
Average of seed germination percentage	90	89.5	91.5	92	90	91

The 4 variant recorded the highest value in terms of germinated seeds, respectively 184 seeds out of 200, the average being 23 seeds per repetition. These results show that the dose of 1l to 20 l/water positively influences the seed germination. Variant 2 recorded the lowest values, respectively 179 germinated seeds, the average being 22.3, lower than the control.
The rootlets were measured individually and then collected resulting in a total of each repetition and variant (Table 6).

Table 6. Rootlets length

Medium length rootlets	V1 - 0%	V2 - 2.5%	V3 - 3.3%	V4 - 5%	V5 - 8.3%	V6 - 20%
R1	2.40	2.87	2.53	2.83	2.61	3.13
R2	2.69	3.88	3.89	3.48	2.07	2.52
R3	3.18	3.60	1.60	2.32	2.89	3.51
R4	3.16	1.40	3.44	2.48	3.69	3.12
R5	3.23	3.60	2.78	2.55	1.64	3.51
R6	2.14	3.26	2.48	3.49	1.56	3.24
R7	3.12	2.54	3.12	3.10	3.41	2.59
R8	3.28	2.46	2.77	3.28	2.93	2.95
Avarage - Medium length rootlets cm	2.90	2.95	2.83	2.94	2.60	3.07

Regarding the development of the rootlets, variant 6 registered the highest value, respect-tively 3.07 cm, proving that the dose of 1 l to 5 l/water is much more effective than the control variant where only water was used.

Effects of vermicompost on maize germination and root and leaf development

The experience was established on June 5, 2021 within the Research-Development Institute for Plant Protection Bucharest.
The pots were kept in a mini greenhouse inside the institute.
The average temperature in this range was 30°C. 14 maize seeds were added to each pot. The doses used for each variant are Tables 7, 8.

Table 7. Doses of vermicompost administered

V2	36.4 g/pot	6.5 t/ha
V3	56 g/pot	10 t/ha
V4	84 g/pot	15 t/ha
V5	112 g/pot	20 t/ha

Table 8. Agrochemical analysis of vermicompost and vermicompost extract

Material	pH	N mg/l	P mg/l	K mg/l
Vermicompost	7.1	2	1.8	4
Soil	6	0.8	0.1	0.3

The first reading was made 3 days after sowing the seeds in pots. The results are in the Table 9.

Table 9. First reading - seed germination

	Control	6.5 t/ha	10 t/ha	15 t/ha	20 t/ha
R1	0	4	4	3	3
R2	3	4	5	6	5
R3	2	6	7	7	5
R4	4	4	6	5	9
TOTAL Seeds germinated and come out at the first observation	9	18	22	21	22

After the first reading we can see that the impact of the vermicompost is considerable. Variant 3 and variant 5 recorded the most germinated seeds, respectively a total of 22 seeds, which means 39% of 56 seeds, compared to the control which recorded a total of 9 seeds, respectively a percentage of 16%.
The use by incorporation of doses of 10-20 t/ha offers a good yield for the germination of corn seeds.

Table 10. Second reading - seed germination

	Control	6.5 t/ha	10 t/ha	15 t/ha	20 t/ha
R1	13	13	13	14	14
R2	14	14	14	14	14
R3	13	13	14	14	14
R4	13	14	14	14	14
TOTAL Germinated seeds and second observation	53	54	55	56	56

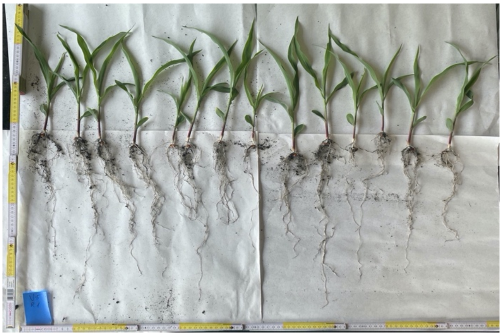
The second reading was performed 3 days after the first reading, respectively 6 days after sowing the seeds, variant 5 as in the first observation, registering a germination of 100% compared to the control (94%), as well as variant 4 registering a germination of 100%, the control remaining with the lowest percentage and number of germinated seeds (Tables 10, 11).
The next determinations were made at 6-day intervals, when the plants reached the stage of 3-4 true leaves, respectively on the 13-14 BBCH scale.

Table 11. Average root length of maize shoots

	Control	6.5 t/ha	10 t/ha	15 t/ha	20 t/ha
R1	21.61	21.89	27.02	27.39	35.52
R2	21.91	20.43	25.24	25.04	32.88
R3	24.73	19.16	25.96	23	24.79
R4	24.17	23.4	26.93	27.14	24.12
The average length of the root of the corn shoots	23.11	21.22	26.29	25.64	29.33

The best results were obtained in variant 5 where the dose of 20 t/ha was used, the corn roots having a much stronger and more developed root system compared to the control. The percentage compared to the control being 27% higher. Variant 2 registered much lower values than the control (these low values must be due to the damage of the roots when separating them from the soil and pots). The percentage compared to the control was 8% lower.
Regarding leaf development, the dose of 15 t/ ha of vermicompost helped the maize shoots to develop the leaves much faster than the control (Table 12). Their development is significant both in length and width, this aspect is found in Tables 13 and 14. A much more developed foliage in both length and width, helps a lot against plants pests such as *Tanymecus dilaticollis* and *Opatrum sabulosum* that attack maize shoots in the 1-4 leaf stage causing serious damage to the crops in our country. Plants with much more developed leaves are much more resistant to these pests, so that their attack is not so strong.
Another important aspect regarding the nutrients is that when applying liquid fertilizers, a larger foliage results and a stronger absorption of nutrients.

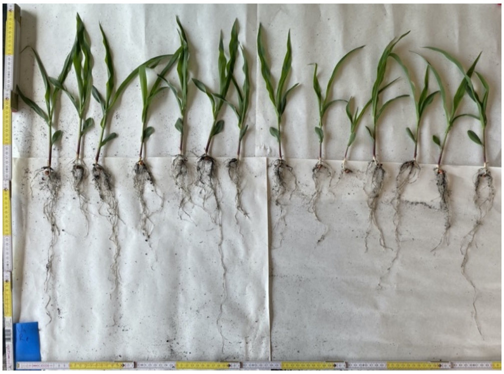
Picture 1. Root length - Control Variant 1 Replicate 2



Picture 2. Root length - Variant 5 Replicate 1

Table 12. Leaf length

	Control	6.5 t/ha	10 t/ha	15 t/ha	20 t/ha
R1	37.12	41.69	45.3	54.55	52.48
R2	36.45	40.17	39.88	56.24	57.68
R3	32.58	32.24	40.32	48.12	52.69
R4	32.78	45.11	44.09	55.42	46.16
Average leaf length (cm)	34.56	39.80	42.40	53.58	52.25



Picture 3. Root length - Variant 4 Replicate 1

Table 13. The width of the maize leaves

	Control	6.5 t/ha	10 t/ha	15 t/ha	20 t/ha
R1	1.37	1.44	1.44	1.56	1.74
R2	1.46	1.44	1.44	1.49	1.7
R3	1.27	1.24	1.31	2.22	1.52
R4	1.22	1.36	1.29	1.54	1.41
Average maximum leaf width (cm)	1.33	1.37	1.37	1.70	1.59

Tabel 14. Average length of shoots

„	Control	6.5 t/ha	10 t/ha	15 t/ha	20 t/ha
R1	26.86	27.01	30.1	31.27	31.1
R2	29.04	29.84	28.44	33.21	34.29
R3	23.12	25.23	30.49	31.1	31.84
R4	25.36	31.78	29.8	32.77	30.89
Average length of shoots	26.10	28.46	29.71	32.09	32.03

Regarding the length of the shoots, also variant 4 with the vermicompost dose of 15 t/ha registered the best values as well as the highest percentage of 18.67%, the control remaining with the lowest values. From the table and graph it can be seen that in the other variants where vermicompost was added, the yield was higher.
From the results obtained determining the leaf area in all 5 variants, we observe that variant 4 with a dose of 15t / ha offers the best yield in terms of foliar development in maize.

CONCLUSIONS

Regarding the vermicompost extract, we cannot say that it positively influences the corn seeds, due to this fact, this experiment must be repeated with other doses and other hybrids, instead, the vermicompost applied in the soil gave a very good yield. Due to the bacteria and nutrients in the vermicompost, the maize at a dose of 15t / ha registered the best yield both in terms of root and foliar development. A very important aspect is the pests *Tanymecus dilaticollis* and *Opatrum sabulosum* which attack the corn shoots in the 1-4 leaf stage causing serious damage to the crops in our country, the maize being very well developed at this stage, the damage will be considerably lower. This aspect is also demonstrated by the leaf area index, which means a stronger photosynthesis and a higher production of sugars essential for the growth and feeding of the plant. It should also be noted that a strong root system means better plant nutrition and strong resistance to external factors such as drought. The bacteria in the vermicompost not only help the plant to assimilate nutrients much faster, but also improve the soil microflora.
According to the new CAP and its goal of reducing chemical fertilizers by 20% by 2030, the use of vermicompost is a cheap and effective alternative for farmers, given the growing growth of chemical fertilizers and the need to use more and more every year, due to soil degradation, and negative effects on the environment and atmosphere and soil biodiversity.

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CHANGES IN CROP YIELD AND QUALITY OF CROP PRODUCTS AGAINST THE EFFECTS OF SEWAGE SLUDGE FROM URBAN WASTEWATER AND THEIR COMBINATIONS WITH ZEOLITE-CONTAINING AGRO-ORE

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Abstract

The most important task of agriculture at the present stage of its development is to increase the production of high-quality crop products. In this regard, the development of technological methods for the use of local raw materials in order to increase the yield and quality of crop products is relevant. The purpose of the research was to study the aftereffect of urban sewage sludge and their combinations with zeolite-containing agro-ore on crop yields and the quality of crop production in the conditions of the forest-steppe of the Middle Volga region. It has been established that the complex aftereffect of increased norms of urban sewage sludge (160 and 180 t/ha) and zeolite-containing agricultural ore increased the yield of Jackpot peas in 2019 by 1.12-1.14 t/ha, or by 48.9-49.8%, protein content in pea grain by 2.3-2.7%,

Key words*: sewage sludge, zeolite-containing agro-ore, productivity, gluten, protein.*

INTRODUCTION

In modern agriculture, the most important task is to increase the scale of crop production with high quality. Currently, the productivity of agricultural crops remains low due to the lack of means of intensification and to their high cost. The needs of crop production are especially poorly met by means of chemisation, which are the main factor in the growth of crop productivity (Arefiev et al., 2020a; Grishin et al., 2007). One of the promising methods for increasing the yield and the quality of agricultural products against the backdrop of constantly rising prices for mineral fertilizers is the use of cheaper local raw materials. Of the local raw materials in the Penza region (Russia Federation), sewage sludge (SS) can be used in large volumes as organo-mineral fertilizers, and zeolite-containing agricultural ore can be used as a chemical amendment. The use of SS in the form of organo-mineral fertilizers for agricultural crops is an environmentally safe method of their disposal. Thus, the use of SS as a fertilizer allows solving not only agronomic and environmental, but also resource problems (Grishinet al., 2009; Arefiev et al., 2020b; Vuaille et al., 2022).

At present, considerable foreign experience has been accumulated in the use of local non-traditional organic fertilizers (OSV) in the cultivation of agricultural crops (Tran et al., 2021; Wydro et al., 2021; Piersa et al., 2021). In the Russian Federation, the use of SS as an organo-mineral fertilizer when growing crops is limited, so there is a need for scientific justification for the development and application of methods for using sewage sludge in agriculture in the Volga forest-steppe region (Stelmakh et al., 2021; Kuzin et al., 2019).

According to numerous studies, the effectiveness of the effect of sewage sludge on soil fertility, crop yields, and crop production quality increases when sludge is used in combination with chemical amendments (Kuzin et al., 2013; Kuzina et al., 2021).

The purpose of the study was to study the aftereffect of the ameliorative norms of sewage sludge of urban wastewater (SS) in Penza (Russia) and their combinations with zeolite-containing agro-ore on crop yields and the quality of crop products.

MATERIALS AND METHODS

To achieve the aim of the current research, in 2014, a field experiment was established on a meadow-chernozem leached low-humus medium-thick medium-loamy soil according to the following scheme: 1. Without SS and zeolite-containing agricultural ore (control); 2. Zeolite-containing agricultural ore; 3. SS 100 t/ha; 4. SS 120 t/ha; 5. SS 140 t/ha; 6. SS 160 t/ha; 7. SS 180 t/ha; 8. SS 100 t/ha + zeolite-containing agricultural ore; 9. SS 120 t/ha + zeolite-containing agricultural ore; 10. SS 140 t/ha + zeolite-containing agricultural ore; 11. SS 160 t/ha + zeolite-containing agricultural ore; 12. SS 180 t/ha + zeolite-containing agricultural ore. The experiment was organized in three replicates, and the variants in the experiment were placed by the method of randomized repetitions. Each plot had 4 m^2. In the experiment, SS from the city of Penza was used, which is characterized by the following indicators: pHCL value - 6.0 units; hydrolytic acidity - 2.4 mg-equiv/100 g of precipitation, the amount of exchangeable bases - 31.6 mg-equiv/100 g of precipitation.. The content of nutrients: nitrogen (N)- 291%, phosphorus (P)- 116%, and potassium (K)- 120 mg/100 g of precipitation; carbon of organic matter - 21.2%. The concentration of heavy metals in the dry matter of sewage sludge, in the city of Penza, was significantly below the maximum permissible concentration. Zeolite-containing agricultural ore from the Luninskoye deposit with a clinoptilolite content of 41% was used as a chemical amendment in the experiment. Sewage sludge and zeolite-containing agricultural ore were introduced into the fallow field in 2014 for the main tillage. The dose of the amendment (zeolite) was calculated according to the content of clinoptilolite in the agricultural ore and was equal to 24.4 t/ha. Jackpot peas, winter wheat Moskovskaya 56, maize hybrid Ladoga 191 MV were cultivated in the experiment. Agrotechnics for the cultivation of peas, winter wheat and corn was generally accepted for the Penza region.

RESULTS AND DISCUSSIONS

In the conditions of 2019, the pea yield on the control variant was 2.29 t/ha. Against the background of the aftereffect of zeolite-containing agricultural ore, the pea yield was 2.67 t/ha. The increase in relation to the control variant was significant and amounted to 0.38 t/ha, or 16.6% (Table 1).

Table 1. The yield of Jackpot peas

Indicator	Yield (t/ha)	Deviation from control	
		t/ha	%
1. Without SS and zeolite-containing agro-ore (control)	2.29	-	-
2. Zeolite-containing agro-ore	2.67	0.38	16.6
3. SS 100 t/ha	2.69	0.40	17.5
4. SS 120 t/ha	2.71	0.42	18.3
5. SS 140 t/ha	2.85	0.56	24.5
6. SS 160 t/ha	3.08	0.79	34.5
7. SS 180 t/ha	3.09	0.80	34.9
8. SS t/ha + zeolite-containing agricultural ore	2.90	0.61	26.6
9. SS 120 t/ha + zeolite-containing agricultural ore	3.08	0.79	34.5
10. SS 140 t/ha + zeolite-containing agricultural ore	3.10	0.81	35.4
11. SS 160 t/ha + zeolite-containing agricultural ore	3.41	1.12	48.9
12. SS 180 t/ha + zeolite-containing agricultural ore	3.43	1.14	49.8
NSR_{05}		0.18	

Source: Compiled by the authors on the basis of the results obtained

The aftereffect of ameliorative norms of SS in combination with zeolite-containing agricultural ore had the highest effect on the impact on pea yield. The yield of peas in these variants varied from 2.90 (SS 100 t/ha + zeolite-containing agricultural ore) to 3.43 t/ha (SS 180 t/ha + zeolite-containing agricultural ore).

The protein content in pea grain in the variant without the use of sewage sludge and zeolite-containing agricultural ore was 20.5%. Against the background of a unilateral aftereffect of zeolite-containing agro-ore and urban sewage sludge with a norm of 100 t/ha, there was a tendency to increase the protein content in pea grain (20.8-21.4%).

The unilateral aftereffect of urban sewage sludge with norms from 120 to 180 t/ha significantly increased the protein content in pea grain by 1.2 (SS 120 t/ha) - 2.3% (SS 180 t/ha). The protein content against the background of their aftereffect varied in the range from 21.7 to 22.8%.

Against the background of the aftereffect of SS in combination with zeolite-containing agro-ore, the protein content in pea grain varied from 21.7 (SS 100 t/ha + zeolite-containing agricultural ore) to 23.2% (SS 180 t/ha + zeolite-containing agricultural ore), significantly exceeding the control by 1.2-2.7%.

According to the research results, in the variant without the use of urban sewage sludge and zeolite-containing agricultural ore, the yield of winter wheat in 2020 was 4.71 t/ha (Table 2).

Zeolite-containing agro-ore against the background of its unilateral aftereffect significantly increased the yield of winter wheat by 0.33 t/ha, or 7.0%.

Despite the background of a unilateral aftereffect of urban sewage sludge, the yield of winter wheat varied from 5.05 (SS 100 t/ha) to 5.97 t/ha (SS180 t/ha). The deviation from the control variant was significant and amounted to 0.34-1.26 t/ha, or 7.2-26.8%.

The aftereffect of SS in combination with zeolite-containing agricultural ore significantly increased the yield of winter wheat by 0.68 (SSUW 100 t/ha + zeolite-containing agricultural ore) - 1.62 t/ha (SSUW 180 t/ha + zeolite-containing agricultural ore), or by 14 .4-34.4%.

Table 2. Yield of winter wheat variety Moskovskaya 56

Indicator	Yield (t/ha)	Deviation from control	
		t/ha	%
1. Without SSUW and zeolite-containing agro-ore (control)	4.71	-	-
2. Zeolite-containing agro-ore	5.04	0.33	7.0
3. SS 100 t/ha	5.05	0.34	7.2
4. SS 120 t/ha	5.31	0.60	12.7
5. SS 140 t/ha	5.49	0.78	16.5
6. SS 160 t/ha	5.90	1.19	25.3
7. SS 180 t/ha	5.97	1.26	26.8
8. SS t/ha + zeolite-containing agricultural ore	5.39	0.68	14.4
9. SS 120 t/ha + zeolite-containing agricultural ore	5.64	0.93	19.7
10. SS 140 t/ha + zeolite-containing agricultural ore	5.87	1.16	24.6
11. SS 160 t/ha + zeolite-containing agricultural ore	6.28	1.57	33.3
12. SS 180 t/ha + zeolite-containing agricultural ore	6.33	1.62	34.4
NSR_{05}		0.24	

Source: Compiled by the authors on the basis of the results obtained

The content of gluten in the grain of winter wheat in the control variant was 22.4%. A significant increase in the gluten content against the background of a one-sided aftereffect of urban sewage sludge was noted in variants with aftereffect of sludge at rates of 120-180 t/ha. The content of gluten in the grain against the background of their aftereffect varied from 23.6 to 26.0%, exceeding the control by 1.4-3.6%.

The aftereffect of SS in combination with zeolite-containing agro-ore significantly increased the gluten content in winter wheat grain by 1.8-4.7%. The content of gluten against the background of their aftereffect varied in the range from 24.2 to 27.1%.

In the conditions of 2021, the yield of corn grain in the variant without the use of urban sewage sludge and zeolite-containing agricultural ore was 4.82 t/ha. Against the background of a unilateral aftereffect of the zeolite-containing agro-ore, the yield of corn grain was 5.19 t/ha, exceeding the control by 0.37 t/ha, or 7.6% (Table 3).

Table 3. Productivity of corn hybrid Ladoga 191 MB

Indicator	Yield (t/ha)	Deviation from control	
		t/ha	%
1. Without SSUW and zeolite-containing agro-ore (control)	4.82	-	-
2. Zeolite-containing agro-ore	5.19	0.37	7.6
3. SSUW 100 t/ha	5.22	0.40	8.3
4. SSUW 120 t/ha	5.47	0.65	13.5
5. SSUW 140 t/ha	5.66	0.84	17.4
6. SSUW 160 t/ha	5.93	1.11	23.0
7. SSUW 180 t/ha	5.96	1.14	23.6
8. SSUW t/ha + zeolite-containing agricultural ore	5.69	0.87	18.0
9. SSUW 120 t/ha + zeolite-containing agricultural ore	5.90	1.08	22.4
10. SSUW 140 t/ha + zeolite-containing agricultural ore	6.00	1.18	24.5
11. SSUW 160 t/ha + zeolite-containing agricultural ore	6.47	1.65	34.2
12. SSUW 180 t/ha + zeolite-containing agricultural ore	6.68	1.76	36.5
NSR_{05}		0.36	

Source: Compiled by the authors on the basis of the results obtained

The yield of corn grain against the background of a one-sided aftereffect of SS with dose from 100 to 180 t/ha varied in the range from 5.22 to 5.96 t/ha, exceeding the control by 0.40-1.14 t/ha, or by 8.3-23.6%.

The aftereffect of urban sewage sludge in combination with zeolite-containing agro-ore increased the yield of corn grain by 0.87-1.76 t/ha, or by 18.0-36.5%. The maximum yield of corn grain was obtained against the background of the aftereffect of urban sewage sludge at rates of 160 and 180 t/ha, both in pure form and in combination with zeolite-containing agricultural ore.

The yield of corn grain against the background of one-sided aftereffect of urban sewage sludge with norms of 160 and 180 t/ha was 5.93-5.96 t/ha, and in combination with zeolite-containing agricultural ore 6.47-6.68 t/ha, exceeding the control in in the first case by 23.0-23.6%, in the second by 34.2-36.5%.

The results of the study showed that the unilateral aftereffect of SS and their aftereffect in combination with zeolite-containing agro-ore had a positive effect on the protein content in corn grain.

In corn grain without the use of SS and zeolite-containing agricultural ore, the protein content was 8.91%, and its collection was 429.5 kg/ha. Against the background of a one-sided aftereffect of zeolite-containing agro-ore, the protein content in corn grain was 9.22%, and its collection was 478.5 kg/ha. The deviation from the control in the first case was 0.31%, and in the second one was 49.0 kg/ha.

The aftereffect of SS, depending on their dose, increased the protein content in corn grain by 0.43 (SSUW 100 t/ha) - 1.00% (SSUW 180 t/ha), protein collection by 58.0- 161.1 kg/ha. The protein content in the unilateral aftereffect of urban sewage sludge varied from 9.34 (SSUW 100 t/ha) to 9.91% (SSUW 180 t/ha), and its collection from 487.5 to 590.6 kg/ha.

The protein content in corn grain against the background of the aftereffect of SS in combination with zeolite-containing agricultural ore varied from 9.50 (SSUW 100 t/ha + zeolite-containing agricultural ore) to 10.21% (SSUW 180 t/ha + zeolite-containing agricultural ore), significantly exceeding control by 0.59-1.30%.

The content of protein in these variants of the experiment varied from 540.6 to 682.0 kg/ha. The increase in relation to the control was of 111.1-252.5 kg/ha, or 25.9-58.8%.

CONCLUSIONS

From the above, it follows that the most significant impact on the yield of Jackpot peas, winter wheat Moskovskaya 56, maize hybrid Ladoga 191 MV, protein and gluten content, and the collection of digestible protein had a complex aftereffect of urban sewage sludge with zeolite-containing agricultural ore.

The aftereffect of increased norms of urban sewage sludge in combination with zeolite-containing agro-ore increased the yield of peas by 48.9-49.8%, the protein content in pea grain - by 1.2-2.7%, the yield of winter wheat by 33.3-34%. 4%, gluten content in winter wheat grain - by 4.5-4.7%, corn grain yield - by 34.2-36.5%, protein harvest - by 227.1-252.5 kg/ha.

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YIELD RESPONSE OF TWO *Camelina sativa* VARIETIES UNDER DIFFERENT FERTILIZATION IN WESTERN PART OF ROMANIA

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Abstract

Due to the recent changes of the climatic conditions, new crops emerged and were taken into consideration by farmers all around the world. One such crop is Camelina sativa from the Brassicaceae botanical family which gained its attention due to the high oil content and balanced fatty acid ratio. In Romania, being a non-traditional crop, Camelina lacks a specific cultivation technology adapted to local pedo-climatic conditions. Although Camelina is not a pretentious crop, the yield response to fertilization is significant and that's what this paper covers. The experimental field was situated in the western part of Romania and we followed the yield response of two Camelina varieties under different fertilization schemes. The obtained results ensure the statistical significance of the positive yield variation of Camelina under different fertilization.

***Key words**: camelina, crop, fertilization, technology.*

INTRODUCTION

For the last decades, *Camelina sativa* is in the spotlight of the science community, and can be considered an emerging crop worldwide due to high interest in its oil (Zanetti et al., 2021; Carciumaru, 2007; Laurentiu et al., 2018; Zubr, 1997; Séguin-Swartz et al., 2009). The fatty acid composition of camelina oil ensures both industrial and feed utilization of its seeds. (Imbrea et al., 2017). Camelina oil is high on linoleic and α-linolenic acid and it has an almost 1:1:1 ratio of omega-3, omega-6 and omega-9 fatty acids (Angelini et al., 2020; Imbrea et al., 2011; Gesch et al., 2011; Malhi et al., 2014; Zubr, 2003; Meunier et al., 2016) thus showing antimicrobial properties (Batrina et al., 2021). Furthermore, camelina also has a good ratio of essential and non-essential amino acids (Batrina et al., 2020). Camelina has little economic importance but it can be a good alternative to the commonly grown oilseed rape (Jarecky, 2021) due to the possibility of growing it on low performance lands and marginal lands with a minimum of fertilisation inputs (Von Cossel et al., 2019; Wittenberg et al., 2019; Wysocky et al., 2013) and almost no pesticides due to its natural resistance to pathogens (Jiang et al., 2016).

This study aims to point out the influence of fertilization schemes on Camelina seed.

MATERIALS AND METHODS

The experiment set was bifactorial one, with three repetitions, with the following graduation of the experimental factors:

1. Factor A - Camelina variety/hybrid
a1 - Madalina
a2 - Calena
2. Factor B - Fertilization
b1 - $N_{45}P_{45}K_{45}$
b2 - $N_{66}P_{57}K_{45}$ + $24SO_3$ + 7CaO + 2Mg + 0.1 B +0.15 Zn
b3 - $N_{101}P_{78}K_{45}$ + $48SO_3$ + 14CaO + 4Mg + 0.2 B +0.3 Zn

The soil on which the camelina experiment was placed is a molic preluvosol, a soil characteristic of the studied area, having the largest share in the agricultural land of Bocsig Administrative Territorial Unit.

The analyses were performed in the Agrochemistry laboratory of USAMVBT and

the results indicated humus content between 1.52-3.54% showing an average supply of organic matter; the values being specific to a molic preluvosol.
The soil reaction was moderately acidic to neutral with pH values ranging from 5.57 in the A horizon to 7.16 in the B/C horizon. The nitrogen index varies between 2.04 and 3.08, being closely dependent on the humus content. The supply of mobile phosphorus is low with values ranging between 2.6-13 ppm, thus explaining the need to apply phosphorus fertilizers. The soil under study has a medium supply of mobile potassium with values ranging between 128-184 ppm. The degree of saturation of bases (V%) is high, especially in the lower horizons and oscillates within the range 84.3-91.8%.
In conclusion, the soil identified on which the experiment was carried out has a series of favourable chemical properties, like having a medium fertility so in order to achieve the full potential of production, it requires a series of agrochemical and agrotechnical measures to positively modify the physical and chemical properties.
The climatic conditions analysis of the studied area was made based on the interpretation of the data recorded at the Arad Meteorological Station within INMH Bucharest network.
The territory of Bocsig village can be characterized by a moderate- temperate continental climate, with shorter and milder winters, the value of average annual temperatures is over 10ºC with the passage of the average temperature through the threshold of 5ºC (which is the biological threshold for most crops) between March 12-18.
The soil works consisted of performing plowing in the autumn at a depth of 30-35 cm, and the preparation of the germination bed was done with a milling cutter, thus fulfilling an essential condition for the establishment of the camelina culture; that of having prepared a gardenly germination bed. The sowing was done as fast as possible in the the spring, in order to get the best yields (Righini et al., 2019) in close rows: with the distance between the rows at 12.5 cm, with an "Accord" seed drill.
The basic fertilization was done with 300 $kg \cdot ha^{-1} N_{45}P_{45}K_{45}$ before sowing alongsidethe preparation of the germination bed. The next fertilization was done when the plants reached the rosette stage and consisted in the application of Eurofertil NPS complex fertilizer produced by Timac Agro in a dose of $100 kg \cdot ha^{-1}$ and $200 kg \cdot ha^{-1}$ respectively, so that the variants are fertilized according to the field sketch.
NPS 56 fertilizer produced by Timac Agro is a complex fertilizer with an active substance content of $21N + 12P_2O_5 + 24SO_3 + 7CaO + 2Mg + 0.1\ B + 0.15\ Zn$.

RESULTS AND DISCUSSIONS

The results from the experimental cycle 2018-2020, from Bocsig (Table 1) shows that both, the variety and the fertilization treatments, respectively the interaction of these two factors had a considerable influence, statistically assured, on camelina yield. Climatic conditions also had the highest contribution to production variability (39.99%).
The combinations of macroelements and microelements had a significant contribution to the variability of production (30.78%), superior to the effect of the variety (21.27%). Also, the combined effect of the two factors showed a significant influence (0.96%), but considerably less than their separate effects.
At the experience level, the results obtained were influenced to a small extent (3.91%) by other sources of variation not included in the experimental device.

Table 1. Variance analysis for the effect of variety and fertilization on camelina yield at Bocsig during 2018-2020

Source of variation	SP	GL	S2	Test F
The total	2229235	53		
Repetition	820	2	410	0.51
Years	435867	2	217933	271.73 **
Error years	32087	4	802	
Variety	238722	1	238722	144.51 **
Years x Varieties	38540	2	19270	11.66 **
Variety error	9912	6	1652	
Fertilization	1275581	2	637791	209.14 **
Years x Fertilizers	68621	4	17155	5.63 **
Varieties x Fertilizers	39912	2	19956	6.54 **
Years x Varieties x Fertilizers	44862	4	11216	3.68 *
Fertilization error	73189	24	3050	

Comparing the suitability of agricultural years for camelina cultivation (Table 2), it can be observed that the highest yield was registered in 2019 compared to 2018, corresponding to a significant increase in yield value of 87 kg·ha^{-1}, equivalent to 4.34%. In 2020 there was a negative increase in production compared to the previous year and the first year of experience.

Table 2. The yearly average yields for camelina recorded at Bocsig in 2018

Years	Yield (kg ha^{-1})		Percent (%)	Difference/ meaning
2019-2018	2093	2006	104.34	87 ***
2020-2018	1874	2006	93.42	-132000
2020-2019	1874	2093	89.54	-219000

DL5% = 26 kg·ha^{-1} DL1% = 44 kg·ha^{-1} DL0.1% = 81 kg·ha^{-1}

The behavior of the tested varieties (Table 3) shows that during this period, at the level of the whole experience, the Madalina variety achieved a significantly higher yield by 133 kg·ha^{-1}, associated with an increase of 6.91% compared to the Calena variety whose average yield was of 1924 kg·ha^{-1}.

Table 3. The average yields for camelina varieties studied at Bocsig during 2018-2020

Variety	Yield (kg ha^{-1})		Percent (%)	Difference/ meaning
Madalina-Calena	2057	1924	106.91	133 ***

The yield results of camelina under the effect of different combinations of macroelements and microelements (Table 4) showed an amplitude of 372 kg·ha^{-1}, withlimits from 1788 kg·ha^{-1} in the case of the$N_{45}P_{45}K_{45}$ variant and up to 2160kg·ha^{-1} for the $N_{101}P_{78}K_{45}$ variant supplemented with microelements.
Considering the multiple comparisons between the treatments in terms of seed yield , it can be observed that the variant, $N_{101}P_{78}K_{45}$ supplemented with microelements had a significantly higher efficiency than the other two combinations, materialized with an increases between 6.72% compared to the variant $N_{66}P_{57}K_{45}$ and 20.81 % compared to $N_{45}P_{45}K_{45}$ without microelements. Also, the application of the $N_{66}P_{57}K_{45}$variant with microelements showed an increase of seed yield by 13.20% compared to the simple fertilisation variant $N_{45}P_{45}K_{45}$.

Table 4. Average yields for fertilization treatments studied at Bocsig during 2018-2020

Fertilization	Yield (kg ha^{-1})		Percent (%)	Difference / Significance
B2-B1	2024	1788	113.20	236 ***
B3-B1	2160	1788	120.81	372 ***
B3-B2	2160	2024	106.72	136 ***

DL5% = 38 kg·ha^{-1} DL1% = 52 kg·ha^{-1} DL0.1% = 69 kg·ha^{-1}
B1 -$N_{45}P_{45}K_{45}$;
B2 - N66P57K45 + 24SO_3 + 7CaO + 2Mg + 0.1 B +0.15 Zn;
B3 - $N_{101}P_{78}K_{45}$ + 48SO_3 + 14CaO + 4Mg + 0.2 B +0.3 Zn

Comparing the suitability of the experimental years 2018 - 2020 in terms of climate and variety on the yield of camelina seeds at Bocsig (Table 5, Figure 1) it is observed that in the case of the year 2020 the smallest difference between the 2 varieties was insignificant, while in the rest of the years the difference between the varieties is higher.

Table 5. The effect of camelina variety on yield at Bocsig during 2018-2020

Years	Variety			
	Calena	**Madalina**	$\bar{x} \pm s_{\bar{x}}$	S%
2018	y1950± 110 b	x2062± 130 b	2006 + 87	18.32
2019	y2000± 102 a	x2185± 122 a	2093 + 89	18.16
2020	y1823± 94 c	x1925± 106 c	1874 + 73	16.55
$\bar{x} \pm s_{\bar{x}}$	1924 + 64	2057 + 78	1991 + 53	
S%	17.22	19.81	18.67	

Year DL5%=37 kg·ha^{-1} DL 1%=53 kg·ha^{-1} DL 0.1% = 76 kg·ha^{-1}(a,b,c)
Varieties DL5%=47 kg·ha^{-1} DL 1%=71 kg·ha^{-1} DL 0.1%=114 kg·ha^{-1} (x,y)

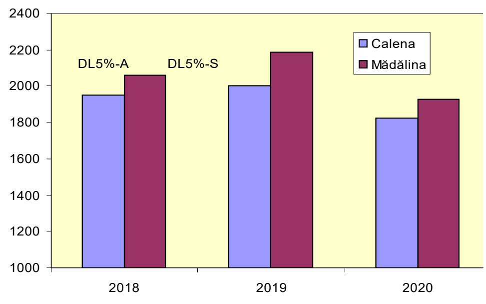

Figure 1. The yearly yield of camelina varieties recorded at Bocsig during 2018-2020

Given the combined effect of the agricultural year and the level of fertilization on camelina yieldat Bocsig in the period 2018-2020 (Table 6, Figure2) it is observed that the production differences between the agricultural year 2018 and 2020 related to the level of fertilization B1 are significant.

A significantly difference inyield increase was also recorded in 2019. For the higher levels of fertilization, there are significant differences of yield between years, the highest being in 2019 for both fertilization variants.

Table 6. Effect of fertilization treatment on camelina yield at Bocsig during 2018-2020

Years	Fertilization				
	B1	B2	B3	$\bar{x} \pm s_{\bar{x}}$	S%
2018	z1805± 30 b	y1996± 64 b	x2217± 60 a	2006 + 87	18.32
2019	z1878± 74 a	y2149± 78 a	x2251± 104 a	2093 + 89	18.16
2020	z1682± 36 c	y1927± 64 c	x2013± 42 b	1874 + 73	16.55
$\bar{x} \pm s_{\bar{x}}$	1788 + 48	2024 + 58	2160 + 64	1991 + 53	
S%	11.36	12.26	12.70	18.67	

Year DL5%=57 kg·ha^{-1} DL 1%=77 kg·ha^{-1} DL 0.1%=102 kg·ha^{-1}(a,b,c)
Fertilization DL5%=66 kg·ha^{-1}DL 1% = 89 kg·ha^{-1} DL 0.1%=120 kg·ha^{-1} (x,y,z)

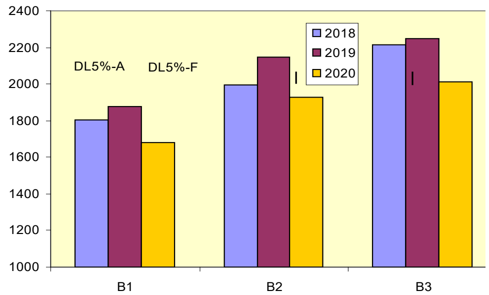

Figure 2. Yearly yield of fertilization treatments recorded at Bocsig during 2018-2020

Analyzing the cross effect of fertilizer and variety in the period 2018-2020 at Bocsig on the yield of camelina seeds (Table 7, Figure 3) it is observed that in the case of fertilization with $N_{45}P_{45}K_{45}$ the smallest difference betweenvarieties was registered while on the background of application of microelements supplemented treatments the difference between the yield potential of the varieties was more obvious, being higher for the Madalina variety.

Table 7. The effect of variety and fertilization on camelina yield at Bocsig during 2018-2020

Variety	Fertilization				
	B1	B2	B3	$\bar{x} \pm s_{\bar{x}}$	S%
Calena	z1741 + 48 b	y1948 + 60 b	x2084 + 58 b	1924 + 64	17.22
Madalina	z1836 + 68 a	y2100 + 70 a	x2237 + 92 a	2057 + 78	19.81
$\bar{x} \pm s_{\bar{x}}$	1788 + 48	2024 + 58	2160 + 64	1991 + 53	
S%	11.36	12.26	12.70	18.67	

Varieties DL5%=49 kg·ha^{-1} DL 1%=66 kg·ha^{-1} DL 0.1%=87 kg·ha^{-1} (a,b)
Fertilization DL5%=54 kg·ha^{-1} DL 1%=73 kg·ha^{-1} DL 0.1%=98 kg·ha^{-1} (x,y,z)

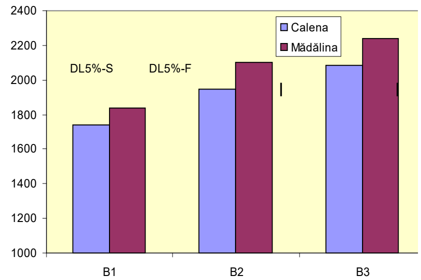

Figure 3. Yields of camelina varieties under different fertilization schemes at Bocsig during 2018-2020

CONCLUSIONS

The results from the experimental cycle 2018-2020 obtained in the experimental field at Bocsig, show that both variety and fertilization schemes, respectively the interaction of these two factors had considerable influences, statistically assured on the yield of camelina seeds.
Climatic conditions also had a high contribution to the yield variability of 39.99%.
The combinations of macroelements and microelements had a significant contributionof 30.78% to the yield, higher than the effect of the variety of 21.27%.
The combined effect of the two factors also showed a considerably lower influence than their separate effects on the level of camelina yield.
The highest seed yield was obtained in the $N_{101}P_{78}K_{45}$ supplemented with microelements variant, with a 6.72% increase compared to the $N_{66}P_{57}K_{45}$ variant and 20.81% compared to the $N_{45}P_{45}K_{45}$ variant without microelements.
The combined effect of fertilization and variety on camelina seed yield highlights that in the case of the $N_{45}P_{45}K_{45}$variant the smallest difference between the varieties was registered, while on the background of the application of some treatments supplemented with microelements, the difference between the yield potential of the varieties was more obvious, being higher for the Madalina variety.

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AGRO-ECOLOGICAL ZONING OF SUNFLOWER HYBRIDS IN PENZA REGION, RUSSIA

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Abstract

The paper presents the materials obtained as a result of the environmental assessment of sunflower hybrids. This rating is used for recommendations for optimal cultivation regions and active introduction of sunflower varieties and hybrids into production. As a rule, environmental assessment is carried out on the basis of the parameters of environmental plasticity and stability. The aim of the research was the agro-ecological zoning of the following sunflower hybrids NK Roki (Syngenta) – St; NK Kondi (Syngenta); NK Brio (Syngenta); Sumiko (Syngenta); ES Amis (Euralis); ES Florimis (Euralis); P64LE25 (Pioneer); P64LE20 (Pioneer); P64LE99 (Pioneer) in the conditions of the Penza region. The soil of the experimental plot is leached chernozem, heavy loamy in terms of granulometric composition. Humus content - 6%, nitrogen 82-86 mg per1 kg soil, phosphorus - 80-110 mg and potassium 110-140 mg per1 kg soil, pH-6.0-6.2. The predecessor of sunflower is spring wheat, after its harvesting, disk stubble plowing was carried out, then autumn plowing was carried out to a depth of 28-30 cm. The weather conditions during the research were different. The amount of precipitation during the growing season ranged from 92.3 mm up to 217.1 mm, and the sum of positive temperatures (above +10°C) ranged from 2115.9°C (HTC = 1.0) to 2365.1°C (HTC = 0.39). The duration of the growing season is 119-135 days, field germination ranges from 90.1% to 92.7%. The sparseness of sunflower crops is 1.7-5.2%. The highest yield was recorded in the hybrid NK Roki-St (2.48 t/ha), and the lowest in the hybrid P64LE25 (2.35 t/ha). Oil content in sunflower hybrids ranged from 49.9% to 50.7%, *with a profitability level of 42.7% (hybrid NK Rocki-St) to 29.1% (hybrid P64LE25).*

Key words*: sunflower, hybrids, agro-ecological zoning, productivity, oil content.*

INTRODUCTION

To date, the most urgent problem is the supply of food to the population, because the population is growing rapidly. In solving this problem, oilseeds occupy a priority place. (Bruniard et al., 2001; Balov, 2003; Gromov et al., 2006; Belyakov et al., 2008; Fernandez-Martinez et al., 2008; Joita-Pacureanu et al., 2010; Gorshenin et al., 2012; Kaya, 2014; Gryazeva et al., 2020; Koryagin et al., 2020; Koryagin, Kulikova et al., 2020).

The main oilseed crop grown in Russia is sunflower. Sunflower is the main crop for the production of vegetable oil, belongs to the group of the most valuable and highly profitable crops, which plays an important role in creating a strong economy for agricultural enterprises. Sunflower belongs to the type of crops in which the entire above-ground mass is used as a raw material for such industries as oil and fat, food, chemical, pharmaceutical, paint and varnish, soap and others. Sunflower seeds contain up to 50-55% fat and 20-25% protein. The vegetable oil obtained from them has nutriational advantages. High-quality margarines, vegetable fats, mayonnaises, paints and varnishes are obtained from it. Sunflower oil contains semi-saturated fatty acids, vitamins (A, D, E) and other biologically active, substances vital for human health. Sunflower cake and meal, by-products of seed processing, are valuable animal feed. Sunflower baskets can be used as additional feed for livestock. Sunflower is used as a silage crop. Its nutriational value is average. Sunflower is a good honey plant that could give 20-30 kg of honey per hectare. The center of sunflower origin is the steppe part of North America (Fomin et al., 2001; Rymar et al., 2004; Kolomeychenko, 2007; Pleskachev et al., 2013; Khaibullin et al., 2013; Makoveev et al., 2015; Stolyarov et al., 2015; Chudakov, 2015; Pirogovskaya et al., 2016; Puzikov et al., 2016; Gryazeva et al., 2020).

In Russia, its main areas (80%) are concentrated in the North Caucasus, in the Rostov region, the Central Black Earth region, the Middle and Lower Volga regions. On a small scale, it is cultivated in the Urals. As early maturing varieties and hybrids are obtained, new methods of agricultural technology are developed, sunflower is gradually moving into the Non-Chernozem regions, as well as into Eastern Siberia and the Far East (Shekhovtsov et al., 2012; Gulidova et al., 2016; Depar et al., 2018; Detsyna et al., 2019; Suvorov, 2019).

Due to the wide use of sunflower, its crops are located on a vast territory of the globe and in Russia. Worldwide, sunflower areas now amount to more than 27 million hectares. In the Russian Federation, the area under crops is more than 6 million hectares. The yield of this crop in the world is 17.8 c/ha, in Russia 12.3 c/ha (Alabushev, 2011; Kholghi, 2011; Gulidova et al., 2016; Khan, 2017; Depar et al., 2018; Volgin et al., 2019; Detsyna et al., 2019; Suvorova, 2019).

The purpose of the work is an agronomic assessment of hybrids from various manufacturers: Syngenta, Eurolighting, Pioneer and their technological advantages (yield and oil content) in the soil and climatic conditions of the Penza region.

MATERIALS AND METHODS

The research was carried out by organizing experiments in 2017-2019 in the conditions of the agricultural entity "Kamenskoye" in the village Mochaleyka of the Penza region (Russia). In the current research, the following sunflower hybrids NK Roki (Syngenta) – St; NK Kondi (Syngenta); NK Brio (Syngenta); Sumiko (Syngenta); EC Amis (Euralis); EC Florimis (Euralis); P64LE25 (Pioneer); P64LE20 (Pioneer); P64LE99 (Pioneer).

The soil of the experimental plot is leached chernozem, heavy loamy in terms of granulo-metric composition. Humus content - 6%, nitrogen 82-86 mg per 1 kg of soil, phosphorus - 80-110 mg and potassium 110-140 mg per 1 kg of soil, pH-6.0-6.2.

The predecessor of sunflower was spring wheat, after its harvesting, disk stubble plowing was carried out, and then autumn plowing was carried out to a depth of 28-30 cm. In the spring, at the onset of the physical ripeness of the soil, harrowing was carried out. Further, pre-sowing cultivation was carried out to the depth of sowing and sowing with a seeding rate of 70 thousand seeds per hectare, to a depth of 6-7 cm. Row spacing -70 cm, butt spacing 70 cm (+/- 5cm). Sowing was carried out in 2017 - April 26, in 2018 - May 3, in 2019 - April 28. In sunflower plants grown according to the classical technology, inter-row cultivation was carried out with row cultivators. Sunflower plants grown using the Clearfield technology were subjected to Eurolighting herbicide treatment with a rate of 1.2 l/ha in the phase of two pairs of true leaves, and sunflower plants grown using the Express technology were subjected to one herbicide treatment with a rate of 50 g/ha. Sunflower harvesting was carried out at a seed moisture content of no more than 10-12%, i.e. at the onset of technical ripeness of seeds on a daily basis with subsequent weighing of grain. Yield data were processed by the mathematical method of disperse analysis and according to the methodology of the state variety testing of agricultural crops (Methodology of state variety testing of agricultural crops/State Commission for Variety Testing of Agricultural Crops under the Ministry of Agriculture of the USSR, 1983; Kulikova et al., 2019; Koryagina et al., 2020; Koryagin et al., 2021).

RESULTS AND DISCUSSIONS

The weather conditions during the research period (2017-2019) were different. In 2017, during the growing season of sunflower, 217.1 mm fell (98.5% of the norm), which is 3.2 mm below the norm. Precipitation during the growing season was unevenly distributed (Table 1).

In May, they fell out (since the 2nd decade) - 23.1 mm, which is 4.9 mm below the norm. In June, 56.8 mm fell, which is 8.2 mm below the norm (87.3% of the norm). In July, 83.9 mm fell, which is 24.9 mm higher than the norm (142% of the norm), which had a favorable effect on the growth of sunflower, given that at that time it was in the budding-flowering phase. In August, 11.7 mm fell, which is 39.3 mm below the norm (22.9% of the norm). In September (1st decade), 41.6 mm fell, which is 24.3 mm higher than the norm.

Table 1. Precipitation for the period 2017-2019 (mm)

Years	Decades	Months					
		pri	May	Jun	Jul	ugu	te
2017	1	15.2	2.2	14.1	55.8	1.8	41.6
	2	22.6	16.9	19.1	14.2	0.3	6.9
	3	16.0	6.2	23.6	13.9	9.6	2.6
	∑ per month	53.8	25.3	56.8	83.9	11.7	51.1
2018	1	12.0	3.0	7.4	42.3	13.3	0.0
	2	10.9	0.8	0.0	12.1	0.0	1.0
	3	43.0	6.7	0.0	6.7	3.0	20.6
	∑ per month	65.9	10.5	7.4	61.1	16.3	21.6
2019	1	10.0	10.6	2.6	18.8	55.0	2.0
	2	6.0	4.3	0.9	21.3	1.8	19.3
	3	0.0	12.0	20.0	5.0	2.0	11.7
	∑ per month	16.0	26.9	23.5	45.1	58.8	33.0

Source: own calculations

In 2018, during the growing season of sunflower, 92.3 mm fell, although the distribution of precipitation by months was uneven. In June, the amount of precipitation amounted to 7.4 mm, which fell in the 1st decade of June, the 2nd and 3rd decades of the month were without rain. The amount of precipitation was below the norm by 57.6 mm, which negatively affected the growth of sunflower. In July, 61.1 mm fell, which is 2.1 mm higher than the norm, which created favorable conditions for the growth of sunflower, although the distribution of precipitation over decades was uneven, in the 1st decade 42.3 mm fell, in the 2nd 12.1 mm, and in the 3rd decade 6.7 mm. In August, a total of 16.3 mm of precipitation fell, which is 34.7 mm below the norm (31.9% of the norm). There was no precipitation in the first decade of September.

2019 was characterized by uneven distribution of precipitation. During the growing season of sunflower, the amount of precipitation amounted to 145.7 mm, which is below the norm by 74.6 mm or 66.1% of the norm. In June, the largest amount of precipitation fell in the 3rd decade - 20.0 mm, in the 2nd decade - 0.9 mm, in the 1st decade - 2.6 mm. As a result, the amount of precipitation in June amounted to 23.5 mm, which is 41.5 mm below the norm. (36.1% of the norm). In July, 45.1 mm fell, which is 13.9 mm below the norm. The greatest amount of precipitation fell on the 2nd decade of July 21.3 mm, on the 1st decade 18.8 mm, and in the 3rd decade only 5.0 mm of precipitation fell. The largest amount of precipitation during the growing season of sunflower was characterized by August, where 58.8 mm of precipitation fell, which is 7.8 mm above the norm. The bulk of precipitation fell in the 1st decade of August, in the amount of 55.0 mm, which had a beneficial effect on sunflower, because at this time it was in the flowering phase. The least and insignificant amount of precipitation fell in the 2nd and 3rd decades in the amount of 1.8 and 2.0 mm. In September (1st decade), 2.0 mm fell, which is 15.3 mm below the norm.

In 2017, during the growing season of sunflower, the sum of positive temperatures was 2115.9°C, which is quite favorable. In May, the average monthly temperature was 13.9°C, which is -0.4°C below the norm. Of the summer months, August was characterized by the highest average daily temperature, where the average daily temperature was +20.3°C, which is +2°C above the norm. The lowest average daily temperature in June was +15.8°C, which is 2.7°C below the norm. In July, the average daily temperature was +19.5°C, which is almost normal. In September (1st decade), the average daily temperature was +14.3°C, which is 1.8°C above the norm.

In 2018, the sum of positive temperatures during the growing season was 2365.1°C. In May, the average monthly temperature was +16.6°C, which is +2.3°C above the norm. In June, the average monthly temperature is + 17.8°C, which is 0.7°C below the norm. (Table 2).

Table 2. Temperature for the period 2017-2019 (°C)

Years	Decades	Months					
		pri	May	Jun	Jul	ugu	te
2017	1	4.6	16.2	13.8	17.2	21.4	14.3
	2	5.6	10.4	16.2	20.1	20.6	16.7
	3	8.8	15.3	17.5	21.4	19.0	8.2
	∑ per month	6.3	13.9	15.8	19.5	20.3	13.0
2018	1	3.5	17.6	13.2	21.5	21.2	18.9
	2	6.7	17.2	16.7	22.5	19.8	17.2
	3	7.2	15.1	23.6	21.7	19.1	11.7
	∑ per month	5.8	16.6	17.8	21.9	20.0	15.9
2019	1	4.2	15.2	21.1	18.0	14.7	14.5
	2	8.0	18.5	20.3	19.0	20.2	13.1
	3	11.3	18.0	20.2	20.0	16.6	5.9
	∑ per month	7.8	17.2	20.5	19.0	17.1	11.1

Source: own calculations

The 3rd decade of June was characterized by the greatest amount of heat, where the temperature was +23.6°C, and the 1st decade was marked by a lower temperature of

+13.2°C. July was characterized by the highest average monthly temperature, +21.9°C, which is +1.5°C above the norm. The average monthly temperature in August was also above the norm and amounted to +20.0°C, which is 1.7°C above the norm. In September (1st decade), the average temperature for the decade was +18.9°C, which exceeds the norm by 6.4°C.

In 2019, the sum of positive temperatures during the growing season was 2267.9°C. In May, the average monthly temperature was +17.2°C, which is 2.9°C higher than the norm. In June, the average daily temperature was +20.5°C, which is +2°C higher than the norm; the 3 decades of June are characterized by the absence of sudden temperature changes. In July, the largest amount of heat fell on the 3rd decade of July, where the average temperature was +20°C, which corresponds to the norm, and the least amount of heat fell on the 1st decade, where the average temperature was +18°C. July is characterized by a gradual increase in temperatures from +18°C in the 1st decade of the month, +19°C in the 2nd decade, and +20°C in the third. As a result, the average monthly temperature was +19.0°C, which is 1.4°C below the norm. In August, the average monthly temperature was +17.1°C, which is +1.2°C below the norm. August is characterized by sharp temperature drops in decades, from +14.7°C (average) in the first decade. The main heat fell on the second decade of the month +20.2°C. The third decade occupied an intermediate position in the temperature regime, +16.6°C. In September, the 1st and 2nd decades were not characterized by sharp drops, but did not correspond to the norm +14.5 °C +13.1°C, which is below the norm by +3.8 and +5.2°C. And in the 3rd decade, the average air temperature dropped to +5.9°C. As a result, the average September temperature was +11.1 °C, which is +1.4°C below the norm which is below the norm by +3.8 and +5.2°C.

Thus, over the 3 years of the study, 2017 was characterized by the largest amount of precipitation during the growing season and amounted to 217.1 mm, and the sum of positive temperatures (above +10°C) was 2115.9°C (HTC=1.0).

In 2018, the amount of precipitation was the lowest in 3 years of research: 92.3 mm, and the sum of positive temperatures was 2365.1°C (HTC = 0.39)

In 2019, it occupied an intermediate position in terms of the amount of precipitation, which amounted to 145.7 mm during the growing season, and the sum of active temperatures was 2267.9° C (HTC = 0.64).

Research on the phenology of sunflower crops showed that the growing season of sunflower for three years of research ranges from 119-135 days. In 2017, the shorter growing season was characterized by the hybrids ES Amis - 124 days and NK Roki - 124 days, and the longest growing season was observed in the hybrid P64LE99 - 135 days.

In 2018, the longest growing season was observed for sunflower hybrids P64LE20 - 128 days and P64LE25 - 129 days, and the shortest growing season was for hybrids ES Amis - 118 days and NK Roki - 117 days.

In 2019, the shortest vegetation period was characterized by the ES Amis hybrid - 125 days and the NK Roki hybrid - 124 days, and the longest vegetation period was for sunflower hybrids P64LE20 and P64LE99 - 131 days and 132 days, respectively.

For three years of research, the average duration of the interphase period for cultivated sunflower hybrids from sowing to germination was 10 days, and only for hybrids ES Amis and NK Roki - 11 days. The duration of the interphase period from seedlings to the first pair of true leaves was 7 days, and for hybrids ES Amis and P64LE25 it was 6 days (Table 3).

The duration of the interphase period from the first to the seventh pair of leaves in the studied hybrids ranged from 32 to 37 days. The shortest period was characterized by hybrids: ES Amis, NK Roki, P64LE25 - 32 days, and the longest period was observed in hybrids: P64LE99 and P64LE20. For other hybrids, this interphase period was: 34-35 days. The duration of the interphase period from budding to flowering in all evaluated sunflower hybrids ranged from 18 to 21 days. The shortest interphase period of 18 days was recorded in the following hybrids: ES Amis, ES Florimis, Sumiko and P64LE25, and the longest interphase period of 20 days was typical for hybrids: NK Kondi, P64LE20 and P64LE99. The length of time between the flowering phase and the economic ripeness of sunflower is characterized by the longest interphase period for it, which ranged from 52 to 57 days. The following hybrids had the shortest interphase period: NK Roki - 52 days, and the longest hybrid P64LE99 - 57 days, and in the rest of the studied sunflower hybrids this period ranged from 55 to 56 days.

Table 3. Duration of interphase periods of plants of sunflower hybrids

Sunflower hybrids	Length of interphase periods (days)						
	sowing-seedlings	seedlings - 1 pair of leaves	1st pair of leaves-7pair of leaves	7 pair of leaves-budding	budding-blooming	flowering - economic ripeness	sprouts - economic ripeness
NK Rocki-St	11	7	32	1	19	52	122
NK Kondi	10	7	34	1	20	54	126
NK Brio	10	7	35	1	21	55	128
ES Amis	11	6	32	1	18	56	124
ES Florimis	10	7	34	1	18	55	125
Sumiko	10	7	34	1	18	55	125
P64LE25	10	6	32	1	18	56	123
P64LE20	10	7	37	1	20	56	131
P64LE99	10	7	37	1	20	57	132

Source: own calculations

As shown by our research on the study of field germination (Table 4), that during the period of research presented in the table of hybrids of sunflower plants, the average percentage of field germination ranged from 90.1 to 92.7%. The lowest field germination was in the EC Florimis hybrid (90.1%) and the P64LE99 hybrid (90.1%), and the highest field germination rate was in the NK Amis hybrid - 92.7%, in the remaining hybrids the field germination was within 90.4-91.9%.

Table 4. Completeness of seedlings and percentage of plants preserved for harvest

Sunflower hybrids	Germination (%)		plant density (thousand pieces/ha)		Thinness (%)
	laboratory	field	in the germination phase	before cleaning	
NK Rocki-St	96.8	90.5	58.374	57.399	1.7
NK Kondi	96.7	91.6	59.316	56.254	5.2
NK Brio	97.8	91.3	58.951	56.882	3.6
ES Amis	96.7	92.7	59.810	57.594	3.8
ES Florimis	97.2	90.1	58.175	56.968	2.1
Sumiko	97.8	90.6	58.450	56.930	2.7
P64LE25	96.8	91.9	59.332	57.870	2.5
P64LE20	97.5	90.4	58.349	56.857	2.6
P64LE99	96.9	90.1	58.125	56.485	2.9

Source: own calculations

The analysis of the standing density of sunflower plants in the germination phase showed that the highest plant density was recorded in the hybrid NK Amis - 59.810 thousand/ha, and the lowest density in the hybrid P64LE99 - 58125 thousand/ha, in other studied hybrids of sunflower plants, the density of standing ranged from 58.175 thousand/ha to 59.316 thousand/ha. The lowest standing density of sunflower plants in the phase before harvesting was in the P64LE25 hybrid - 57.870 thousand/ha, and the highest in the NK Kondi hybrid - 56.254 thousand/ha.

Our studies on the study of morphological features in sunflower hybrids in the phase of flowering and economic ripeness showed that the diameter of the basket in sunflower hybrids at the end of the budding phase was 8.2-8.8 cm, and at the end of the flowering phase it reached 19.9-21.0 cm hybrid NK Brio - 19.9 cm (Figure 1).

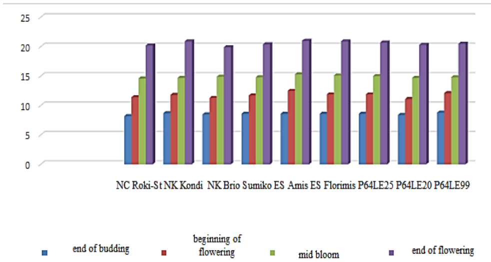

Figure 1. Budding growth dynamics

The total number of seeds in one bud in sunflower hybrids ranged from 870 pcs in a hybrid NK Rocky-St up to 906 pcs in a hybrid P64LE25 (Figure 2).

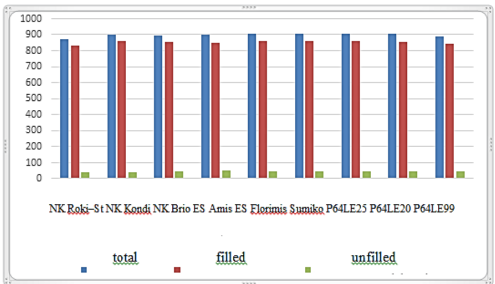

Figure 2. The number of seeds in one bud

The number of filled (fulfilled) seeds in one basket ranged from 829 pcs at the hydride NK Rocky - St before 861 pcs at the hydride Sumiko. The largest number of unfilled (empty) seeds in one basket was recorded in the following sunflower hybrids ES Amis (50.0PCS.), P64LE20 (47.0 pcs.) and P64LE99

(47.3 pcs.), and the smallest quantity is 39.3 pcs and 41.0 pcs in hybrids NK Kondi and NK Roki - St, respectively.
The average maximum weight of achenes per basket was 56.2 g in the Sumiko sunflower hybrid, and the smallest in the NK Roki sunflower hybrid was 53.3 g. In other sunflower hybrids, the weight of achenes from one basket was 55.2-56.0 g. The highest mass of 1000 seeds was in the sunflower hybrid Sumiko - 62.2 g, and the smallest in the sunflower hybrid NK Kondi - 60.9 g.
Increasing the yield of agricultural crops by a single increase in sown areas is not advisable, but should be carried out in search of new ways to increase the yield of sunflower. To do this, introduce into production sunflower hybrids with high yields. On average, over the three years of our research, the highest yield was recorded for the hybrid NK Roki St - 2.48 t/ha, and for other sunflower hybrids, the yield was 0.2-0.13 t/ha lower.
The highest yield over the three years of research has a hybrid - NK Roki - 2.48 t/ha, slightly lower in the hybrid NK Brio - 2.46 t/ha In 2019, the yield of the hybrid NK Amis compared to 2017 is higher by 0.06 t/ha, and in comparison with 2018 more by 0.12 t/ha. In 2019, the yield of the ES hybrid Florimis is higher by 1.1 t/ha compared to 2017, and lower by 0.01 t/ha compared to 2018. The yield of the NK Rocki hybrid in 2019 was higher by 0.03 t/ha compared to 2017, and compared to 2018 by 0.02 t/ha. The yield of the NK Kondi hybrid in 2019 is higher by 0.01 t/ha compared to 2017, and by 0.09 t/ha higher than in 2018. The yield of the hybrid NK Brio in 2019 is lower by 0.01 t/ha compared to 2017, and compared to 2018 is higher by 0.04 t/ha. The Sumiko hybrid had a maximum yield in 2019 - 2.52 t/ha, and the lowest in 2017 is 2.40 t/ha.
Thus, the yield of sunflower hybrids in 2019 was higher compared to 2018 and 2017.
The main product obtained from sunflower is vegetable oil, the quality of which depends on the oil content of the seeds. The oil content in sunflower, depending on the hybrids, ranged from 47-55%.
The average oil content in sunflower hybrids over the years of research was 49.9-50.5%. The following hybrids NK Rocky and ES Florimis had the highest oil content - 50.5%. The lowest oil content in the process of assessing sunflower hybrids was found in hybrids P64LE20 and P64LE99 - 49.9%.
The end result of growing agricultural products is economic efficiency, which is an indicator of the effectiveness of the measures taken in the cultivation of agricultural products. The efficiency of agricultural production is directly related to costs. Therefore, the efficiency of the resulting products will be high, only at low costs, and the final result that determines economic efficiency is always the level of profitability (Kholghi, 2011; Chalova, 2011; Titovskaya et al., 2018; Gryazeva et al., 2020).
Calculations of the economic efficiency of growing sunflower hybrids for seed oil of various manufacturers in the soil and climatic conditions of the Penza region showed that the highest conditionally net income was 16844.0 rubles/ha for the sunflower hybrid NK Rocki-St at a profitability level of 42.7%. The smallest conditionally net income (12015.0 rubles/ha) and the level of profitability (29.1%) were obtained from the P64LE25 sunflower plant hybrid, thus, compared with the hybrid NK Rocki-St, the conditionally net income was lower by 4829.0 rubles/ha at a profitability level of 13.6%.

CONCLUSIONS

When conducting an agronomic assessment of the cultivation of sunflower hybrids on the seed oil of various producers in the soil and climatic conditions of the Penza region, the following conclusion can be made that the duration of the growing season for hybrids was 119-135 days, field germination ranged from 90.1% to 92.7%. The highest field germination was recorded in the sunflower hybrid - ES Amis, and the lowest in the sunflower hybrid - Florimis. The sparseness of sunflower plantings was in the range of 1.7-5.2%. The smallest sparseness was in the sunflower hybrid - Rocki-St, which amounted to - 1.7%, and the highest sparseness of sunflower plantings in the hybrid - NK Kondi - 5.2%. The highest yield on average over three years of research was 2.48 t/ha for the sunflower hybrid Roki-St, and the lowest for the P64LE25 sunflower hybrid was 2.35 t/ha. The oil content in sunflower hybrids ranged from 49.9% to 50.7%. The highest oil content of sunflower achenes in the hybrid NK Kondi (50.7%), and the lowest oil content of achenes were recorded in the sunflower hybrid P64LE20. - 49.9% The highest net income was when growing sunflower hybrid Roki-St which amounted to 16844.0 rubles/ha, and the lowest net income was obtained from sunflower hybrid P64LE25, in the amount of 12015.0 rubles/ha. At the same time, the level of profitability for the sunflower hybrid Roki-St was 42.7%, and for the sunflower hybrid P64LE25 - 29.1%.

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CYTO-PALYNOLOGICAL OBSERVATIONS ON SOME PEA (*Pisum sativum*) GENOTYPES

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Abstract

The biological function of pollen grains in plants is to transfer the genetic material from the male to the female reproductive organ. Pollen viability has a particular importance because it allows knowing the value of a genotype as a pollinator in various interfertile combinations or artificial hybridization. Pea (Pisum sativum) has an impressive nutritional profile and is considered to be an essential food for the proper functioning of the human body, especially since it is an important source of protein. The purpose of this study was to evaluate the viability of pollen grains to some pea genotypes and the percentage of pollen germination on artificial substrate (in distilled water). The anthers were harvested in the advanced flower bud phase from four pea genotypes experimented at SCDA Caracal, University of Craiova. The results obtained showed a high viability of pollen grains in all four peas genotypes tested, with values between 95.36-98.55%. On the other hand, it was found that on the artificial medium, after 24 hours the germination percentage was reduced (39.25%), only a small part of the pollen tubes presenting the entire content expelled. This suggests that the rainfalls during peas flowering can negatively affect the germination of pollen grains, by diluting the stigmatic liquid. Regarding the length of the pollen tubes after 24 hours, it was found that, on the artificial medium, the values recorded were higher than on the stigma, the elongation rate having a more accentuated rate at the beginning of germination, after which there is a gradual decrease of this rate.

Key words: *pea, cyto-palynology, pollen grains, viability, germination.*

INTRODUCTION

Pollen is a mass of fine, generally yellowish powder, made up of numerous grains and located on the surface of the anthers. At plants, pollen is a male product of the reproductive organs, having the role of fertilizing the floral ovules, in order to transform them into fruits or seeds (Dahlhausen et al., 2020).

The pollen grain is a microspore, representing the male gametophyte, usually reduced to two unclosed cells, each with a haploid male nucleus (n): the generative nucleus and the vegetative nucleus. A pollen grain has microscopic dimensions (15-250 microns), and can have different shapes. The pollen grain consists of the exine (outer membrane, with characteristic relief for each species); intina (inner membrane, cellulosic, translucent); faviol (the cytoplasmic viscous mass in which the two nuclei float); generative nucleus (from which male gametes are formed); vegetative nucleus (which controls the activity of the whole grain) and pores. Through the pores on the surface of the exine are made the exchanges with the external environment and also here, the pollen tube will come out from inside the grain.

The formation of fruit at different species is influenced by genetic characteristics (including pollen and pollinators) and environmental conditions (Vuletin Selak et al., 2014; Bonciu, 2019; Paraschivu et al., 2019). The reproductive system of a plant can also be a key to its survival and to maintaining the genetic diversity of populations (Russo Godoy et al., 2018; Bonciu et al., 2021).

A systemic understanding of how agriculture, the economy and environmental health are interconnected is essential for identifying best practices available (Paraschivu et al., 2020; Durău et al., 2021; Paraschivu et al., 2021). This is all the more necessary after some periods with serious consequences in the economy, like pandemic crisis which has put a lot of pressure on agriculture in a number of ways (Paraschivu and Cotuna, 2021).

Pollen morphology could be useful as an identity element for clarifying the classification of many plant species (Sharafi, 2011; Khaleghi et al., 2019). Pollen preservation is a common practice in breeding work, especially when there is no agreement between the date of flowering on female and male inflorescences (Dinato et al., 2020). Mature pollen, able to withstand a high degree of dehydration, can be easily preserved at low temperatures without the prior cryoprotection (Kulus, 2019).

Pea (*Pisum sativum*) is an annual herbaceous legume from the *Fabaceae* family, cultivated for its edible seeds and pods. The root system is strong and penetrates into the soil up to 40-60 cm deep, but, if the soil allows, it can penetrate up to one meter. The stem is hollow inside and slightly branched. The leaves are pinnately compound, alternately arranged, consisting of 2-3 pairs of leaflets, the last leaflet being transformed into a prison. Flowering takes place 30-50 days after sowing, and on a plant, flowering lasts 10-25 days. The fruit is a pod, straight or arched with a length between 3 and 12 cm. Pea seeds are yellow or green in the dry state.

The flowers, white or slightly purple-reddish, are arranged in the underside of the leaves, one for the early varieties and 2-5 for the late ones. The corolla has a butterfly shape. The stamens - the male reproductive organs - in peas are 9 in number through their filaments and the 10th free. In the middle of the flower is the gynoecium which is monocarpic - the carpels are modified leaves and adapted to the function of multiplication.

Pea is unpretentious to vegetation factors, well-adapted to temperate climates. It is a drought-resistant plant, but requires higher amounts of water during flowering to grain formation.

Transfer of pollen grains from the anther to the stigma of same flower is known as autogamy or self-pollination. Autogamy is a type of self-pollination which is made by the union of two Greek words (*auto* and *gamy*). It means autogamy is the "self-union" in which female gamete ovule and male gamete pollen grain are united and fused to form zygote that comes from the same flower. Autogamy is the closest form of inbreeding and leads to homozygosity. Such species develop a homozygous balance and do not exhibit significant inbreeding depression.

Pea plants are naturally self-pollinating. In self-pollination, pollen grains from anthers on one plant are transferred to stigmas of flowers on the same plant. The pollination is done directly, the pollen reaching the stigmas of the same flower, but cross-pollination is not excluded, when the pollen passes from one flower to another, through wind, insects, water and under human action.

MATERIALS AND METHODS

The purpose of this study was to evaluate the viability of pollen grains to some pea genotypes and the percentage of pollen germination on artificial substrate (in distilled water).

The anthers were harvested in the advanced flower bud phase from four pea genotypes experimented at SCDA Caracal, University of Craiova, in the year 2021. The four pea varieties experimented were as follows: Omega, Tiara, Favorit and Lehel.

For this study, pollen was harvested from ripe pea flowers, for each genotype, in full bloom. The viability of the pollen was tested by responding to the staining with a 1% acetocarmin solution. The pollen germination was observed by being cultivated on an artificial substrate (distilled water), for 24 hours. Cyto-palynological observations were made at room temperature (22-24^{0}C).

The microscopic examination was performed under the LCD digital display microscope (Optika, Italy), using 40x and 100x objective. Five slides for each pea variety and 10 microscopic fields from each microscopic slides were analysed under microscope, so a total of 50 microscopic fields. From each microscopic field 10 pollen grains were examined (500 pollen grains in total for each genotype). In the chosen microscopic fields, on the one hand, there were examined the red coloured pollen grains, which have completely preserved their viability and on the other hand, there were those with partial viability, which coloured light red. Also, there were unviable, uncoloured pollen grains. The viability of the pollen is directly proportional with the reaction intensity of colouring with a acetocarmine solution.

Pollen viability was calculated as the number of viable pollen grains divided by the total number of pollen grains, expressed as a percentage.

The length of the pollen tubes was also determined using the ocular-micrometer in conventional units (micron-µ).

RESULTS AND DISCUSSIONS

In terms of climatic conditions, in the experimental year (2021) there were deviations of the monthly temperatures average compared to the multiannual average, especially in January, February and April (Table 1).
In April, May and June, the monthly temperatures averages were below the multiannual average.

Table 1. The evolution of the main climatic factors during the vegetation period of the pea genotypes tested at S.C.D.A. Caracal (2021)

Specification		I	II	III	IV	V	VI
T⁰C	Mmin	-12.1	-8.9	-7.3	-2.8	4.3	9.6
	Mmax	12.3	21.1	19.4	27.3	31.1	37.0
	Mavr	1.4	3.2	4.9	9.7	17.3	19.8
Pp mm	Mtot	98	29.6	92.4	32.6	55.6	102.8
	Mltavr	30.8	26.3	34.2	47.8	58.6	69.7
	Diff	+67.2	+3.3	+58.2	-15.2	-3.0	+33.1
H %	Avr	95.3	85.5	80.8	73.1	69.5	82.1
	Min	65.1	29.6	18.6	17.7	17.1	32.9

T = Temperature; Pp = Precipitations; H = Humidity; Mmin = Monthly minimum; Mmax = Monthly maximum; Mavr = Monthly average; Mtot = Monthly total, Mltavr = Multiannual average; Diff = Difference; Avr=Average; Min=Minimum

The flowering date for the tested pea genotypes is shown in Figure 1.

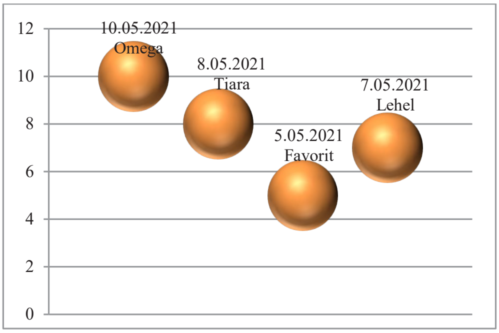

Figure 1. Date of flowering to some pea genotypes tested at S.C.D.A. Caracal (2021)

The pollen viability to pea genotypes tested at S.C.D.A. Caracal is showed in Table 2 and Figure 2. Thus, the highest value from this point of view was recorded by Omega genotype (98.55%), followed by Tiara (97.24%), Lehel (96.18%) and Favorit (95.36%).

Table 2. The pollen viability to pea genotypes tested at S.C.D.A. Caracal (2021)

Genotype	Npge	Nvpg	Nupg	Pollen viability (%)
Omega	500	493	7	98.55
Tiara	500	486	14	97.24
Favorit	500	477	23	95.36
Lehel	500	481	19	96.18

Npge=Number of pollen grains examined; Nvpg=Number of viable pollen grains; Nupg=Number of unviable pollen grains

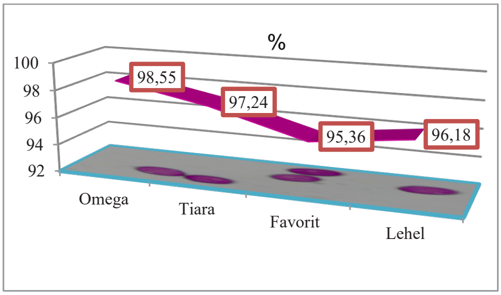

Figure 2. Graphical representation of pollen viability results in some pea genotypes

The results obtained showed a high viability of pollen grains in all four peas genotypes tested, However, as some authors suggest, even if pollen grains are viable, subsequent steps in pollination and fertilization may fail during heat. These heat sensitive steps are stigma receptivity of pollen, pollen grain retention on the stigma surfaces, successful pollen hydration, and pollen tube germination (Kaushal et al., 2016; Sita et al., 2017). Also, heat exposure negatively affected the pollen–pistil interaction at pea (Jiang et al., 2019).
Some climatic risk phenomena most oftenly limit the plant productivity (Ahmed et al. 1992; Hatfield and Prueger, 2015). Therefore, knowing the singular or cumulative effects of climate risks are the main criteria in the elaboration of a sustainable agricultural management (Paraschivu et al., 2015; Partal and Paraschivu, 2020).
Vital and nuclear colorations which indicate the presence of cytoplasm or enzymes are used to determine the viability of pollen (Nepi et al., 2005). Pollen germination can also be used as an indicator of viability.
The study of pollen grains has been the concern of many researchers since the last century. However, the interest for the pollen study is very evident from the works published in the last 10 years, works carried out with the most modern methods and which aim at the most

diverse aspects of cyto-palinology (Sita et al., 2017; Khaleghi et al., 2019; Dinato et al., 2020; etc.).

The generative growth of the pea plants and the increase of the biomass accumulation can be ensured by stimulating the fertility of the flowers, by increasing the percentage of fertile pollen grains and by the lengthening of the pollen tubes.

When several hundred pollen grains reach the stigma, each grain of pollen develops its own pollen tube in the stigmatic tissue. The fastest pollen tubes in terms of growth first reach the ovules and then fertilize them. Pollen grains with the fastest growing pollen tube carry genes that produce more vigorous offspring. Therefore, the growth rate of pollen tubes can establish a selective mechanism during early flowering (Figures 3,4).

Figure 3. Field images from SCDA Caracal (2021)

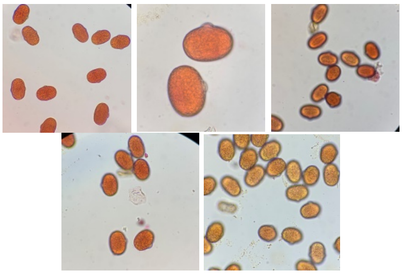

Figure 4. Microscopic aspects of cyto-palinologic studies at tested pea's genotypes

In terms of pollen germination and the length of the pollen tubes (Table 3), it was found that on the artificial medium, after 24 hours, the germination percentage was reduced (average 39.25%), only a small part of the pollen tubes presenting the entire content expelled. This suggests that the rainfalls during peas' flowering can negatively affect the germination of pollen grains, by diluting the stigmatic liquid. Regarding the length of the pollen tubes after 24 hours, it was found that, on artificial medium, the average values recorded were higher than on the stigma (842.72 μ versus 549.07 μ), the elongation rate having a more accentuated rate at the beginning of germination, after which there is a gradual decrease of this rate.

Table 3. The germination percentage and the length of the pollen tubes on the artificial growth medium versus stigma (average values after 24 hours)

Genotype	Pollen germination (%)	Length of the pollen tubes on the stigma (μ)	Length of the pollen tubes on the distilled water (μ)
Omega	41.2	618.3	985.4
Tiara	39.3	584.5	821.8
Favorit	37.6	473.4	693.2
Lehel	38.9	520.1	870.5
Average	39,25	549.07	842.72

CONCLUSIONS

Peas are in the group of foods known as legumes. Legumes are plants that produce pods with seeds or grains inside. Peas from harvested varieties at green maturity are used in human nutrition. At this stage, the beans are used fresh, in the form of pods (before seed formation), green/dried, frozen or canned grains and are usually combined with other foods.

The results obtained showed a high viability of pollen grains in all four genotypes of peas tested. Thus, the highest value from this point of view was recorded by the Omega genotype, followed by Tiara, Lehel and Favorit. The viability of the pollen was directly proportional with the reaction intensity of colouring with acetocarmine solution.

The pollen germination percentage on the artificial medium was reduced and only a small part of the pollen tubes showed the entire content expelled. This result suggests that the rainfalls during peas' flowering can negatively affect the germination of pollen grains, by diluting the stigmatic fluid.

The length of the pea pollen tubes was higher on the artificial medium (distilled water). From this point of view, the elongation rate having a more accentuated rate at the beginning of germination, after which there is a gradual decrease rate. However, the shelf life of pollen grains to pea tested genotypes is usually longer than in the artificial medium.

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BOTANICAL COMPOSITION AND NUTRITIONAL VALUE OF FODDER FROM OF SPECIES AND VARIETIES PERENNIAL MEADOW GRASSES

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Abstract

The botanical and chemical composition with perennial forage grasses in the conditions of the Central Balkan Mountain was analyzed, where Festuca arundinacea (98.3%) had the highest share in spring, while Bromus inermis in summer grass stand (94.8%). Meadow fescue and Italian ryegrass (cv.K-13) had the slightest share in the first and second regrowth, respectively. The perennial meadow grasses are of good quality and high DM content. Bromus inermis (DM-911.7 and CP-145.2 g kg^{-1}) and Dactylis glomerata (DM-910.1 and CP-138.7 g kg^{-1}) had the highest values of DM and CP. The aboveground mass of Lolium perenne had the least amount of DM (901.1 g kg^{-1}), but with a good content of CP (131.7 g kg^{-1}). The dry matter and CP in the biomass of Lolium multiflorum varied from 905.5 to 905.8 g kg^{-1} and from 96.0 to 110.1 g kg^{-1}, respectively, with CP concentration prevailing by 14.7% in the feed mass of cv.K-29t compared to cv.K-13. Festuca pratensis formed biomass with a higher CP content (by 3.1%) and CFr (by 10.6%) compared to Festuca arundinacea. A high correlation was found (r = 0.92) between the amount of DM and the percentage share of the species. Crude protein content correlated positively with the amount of CF (r = 0.77), calcium (r = 0.76), GE (r = 0.84) and FUG (r = 0.89).

Key words*: botanical composition, quality, crude protein.*

INTRODUCTION

Meadow grasses of the family *Poaceae* are a major and widespread component in natural meadows and pastures (Tenikecier & Ates, 2018). Their share in the grass stand dominatesd (up to 80-90%) compared to other types of perennial grasses. Abiotic and edaphic environmental factors conditionally limit or stimulate their development in the formation of sustainable and long-lasting fresh biomass with maximum efficiency (Deru et al., 2015).

Perennial meadow grasses are a cheap resource for meeting the food needs of farm animals. In this regard, the following species are extremely important: *Dactylis glomerata* L., *Lolium perenne* L., *Festuca pratensis* Huds., *Festuca arundinacea* Schreb., *Phleum pratense* L., *Lolium multiflorum* Lam., *Arrhenatherum elatius* (L., P. Beauv. ex J. Presl & C. Presl.), *Festuca rubra* L. and *Bromus inermis* Leyss. (Tomić et al., 2007).

The nutritional value of the feed mass is a variable related to the structure and quantitative share of the plants. Therefore, the botanical composition of grass stand gives a real idea of the quality and degree of digestibility of the vegetative mass by ruminants (Sabiniarz & Kozłowski 2009; Churkova, 2010; Churkova & Churkova, 2021a). The content of nutrients affects the taste of aboveground biomass and its better utilization.

In mountainous areas, the grass stand of *Festuca pratensis* Huds. are also slightly preferred with lower digestibility by animals compared to meadow fescue and perennial ryegrass (Cougnon, 2013; Cougnon et al., 2014).

In the conditions of the Central Balkan Mountain, the pure and mixed crops of Kenthucky bluegrass, red and tall fescue, show high resistance and adaptability (Naydenova & Mitev, 2017) correlating with relatively constant annual productivity.

Artificial grass stand with a predominant share of *Dactylis glomerata* L. (over 75%), register a high content of dry matter (909.7 g kg^{-1}) and crude fiber (346.3 g kg^{-1}) (Bozhanska et al., 2018). Crops with *Lolium perenne* L. show tolerance of grazing and are characterized by high productivity and quality of the feed mass (Katova, 2019).

The aim of the present study is to determine and analyze the botanical and basic chemical composition of grass stand of perennial forage grasses originating in Serbia in the conditions of the Central Balkan Mountains.

MATERIALS AND METHODS

The field experiment was conducted in 2016-2019, in the experimental field of the Research Institute of Mountain Stockbreeding and Agriculture - Troyan, Bulgaria.

Agroclimatic characteristics in the experimental area

The soils in the experimental area are light gray, pseudopodzolic. The content of the main nutrients in the soil layer was: from 0-20 cm - total N - 20.2 mg/1000 g, P_20_5 - 2.4 mg/100 g, K_2O - 9.9 mg/100 g, humus - 1.44% and from 20-40 cm - total N - 8.6 mg/1000 g, P_20_5 - 1.2 mg/100 g, K_2O - 5.9 mg/100 g, humus - 0.96%.

Perennial species of meadow grasses are characterized by a long vegetation period, and the water and temperature regime in the experimental area play a crucial role in the adaptation, development and quality of the feed mass (Staniak, 2016). For the experimental years, the air temperature during the vegetation period (15.2°C) was 0.4°C higher than for the multi-year period (14.8°C), Table 1.

The average daily temperature was with the lowest values (15.0°C) in 2017 and with the highest (15.3°C) in 2018.

Table 1. Average monthly temperatures and precipitation amounts during the vegetation periods of the experiment

Months \ Years	2016	2017	2018	2019	Average for 2016-2019	Average for 1967-2015
Temperature (°C)						
March	7.4	8.1	5.1	7.5	7.0	5.5
April	13.4	10.1	14.5	10.2	12.1	10.6
May	14.0	14.5	16.7	14.8	15.0	15.5
June	20.0	19.9	18.7	19.9	19.6	18.8
July	21.1	20.6	20.4	20.2	20.6	20.8
August	20.0	20.4	20.3	20.4	20.3	20.7
September	16.2	16.4	15.8	16.2	16.2	15.8
October	9.5	9.8	11.2	11.5	10.5	10.9
Average	15.2	15.0	15.3	15.1	15.2	14.8
Precipitation (mm)						
March	58.5	60.7	83.2	16.5	54.7	63.2
April	115.2	90.4	22.8	106.9	83.8	65.6
May	161.5	133.1	82.5	82.4	114.9	107.7
June	56.9	113.2	174.3	234.6	144.8	113.3
July	42.2	186.6	241.1	106.7	144.2	99.7
August	82.8	13.2	9.4	37.7	35.8	76.9
September	26.2	38.9	30.0	21.9	29.3	87.6
October	51.3	126.3	56.2	48.0	70.5	66.6
Sum	594.6	762.4	699.5	654.7	678.0	680.6

In the second vegetation, meadow grasses grew in the conditions of the highest average temperatures for March (8.1°C) and the lowest for April (10.1°C), and in the third vegetation their development started at the lowest temperatures in March (5.1°C) and the highest for April (14.5°C) and May (16.7°C) compared to the same months in 2016 and 2019, and compared to the multiannual period.

The average air temperature in the first and fourth vegetation was 15.2°C and 15.1°C., respectively. The vegetation amount of precipitation in the year of sowing (594.6 mm) and in the fourth vegetation (654.7 mm) was inferior in amount to that for a four-year (678.0 mm) and multi-year period (680.0 mm).

The relative difference of the indicator for 2016 and 2019 was 14.0-14.4% and 3.6-3.8%, respectively.

In the third vegetation (second harvest year) the precipitation amount was 699.5 mm with a total maximum (241.1 mm) and minimum (9.4 mm) of the indicator in the summer months (July and August) compared to the other experimental years and the multiannual period.

The highest amount of vegetation precipitation

(762.4 mm) was registered in the year after sowing. In relative terms, the difference in value during the year compared to the average for the study period and that for a longer period was equal to 12.4 and 12.0%, respectively.

The experiment included seven cultivars of fodder grasses originating in Serbia, such as: perennial ryegrass - cv. K-11 (*Lolium perenne* L.); Italian ryegrass - cv. K-13 (*Lolium multiflorum* L.); Italian ryegrass - cv. K-29t (*Lolium multiflorum* L.); tall fescue – cv. K-20 (*Festuca arundinaceae* Scherb.); meadow fescue - cv. K-21 (*Festuca pratensis* Huds.); cock's foot – K-24 (*Dactylis glomerata* L.); smooth brome – cv. BV-1 exp. *Bromus inermis* Leyss. The variants were set by the block method in four replications with the size of the harvest plot 5 m^2. Sowing was done by hand, scattered, with a sowing rate consistent with that for the species in pure condition at 100% seed germination. A single fertilization with N at a dose of 60 kg/ha active substance was applied. For the experimental period, nine cuttings were made: three in the year of sowing (2016) - in the form of sanitary mowing and six - distributed in the period of the second (2017), third (2018) and fourth (2019) vegetation.

For the purpose of the study, the following indicators were reported and analyzed:

Botanical composition of the grass stand - determined by weight by analysis of grass samples (in the air-dry state) at each mowing and from each variant, taken at each mowing from each variant. They were weighed in air dry condition and the percentage of weeds was determined by weight.

Basic chemical composition of dry fodder mass analyzed by *Weende* method: Crude protein (CP, g kg^{-1}) according to *Keldahl* (according to BDS/ISO-5983); Crude fiber (CFr, g kg^{-1}); Crude fat (CF, g kg^{-1}) (according to BDS/ISO-6492) - extracted in an extractor type *Soxhlet*; Ash (g kg^{-1}) - (according to BDS/ISO-5984) decomposition of organic matter by gradual combustion of the sample in a muffle furnace at 550°C; Dry matter (DM, g kg^{-1}) - empirically calculated from % of moisture; Nitrogen-free extracts (NFE, %) = 100 - (CP, % + CFr, % + CF, % + Ash, % + Moisture, %) converted to g kg^{-1}; Calcium (Ca, g kg^{-1}) - according to Schottz (complexometric) and Phosphorus (P, g kg^{-1}) - with vanadate-molybdate reagent by the method of Gericke and Curmis – spectrophotometer (*Agilent 8453 UV - visible Spectroscopy System*), measuring in the area of 425 ηm.

Feed Units for Milk (FUM) and Feed Units for Growth (FUG) were empirically measured and calculated on the basis of equations, according to the experimental values of CP, CFr, CF and NFE, recalculated by the digestibility coefficients according to Todorov (2010): Gross energy (GE, MJ/kg DM) = 0.0242*CP + 0.0366*CF + 0.0209*CFr + 0.017*NFE - 0.0007*Zx and Exchange energy (EE, MJ/kg DM) = 0.0152*DP (Digestible protein) + 0.0342*DF (Digestible fat) + 0.0128*DFr (Digestible fiber) + 0.0159*DNFE (Digestible NFE) - 0.0007*Zx.

Statistical data processing was performed by analysis of variance (ANOVA).

RESULTS AND DISCUSSIONS

Botanical composition of grass stand of perennial meadow grasses

Climatic conditions in the experimental area and the mode of use have an impact on the botanical composition of the grass stand (Pawluczuk & Grabowski, 2014; Babić et al., 2019; Churkova & Churkova, 2021b).

On average for the period, tall fescue provided the highest share of the main crop (98.3%) in **spring grass stand** and respectively the lowest degree of weed infestation (1.7%) compared to the other perennial grasses included in the experiment. Good drought resistance and a strong root system have had a positive effect on the share of Smooth brome in **summer regrowths**. Representatives of cv. BV-1exp cultivar form a grass mass with the lowest weed infestation (5.2%) and the highest share (94.8%) of that grass in the second regrowths. For the test period, meadow fescue and Italian ryegrass (cv. K-13) had the lowest share in the first and second regrowth, respectively.

Summer grass stand had a higher share of weeds compared to spring. In the first regrowth, the relative share of weeds was from 1.7% (tall fescue) to 4.3% (meadow fescue), and in the second from 5.2% (smooth bromegrass) to 20.1% (perennial ryegrass).

The cultivars of Italian ryegrass (Figures 1 and 2) had the highest percentage share of the main grass crop in the spring (cv. K-13 - 98.1%) and summer biomass (cv. K-29t - 94.7%). In contrast, meadow fescue (93.3%) and smooth brome (93.2%) occupied the lowest share in spring grass stand, while perennial ryegrass (86.9%) in summer grass stand. *Lolium perenne* L. is a perennial forage crop with a clear competitiveness and demanding to soil and air humidity. For the experimental period, perennial ryegrass had the lowest share in the biomass formed in the second regrowth and respectively with the lowest values of the indicator.

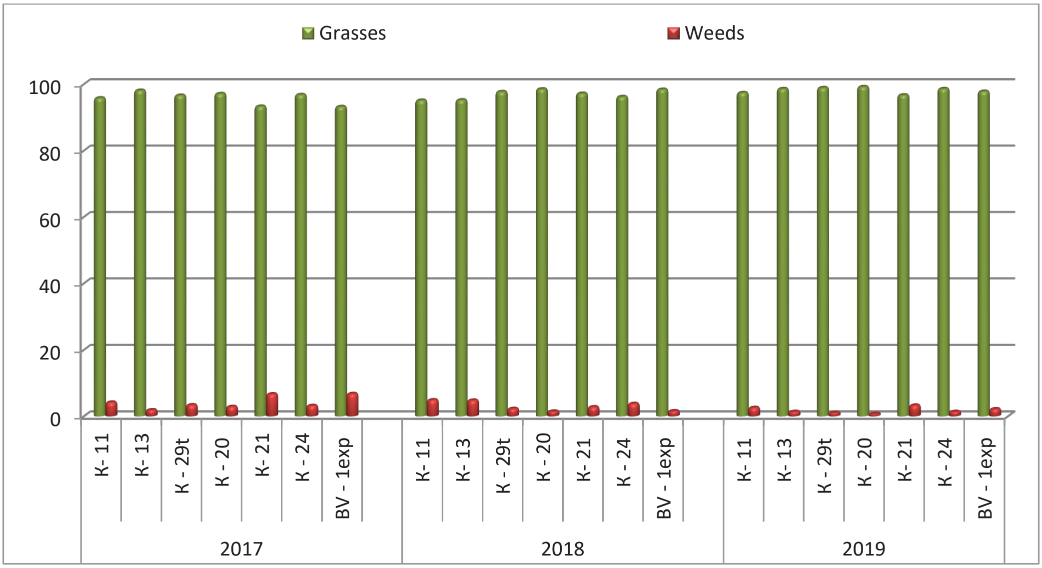

Figure 1. Botanical composition of grass stand of perennial meadow grasses by years (first regrowth, %)

Meadow fescue is tolerant to summer droughts, despite that their persistence negatively affects the growth and yield of the crop (Babić et al., 2010). In this case, the share of meadow fescue and smooth brome in the spring and summer regrowth was extremely equal.

The relative difference between the values was 0.3% (*Festuca pratensis* Huds.) and 0.2% (*Bromus inermis* Leyss). As a typical pasture grass, meadow fescue grows intensively throughout the vegetation season, but after mowing its development is suppressed.

Its share in the grass stand of the first and second regrowth reached 97.2 and 74.1% (2018) and 96.7 and 89.4% (2019).

In the case of smooth brome, this tendency was maintained in the fourth vegetation, when the difference in the weight percentage of the main crop between the regrowths was minimal (0.7%).

In the third and fourth vegetation, tall fescue (98.5 and 99.2%) and smooth brome (94.4 and 97.1%) realized the highest share in the fodder mass during spring and summer mowing compared to the other grasses included in the experiment.

In the experimental area, the soils have an unfavorable water-air regime, but are suitable for growing fodder grasses (Penkov et al., 1992). Cock's foot is not demanding to the soil mechanical composition, but prefers soils with sufficient lime content, which are lacking in the experimental area. For the four-year study period, *Dactylis glomerata* L. demonstrated optimal realization and good distribution of the species in spring and summer grass stand. Its share in the fodder mass of the first regrowth varied from 96.2% to 98.6% and in the second from 91.7% to 96.8%.

There is a cultivar specificity in terms of the botanical composition of the grass stand of Italian ryegrass. In the foothill conditions of the Central Balkan Mountains, cv. K-29t showed better adaptability and ecological plasticity. Its weight percentage in the feed mass was higher by 0.4% (in the spring regrowth) and by 4.9% (in the summer regrowth) compared to that of cv. K-13.

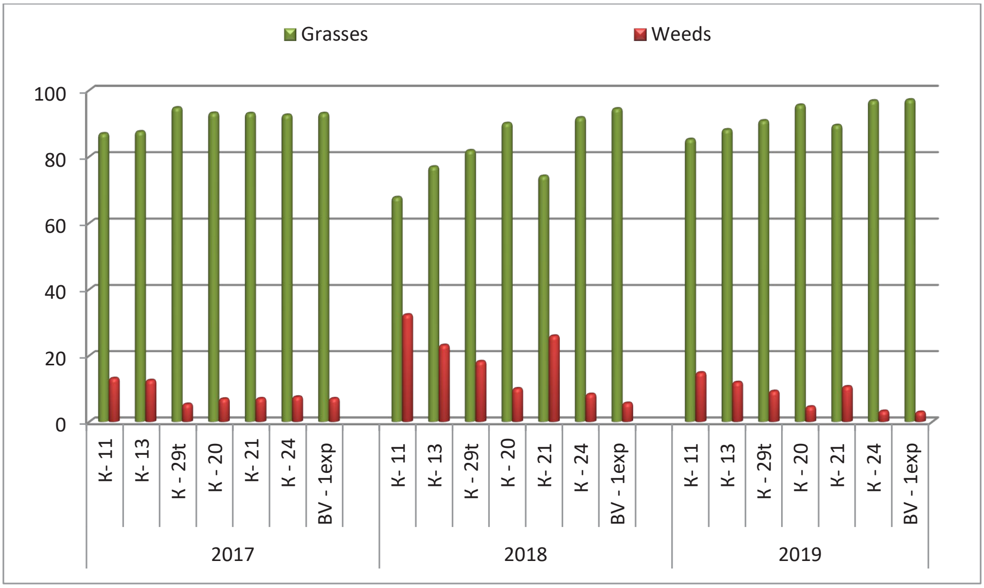

Figure 2. Botanical composition of grass stand of perennial meadow grasses by years (second regrowth, %)

The representatives of cv. K-29t showed higher aggression and competitiveness compared to weeds, as in the spring grass stand the percentage of weeds varied from 1.1 to 3.4% and in the summer from 5.3 to 18.2%.

The spring regrowths of cv. K-13 had 34.8% higher degree of weed infastation than cv. K-29t and the summer by 48.3%.

The biological characteristics and the ability of grasses to compete are important factors for maintaining the dynamic stability of the grass stand and suppressing the development of weeds. On the other hand, the dynamics of weed infestation gives a clear idea of the cleanliness of grass areas.

Spring grass stand had a lower degree of weed infestation than summer ones. In the first regrowth, smooth bromegrass, perennial ryegrass and cock's foot registered maximum values of the indicator, respectively 6.8%, 4.9% and 3.3%.

In the second regrowth, the trend was preserved only in the biomass of perennial ryegrass, where the values of the indicator varied from 13.1% to 32.3%.

Qualitative characteristics of fodder biomass from perennial meadow grasse

The biomass of perennial meadow grasses is characterized by good quality and high dry matter content (Table 2). The botanical composition of the grass stand is a major indicator influencing the quality and economic characteristics of the feed (Woodward et al., 2013). The high percentage of smooth bromegrass combined with a high share of leaves in the grass stand, implies the formation of biomass rich in protein and high dry matter digestibility. On average for the period, the data from the analysis show the highest content of dry matter (911.7 g kg^{-1}) and crude protein (145.2 g kg^{-1} DM) in the grass stand of *Bromus inermis* Leyss, followed by those of *Dactylis glomerata* L. (DM - 910.1 g kg^{-1} and CP - 138.7 g kg^{-1} DM). The values of these characteristics exceed the average by 0.5 and 16.7%, respectively. According to Babić et al. (2017) the ripening phase of cock's foot (cv. K-24) occurs later, which favours the yield of crude protein (1322 kg ha^{-1}) and increases the quality of the dry matter in the grass stand.

In the mountainous conditions of the Central Balkan Mountains the dry matter in the biomass of Italian ryegrass varied from 905.5 to 905.8 g kg^{-1}, and the crude protein content from 96.0 to 110.1 g kg^{-1} DM. The protein concentration prevailed with 14.7% in the dry feed mass of the tetraploid cultivar (K-29t) compared to the diploid (cv. K-13).

In the representatives of genus *Festuca* the difference in the values of dry matter is minimal (0.3%). Meadow fescue (cv. K-21) is characterized by high quality of dry matter, in the composition of which the average value of crude protein and crude fiber reached 124.8 and 290.7 g kg^{-1} DM, respectively (Ignjatović et al., 2004). The data obtained in the present study showed lower average values regarding the amount of crude protein (122.7 g kg^{-1} DM) and higher regarding the amount of fiber fraction (352.2 g kg^{-1} DM). Compared with tall fescue (the species with the lowest amount of fiber fraction, average for the period), *Festuca pratensis* Huds. had a higher content of crude protein (by 3.1%) and crude fiber (by 10.6%).

The aboveground matter of perennial ryegrass had the least amount of dry matter (901.1 g kg^{-1}), but with a good content of crude protein (131.7 g kg^{-1} DM).

Agroecological characteristics in the habitat area, as well as the concentration of micro and macronutrients in the soil composition, have a significant effect on the mineral composition of the grass cover (Baryła et al., 2009; Pawluczuk & Grabowski, 2014). The content of mineral and nitrogen-free extracts in the dry fodder varied respectively from 60.1 g kg^{-1} DM (Italian ryegrass - cv. K-13) to 66.7 g kg^{-1} DM (tall fescue) and from 386.5 g kg^{-1} DM (cock's foot) to 442.0 g kg^{-1} DM (Italian ryegrass - cv. K-13).

Table 2. Basic chemical composition of dry mass of perennial grasses on average for the period 2017-2019 (g kg^{-1} DM)

Variant	DM	CP	CFr	CF	Ash	NFE	Ca	P
				2017				
K-11	905.6	172.5	341.5	23.5	65.8	396.6	10.0	0.5
K-13	908.0	131.6	409.1	26.7	63.3	369.3	8.0	0.3
K-29t	906.7	88.3	386.9	18.8	60.8	445.2	6.0	0.6
K-20	901.8	152.6	363.4	15.9	72.6	395.5	8.0	0.3
K-21	910.1	130.4	366.7	18.4	71.8	412.8	9.0	0.7
K-24	909.3	150.4	418.1	31.1	54.1	346.2	10.0	0.2
BV-1	914.3	152.7	412.3	23.1	56.7	355.2	9.0	0.6
				2018				
K-11	899.5	125.2	380.0	26.3	58.0	410.3	16.3	0.6
K-13	898.6	75.2	360.1	15.1	57.8	491.8	15.1	1.4
K-29t	900.1	153.1	382.7	10.3	61.7	392.1	17.6	1.8
K-20	913.1	117.0	320.6	14.9	63.7	483.8	15.9	1.7
K-21	897.3	134.7	368.6	23.3	70.9	402.7	16.4	2.3
K-24	905.8	133.6	361.4	25.4	64.6	415.1	11.3	1.6
BV-1	907.1	150.4	343.0	21.7	67.1	417.8	13.6	1.9
				2019				
K-11	898.1	97.2	365.2	19.8	60.3	457.5	23.8	1.2
K-13	910.8	81.0	379.9	14.4	59.3	465.4	23.2	1.6
K-29t	909.6	89.3	370.5	19.5	61.8	458.9	18.4	0.9
K-20	911.9	98.9	372.7	24.0	63.9	440.4	23.1	1.5
K-21	910.6	114.5	433.3	20.4	52.4	379.3	23.2	1.2
K-24	915.2	132.2	384.8	15.3	69.4	398.2	32.5	3.0
BV-1	913.6	132.6	371.3	22.1	58.7	415.5	27.8	2.1
				2017-2019				
K-11	901.1	131.7	362.2	23.2	61.4	421.4	17.1	0.8
K-13	905.8	96.0	383.1	18.7	60.1	442.0	15.7	1.1
K-29t	905.5	110.1	380.0	16.2	61.4	432.2	14.2	1.1
K-20	908.9	122.7	352.2	18.3	66.7	440.1	16.0	1.2
K-21	906.0	126.5	389.6	20.7	65.0	398.2	16.5	1.4
K-24	910.1	138.7	388.2	23.9	62.7	386.5	18.3	1.6
BV-1	911.7	145.2	375.6	22.3	60.8	396.1	17.1	1.5
Mean±Sx	***907.0±1.3***	***124.4±6.4***	***375.8±5.3***	***20.5±1.1***	***62.6±0.9***	***416.7±8.6***	***16.4±0.5***	***1.3±0.1***
SD	***3.5***	***16.9***	***13.9***	***2.9***	***2.4***	***22.8***	***1.3***	***0.3***

The content of calcium and phosphorus affects the biological value of the feed mass (Wyłupek et al., 2014). Cock's foot is extremely adapted for growing in mountain conditions (Babić et al., 2017). The present studies show that the grass stand of *Dactylis glomerata* L. had the highest content of Ca (18.3 g kg^{-1} DM) and P (1.6 g kg^{-1} DM). The quantitative ratio of both macroelements (Ca/P) in the dry matter composition was 11.4/1, which positively affected the quality and nutritional value of feed, as well as the health of ruminants.

The content of calcium in the grass stand of smooth brome and perennial ryegrass was 17.1 g kg^{-1} DM. The values of the indicator exceeded genus *Festuca* from 3.6 to 6.9% and the cultivars of Italian ryegrass from 8.9 to 20.4%.

Crude fat improves the taste of feed and is a major source of energy for ruminants. For the period 2017-2019 the highest content was found in cock's foot (23.9 g kg^{-1} DM), perennial ryegrass (23.2 g kg^{-1} DM) and smooth brome (22.3 g kg^{-1} DM). The values of the trait exceeded the average for the period (20.5 g kg^{-1} DM) by 16.6%, 13.1% and 8.8%, respectively.

Dependencies between indicators of botanical and chemical composition of grass stand

A high correlation was found (r = 0.92) between the amount of dry matter (as a main indicator in the selection programs of meadow grasses) and the percentage share of the species in the formed biomass (Table 3).

Table 3. Correlation dependences between percentage share of meadow grasses, dry matter and some basic quality indicators

	Grasses %	DM g kg^{-1}	CP g kg^{-1}	CFr g kg^{-1}	CF g kg^{-1}	NFE g kg^{-1}	Ca g kg^{-1}	GE MJ/kg	EE MJ/kg	FUM	FUG
Grasses	1										
DM	**0.92**	1									
CP	0.36	0.44	1								
CFr	0.05	0.25	-0.03	1							
CF	-0.06	0.15	**0.77**	0.14	1						
NFE	-0.18	-0.37	-0.79	-0.55	-0.77	1					
Ca	0.15	0.35	**0.76**	0.14	**0,95**	-0.74	1				
GE	0.13	0.32	**0.84**	0.38	**0.89**	-0.93	**0.81**	1			
EE	0.00	-0.13	0.31	-0.89	0.19	0.29	0.13	0.00	1		
FUM	-0.02	-0.17	0.16	-0.94	0.04	0.44	0.00	-0.17	**0.99**	1	
FUG	0.11	0.24	**0.89**	-0.01	**0.90**	-0.73	**0.80**	**0.92**	0.40	0.24	1

$P < 0.05$; FUM - Feed Units for Milk (number in kg DM); FUG - Feed units for growth (number in kg DM).

Crude protein is positively correlated with the amount of crude fat (r = 0.77), calcium content (r = 0.76), gross energy of grass stand (r = 0.84) and the number of feed units for growth (r = 0.89), and in contrast with a high negative correlation with the amount of nitrogen-free extracts (r = -0.79).

A strong negative correlation was found between the values of the fiber fraction with the amount of metabolic energy (r = -0.89) and the number of feed units for milk (r = -0.94). The variable values of nitrogen-free extracts maintained a negative correlation with calcium content (r = -0.74), the total energy value of the feed (r = -0.93) and the number of feed units for growth (r = -0.73).

Among the indicators characterizing the nutritional value of perennial forage grasses, feed units for milk show a dependence on the exchange energy expressed by a high correlation coefficient (r = 0.99 - the highest compared to all other indicators), and feed units for growth with a gross energy value (r = 0.92).

The balanced mineral composition of the grass stand is one of the prerequisites for good feed quality. Calcium amount (preferred in the rations of growing animals) strongly correlates with the gross energy (r = 0.81) and the number of feed units for growth (r = 0.80) in the dry matter of the harvested biomass.

Crude fats had a high negative correlation with the amount of nitrogen-free extracts (r = -0.77) and a very high positive correlation with calcium concentration (r = 0.95), the amount of gross energy (r = 0.89) and the number of feed units for growth (r = 0.90).

CONCLUSIONS

On average for the period, tall fescue provided the highest share of the main crop (98.3%) in **spring grass stand** and respectively the lowest degree of weed infestation (1.7%) compared to the other perennial grasses included in the experiment. Smooth brome had the highest (94.8%) share in the biomass of **summer regrowths**. In contrast, meadow fescue and Italian ryegrass (cv. K-13) had the lowest share in the first and second regrowth, respectively.

With the highest dry matter content (911.7 g kg^{-1}) and crude protein (145.2 g kg^{-1} DM) were the grass stand of smooth brome and cock's foot (DM - 910.1 g kg^{-1} and CP - 138.7 g kg^{-1} DM). In the mountainous conditions of the Central Balkan Mountains the dry matter in the biomass of Italian ryegrass varied from 905.5 to 905.8 g kg^{-1}, and the crude protein content from 96.0 to 110.1 g kg^{-1} DM. There was cultivar specificity in In Italian ryegrass in terms of protein concentration in the dry feed mass. The values of the trait are 14.7% higher at cv. K-29t compared to those of cv. K-13. Meadow fescue formed an aboveground mass with higher content of crude protein (by 3.1%) and crude fiber (by 10.6%) compared to tall fescue.

The percentage share of the species affects the amount of dry matter expressed with a high correlation (r = 0.92). Crude protein content correlated positively with the amount of crude fat (r = 0.77), calcium (r = 0.76), gross feed energy (r = 0.84) and the number of feed units for growth (r = 0.89).

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PRODUCTION OF HIGH-QUALITY SEED POTATOES IN PROTECTED AREA FOR TRUE SEED PROGENIES, WHO SHOWED TOLERANCE TO *IN VITRO* INDUCED WATER STRESS

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Abstract

Given the current climate context, the main objective of this study was to identify genotypes tolerant to water stress in true potato seed populations. The research was initiated by inoculating of true potato seeds on culture medium, regenerating viable plantlets and testing their tolerance to in vitro induced water stress. Three from nine tested genotypes obtained the best results in terms of tolerance to water stress induced in vitro. ELISA testing revealed that the three genotypes (GIL 19-03-07, ZIL 19-02-43 and GIL 19-03-29) are virus-free. In vitro true seed derived plantlets owning a very high health status were transplanted, after acclimatization, in protected area in order to produce top quality, disease-free seed potato material. Several planting variants were used in terms of biological material used, number of plants/pot and location. After minitubers were harvested, it was analyzed how the planting variants influenced number, size and weight of the minitubers obtained in the protected area. This study aimed to obtain an alternative planting material with a high phytosanitary quality and drought tolerance, to supplement the seed potato required by the market.

***Key words**: in vitro plantlets, minituber, potato, true potato seed, water stress.*

INTRODUCTION

According to FAO estimates, in 2019 over 370 million tons of potatoes were produced worldwide. Potatoes are recommended as a food security crop by the United Nations. In 2019, more than 17 million hectares of potatoes were harvested worldwide (Shahbandeh, 2021). One of the pressing problems of the contemporary world is to ensure food for a continuously growing population. Also, the world economic crisis leads to necessity of finding some abundant food sources as minimal cost. Hence, enhancing the productivity of potato crops can contribute to fulfilling the nutritional requirements of the rising population (Birch et al., 2012). However, drought stress represents a major challenge to the production of potatoes worldwide. Climate change is predicted to further aggravate this challenge by intensifying potato crop exposure to increased drought severity and frequency (Gervais et al., 2021). To find solutions for these climate challenges researchers around the world are making continuous efforts to find new potato genotypes tolerant to water stress. The shallow root system of potatoes makes this crop one of the most drought-sensitive species (Gervais et al., 2021; Zarzynska et al., 2017; Iwama and Yamaguchi, 2006; Yuan et al., 2003). Drought strongly inhibits key physiological and biochemical processes, leading to poor plant performance and tuber yield loss (Evers et al., 2010; Stark et al., 2013; Obidiegwu et al., 2015; Aliche et al., 2018; Plich et al., 2020; Hill et al., 2021).

Although the potato plant is multiplied using a number of different techniques, *in vitro* nodal cuttings are probably the most common propagules used in early stages of commercial seed potato production (Pruski, 2007). The technology of production potato minitubers by direct transplantation of *in vitro* plantlets in protected areas is a frequently used technique in seed potato production system.

Seed potato production involving minituber production systems creates a bridge between the *in vitro* rapid multiplication and the field multiplication of seed tubers and is thus a classical way to multiply or acclimatize *in vitro* material before its use in the open field (Sharma and Pandey, 2013). Producing minitubers from *in vitro* plantlets allows a faster rate of multiplication and reduces the number of field generations needed in seed production (Ranalli, 1997).

The phytosanitary condition of planting material is largely responsible for the size and quality of potato production. The real production capacity of a variety can be expressed only in healthy crops, obtained from a high quality planting material. Due to the physiological and virotic degeneration of potato, there is a progressive decrease in production. Virotic infections disrupt plant metabolism manifesting itself by shortening the growing season, accentuated decrease of production, depreciation of its quality (Donescu, 2003).

Abiotic stresses such as extreme temperature and drought often result in significant losses to the yields of economically important crops such potato (El-Magawry et al., 2015). *In vitro* screening of new genotypes represents valuable tool as alternative to field trials.

The objectives of the present study were to produce an alternative seed potato planting material with a high phytosanitary quality and drought tolerance.

MATERIALS AND METHODS

The biological material was represented by three potato genotypes (GIL 19-03-07, ZIL 19-02-43 and GIL 19-03-29) derived from botanical seed and obtained best results regarding the tolerance to *in vitro* induced water stress. The experiment was conducted at the Plant Tissue Culture Laboratory of the National Institute of Research and Development for Potato and Sugar Beet Brasov, Romania. The *in vitro* disease-free plantlets were acclimatized and planted in protected *insect-proof* area in order to produce high quality potato seed. Genotypes were evaluated in terms of number, size and weight of minitubers, both under optimal watering conditions and thermohydric stress.

Several planting variants were used:

- biological material: plantlets and minitubers;
- number of plantlets/pot: 1 plantlet/pot (control) and 2 plantlets/pot;
- location: greenhouse with thermohydric stress conditions (control) and tunnel "*insect-proof*" with optimal watering but high temperatures.

After the minitubers were harvested, it was analyzed how the planting variants influenced the number, size and weight of the minitubers obtained in protected area.

Whereas potato plantlets obtained *in vitro* are fragile, in order to have a high percentage of survival after transplantation, the microplants were acclimatized in greenhouse, for 3 weeks. The substrate used for planting consisted of a mixture of red peat with bentonite, black peat and perlite in a 4:2:1 ratio. The substrate was distributed in plastic pots with a diameter of 7 cm, 12.9 cm height and volume of 2 l. In order to enrich the substrate with nutrients, complex NPK 15:15:15 + 6% sulfur fertilizer was applied before planting, after which the substrate was watered daily (2 hours/day). Also, to ensure the nutrients necessary for growth and development of potato plants, organic foliar fertilizer (Cropmax) treatments were applied once a week.

During the growth season daytime temperature was monitored both in tunnel *insect-proof* and greenhouse (Table 1). In tunnel *insect-proof* the plants had an optimal watering regime, while in the greenhouse the potato plants were grown under water stress conditions.

Table 1. Daytime temperature (minimum and maximum) during the growing season

Month	Minimum and maximum temperatures recorded during the growing season (°C)			
	Tunnel *insect-proof*		Greenhouse	
	Morning (9^{00})	Afternoon (14^{00})	Morning (9^{00})	Afternoon (14^{00})
June	11 – 34	14 - 53	12 - 33	16 - 47
July	20 – 32	24 - **56**	21 - **38**	25 - **50**
August	15 – **37**	28 - 54	16 - 31	25 - 46
September	8 – 19	23 - 46	13 - 18	22 - 36

Planting has been carried out on May 20 (Figure 1), watering stop on September 1, manual removal of haulms was performed on September 15 (Figure 3) and harvesting minitubers was made in September 30 (Figure 4).
Chemical treatments have been carried out periodically to control pests and diseases (Figure 2). Foliar fertilizer was also applied weekly in order to ensure the harmonious development of the potato plants.

Figure 1. Planting of microplants in tunnel *insect-proof*

Figure 2. Chemical treatments and fertilization

Figure 3. Manual removal of haulms

Figure 4. Harvesting minitubers

In order to obtain a high quality planting material, a series of preventive measures have been taken to allow the most effective control of possible viral infections: destruction of weeds around the tunnel, which could be host plants for aphids (vector for potato viruses); placement of Moericke water traps inside the tunnel, collection of insects caught in these traps and their identification by qualified personnel; performing chemical treatments to control aphids. In order to verify the effectiveness of the preventive measures of virotic control on the phytosanitary quality of the material, samples of leaves were taken for ELISA testing during the vegetation. The ideal time to harvest the leaves is before flowering, when the plant is young, or at the latest during flowering. Only the top leaflet is detached from the upper third of the plant. The ELISA results showed that all 3 genotypes tested (GIL19-03-07, ZIL19-02-43 and GIL19-03-29) are healthy.
Minitubers were harvested approximately 19 weeks after planting and true potato seed progenies were evaluated for average number, size and weight of minitubers. The obtained results were processed by the analysis of variance (Săulescu and Săulescu, 1967).

RESULTS AND DISCUSSIONS

In this study, 3 true potato seed progenies, who showed tolerance to *in vitro* induced water stress, were grown in protected areas in order to obtain a high-quality pre-basic seed from *in vitro* plantlets. After 19 weeks from planting, the minitubers were harvested and evaluated in terms of number, size and weight depending on planting variants.

Effect of growth conditions, number of plantlet/pot and genotypes on the number of minitubers

Both in tunnel *insect-proof* and greenhouse conditions in the case of the planting variant with 2 plantlets/pot a higher number of minitubers was obtained compared to the control (Table 2), the differences being significant both in the tunnel (2.89) and in the greenhouse (2.44).
Under the tunnel *insect-proof* growth conditions, the genotypes GIL19-03-07 and ZIL19-02-43 registered a distinctly significant positive

difference (3.25) and respectively significant positive (2.17) compared to the control. In the greenhouse conditions (thermohydric stress) it was highlighted genotype ZIL19-02-43 which obtained the highest number of minitubers/pot (ave. 8.67 minitubers/pot) with a very significant positive difference (6.33) compared to the control. By comparing the results obtained in the tunnel with those obtained in the greenhouse, regarding the number of minitubers, a distinctly significant positive difference (4.33) can be observed in the tunnel conditions for the genotype GIL19-03-07 (Table 3).

The results presented in Table 3 show an important aspect regarding the behavior in different growth conditions of tested potato genotypes about the number of minitubers. Thus, ZIL 19-02-43 showed tolerance in the conditions of thermohydric stress by obtaining a higher value of the number of minitubers in the greenhouse (8.67) compared to the tunnel (6.58).

Table 2. Effect of growth conditions and number of plantlet/pot on the number of minitubers

Tunnel	Mean	Diff.	Sign.	Greenhouse	Mean	Diff.	Sign.	a_1-a_2	Sign.
1 plantlet/pot (Ct)	4.78	-	-	1 plantlet/pot (Ct)	3.56	-	-	1.22	ns
2 plantlets/pot	7.67	2.89	*	2 plantlets/pot	6.00	2.44	*	1.67	ns

DL 5%: 2.02; 1%: 3.34; 0.1%: 6.25 DL 5%: 1.95; 1%: 3.83; 0.1%: 9.96

Table 3. Effect of genotypes and growth conditions on the number of minitubers

Tunnel	Mean	Diff.	Sign.	Greenhouse	Mean	Diff.	Sign.	a_1-a_2	Sign.
GIL19-03-07	7.67	3.25	**	GIL19-03-07	3.33	1.00	ns	4.33	**
ZIL19-02-43	6.58	2.17	*	ZIL19-02-43	8.67	6.33	***	-2.08	ns
GIL19-03-29 (Ct)	4.42	-	-	GIL19-03-29 (Ct)	2.33	-	-	2.08	ns

DL 5%: 1.79; 1%: 2.46; 0.1%: 3.39 DL 5%: 2.10; 1%: 3.67; 0.1%: 8.53

Table 4. Effect of number of plantlet/pot and genotypes on the number of minitubers

1 plantlet/pot	Mean	Diff.	Sign.	2 plantlets/pot	Mean	Diff.	Sign.	b_2-b_1	Sign.
GIL19-03-07	5.08	2.17	*	GIL19-03-07	5.92	2.08	*	0.83	ns
ZIL19-02-43	4.50	1.58	ns	ZIL19-02-43	10.75	6.92	***	6.25	***
GIL19-03-29 (Ct)	2.92	-	-	GIL19-03-29 (Ct)	3.83	-	-	0.92	ns

DL 5%: 1.79; 1%: 2.46; 0.1%: 3.39 DL 5%: 2.02; 1%: 3.02; 0.1%: 4.86

When used a single plantlet/pot, GIL19-03-07 registered a significant positive difference (2.17) compared to the control, and in planting variant with 2 plantlets/pot very significant differences were obtained (6.92) and significant positives (2.08) for ZIL19-02-43 and GIL19-03-07, respectively (table 4). When used 2 plantlets/pot the genotype ZIL19-02-43 recorded the highest number of minitubers (ave. 10.75), registering a very significant positive difference compared to the variant with 1 plantlet/pot (Table 4).

Effect of growth conditions, number of plantlet/pot and genotypes on the weight of minitubers

Under the tunnel *insect-proof* growth conditions, the variant with 2 plantlets/pot led to obtaining minitubers with a higher weight compared to the control variant (1 plantlet/pot), registering a distinctly significant positive difference (56.23 g). Comparing the results obtained in tunnel with those obtained in greenhouse, in terms of minitubers weight there is a distinctly significant positive difference (49.34 g) in the case of variant with 1 plantlet/pot and a very significant positive difference (111.25 g) in the case of variant with 2 plantlets/pot (Table 5).

Under the tunnel *insect-proof* growth conditions, regarding the weight of the minitubers, the best results were obtained by ZIL19-02-43 (ave. 100.10 g), with a significant positive difference (23.34 g) compared to the control. By comparing the results obtained in tunnel with those obtained in greenhouse conditions, in terms of the weight of the minitubers, there were very significant differences for all three studied genotypes (Table 6).

Table 5. Effect of growth conditions and number of plantlet/pot on the weight of minitubers

Tunnel	Mean	Diff.	Sign.	Greenhouse	Mean	Diff.	Sign.	a_1-a_2	Sign.
1 plantlet/pot (Ct)	59.28	-	-	1 plantlet/pot (Ct)	9.94	-	-	49.34	**
2 plantlets/pot	115.52	56.23	**	2 plantlets/pot	4.27	-5.68	ns	111.25	***

DL 5%: 28.18 g; 1%: 46.63 g; 0.1%: 87.27 g   DL 5%: 22.18 g; 1%: 39.49 g; 0.1%: 86.79 g

Table 6. Effect of genotypes and growth conditions on the weight of minitubers

Tunnel	Mean	Diff.	Sign.	Greenhouse	Mean	Diff.	Sign.	a_1-a_2	Sign.
GIL19-03-07	85.34	8.58	ns	GIL19-03-07	10.15	2.38	ns	75.19	***
ZIL19-02-43	100.10	23.34	*	ZIL19-02-43	3.40	-4.37	ns	96.70	***
GIL19-03-29 (Ct)	76.76	-	-	GIL19-03-29 (Ct)	7.77	-	-	68.99	***

DL 5%: 18.18 g; 1%: 25.04 g; 0.1%: 34.47 g   DL 5%: 18.27 g; 1%: 29.35 g; 0.1%: 59.15 g

Regarding the average weight of minitubers/pot in the case of 1 plantlet/pot variant, there were no significant differences between genotypes, but in the case of 2 plantlets/pot variant, the genotype GIL19-03-07 was noted, which recorded a distinctly significant positive difference (27.98 g) compared to the control, obtaining the highest value for the average weight of the minitubers/pot (ave. 74.76 g). Comparing the results obtained in the case of 2 plantlets/pot variant with those obtained in the case of 1 plantlet/pot variant in terms of the weight of minitubers, a distinctly significant positive difference (54.03 g) was observed for the GIL19-03-07 genotype (Table 7).

Table 7. Effect of number of plantlet/pot and genotypes on the weight of minitubers

1 plantlet/pot	Mean	Diff.	Sign.	2 plantlets/pot	Mean	Diff.	Sign.	b_2-b_1	Sign.
GIL19-03-07	20.73	-17.02	ns	GIL19-03-07	74.76	27.98	**	54.03	**
ZIL19-02-43	45.36	7.61	ns	ZIL19-02-43	58.14	11.37	ns	12.78	ns
GIL19-03-29 (Ct)	37.75			GIL19-03-29 (Ct)	46.78			9.02	ns

DL 5%: 18.18g; 1%: 25.04 g; 0.1%: 34.47 g   DL 5%: 24.63 g; 1%: 37.87g; 0.1%: 63.81g

Calibration on size fractions of minitubers harvested from protected area

After harvesting, the minitubers were calibrated in size fractions. Depending on their size, the minitubers were distributed on several calibration classes as follows: <10 mm, 10-15 mm, 15-20 mm, 20-25 mm, 25-30 mm and >30 mm. It was followed how aspects such as: genotype, cultivation conditions (tunnel, greenhouse), number of plantlet/pot (1 or 2 plantlets/pot) and the type of material used for planting (minitubers or microplants) influenced the size of the minitubers and which was their proportion in different planting variants.

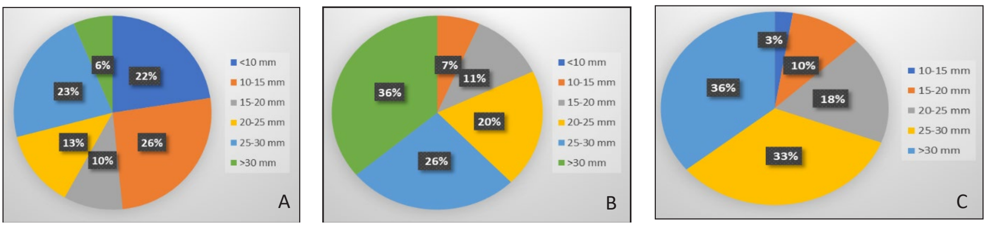

Figure 5. Percentage of minitubers by size fractions for GIL 19-03-07 in tunnel *insect-proof* depending on planting variant (A - 1 plantlet/pot; B - 2 plantlets/pot; C - minitubers)

Regarding genotype GIL 19-03-07, in tunnel *insect-proof* cultivation conditions, for planting variant in which 1 plantlet/pot was used, the highest percentage of minitubers was in 10-15 mm size fraction, and in case of variant in which minitubers and 2 plantlets/pot were used for planting, the highest percentage was registered at the size fraction > 30 mm (Figure 5).

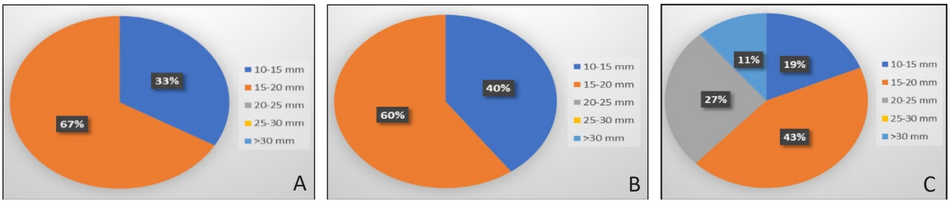

Figure 6. Percentage of minitubers by size fractions for GIL 19-03-07 under thermohydric stress conditions (greenhouse) depending on planting variant (A - 1 plantlet/pot; B - 2 plantlets/pot; C - minitubers)

In the greenhouse cultivation conditions, for GIL 19-03-07, the minitubers from the calibration class 15-20 mm had the highest frequency, followed by the size fraction 10-15 mm in the case of variants with 1 plantlet/pot and 2 plantlets/pots and the size fraction 20-25 mm when using minitubers as planting material (Figure 6).

Regarding genotype ZIL 19-02-43, under tunnel *insect-proof* conditions, for all three planting variants used (1 plantlet/pot, 2 plantlets/pot and minitubers) the highest percentage of minitubers was framed in the size fraction >30 mm, followed by size fraction 25-30 mm (Figure 7).

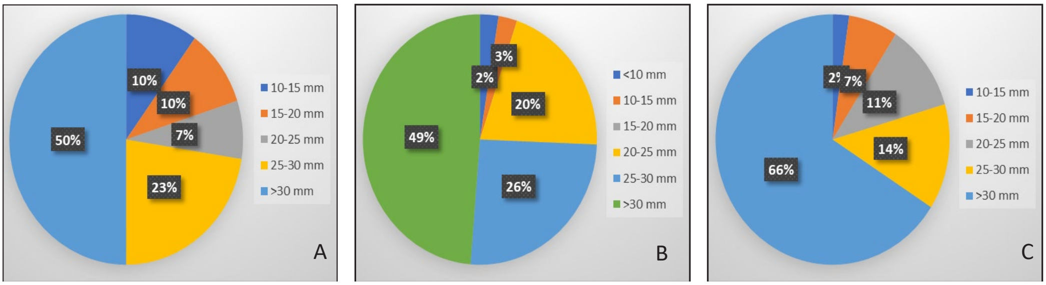

Figure 7. Percentage of minitubers by size fractions for ZIL19-02-43 in tunnel *insect-proof* depending on planting variant (A - 1 plantlet/pot; B - 2 plantlets/pot; C - minitubers)

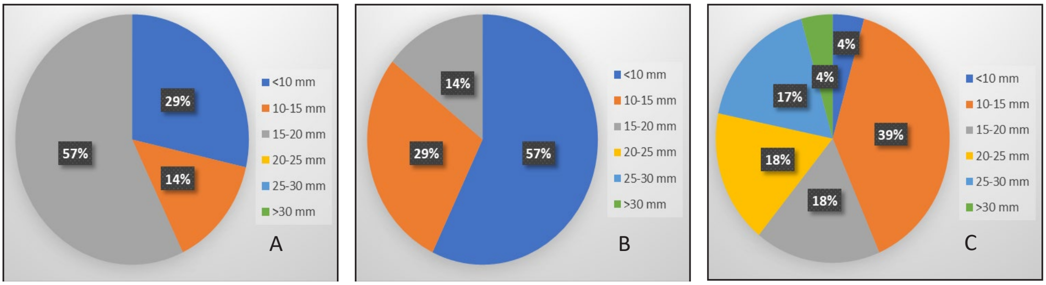

Figure 8. Percentage of minitubers by size fractions for ZIL19-02-43 under thermohydric stress conditions (greenhouse) depending on planting variant (A - 1 plantlet/pot; B - 2 plantlets/pot; C - minitubers)

Under greenhouse conditions of cultivation genotype ZIL 19-02-43 had a different behavior in terms of the size of the minitubers, depending on the material used for planting. Thus, for the variant with 1 plantlet/pot minitubers from the calibration class 15-20 mm had the highest frequency, for the variant with 2 plantlets/pot most minitubers were in the calibration class <10 mm, and in the case of the variant in which minitubers were used as planting material, the largest share of harvested minitubers was in the size fraction 10-15 mm (Figure 8).

Figure 9 shows the results obtained regarding the size of minitubers belonging to genotype GIL 19-03-29 and their distribution by calibration classes under the cultivation conditions specific to *insect-proof* tunnel. Thus,

in the case of planting variants with minitubers and 1 plantlet/pot the highest percentage was held by the minitubers from the size fraction > 30 mm, and in the case of the variant with 2 plantlets/pot, the minitubers had the highest share from the size fraction 25-30 mm.
Under greenhouse conditions for GIL 19-03-29 minitubers from the calibration class 10-15 mm had the highest frequency in the case of variants with 1 plantlet/pot and 2 plantlets/pot, and in the case of using minitubers as planting material the largest percentage of minitubers was in the size fraction 15-20 mm.
On the next place was located as frequency the minitubers from calibration class 20-25 mm (Figure 10).

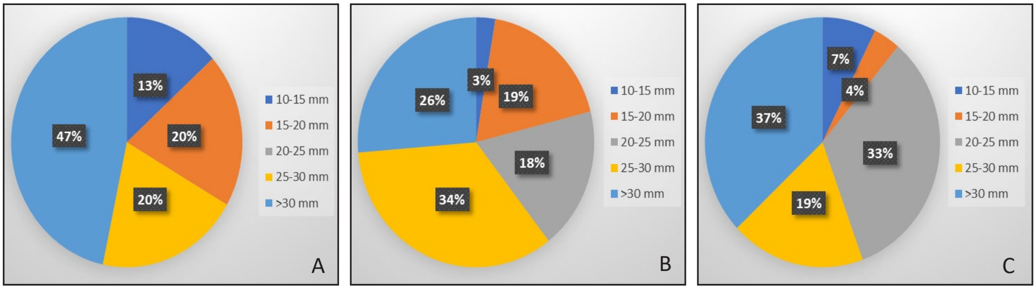

Figure 9. Percentage of minitubers by size fractions for GIL 19-03-29 in tunnel *insect-proof* depending on planting variant (A - 1 plantlet/pot; B - 2 plantlets/pot; C - minitubers)

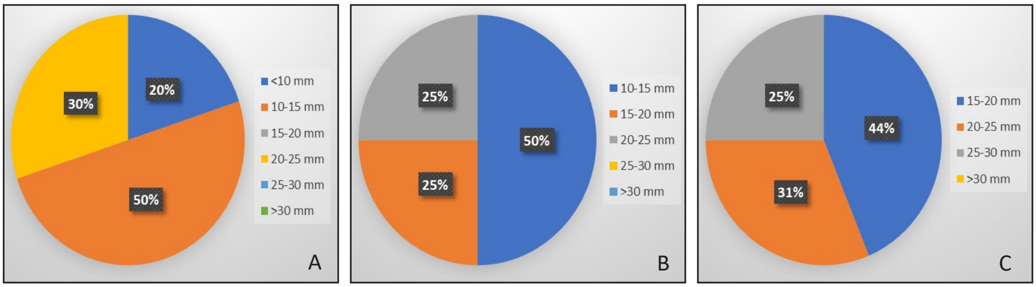

Figure 10. Percentage of minitubers by size fractions for GIL 19-03-29 under thermohydric stress conditions (greenhouse) depending on planting variant (A - 1 plantlet/pot; B - 2 plantlets/pot; C - minitubers)

As there are no official regulations regarding calibration of minitubers on size fractions, all minitubers larger than 10 mm are accepted as planting material. Also, considering the phytosanitary top quality of the biological material obtained in the *insect-proof* spaces and the high costs necessary to obtain this material, the minitubers smaller than 10 mm are kept and will be replanted in the protected area next year.

Table 8. Frequency of minitubers on size fractions depending on cultivation conditions and planting variant

Planting variant	**Size fraction**					
	GIL19-03-07		ZIL19-02-43		GIL19-03-29	
	Tunnel	Greenhouse	Tunnel	Greenhouse	Tunnel	Greenhouse
1 plantlet/pot	10-15 mm	15-20 mm	>30 mm	15-20 mm	>30 mm	10-15 mm
2 plantlets/pot	>30 mm	15-20 mm	>30 mm	<10 mm	25-30 mm	10-15 mm
Minitubers	>30 mm	20-25 mm	>30 mm	10-15 mm	>30 mm	15-20 mm

As can be seen in Table 8, for all three genotypes, the highest percentage of harvested minitubers was recorded in calibration classes larger than 10 mm, with one exception: genotype ZIL19-02-43 in greenhouse conditions and in case of variant with 2 plantlets/pot.

Under the tunnel *insect-proof* conditions (optimal watering but high temperatures), the obtained minitubers were mainly classified in the calibration classes > 30 mm and 25-30 mm in all genotypes and on all planting variants, except for the genotype GIL19-03-07 in which the highest frequency of minitubers obtained on variant with 1 plantlet/pot was in calibration class 10-15 mm.

Even in thermohydric stress conditions (greenhouse), the highest percentage had the minitubers from the fractions of size 10-15 mm and 15-20 mm, for all 3 potato genotypes, except for the genotype ZIL19-02-43 on variant with 2 plantlets/pot.

Regarding the production of minitubers (kg/m^2) obtained both in thermohydric stress conditions (greenhouse) and in optimal watering conditions but high temperatures (tunnel), the three genotypes obtained higher yields in tunnel compared to greenhouse (Table 9).

Table 9. The yield of true potato seed progenies depending on the cultivation conditions and the planting variant

Planting variant	**Minitubers yield (kg/m^2)**					
	GIL19-03-07		ZIL19-02-43		GIL19-03-29	
	Tunnel	Greenhouse	Tunnel	Greenhouse	Tunnel	Greenhouse
1 plantlet/pot	1.0	0.5	3.0	0.2	2.5	0.4
2 plantlets/pot	5.0	0.2	4.0	0.1	3.0	0.2
Minitubers	4.0	2.0	7.5	0.7	3.5	0.8

Regarding the planting variant, analyzing the results presented in Table 9, in tunnel *insect-proof* conditions the true potato progenies obtained higher yields in case of using 2 plantlets/pot and minitubers as initial material compared to the variant with 1 plantlet/pot. Two important aspects can be deduced from this, namely:

- increasing productivity by optimizing the capitalization of small fraction minitubers;
- more efficient use of culture space.

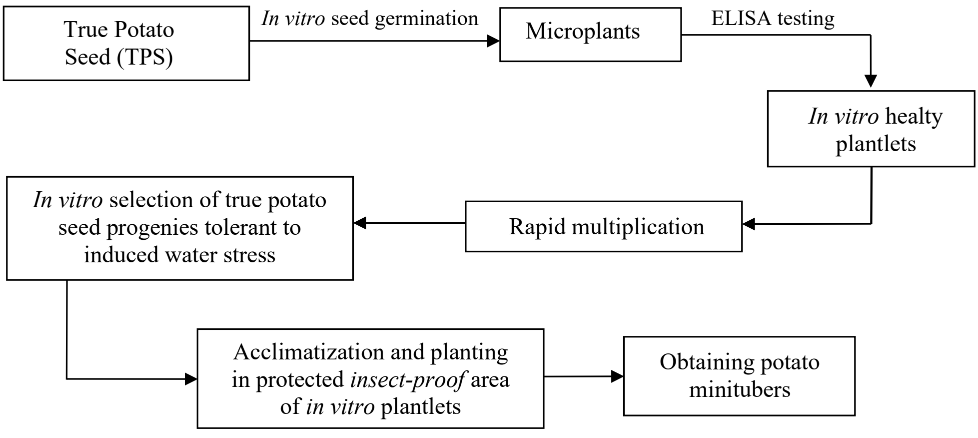

Figure 11. Scheme for production in protected area of potato minitubers (Prebase) starting from *in vitro* germination of true potato seeds

Figure 11 shows the steps that were followed to obtain potato minitubers in protected *insect-proof* area starting from true potato seed (TPS) cultivated under *in vitro* conditions. This scheme includes both the stage of testing tolerance to *in vitro* induced water stress of potato genotypes derived from true seed, and the acclimatization of potato microplants obtained *in vitro* before planting them in protected *insect-proof* area.

CONCLUSIONS

Based on *in vitro* screening for drought stress three of nine true potato seed progenies were selected as tolerant.

Regarding the average number of minitubers/pot obtained under *insect-proof* conditions the genotypes GIL19-03-07 (7.67) and ZIL19-02-43 (6.58) were highlighted. Under thermohydric stress conditions the genotype ZIL19-02-43 obtained the highest number of minitubers (ave. 8.67). For variant with 2 plantlets/pot a higher number of minitubers was obtained both in tunnel (ave. 7.67) and in the greenhouse (ave. 6.00), compared to variant in which 1 plantlet/pot was used (ave. 4.78, respectively ave. 3.56).

Regarding the average weight of the minitubers, in tunnel the variant with 2 plantlets/pot led to obtaining minitubers with a higher weight (ave. 115.52 g) compared to 1 plantlet/pot variant (ave. 59.28 g), but in conditions of thermohydric stress the weight of minitubers was higher on the control variant (ave. 9.94 g) compared to 2 plantlets/pot variant (ave. 4.27 g).

In tunnel the best results regarding the weight of the minitubers were recorded at genotype ZIL19-02-43 (ave. 100.10 g), and under thermohydric stress conditions genotype GIL19-03-07 (ave. 10.15 g) was noted with a positive difference of 2.38 g compared to the control. On the variant in which 1 plantlet/pot was used, the genotype ZIL19-02-43 obtained the best results regarding the average weight of the minitubers (45.36 g), and on the variant with 2 plantlets/pot, genotype GIL19 03-07 (74.76 g) was highlighted.

In tunnel cultivation conditions, the obtained minitubers were mainly classified in the calibration classes > 30 mm and 25-30 mm for all genotypes and all planting variants. Under thermohydric stress conditions (greenhouse) the highest percentage of minitubers was noticed mainly in fractions of size 10-15 mm and 15-20 mm, for all 3 potato genotypes.

The larger size of minitubers that will be planted next year in field conditions, the more vigorous potato plants will be, and the higher production of tubers in the clonal field will be obtained.

The size of the minitubers influences duration of the germination period, the vigor of the seed tubers, number of stems, percentage of emergence, number of surviving plants, the vigor of the stems and their production capacity.

Regarding the production of minitubers obtained both in thermohydric stress conditions (greenhouse) and in optimal watering conditions but high temperatures (tunnel), all three genotypes obtained higher yields in tunnel compared to greenhouse. In potato cultivation, this aspect is similar to what happens in field conditions. If it is a year with high temperatures during the growing season, but the crop is irrigated, higher yields will be obtained than if the potato plants in addition to high temperatures, will be subjected also to water stress.

Minitubers (pre-basic seed) from *insect-proof* protected area will be used as planting material to monitor the behavior of potato genotypes in open field conditions.

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RESEARCH ON MICROFLORA ASSOCIATED WITH ALFALFA SEEDS (*IN VITRO*)

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Abstract

The aim of the research was to identify fungi and the presence of other microorganisms on alfalfa seeds. The genetic material was represented by seeds of the Dobrogea genotype. We worked with three variants in three repetitions, untreated seeds (control variant), seeds passed through sterile water and disinfected seeds with 70% ethanol solution variant, under controlled conditions. Observations were made on microorganisms present on alfalfa seeds, under controlled conditions. The incidence of fungal microorganisms that developed on the culture medium, PDA (potato-dextrose-agar) was determined. Among the fungi, pathogens were detected: Fusarium spp., Alternaria spp., Cladosporium herbarum, Aspergillus spp., Penicillium spp. The highest incidence in the case of fungi was calculated in Fusarium spp. and Aspergillus spp. In the sterile water variant (F = 22.2%). Penicillium spp and Fusarium spp pathogens were present in all variants studied.

***Key words**: alfalafa, pathogens, seeds, incidence.*

INTRODUCTION

Alfalfa (*Medicago sativa* L.) is known as the oldest and most important perennial legume in the world. Lucerne is an important component of pastures in dry regions, rain-dominated areas and Mediterranean areas (Barbetii et al., 2006; Walsh et al., 2001; Piano and Francis, 1992). In some countries, alfalfa is the most important cultivated legume (Askar et al., 2012). The special importance of this plant is that it is a source of nitrogen fixation in the soil, provides a large amount of protein per hectare and an attractive honey plant for bees in obtaining honey (Stuteville and Erwin, 1990). Also, being a perennial plant, it can be exploited for 3-5 years and has a role as an ameliorating soil in the crop rotation. Alfalfa is the most important fodder crop in our country, representing 45.01% of the area cultivated with fodder plants (Schitea et al., 2020). Studies on the importance of crops and their market are important for agricultural research (Toth and Cristea, 2018, Popescu et al., 2018). Seed is an important means of transmitting plant diseases (Berca and Cristea, 2015; Dudoiu et al., 2016; Zaharia et al., 2022). The transmission of diseases through the pathogen-carrying seed also implies an adequate management of their control. Alfalfa seed pathogenic fungi cause significant losses by reduced germination, seedling rot, seed rot (Couture et al., 2002; Krnjaja et al., 2003). *Fusarium* spp. causes root rot of seedlings and plant chlorosis of leaves and wilting of plants. Affected alfalfa seedlings show discoloration and damage to the roots that lead to seed rot and may contain mycotoxins (Goswami et al., 2008, Barbetti and Allen, 2005). The pathogens such as *Fusarium* spp., *Penicillium* spp. *Alternaria* spp. frequently populate seeds. Research on both foliar and seed diseases is relevant to alfalfa because some are transmitted to the crops with which it rotates (Barbetti et al., 2006).

MATERIALS AND METHODS

The research aimed to determine the spectrum of alfalfa seed microflora. The biological material was represented by seeds from the Dobrogea variety. The Dobrogea variety is a Romanian alfalfa variety, registered in 2019, in

Romania. We worked with three variants in three repetitions: variant one (V1) untreated seeds, variant two (V2) seeds disinfected with sterile water and then dried on filter paper and variant three (V3) seeds disinfected in 70% ethanol solution one minute and then passed through a sterile water bath and dried on sterile filter paper. The seeds were placed on the PDA-Roth medium in 90 mm Petri dishes, 6 seeds/Petri dish, in three repetitions. Seed were incubated at 22°C in a thermostat. The identification of the pathogens was made according to the morphological characteristics of the specific fructifications taken from the 6-day-old colonies. The Zeiss primo star microscope used to mount and the Zen software were used. In addition to fungi, the presence of other microorganisms, bacterial colonies and yeasts was noted. The incidence was calculated according to the formula F = n x 100/N, where F = frequency (%), n = number of seeds with pathogen attack/variant, N = total number of seeds/variant.

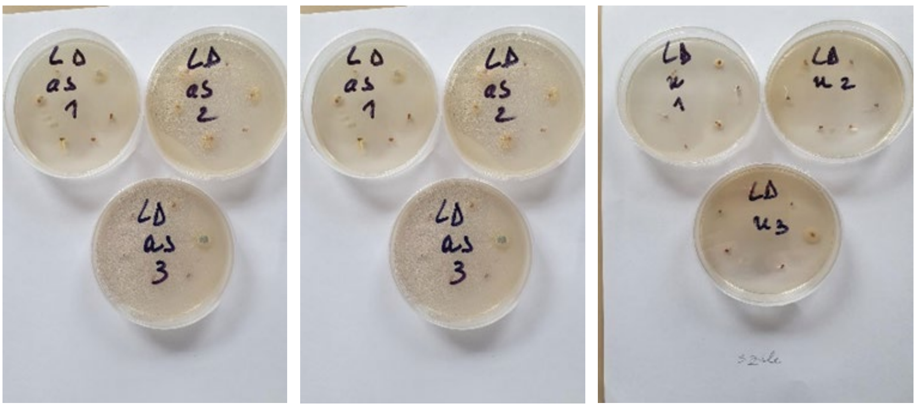
RESULTS AND DISCUSSIONS

The observations regarding the presence of pathogens on alfalfa seeds, Dobrogea variety presented in Table 1 show that pathogens belonging to the genus *Fusarium* were present in all analyzed variants. Also, microorganisms from the category of yeasts and bacterial colonies developed around the seeds in all the variants studied. Colonies of *Alternaria* spp. were identified in the sterile water and control variants and *Penicillium* spp. in the sterile water variant. Colonies belonging to the species *Cladosporium herbarum* were observed in the sterile water variant. The colonies of yeasts and bacterial microorganisms developed from the third day of observation. In the sterile water variant, a greater pathogenic diversity was found and the growth rate of the colonies was faster, which can be explained by the fact that a weakly activates the microbial flora (Figure 1: A and B). The spectrum of microorganisms that populate alfalfa seeds are found on the seeds of cultivated plants (Berca and Cristea, 2015; Cristea et al., 2015; Gheorghieş et al., 2004). Also, the growth of microorganism colonies was faster compared to the other variants studied.

Table 1. Microflora associated with alfalfa seeds

Variety	Variants	The fungal pathogen/ 6 days					Other microorganisms	
Dobrogea	AS/E/C	*Fusarium* spp.	*Alternaria* spp.	*Aspergillus* spp.	*Penicillium* spp.	*Cladosporium herbarum*	Yeasts	Bacteria
	AS	+	+	+	+	+	+	+
	E	+	-	-	-	-	+	+
	C (untreated)	+	+	+	-	-	+	+

*AS=sterile water; E 70%= ethanol 70%; C= control



A

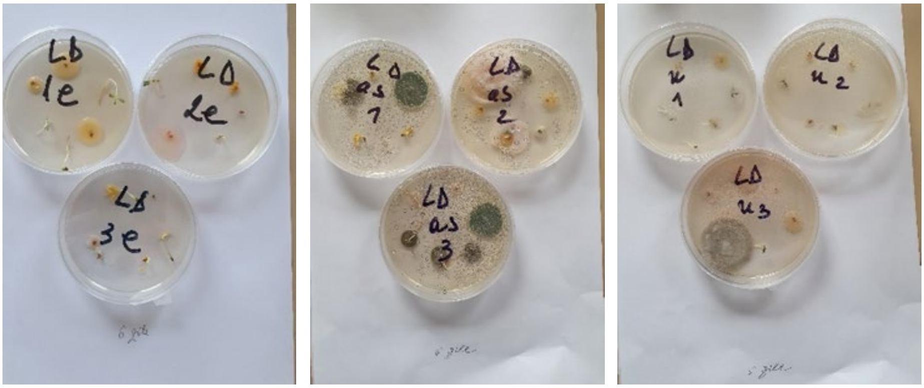
B 

Figure 1. Microflora of alfalfa seeds, Dobrogea variety; variants: AS = sterile water; E 70% = ethanol 70%; C = control (A - 3days; B - 6 days)

The incidence of pathogens in total alfalfa seeds per variant was calculated and it was found that the most common microorganisms were yeasts and bacterial colonies, with 70% ethanol and control variants.

In the sterile water variant, the incidence of 22.2% was determined for the fungi *Fusarium* spp. and *Aspergillus* spp. (Figure 2).

In this variant, the presence of the fungi of the genera *Penicillium* and *Alternaria* was also determined, with a frequency of 11.1% (Figure 3, Figure 5).

In the 70% ethanol variant, *Fusarium* (Figure 4) pathogens were found to be present with a frequency of 11.1% and *Penicillium* spp with 5.5%. *Fusarium* species of fungi were generally found on alfalfa seeds (Askar et al., 2012, 2013). In this variant, the pathogenic spectrum is the poorest, which can be explained by the fungicidal action of the substance in the tested concentration. In the case of the (untreated) control variant, the frequency of *Fusarium* spp fungi was 22.2% and the fungi of the genera *Alternaria*, *Penicillium* and *Cladosporium herbarum* (Figure 6) were 5.5%. *Cladosporium* and *Alternaria* species are mentioned as being present on alfalfa seeds (EL-Garhy and EL-Wakil, 2014). Vasic et al., (2011) estimate that most fungi that affect alfalfa are transmitted through seeds.

Table 2. Incidence of alfalfa seed microflora

Variety	Variants	The fungal pathogen					Other microorganisms	
	AS/E/C	*Fusarium* spp. F (%)	*Alternaria* spp. F (%)	*Aspergillus* spp. F (%)	*Penicillium* spp. F (%)	*Cladosporium herbarum* F (%)	Yeasts	Bacteria
Dobrogea	AS	22.2	11.1	22.2	11.1	-	16.6	16.6
	E 70%	11.1	-	-	5.5	-	38.8	44.4
	Control (untreated)	22.2	5.5	-	5.5	5.5	16.6	44.4

*AS=sterile water; E 70%= ethanol 70%; C= control

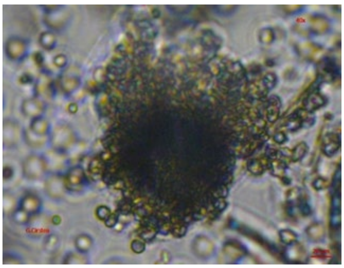


Figure 2. *Aspergillus* spp. (AS) (original)

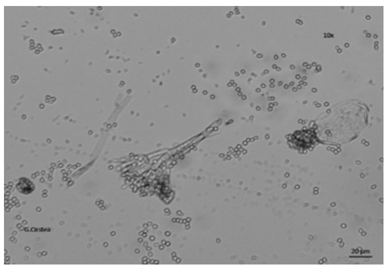


Figure 3. *Penicillium* spp. (AS) (original)

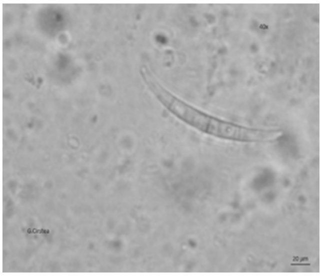


Figure 4. *Fusarium* spp. (etanol 70%) (original)

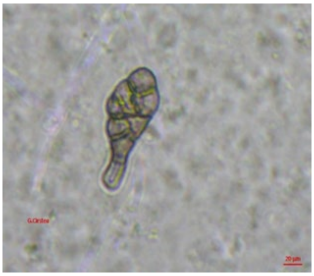


Figure 5. *Alternaria* spp. (AS) (original)

Figure 6. *Cladosporium herbarum* (control) (original)

CONCLUSIONS

Alfalfa seed microflora was composed of species of the genera *Fusarium*, *Alternaria*, *Penicillium, Aspergillus* and *Cladosporium herbarum.* Along with pathogens from the category of fungi, microorganisms belonging to yeasts and bacteria were also observed, which proved to be the most common. Among the fungi, the most common were those belonging to the genera *Fusarium* and *Aspergillus* (22.2% incidence).

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RESEARCH REGARDING THE INFLUENCE OF SOME HERBICIDES ON THE STRUCTURE OF SEGETAL FLORA AND NODOSITIES IN CHICKPEAS CULTURE, AT A.R.D.S. TELEORMAN

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Abstract

Chickpeas are a small plant with slow growth rates, the passage of phenophases falls within time intervals, which can be influenced by soil and climate conditions. The research took place in the years 2019-2020, at A.R.D.S. Teleorman, being studied the combinations and associations of herbicides applied to chickpea culture. The experiment was placed on a fertile chernozem vertric soil with good fertility (more than 3,1% humus, clay content more than 42% on the horizon 0-24 cm, pH-> 5.9), using the Burnas chickpea variety. The forerunner was autumn wheat. Chickpea plants are very easily competed by weeds within the first days of emergence. The influence of weeding in the first 2-3 weeks after emergence has an influence on production even if the culture can be kept clean later on. To achieve good effectiveness in weed control in chickpeas culture, herbicides must be applied correctly taking into account their mechanism of action and control spectrum. Biometric determinations performed on nodes highlight the difference in bacterialization between the experimental variants and productivity elements of the chickpea plant.

***Key words**: chickpeas, Cicer arietinum L., herbicides, weeds, control, efficacy, nodulation.*

INTRODUCTION

Chickpeas (*Cicer arietinum* L.) is one of the most resistant species of legumes for drought and heat grains, withstanding high heat and strong insolation during fertilization and fruiting, it can be successfully grown in areas with arid climates, where beans and soybeans do not give satisfactory results without water supply through irrigation.

Chickpeas are a sustainable crop, grown on medium, fertile soil with residual moisture, which may not be suitable for other legumes and grains, but is very sensitive to alkaline soils (Fisher and Goldworthy, 1984).

In Romania's conditions, grain legumes find very favorable conditions.

Chickpeas compete poorly with weeds due to their slow growth rate, especially in the early stages of vegetation, and the lack of weed control techniques can produce production losses between 40-87%, it is generally cultivated on slopes, on soils without excess moisture, in areas with lower rainfall (Solh and Pala, 1990).

Increased chickpea production may depend on the proper use of moisture, nutrients, light and sowing density of chickpeas, in the absence of competition with weeds.

The results are corroborated with data supported by (Arya, 2004) and (Patel et. al., 2006).

Simultaneous and rapid growth of weeds in chickpea culture, lead to severe competition for light, moisture, space and nutrients, which leads to a drastic reduction in yield. Production losses ranged from 40 to 94% (Bhan and Kukula, 1987).

The best control of weeds in chickpeas was obtained by applying pendimethalin and trifluralin (Hassan et. al., 1995).

In subsequent studies, (Vaishya et. al., 1999) reported 41-44% loss in chickpeas by increasing weeding.

There is an urgent need to identify more effective herbicides with a broad spectrum of weed control and increased adaptability in chickpea culture (Singh and Sharma 2013).

The reduction of chickpea yield due to the presence of weeds in chickpea culture, in

proportion of 75% was also observed by Chaudhary et. al., 2005.
Chickpeas form nodules, roots that support the biological fixation of N (BNF) and host symbiotic bacteria that fix N. These findings suggest that variety selection can improve (PNF) with a wide variety of symbionts, leading to higher yields, higher protein content and/or more residual N for subsequent crops (Rita Abi-Ghanem et al., 2012) .
The findings reveal a unique opportunity to improve N-fixation by cross-breeding and genetic selection. Nitrogen (N) is the most limited nutrient in crops worldwide. N industrially produced has grown in recent years and is not available in many regions of the world. Biological fixation of N by rhizobic bacteria is a large underutilized resource that this study aims to maximize (Rita Abi-Ghanem et al., 2011).

MATERIALS AND METHODS

The research took place in the years 2019-2020, at A.R.D.S. Teleorman, being studied the combinations and associations of herbicides applied to chickpea culture. The experiment was placed on a fertile chernozem vertric soil with good fertility (more than 3.1% humus, clay content more than 42% on the horizon 0-24 cm, pH > 5.9), using the Burnas chickpea variety. The forerunner was autumn wheat.
The location of the experiment was done according to the method of randomized blocks, with a plot area of 25 m^2, in four repetitions.
The sowing density is provided for 40-46 plants/m^2, the distance between rows 50 cm, the sowing depth 4-5 cm.
In terms of water, in 2019 chickpeas benefited from 376.6 mm of rainfall over the entire vegetation period, with 76.6 mm more than the crop's requirements for humidity, but their distribution was unfavorable to the chickpea culture. Thus, in the first part of the vegetation period the precipitations were quantitatively higher than the multiannual average with (+27.2 mm) in April, (+48.1 mm) in May and (+99.3 mm) in June.
In 2020, there were small excesses of precipitation in May (7.8 mm) and June (11.6 mm), and in April a deficit (21.8 mm), compared to the multiannual averages of the area (Figure 1).

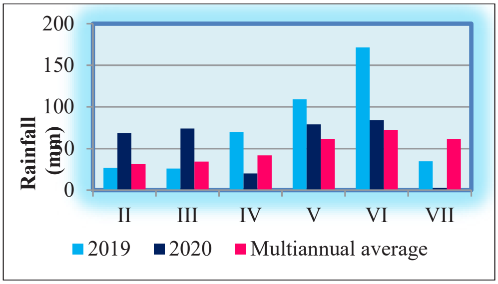

Figure 1. The evolution of precipitations A.R.D.S. Teleorman, 2019-2020.

In July, it can be said that the total drought installed, only 2.8 mm of rainfall was recorded, the rainfall being practically absent, the deficit of the month being (58.6 mm).
The productions made in 2020 for chickpeas were slightly affected by the water deficit, from the first part of the vegetation period (April), and favored by the moderate surpluses of precipitation during the period of intense growth and formation of the elements of productivity May-June (Figure 2).

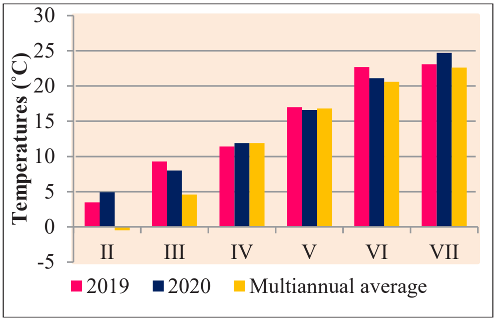

Figure 2. Temperature evolution at A.R D.S. Teleorman, 2019-2020

Chickpeas are a small plant with slow growth rates, the passage of phenophases falls in time intervals, which can be influenced by soil and climate conditions.
Chickpea plants are very easily competed by weeds in the first days of emergence. The influence of weeding in the first 2-3 weeks after emergence is very much felt on the production even if later the crop can be kept clean. Weed control by mechanical plowing between rows can be done, but it requires a lot of labor to weed the weeds by hand.
All these factors can be eliminated by using herbicides and herbicide combinations.

Chemical weed control is an important program and the following key issues need to be considered:

- Knowledge of the dominant weed species that influence the chickpea culture;
- Knowledge of the mechanism of action of herbicides and their control spectrum;
- The most appropriate application technique and the maximum effect in weed control.

In the conditions of our country, weed infestation differs from one area to another (Anghel et al., 1972).

From the determinations performed in the experiment with herbicides at the resort in the two years, it is found a permanent presence of both groups of monocotyledonous and dicotyledonous weeds (Figures 1 and 2).

Due to the fact that in most variants a mixed flora predominates, the application of a single herbicide does not solve the problem of weeds, so satisfactorily that it may require weeding and plowing.

In order to achieve a good effectiveness in controlling chickpea weeds, it is necessary that the herbicides presented in (Table 1) are applied correctly taking into account their mechanism of action, control spectrum and predominant species that occur frequently in the area.

Table 1. Experimental variants in chickpea culture. ARDS Teleorman, 2019-2020

Nr. variant	Active substance content	Dose g.s.a./ha	Herbicide treatment	Age of application
V1	Unprepared	-	Control - untreated	-
V2	2 mechanical plows	-	Untreated control 2 mechanical plows	-
V3	50g/l quizalofop-p-ethyl Isoxaflutole 240 g/l Cyprosulfamide (safener): 240 g/l	1.2 l/ha 0.15 l/ha	Leopard 50EC + Merlin Flex	Postem. Postem.
V4	960 g/l S-metolachlor isoxaflutole 240 g/l Cyprosulfamide (safener): 240 4g/l	1.5 l/ha 0.20 l/ha	Dual Gold 960EC+ Merlin Flex	Preem. Preem.
V5	960 g/l S-metolachlor isoxaflutole 240 g/l Cyprosulfamide (safener): 240 g/l	1.2 l/ha 0.30 l/ha	Dual Gold 960 EC + Merlin Flex	Preem. Preem.
V6	312.5 g/lS-metolachlor 187.5 g/l terbuthylazine	4.0 l/ha	Gardoprim Plus Gold 500 SC	Preem.
V7	312.5 g/lS-metolachlor 187.5 g/l terbuthylazine Isoxaflutole 240 g/l Ciprosulfamide (safener): 240 g/l	4.0 l/ha 0.20 l/ha	Gardoprim Plus Gold 500 SC + Merlin Flex	Preem. Preem.
V8	312.5 g/lS-metolachlor 187.5 g/l terbuthylazine isoxaflutole 240 g/l Ciprosulfamide (safener): 240 g/l	4.0 l/ha 0.30 l/ha	Gardoprim Plus Gold 500 SC + Merlin Flex	Preem Preem
V9	312.5 g/lS-metolachlor 187.5 g/l terbuthylazine pyridate 450 g/kg	4.0 l/ha 1.0 l/ha 1.0 l/ha	Gardoprim Plus Gold 500 SC + Lentagran+ Lentagran	Preem. Post. I Post. II
V10	960 g/l S-metolachlor aclonifen	1.5 l/ha 2.5 l/ha	Dual Gold 960EC + Challenge 600 SC	Preem. Preem.
V11	960 g/l S-metolachlor 40 gr/l imazamox	1.5 l/ha 0.7 l/ha	Dual Gold 960EC+ Pulsar 40	Preem. Post.
V12	960 g/l S-metolachlor metribuzin 700 g/kg	1.5 l/ha 0.3 l/ha	Dual Gold 960EC + Sencor 600 SC	Preem. Preem.

RESULTS AND DISCUSSIONS

If climatic conditions do not allow effective control of weeds in pre-emergence (drought, drafts or inadequately prepared ground, etc.), weed control may be used in post-emergence (V3). With a very good selectivity for the crop plant, without affecting the following crops Table 1.

The effectiveness of herbicide combinations, with pre-emergence application gives results, if the soil is very well prepared, uniform and with an optimal degree of humidity from precipitation. This effectiveness is when about 8-12 mm of precipitation falls, within 8-11 days of application.

The control of diseases and pests in chickpeas culture is an important technological factor, and non-compliance with the conditions of application of phytosanitary treatments can significantly reduce chickpea production.

In the first phases of vegetation of the culture, the emergence of monocotyledonous and dicotyledonous weeds, annual and perennial, can affect to a very large degree the evolution of the culture, both at emergence and in the growth and development stages (Figure 3).

The advances in chemistry are remarkable in terms of herbicides in recent decades.

During the study years, the density, dominance and frequency of weed species in chickpea culture were influenced by the pedoclimatic conditions: the amount of precipitation, their distribution, the recorded temperatures. The frequency of weed species was established by the number of plants/m^2, for each calendar year.

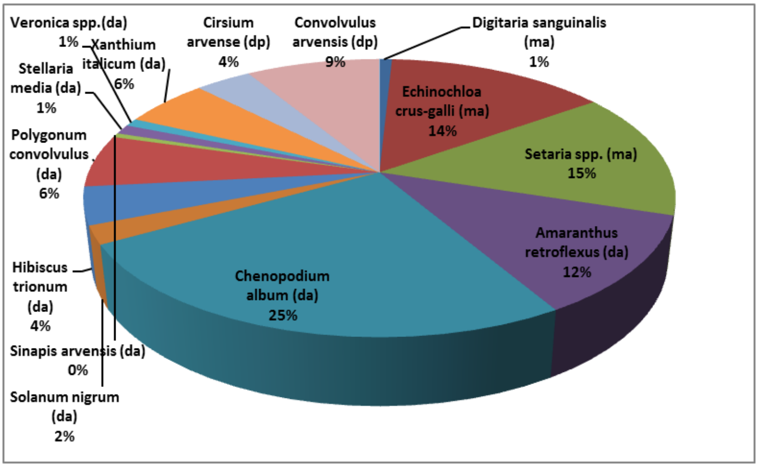

Figure 3. Weed participation in chickpea culture. A.R.D.S. Teleorman, 2019

The most outstanding combined treatments, with average efficacy values, in pre-emergence and early post-emergence, post-emergence, (50 g/l quizalofop-p-ethyl isoxaflutole 240 g/l Cyprosulfamide (safener): 240 g/l (V3); 960 g/l l S-metolachlor isoxaflutole 240 g/l Ciprosulfamide (safener): 240 g/l (V5); 312.5 g/l S-metolachlor 187.5 g/l terbutylazine isoxaflutole 240 g/l Ciprosulfamide (safener): 240 g/l (V8)) .

In soils with a higher level of infestation, in the conditions of practicing integrated control measures, I recommend applying the treatment together with at least one mechanical plow.

Characteristic of each calendar year, the most representative weed species were annual monocotyledons (Figure 4): *Avena fatua, Echinochloa crus-galli, Setaria* spp., and annual dicotyledons: *Amaranthus retroflexus, Chenopodium album, Chenopodium polyspermum, Hibiscus trionum, Polygonum convolvulus, Sinapis arvensis, Stellaria media, Veronica* spp., *Xanthium italicum,* as well as perennials: *Cirsium arvense, Convolvulus arvensis, Sonchus arvensis.*

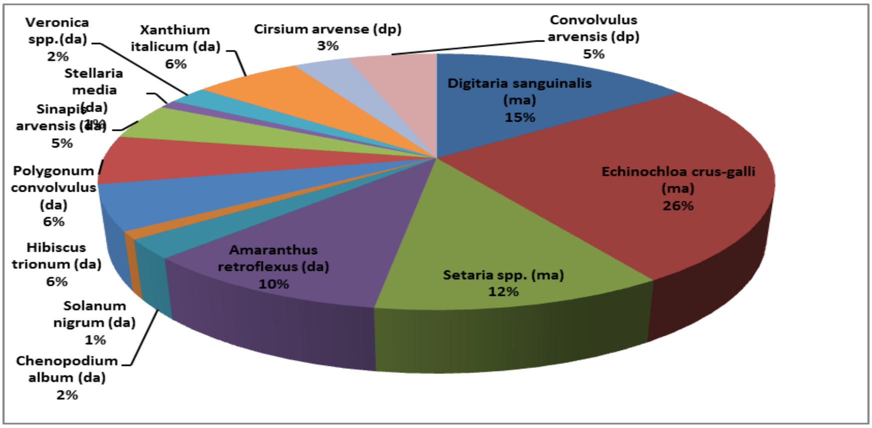

Figure 4. Weed participation in chickpea culture. A.R.D.S. Teleorman, 2020

At the full maturity of the chickpea plants, five typical plants were harvested for biometric determinations and analysis of productivity elements in the laboratory, from each variant, in order to characterize them, in the climatic conditions of the two agricultural years 2019-2020, and the effectiveness of herbicide combinations. The working method was performed by counting and determinations performed in the field, and laboratory analyzes, which were manually processed, centralized, electronically recorded and calculated statistically, being summarized in Table 2.

The height of the plant has as limits of variation 54-69 cm, in 2019 and 62-79 cm, in 2020 with an average character of 67.5 cm. The insertion height of the first pod has an average of 29.2 cm, with variation limits between 29-35 cm in 2019 and 30-36 cm in 2020.

The number of pods formed per plant was between 10-42.8 in 2020, with an average of 27 pods per plant. The total number of grains formed on the pod has an average of 0.92, being between the minimum limits of 0.06 and the maximum of 1.05.

Table 2. Influence of herbicides on the main elements of productivity in chickpea cultivation. A.R.D.S. Teleorman, 2019-2020

No.	Productivity elements of the chickpea plant at harvest											
	The height of the plant		The height of the first pod (cm)		Grain weight/plant (g)		Number of pods/plant		Number grain/pods (g)		TGW (g)	
	2019	2020	2019	2020	2019	2020	2019	2020	2019	2020	2019	2020
V1	54	62	29	36	10	13	12	13.5	0.90	1.00	202	279
V2	69	71	27	32	28	36	31	35.2	1.02	1.03	232	265
V3	67	70	27	31	24	38	30	33.5	1.01	1.03	275	320
V4	69	79	26	32	21	32	25	28.0	1.00	1.01	274	300
V5	79	75	27	35	23	31	23	30.4	1.01	1.02	244	285
V6	63	77	24	31	16	29	18	25.0	1.00	1.00	275	288
V7	67	79	23	30	20	37	23	26.1	1.00	1.01	252	297
V8	69	72	24	31	27	40	35	42.8	1.03	1.04	231	301
V9	68	72	26	33	24	33	22	26.6	1.03	1.05	315	335
V10	68	71	26	30	23	34	23	28.2	1.01	1.04	311	325
V11	41	53	35	28	10	15	4	10.0	0.06	0.08	200	203
V12	60	65	23	34	17	29	19	25.3	1.00	1.00	278	311
Average	64.5	70.5	26.4	31.9	20.2	30.5	22.0	27.0	0.90	0.90	257	292

Thousand grain weight (TWG) values varied depending on the climatic conditions of the two experimental years. In 2019, the highest TWG of (315 g) was registered in the variant (V9).

In 2020, distinctly significant increases were recorded by V9 and V10 (335 g and 325 g, respectively).

The weight of the grains per plant has the variation limits between minimum 10 g in 2019 and maximum 40.5 g in 2020, the average being 26.2 g/pl.

The number of pods that showed a fruit caterpillar attack (*Helicoverpa armigera*) was absent (value 0) in the studied variety, Burnas.

When analyzing the productions made in 2020, the highest were obtained by the V8 variant (2010 kg/ha), the V3 variant (1950 kg/ha) and the V7 variant (1880 kg/ha), with very significant production increases, statistically ensured of 1447 kg/ha, 1387 kg/ha and 1316 kg/ha, compared to the untreated, untreated control (Figure 5).

At harvest, the production realized on variants was registered, statistically calculating the limit differences and the significance of the harvest increase brought by each herbicide and herbicide combination/experimental variant.

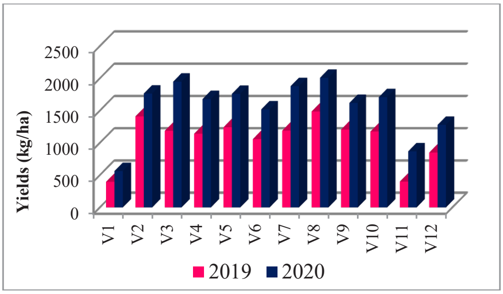

Figure 5. Yields of chickpea cultivation. A.R.D.S. Teleorman, 2019-2020

Table 3. Biometric values of chickpea nodules depending on the treatments applied. A.R.D.S. Teleorman, 2019-2020

No. field	Experimental variant	Volumetry (g/pl în 100 ml water) Frequency of plants with nodules %	Average number of nodules / plant	Of which				Weight of nodules (g/pl.)	
				main root	secundary roots	active nodules	volume for 100 ml water %	green	dry
A. DETERMINATIONS PERFORMED AT 50 DAYS									
Average 2019/2020									
V1	Control - untreated	0.01	4.0	1.0	3.0	4.0	0.1	0.16	0.03
V2	Untreated control 2 mechanical plows	0.20	15.0	13.7	1.7	11.0	0.20	1.13	0.19
V3	Leopard 50EC + Merlin Flex	0.01	9.6	8.3	1.3	9.6	0.05	0.53	0.10
V4	Dual Gold 960EC+ Merlin Flex	0.02	8.6	6.3	2.3	5.6	0.01	0.21	0.02
V5	Dual Gold 960 EC + Merlin Flex	0.05	10.4	9.0	1.4	9.0	0.05	0.38	0.03
V6	Gardoprim Plus Gold 500 SC	0.10	12.0	12.0	-	12.0	0.10	0.59	0.07
V7	Gardoprim Plus Gold 500 SC + Merlin Flex	0.05	10.3	8.3	2.0	8.3	0.05	0.29	0.05
V8	Gardoprim Plus Gold 500 SC + Merlin Flex	0.03	10.0	5.0	5.0	8.0	0.05	0.31	0.05
V9	Gardoprim Plus Gold 500 SC +Lentagran+ Lentagran	0.08	10.0	9.0	1.0	10.0	0.01	0.11	0.02
V10	Dual Gold 960EC + Challenge 600 SC	0.09	12.0	9.3	2.7	12.0	0.01	0.35	0.06
V11	Dual Gold 960EC+ Pulsar 40	0.01	8.0	6.0	2.0	8.0	0.20	0.06	0.01
V12	Dual Gold 960EC + Sencor 600 SC	0.02	11.3	7.0	4.3	9.0	0.01	0.43	0.09

Table 4. Biometric values of chickpea nodules depending on the treatments applied. A.R.D.S. Teleorman, 2019-2020

No. field	Experimental variant	Volumetry (g/pl în 100 ml water) Frequency of plants with nodules %	Average number of nodules / plant	Of which				Weight of nodules (g/pl.)	
				main root	secundary roots	active nodules	volume for 100 ml water %	green	dry
B. DETERMINATIONS MADE AT FLOWERING									
Average 2019/2020									
V1	Control - untreated	0.05	6.3	6.3	-	-	0.05	0.230	0.030
V2	Untreated control 2 mechanical plows	0.01	8.0	6.0	2.0	-	0.01	0.659	0.161
V3	Leopard 50EC + Merlin Flex	0.02	4.5	4.3	0.2	-	0.02	0.593	0.110
V4	Dual Gold 960EC+ Merlin Flex	0.01	4.6	4.6	-	-	0.01	0.291	0.050
V5	Dual Gold 960 EC + Merlin Flex	0.01	4.0	4.0	-	-	0.01	0.114	0.016
V6	Gardoprim Plus Gold 500 SC	0.01	5.0	6.0	-	-	0.01	0.256	0.040
V7	Gardoprim Plus Gold 500 SC + Merlin Flex	0.01	4.0	4.0	-	-	0.02	0.236	0.046
V8	Gardoprim Plus Gold 500 SC + Merlin Flex	0.02	3.6	3.6	-	-	0.01	0.142	0.019
V9	Gardoprim Plus Gold 500 SC+Lentagran+ Lentagran	0.05	6.3	6.3	-	-	0.05	0.787	0.166
V10	Dual Gold 960EC + Challenge 600 SC	0.07	7.3	6.6	0.7	-	0.01	1.186	0.239
V11	Dual Gold 960EC+ Pulsar 40	0	1.5	1.5	-	-	0	0.070	0.009
V12	Dual Gold 960EC + Sencor 600 SC	0.01	3.6	3.3	0.3	-	0.01	0.347	0.068

The results of the determinations regarding the number of nodules (average over the two years) at the two growth phases are presented in Table 3 and Table 4. From the analysis of the obtained data, it is found that the chickpea plant forms nodules with naturalized bacteria existing in the soil, the number of nodules/plant highlights the differentiation of the number of nodules and their weight depending on the experimental variants used in weed control.

The number of nodules was maximum in the control variant (two mechanical plows), respectively, 15 nodules per plant compared to other experimental variants, and 12 nodules per plant in variant V6 and variant V10. The lowest number of nodules was recorded at V11, V4, V5, V7 and V8, respectively. Analyzing the average number of nodules per plant outlines the idea of a phytotoxic, attenuating and inhibiting effect in herbicide combinations, in which isoxaflutole is present, at a dose of 0.300 l/kg with pre-emergent application. In V3, a similar effect is found, even under conditions of dose reduction and early post-emergence application.

The influence of isoxaflutole on the decrease of the weeding degree is evident in all variants, with the specification that at the used doses the process of biological fixation of (N) is inhibited in certain percentages.

The realized productions kept obvious differentiations considering the fertilization based on (N), the dose applied to the preparation of the germination bed. In the variant with obvious phytotoxic effect on chickpea plants (V11), the use of imazamox reduces the number of nodules per plant, given that the degree of weeding is higher and influences the level of production. These determinations will be repeated, in the 3 year of experimentation, anticipating the deregulation of the biological fixation process of (N), as an indicator regarding their degree of selectivity for the chickpea plant.

From a phenotypic point of view, the selectivity was marked with 1, in the associations with isoxaflutole, which will be completed with the criteria on the influence on the biological fixation process.

From the point of view of the weight of the nodules, these observations are confirmed, and they will be observed in the 3 year of experimentation.

Most nodules are found on the main root, and a small percentage is located on the secondary ones (%).

In choosing the weed control strategy, apart from efficacy and selectivity, the effect of compatibility with the process of fixing (N) for chickpea culture will also be followed.

CONCLUSIONS

The results obtained in the studied variants highlight the favorable effect of herbicides and herbicide combinations, in pre-emergence and some in post-emergence on the elements of chickpea productivity, materialized by harvest increases at (V8), (V5), (V9), (V7) and (V3), compared to the two controls, in the years studied. The production of grains does not correlate positively with bacterization, the highest production being recorded in the non-bacterialized version.

Determinations of nodule formation on the main and secondary roots of chickpea plants, by the total number of nodules per plant and the number of active nodules 50 days after application of the herbicide, show that atmospheric nitrogen (N) fixation differs depending on the dose and the combination of treatment, having high physiological indices only, to certain substances and combinations of herbicides.

A good ability to fix atmospheric nitrogen can be determined, first of all, not by the total number of nodules, but by their total mass and the longevity of the symbiosis, expressed in the active bacterialization process in chickpeas culture.

The use of chemicals in chickpeas to control weeds can also affect the metabolic activity of plants through its phytotoxic effect and can therefore reduce grain production if the doses used are not observed.

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ANALYSIS OF THE RANGE OF PESTS AND THEIR EFFECT ON MAIZE PLANTS GROWING IN THE ORGANIC SYSTEM

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Abstract

Organically grown corn has attracted the attention of producers and traders and is increasingly in demand on the world market. With the expansion of this type of crop in which the use of pesticides is not allowed, the species of harmful insects have also multiplied. In this paper we set out to evaluate two lots of corn in western Romania, one with organic corn after 3 years of practice and another in the first year. Thus, we found that in the lot of 3 years under the organic system, the range of species was much more comprehensive and the population level of each species higher than in the lot in the first year. The active stages (as the case may be, of adults, larvae or nymphs) of the species of hemipteran, coleopteran and lepidopteran, which were the most frequent in the lots under observation, affected both the aerial and the underground part of the plants. The damages produced in the lot with 3 years affected the plants in vegetation (from the plant emergence until the maturity of the cob) in percentages of 17-18% as opposed to the damages from the lot in the first year in which the damages were of 5-7%. It is obvious that the longer the culture is on the same substrate, the more the pests become and produce damage with definite repercussions.

Key words: *corn, organic system, pests, range, damage.*

INTRODUCTION

Romania is considered one of the largest corn producing countries in the EU, according to the European Commission (2020). However, the occupation of agricultural areas with organic crops or ecologically it is quite low, somewhere at 8.5%, therefore, through the Action Plan for the development of organic production of the European Commission for a future period of 10 years, an extension of 25% is foreseen (Uros, 2021).

Sometimes the term "ecological" or" biological" is used in the literature (Stoleru & Sellitto, 2016). In essence, these synonyms express the same characteristics as for organic farming, which is considered to be an increasingly environmentally intensive production system worldwide (Willer et al., 2019). We chose to approach the term "organic" in this paper because it seemed closer to the culture of corn in vegetation.

Organic crops are very often associated with a lower yield on the same land area compared to the conventional system. However, a great advantage of this approach is to protect natural capital through the use of natural enemies, the use of natural fertilizers (by the contribution of nitrogen left by leguminous) and by minimizing tillage (Pretty & Bharucha, 2015).

Given the concern for increasing the cultivation of plants suitable for this system, we turned our attention to corn, which is considered profitable (Brock et al., 2021).

In order to have a holistic picture of all pests in a corn crop (regardless of the cultivation system) it is necessary to know where to focus at the plant level. In this sense, Ortega (1987) recommends an assessment of each essential organ, namely tassel, ear, stem, foliage, roots and seeds.

In organic systems, crops can be more difficult to manage in terms of pests due to the principles of organic farming, especially the limitation of the use of chemicals that have a much higher effectiveness compared to chemicals (Farag, 2019).

Broadly speaking, crop pests include insects, weeds, plant pathogens, insects, and other invertebrates or vertebrates (Ash, 2003). We will focus only on the group of insects, which are in fact the most common and diverse in organic farming (Gomiero et al., 2011) and implicitly in the cultivation of corn.

In addition to limiting the use of pesticides, practicing corn after corn (or monoculture) in large corn-producing areas facilitates the proliferation and growth of harmful insects (He et al., 2019; Piesik A. & Piesik D., 2021).
Among the harmful animals, arthropods and implicitly insects are the most present in corn crops, and the most representative species in Europe is by far *Ostrinia nubilalis*. This pyraustid lepidopterus occurs in any type of culture system and the damage it causes in the absence of adequate control measures reaches up to 30% (Stoleru & Sellitto, 2016).
For 27 years, corn crops in Romania have been affected by the chrysomelid species Diabrotica *virgifera* (Vonica, 1996; Grozea, 2010), another important pest for corn crops. Over time, various non-pollutant strategies have been developed to control this pest, most of them focusing on prevention, through monitoring, with using traps to catch beetles, both local (western part of the country) and national level (Hancu et al., 2001).
Aphids are very common hemipteran (suborder Homoptera) in most crops and other important crops (Wieczorek et al., 2019). They cause direct and indirect damage, leading to a decrease in yields in various ways. Among the common aphids of corn is *Rhopalosiphum maidis* which can develop high population densities that dehydrate and deprive the plants of nutrients, are also important vectors for viruses (Sorensen, 2009). All of these are difficult to control, especially in organic systems, where pesticides are restricted or banned, so they can be considered extremely dangerous. Through our study we aimed to see how the density increases in aphid populations over time without chemical control measures.
After Bailey (2007) corn can be attacked by a wide range of insects that can be major or minor as economic importance. Unlike the major pests who appear regularly, the minors appear irregularly and do not create problems every season.
In the present paper we aimed to analyse the evolution of densities in populations and the range of insect species in maize crops in organic system practiced for a short time or longer and the impact of damage on plant growth.

MATERIALS AND METHODS

The 2 lots with organically grown corn were established and maintained in 2 localities in western Romania (Figure 1), according to the principles of organic agriculture, no chemical element or aggressive method being present. The plot with corn after 1 year of practicing in organic system (Lot 1) was placed in Seleus (46°22'29.5"N 21°45'01.1"E) and the one with corn after 3 years of practice (Lot 2) placed in Sicula (46°30'03.9"N 21°46'51.8"E). There is a distance of 8 km between the 2 lots (locations), so there was no possibility of insect migration.
The size of the analysed area in each of the 2 locations was 9000 m^2 (100 m wide x 90 m long) out of a total compacted area of 7.5 hectares.
The maize hybrid used was of course untreated, namely Pioneer P9757 (FAO 370), which responds positively to any climatic and technological conditions.

Figure 1. a) Images from experimental lots; from the lot after 3 years of practicing the organic system in advanced vegetation (down, left) and the plot after 1 year of practicing the organic system in the emergent phase (down, right); yellow panel traps with attached pheromone (top, left) and detailed study for correct pest identification (top, right); b) Placement of lots and details of their locations (down, right)

In order to evaluate the harmful populations from the experimental lots, during the year 2021, we used 2 types of traps, both from the same producer (Csalomon, Budapest). Thus, for capturing adult beetles (Grozea, 2003) and hemipterans (larvae, nymphs and adults) a type of trap with coloured Panel and pheromone was installed and for adult lepidoptera we used box type traps.
Checking and reading the traps was done directly in the field, every 15 days during the vegetation period of the corn in June-September.

The assessment was made taking into account the stages of maize development according to the BBCH scale (Lancashire et al., 1991).
The monitoring of *Diabrotica* beetles (proven to be very suitable for capture by using traps) consisted of carrying out insect capture activities using sticky yellow panel pheromone traps (type Csalomon PAL) (Figure 1), from the Institute for Plant Protection, MTA ATK. Their principle of operation is based on attraction through chemical and visual stimuli and it catches females as well as males (Toth et al., 2007). Usually, these traps can catch other pests that are not specific to corn but can cause damage (Subchev et al., 2005; Toshova, 2017). Their location was made at a distance of 50 m, on the diagonals thus covering the central and lateral parts of the plot (Horgos & Grozea). The capture of aphids was also done by 2 Yellow Pan Traps (Moericke) effective in monitoring and control.
The sticky traps for coleopterans and hemipterans were placed in the crops on the 2 diagonals (134.5 m long/each diagonal) 3 traps/diagonal (of which 1 commune, central). These were changed every 3 weeks.
For lepidopteran, 2 box traps and 2 light traps were placed on the 2 diagonals, and these were changed every 4 weeks.
To assess the harmful stages in the soil, we used the method of evaluation in terms of direct observation on the root and plucking 10 out of 10 of the plant in a row. Thus, the larvae of genus *Agriotes*, *Diabrotica* or other species present at a given moment in the corn crops were quantified directly in the experimental field with the help of the portable magnifying glass.
In each lot, at the 10th plant on the growth row, at each trap reading, we also analysed the damage both aerially and at the root (uprooted plants). For the damage assessment, the mean values, the standard error (SE) and the median (statistical correlation) were established.

RESULTS AND DISCUSSIONS

Observations in different stages of maize growth in the 2 lots highlighted the presence of several harmful species belonging to the 3 major categories of insects. Thus, in the lot cultivated in organic system after 1 year, the following species were present: *Diabrotica virgifera, Tanymechus dilaticollis, Opatrum sabulosum, Oulema melanopus, Agriotes* sp. and *Phyllotreta vittula* (from Coleoptera) (Table 1). The same species were identified in the lot in the organic corn practiced for 3 years, plus the species *Chaetocnema tibialis*.

Table 1. Status of harmful coleopteran species in the 2 lots of organic maize (Lot 1-after 1 year of practicing of organic system and Lot 2-after 3 years) in correlation with the plant stages (BBCH code)

Harmful species identified in Lot 1 and Lot 2	Active stage of the pest/BBCH code	Status of pest development stages/ maize lots analyzed	
		Lot 1	Lot 2
Diabrotica virgifera	01:18 05: 51-59 06: 61-69 07: 71-75	+(A_t, L_s)	+(A_t, L_s)
Tanymechus dilaticolis	00:09	+ (A_o)	+ (A_o)
Opatrum sabulosum	00:09	+(A_o)	+(A_o)
Oulema melanopus	05: 51-59 06: 61-69	+(A_t, L_p)	+(A_t, L_p)
Agriotes sp.	00:03-09 01:10-18	+(L_s)	+(L_s)
Chaetocnema tibialis	01:11-18	-	+ (A_t)
Phyllotreta vittula	01:11-18	+ (A_t)	+ (A_t)

+/- Presence status; At-adult on traps; Ao- adult observed on plant or soil; Ls- larva in soil; Lp-larva on plant; BBCH code (after Lancashire et al., 1991);

From the group of hemiptera were identified the species *Rhopalosiphum maidis* and *Rhopalosiphum padi* (in the lot with organic corn after 1 year), and *Metcalfa pruinosa* and *Nezara viridula* (only in the lot with organic corn after 3 years). The species of aphids were present in both analysed lots (Table 2).

Table 2. Status of harmful hemipteran species in the 2 lots of organic maize (Lot 1-after 1 year of practicing of organic system and Lot 2-after 3 years) in correlation with the plant stages (BBCH code)

Harmful species identified in Lot 1 and Lot 2	Active stage of the pest/BBCH code	Status of pest development stages/maize lots analyzed	
		Lot 1	Lot 2
Rhopalosiphum maidis	01:14-19 05: 51-59 06: 61-69	+(N_t, A_t)*	+(N_t, A_t)*
Rhopalosiphum padi	01:14-19 05: 51-59 06: 61-69	+(Nt, At)*	+(N_t, A_t)*
Metcalfa pruinosa	05: 51-59	-	+(N_o, L_o)
Nezara viridula	06: 61-69 07: 71-73	-	+(A_o, N_o, L_o)

+/- Presence status; At/Nt-adult/nimph on trap; Ao/No/Lo-adult/larva/nimph observed on plant; *many asexual forms without wings and wings

In the study lot we observed nymphs and adults of *Metcalfa pruinosa* (Table 2), indeed in small numbers compared to the other main species of corn. We assume that they were only accidentally installed on the corn leaves, but it is not excluded that in the future an increasingly large population will develop.

We have the certainty that in the organic system, corn can be easily infested by insects that, even if they are not specific, can become predominant, even leading to significant damage. In fact, this species has been reported in a corn crop in Hungary a few years ago (Bozsik, 2015). We mention that so far, this flatid cicada has not been reported on corn plants in Romania only on the ornamental ones and some fruit and vine species (Vlad & Grozea, 2016).

Among the insects of the order Lepidoptera, we identified the species *Ostrinia nubilalis* and *Helicoverpa armigera*, present both lots and *Agrotis* sp. observed only in the lot after 3 years (Table 3).

Table 3. Status of harmful lepidopteran species in the 2 lots of organic maize (Lot 1-after 1 year of practicing of organic system and Lot 2-after 3 years) in correlation with the plant stages (BBCH code)

Harmful species identified in Lot 1 and Lot 2	Active stage of the pest/BBCH code	Status of pest development stages/ maize lots analyzed	
		Lot 1	Lot 2
Ostrinia nubilalis	01:14-19 05: 51-59 06: 61-69	+(A_t, L_p)	+(A_t, L_p)
Helicoverpa armigera	01:14-19 05: 51-59 06: 61-69	+(A_t, L_p)	+(A_t, L_p)
Agrotis sp.	01:14-19 05: 51-59 06: 61-69	-	+ (A_t)

+/- Presence status; At-adult on traps; Lp-larva on plant

Comparing the number of catches or individuals quantified in the 2 lots, we could find that in the lot with corn in the organic system practiced only 1 year the abundance of species was visibly lower than in the lot in which the organic system was practiced for 3 years. The highest values were recorded, for both lots, in the cases of *Diabrotica virgifera* (adult form) (1248 individuals/Lot 1 and 2277 ind./Lot 2) (Figure 2). Also, with a value over 500 ind. fleas from the genus *Phyllotreta* (648 ind./Lot 2) but also from the genus *Chaetocnema* with 567 ind./Lot2) were highlighted. The other beetle species had values below 500 ind./lots (Figure 2).

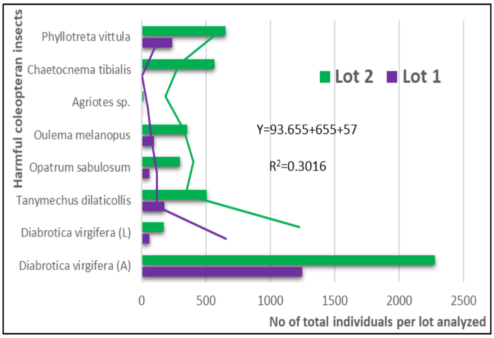

Figure 2. Comparative trends of catches of harmful coleopteran insects quantified in the 2 experimental corn lots (Lot 1-after 1 year of practicing of organic system and Lot 2-after 3 years)

And in terms of the abundance of hemipteran species, these were predominant in Lot 2 compared to Lot 1 (Figure 3). Aphid species such as *Rhopalosiphum maidis* recorded double values (2584 ind. in group 2) compared to Lot 1 (1161 ind.) and *R. padi* had a value of 1787 ind. in Lot 2 compared to Lot 1 (795 ind.) (Figure 3).

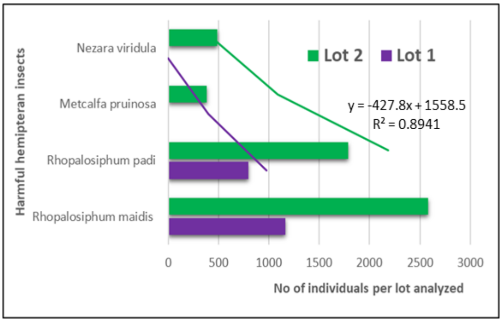

Figure 3. Comparative trends of catches of harmful hemipteran insects quantified in the 2 experimental corn lots (Lot 1-after 1 year of practicing of organic system and Lot 2-after 3 years)

Due to the abundance of lepidopteran insects in the 2 lots, the species of *Ostrinia nubilalis* (in adult form) was captured in higher values in Lot 2 (1268 ind.) than in Lot 1 (697 ind.) (Figure 4). In fact, in the case of *Helicoverpa a.* lepidopteran (adult) the situation was also similar (545 ind./Lot 2 and 269 ind./Lot 1) (Figure 4). Catches of the genus Agrotis were recorded only in Lot 2 (359 ind.).

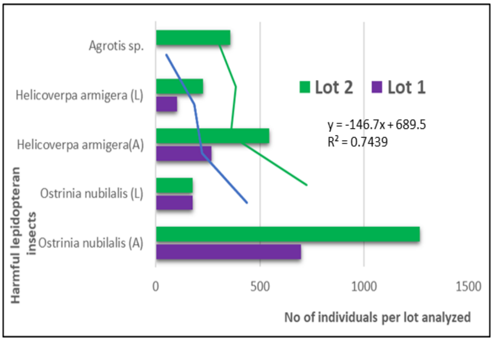

Figure 4. Comparative trends of catches of harmful lepidopteran insects quantified in the 2 experimental corn lots (Lot 1-after 1 year of practicing of organic system and Lot 2-after 3 years)

Analysing the bi-monthly evolution of beetle catches in the 2 lots, it can be seen in Figure 5 that in June-September the adults of Diabrotica had a maximum activity at the beginning of August (308 ind./Lot1; 561ind./Lot 2) while the larvae at the end of June (41 ind./Lot 1; 112 ind./Lot 2). Another chrysomelid (*Oulema m.*) recorded a maximum of activity at the end of July (60 ind./Lot 1; 168 ind./ Lot 2). *Phyllotreta v.* also entered the category of chrysomelids with a maximum of activity at the end of June (107 ind./Lot 1; 269 ind./Lot 2) and the species *Chaetocnema t.* with a maximum also in June (0 ind./Lot 1); 278 ind./Lot 2). Among the beetles active at the beginning of summer, immediately after the emergence of maize plants, we can mention *Tanymechus d.* with a maximum of activity at the beginning of June (100 ind./Lot 1; 279 ind./Lot 2) and similar *Opatrum s.* (32 ind./Lot1; 188 ind./Lot 2) (Figure 5).

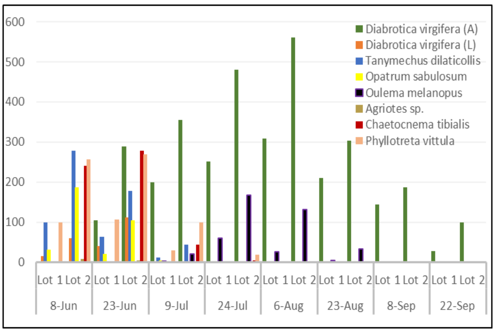

Figure 5. Bimonthly dynamics of harmful coleopteran insects (total caches of adults-A or larva-L) in the 2 lots cultivated in organic system practiced after 1 year and after 3 years

Agriotes larvae were only present in very small numbers, only 1 in Lot 1 and 9 in Lot 2 were observed, and the explanation could be the lack of water in the soil in spring-summer 2021.

The evolution of the bimonthly activity of hemipteran pests is given in Figure 6. It can be seen that the aphids are most active at the end of June when the maximum values were recorded, so for the species *Rhopalosiphum maidis* were captured in the period of maximum activity 420 ind./Lot 1 and 888 ind./Lot 2 and for *R. padi*, 277 ind./Lot 1 and 509 ind./Lot 2. The activity of *Metcalfa pruinosa* and *Nezara viridula* species was only in Lot 2, so for *M. pruinosa*, the maximum activity was registered at the end of June (101 ind.) and for N. *viridula* the maximum was at the end of August with 148 ind. (Figure 6).

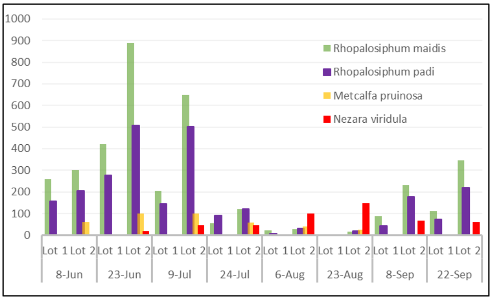

Figure 6. Bimonthly dynamics of harmful hemipteran insects (total caches) in the 2 lots cultivated in organic system practiced after 1 year and after 3 years

The maximum flight of the adult lepidoptera *Ostrinia n.* and *Helicoverpa a.* was achieved at the end of July with 246 ind./Lot 1 and 346 ind./Lot 2 and respectively 128 ind./Lot 1 and 280 ind./Lot 2 (Figure 7). Agrotis adults were quantified only for Lot 2 (where they were present) with maximum flight towards the end of August (132 ind.). The maximum activity of *O. nubilalis* larvae was at the beginning of August (88 ind./Lot 1; 88 ind./Lot 2) and of those of *H. armigera* at the end of July (128 ind./Lot1; 280 ind./ Lot 2) (Figure 7).

The percentage of attack produced by beetle pests had values of the average varied depending on the species and the stage of development for the 2 lots (Table 4). Thus, the adults of *D. virgifera* damaged approximately 10.5% in Lot 1 and 33.4% of the 500 analysed plants and those of *T. dilaticollis* about 12.3% of attacked plants in Lot 1 and 24.7% in Lot 2.

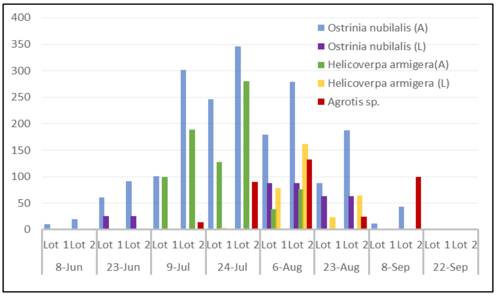

Figure 7. Bimonthly dynamics of harmful lepidopteran insects (total caches of adults-A or larva-L) in the 2 lots cultivated in organic system practiced after 1 year and after 3 years

Adults of *O. melanopus* affected 15.7% (in Lot 1) and 16.2% (in Lot 2) and *O. sabulosum* damaged 4.2% of plants/Lot 1 and 17%/Lot 2. Fleas from the genus Phyllotreta and Chaetocnema affected 4.0% of the plants analysed in Lot 1 and 17.8 % in Lot 2. At the root level, *Diabrotica* larvae caused damage to 3.1% of plants/Lot 1 and 11.4% of plants in Lot 2 (Table 4).

Table 4. Percentage of plant damage by harmful coleopteran in organic maize plots (L1 and L2)

Pest / Lots	Mean ± SE**		Median value	
	Lot 1	Lot 2	Lot 1	Lot 2
Diabrotica virgifera (A)	10.5±1.0	33.4±2.5	6.2	29.4
Diabrotica virgifera (L)	3.1±0.3	11.4±1.3	2.6	8.3
Tanymechus dilaticollis	12.3±2.6	24.7±2.1	9.5	19.1
Opatrum sabulosum	4.2±0.3	17.0±1.7	2.6	13.2
Oulema melanopus	5.7±0.7	16.2±1.9	8.1	9.3
Agriotes sp.	0.1±0.1	1.2±0.2	0.05	0.6
Chaetocnema tibialis	0	5.7±0.7	0	2.3
Phyllotreta vittula	4.0±0.7	17.8±1.0	1.5	13.6

*the standard error (SE)

The species *Chaetocnema tibialis* was observed on plants but also on weeds in lots and on traps, but we cannot comment on their damaging effects because only a few superficial individuals were observed on the leaves. According to Cagáň et al. (2006) these fleas are specific pests of weeds of the species *Amaranthus retoflexus* (very present in corn in the organic system).

The results on the effects of the damage on the plants produced by the hemipteran pests are presented in Table 5. The aphids from *R. maidis* species damaged the plants from the 2 lots in a percentage of 8.6% in Lot 1 and 15.5% in Lot 2. Those from *R. padi* species affected 6.5% of plants in Lot 1 and 17.1% in Lot 2. Stinky bugs of *N. viridula* attacked plants only in Lot 2 in a percentage of 5.6%, as well as *M. pruinosa* cicadas which affected 4.7% of plants from Lot 2 (Table 5).

Table 5. Percentage of plant damage by harmful hemipteran in organic maize plots (L1 and L2)

Pest / Lots	Mean ± SE		Median value	
	Lot 1	Lot 2	Lot 1	Lot 2
Rhopalosiphum maidis	8.6±1.2	15.5±1.4	4.0	10.1
Rhopalosiphum padi	6.5 ±0.9	17.1±1.0	4.2	12.8
Metcalfa pruinosa	0	4.7±0.4	0	1.8
Nezara viridula	0	5.6±0.8	0	2.1

*the standard error (SE)

Nezara viridula was observed only in isolated marginal areas of Lot 2 as well as Marcu (2018) who found 1 single outbreak in a mixed private garden.

We found in the second decade of August, 5 outbreaks of 7 plants with cobs in formation, full of larvae and nymphs, sometimes adults, then the number of individuals/outbreaks doubled in the third decade. The affected cobs could no longer be used due to the foul-smelling substance imprinted in the grains.

The effects of damaging the larvae of harmful lepidopteran in the experimental lots are shown in Table 6. There it can be seen that the larvae of *O. nubilalis* caused damage to 20.3% of the plants analysed in Lot 1 and 40.7% of the plants analysed in Lot 2.

The larvae of *H. armigera* caused damage in 11.5% of the plants under study in Lot 1 and 36.2% of the plants in Lot 2 (Table 6).

Table 6. Percentage of plant damage by harmful lepidopteran (larval active stage) in organic maize plots (L1 and L2)

Pest / Lots	Mean ± SE		Median value	
	Lot 1	Lot 2	Lot 1	Lot 2
Ostrinia nubilalis (L)	20.3±1.5	40.7±2.9	16.5	35.4
Helicoverpa armigera (L)	11.5±1.4	36.2±2.7	9.0	31.7

*the standard error (SE)

CONCLUSIONS

From the results presented in this paper we can conclude that in Lot 2 with maize grown organically after 3 years the diversity and abundance of harmful insects was clearly higher than in Lot 1 with maize grown organically after 1 year.

As repercussions of the feeding activity of coleopteran, hemipteran and lepidopteran insects in the experimental lots, we found that the damage percentage was almost 3 times higher in Lot 2 than in Lot1 (6.4%/Lot 1 and 17.8%/Lot 2).

All this entitles us to agree that organic corn attracts many pests, which multiply and affect the crop from the first year, especially if the crop is kept on the same land for 3 years.

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RESEARCH REGARDING THE CONTAMINATION WITH *Fusarium* spp. OF THE WHEAT GRAINS FROM THE VARIETY *Triticum aestivum* ssp. *spelta* BEFORE AND AFTER THE TREATMENT WITH BIO-FUNGICIDE - CASE STUDY

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Abstract

In the last 20 years, the demand for spelt wheat has increased rapidly and was anticipated that it will continuate to increase with a rate of about 5% annually. The demand is determined by the consumers perceptions and by the scientific proofs that highlight that spelt wheat has a higher nutritional value compared with common wheat. The purpose of this research was to determinate the Fusarium spp. contamination level of the spelt wheat grains treated with bio-fungicide in comparison with the non-treated variants. The biological material used in this research was the spelt winter wheat variety Rokosz. The obtained results after the incubation of the samples show the presence of the fungus Fusarium spp. in the spelt wheat grains from all the variants. The contamination index determined was 73% in the non-treated variant and 80% in the treated one. The insignificant difference was considered to be influenced by the fact that spelt wheat grains are covered with hull, that being the reason why the bio-fungicide doesn’t adhere to the seed surface.

***Key words**: Fusarium sp., Triticum spelta, bio-fungicide, spelt wheat, fungal contamination.*

INTRODUCTION

Spelt wheat (*Triticum aestivum* ssp. s*pelta*) is an ancient wheat with the grain covered with hulls, that was cultivated still from the year 7000-8000 BC (Dvorak et al., 2012; Packa et al., 2019). This wheat subspecies is suitable for cultivation in different climatic and pedological conditions, sometimes even harsher compared to common wheat, it being able to grow in mountainous areas and in nutrient-poor soils too (Bonafaccia et al., 2000; Pospišil et al., 2011). Spelt wheat has been disadvantaged in cultivation for long time in the favour of common wheat, mainly due to the low yields (Krawczyk et al., 2008). However, the ability of spelt wheat to tolerate unfavourable environmental conditions and the valuable nutrients contained in the grains has caught the attention of the farmers as well as the consumers attention. (Haliniarz et al., 2020). Spelt wheat has a higher content of minerals and proteins in comparison with common wheat (Capouchova, 2001; Lacko M., 2010; Suchowilska et al., 2012).

Most experts point out that in the last 20 years, the area cultivated with spelt wheat has increased. There is an annual increase of the areas cultivated in the conventional farming system, but the increase is greater in the ecological farming area with about 5%; thus, there was noticed the expansion of this crop in areas where it wasn’t cultivated before (Lacko-Bartošová et al., 2010; Koutroubas et al., 2012; Wang et al., 2021). *Triticum spelta* is nowadays an attractive crop for cultivation in ecological farming system due to its natural resistance to the attack of the pathogens and pests determined by the hulls that adhere tight to the caryopses and which acts as a protective barrier against all the external factors (Wiwart et Suchowilska, 2009). In addition to diseases and pests, invasive species of weeds are a threat for wheat (Ştef et al., 2013; Vîrteiu et al., 2015).

Spelt wheat cultivated in ecological farming system doesn't needs application of fertilizers and phytosanitary treatments as is necessary for the common wheat and durum wheat (Radomski et al., 2007; Kohajdova et Karovicova, 2008; Krawczyk et al., 2008; Wilson et al., 2008; Zielinski et al., 2008).

Spelt wheat is suitable for organic agriculture where the application of synthesis fertilizers and pesticides are forbidden due to its obvious qualities (valuable nutrients, tolerance for diseases and pests and for unfavourable soil and climate conditions) (Finch et al., 2006; Sinkevičienė et al., 2019).

In Romania, the areas cultivated with spelt wheat in conventional system and organic system are increasing (Eurostat, 2022).

Fusarium head blight is a very dangerous disease of wheat produced by different *Fusarium* species which in the favourable years determinates important harvest loses, both quantitative and qualitative (Becher et al., 2013; Cotuna et al., 2013; Paraschivu et al., 2014). Climate changes from the last years have leaded to the repeated appearance of the fusarium head blight epidemics in the great wheat-growing areas; they have damaged the harvests due to the mycotoxins present in grains (Aboukhaddour et al., 2020). While many aspects of common wheat resistance to fusarium head blight are known nowadays, there are fewer researches referring to the resistance levels and sources of resistance in spelt wheat (Buerstmayr et al., 2020; Zhu et al., 2019; Miedaner et al., 2019).

In these researches was tested a low number of spelt wheat genotypes (Chrpová et al., 2013; Wiwart et al., 2016; Góral și Ochodzki, 2017). Chrpova et al. (2021) shows that most of the modern spelt wheat varieties are susceptible and very susceptible to fusarium head blight and to the contamination with deoxynivalenol (DON).

The researches regarding the use of the biological agents for the control of fusarium head blight are few. Sinkevičienė et Pekarskas (2019) highlight the efficiency of some bio-products (medicinal plants extracts, bio-humus and volatile oils) on some grain pathogens from the experiments carried out on spring wheat varieties. The same authors show that the efficiency of some bio-products against the fungus *Fusarium* was even 50% in some variants. Couto et al. (2021) shows in research that the treatment with *Trichoderma* spp. applied to the common wheat grains had the capacity to prevent and even to control the fungi from the genus *Fusarium*, the number of grains free of fungi being increased after treatment in comparison with the non-treated control.

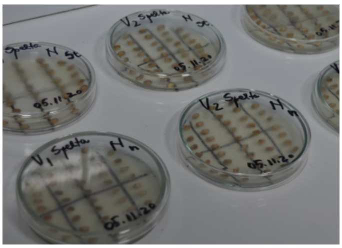
The researchers are even less in the case of spelt wheat, mostly for the cultivation in ecological cropping system where the seeds shall be treated with bio-fungicides.

The relaunch of the spelt wheat crop, especially in the organic cultivation system, requires researches on the effectiveness of bio-fungicides against to the pathogens that infect the seed.

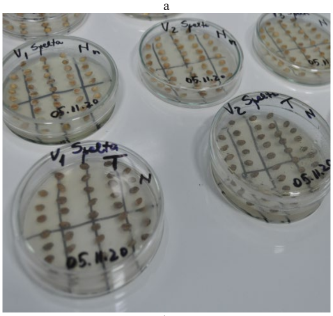
In the present research, samples of organic spelt wheat seed of the Rokosz variety (from Poland) were analysed in the laboratory before and after the treatment with a bio-fungicide based on *Trichoderma* spp. The seeds of spelt wheat were designated for the establishment of an organic crop. The spelt wheat variety Rokosz was analysed to determinate if it is contaminated with *Fusarium* spp. The aim of the study was to assess the fusarium head blight contamination index of spelt wheat before and after treatment; other aspect analysed was the treatment efficiency.

MATERIALS AND METHODS

In this experiment was used as biological material a variety of spelt winter wheat (*Triticum aestivum* ssp. *spelta*) produced in Poland and approved in the year 2012 named Rokosz. This spelt wheat variety is suitable for ecological cropping system due to its features. In laboratory were brought two samples of one kilogram each, one treated and one non-treated with bio-fungicide, to be analysed from the point of view of the contamination with *Fusarium* spp. the two samples were collected from a batch of seeds that was brought from Poland in order to be cultivated in an organic farm from Timiș County. The bio-fungicide used for the spelt wheat seeds is one allowed in ecological agriculture. The product used has the commercial name Micover WP and is formulated as wettable powder. This bio-product contains mycorrhizae (*Rhizophagus irregularis,* AGF 630, 20% (1 x 10^3 prop./g), rhizobacteria (*Bacillus* sp. AGF 527 1 x 10^6 CFU/g) and spores of the antagonist fungus *Trichoderma harzianum* AGF 276 1 x 10^8 UFC/g. The seeds were treated with the dose of 1 kg/t Micover WP in mixture with a product based on marine algae *Ascophyllum nodosum* - 3 l/t (Superfifty). The contamination index of the seeds with *Fusarium* spp. was assessed with the classical method that consists in placing of the seeds in Petri plates on agar culture medium. The culture medium used in this experiment was simple agar that was prepared in laboratory. The preparation of the spelt wheat seeds for the culture medium was done respecting the following preparatory stages: seeds washing with tap water; seeds disinfection in ethanol 96% for 1 minute; the successive washing of the caryopsis disinfected in two sterile water baths; drying of the washed seeds on sterile filter paper. There were prepared three variants with three replicates (about 41 caryopsis/ replicate): non-sterilized and non-treated (V1), sterilized and non-treated (V2) and treated with bio-fungicide (V3). After the placing of the seeds on the culture medium the Petri plates were incubated at the temperature of 24 ºC for 7 days.



a



b

Figure 1. a) and b) Spelt wheat seeds from the variety Rokosz placed on agar culture medium for the stimulation of pathogens growth (Cotuna Otilia, 2020)

The samples were evaluated after 7 days from incubation. The examination of the mycelia growth on seeds was realised at stereomicroscope, being completed with microscopic evaluation for the accurate identification of the fungi that have growth on the seed surface. The obtained data were used for the calculation of the fungal contamination index (ICS%). This index for the spelt wheat was calculated with the formula: *ICS% = contaminated seeds no./total seeds no. on plates x 100* (Doolotkeldieva, 2010)**.** The statistical analysis was performed with the software JASP (Version 0.14) (2020).

RESULTS AND DISCUSSIONS

The use of bio-products based on *Trichoderma* spp. for the wheat seed treatment is mentioned in very few studies nowadays. There are necessary numerous researches to show the efficiency of the *Trichoderma* species against the seed pathogens and to indicate the precise doses for a good control. In the present study, the bio-product used for the seeds of spelt wheat contains *Trichoderma harzianum* spores in a concentration of 1x10^8 UFC/g. The spelt wheat seeds from the V1 weren't treated with bio-fungicide and weren't sterilized before the placing on the culture medium for the observation of the mycelia growing from the exterior and from the interior of the seeds. The three replicates of this variant were contaminated with *Fusarium* spp. in rates comprised between 68% and 78%. The average of the fungal contamination of the variant was 72.35% (Figure 2).

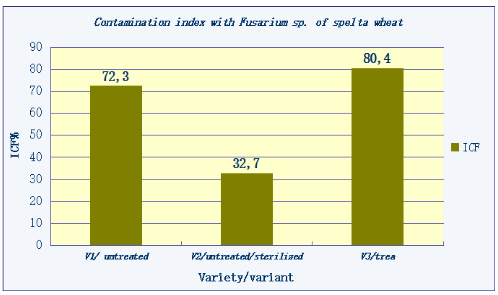


Figure 2. Comparative presentation of the contamination index with *Fusarium* spp. of spelt wheat seeds from variety Rokosz (Cotuna Otilia, 2020)

In V2 the spelt wheat seeds weren't treated with bio-fungicide, but they were sterilized with alcohol 96% for 2 minutes to observe the mycelia growing from the interior of the seeds. The contamination rate with *Fusarium* spp. of this variant was comprised between 25% and 41%. The variant average was 32.72%, much lower in comparison with the V1 in which the seeds weren't sterilized with alcohol.
In V3 the seeds were treated with bio-fungicide, they were left to dry and after were placed on the culture medium. The index of fungal contamination from this variant was comprised between 60% and 93%. The average contamination rate of the sample was 80.48%, the highest from the experiment, even the seeds were treated with bio-fungicide (Figure 2)
After the incubation of the samples, at the surface of the seeds were grew white-pinkish mycelia. The analysis at stereomicroscope revealed the presence of the mycelia with cottony like white-pink mycelia specific to the fungus *Fusarium* spp. on the surface of the spelt wheat seeds in all the analysed variants in different rates (Figures 3-5).
Identification of the pathogen *Fusarium* spp. was done in a first stage visually by analysing the mycelia at the stereomicroscope and second after the fungus was identified using the microscope.

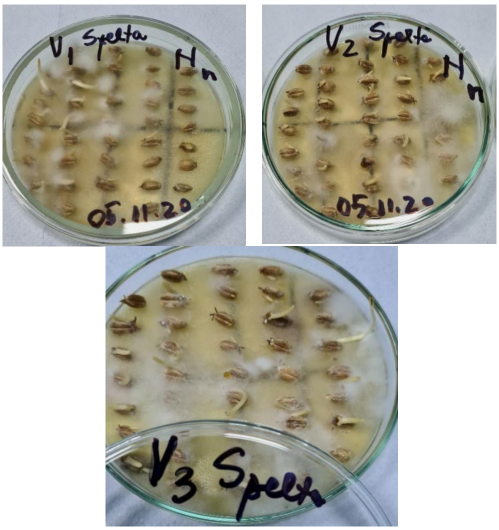


Figure 3. *Fusarium* spp. mycelia grown at the surface of spelt wheat seeds from V1, non-treated and non-sterilized (Cotuna Otilia, 2020)

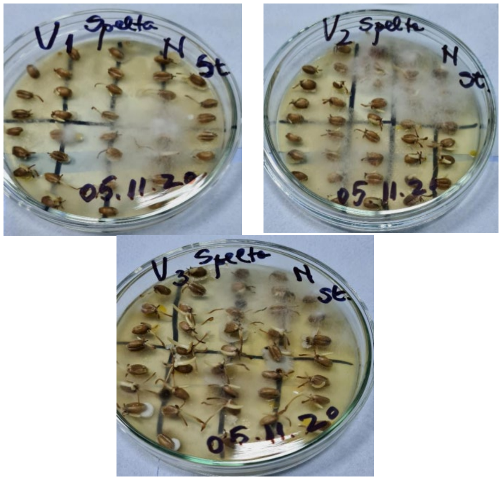


Figure 4. *Fusarium* spp. mycelia grown on spelt wheat seeds surface from V2, non-treated but sterilized with ethanol 96% (Cotuna Otilia, 2020)

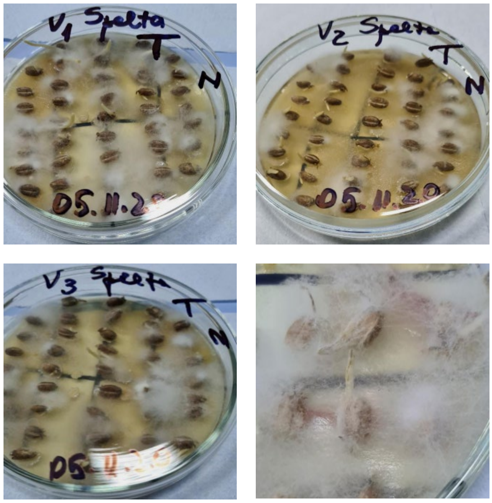


Figure 5. *Fusarium* spp. mycelia grown on spelt wheat seeds surface from V3, treated with cu bio-fungicide based on *Trichoderma sp.* (Cotuna Otilia, 2020)

The microscopic slides prepared for the identification of the fungus were stained with lactophenol blue. Typical *Fusarium* spp. conidia, mycelia and chlamydospores were highlighted at microscope (Figure 6).
The obtained results were processed by variance analysis (ANOVA), respectively F test and Tukey Test. The comparative statistical analysis of the data shows that the difference is insignificant between the V1 non-treated and the V3 treated with bio-fungicide (Table 3).

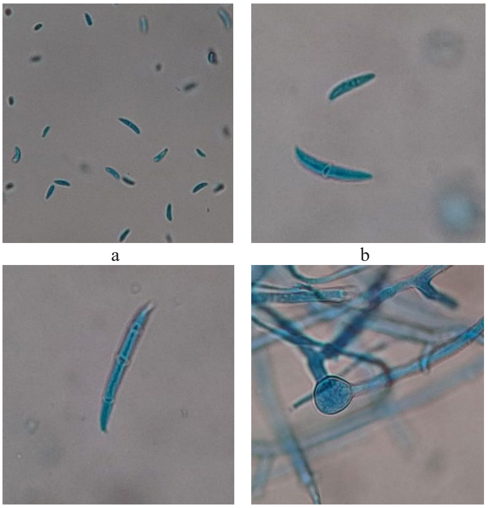


Figure 6. a, b, c) Micro and macroconidia of *Fusarium* spp.; d) mycelium hyphae and chlamydospore of *Fusarium spp.* (Photo at microscope x40, Cotuna Otilia, 2020)

Same statistical significance was registered between V1 (non-treated and sterilized with ethanol) and V2 (non-treated and sterilized with ethanol) (Table 3). The descriptive analysis of the data regarding the contamination index with *Fusarium* spp. (standard deviation, averages and F test) are presented in Table 1 and Table 2, and in Figure 7.

Table 1. Averages and standard deviations for contamination index with *Fusarium* spp. of spelt wheat variety Rokosz

	Fusarium spp. contamination index		
	V1/non-treated control	V2/ non-treated / sterilized	V3/treated
Valid	3	3	3
Missing	0	0	0
Mean	72.353	26.053	80.483
Std. Deviation	5.074	5.201	17.074
Minimum	68.290	21.460	60.970
Maximum	78.040	31.700	92.680

Efficiency of the bio-products on the spelt wheat seeds is quite less studied. In the case of spelt wheat (with hulled grains), the researches are very few and the results are divert, sometimes contradictory, depending by the biological agents used in experiments. The treatment of the wheat seeds with bio-products based on mycorrhizae, fungi and antagonist bacteria could improve a lot their phytosanitary condition and other features too, mostly in the ecological cultivation systems where the chemical substances cannot be applied.

Table 2. Variance analysis (ANOVA) for contamination index with *Fusarium* spp. of spelt wheat variety Rokosz

ANOVA - *Fusarium* contamination index						
Homogeneity Correction	Cases	Sum of Squares	df	Mean Square	F	p
Brown-Forsythe	Sample	5172.412	2.000	2586.206	22.533	0.020
	Residual	688.640	2.745	250.885		
Welch	Sample	5172.412	2.000	2586.206	55.439	0.002
	Residual	688.640	3.653	188.490		

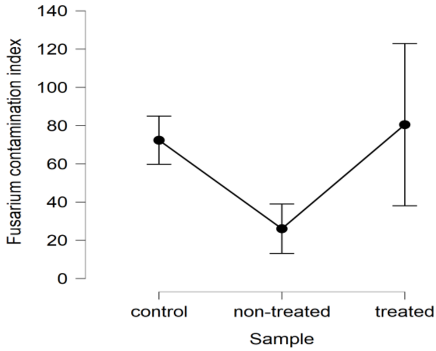


Figure 7. Contamination index with *Fusarium* spp. of spelt wheat grians variety Rokosz (control = V1 non-treated/unsterilized; non - treated = V2 non-treated/sterilized; treated = treated with bio-fungicide)

Table 3. Post Hoc comparison analysis (Tukey test) for the contamination index with *Fusarium* spp. of the spelt wheat variety Rokosz experimental variants

Post Hoc Comparisons - Sample							
			95% CI for Mean Difference				
		Mean Difference	Lower	Upper	SE	t	p_{tukey}
V1/ control	V2/ non-treated/ sterilized	46.300	19.461	73.139	8.747	5.293	0.004^{**}
	V3/ treated	-8.130	-34.969	18.709	8.747	-0.929	0.643
V2 non-treated	V3 treated	-54.430	-81.269	-27.591	8.747	-6.222	0.002^{**}
** $p < 0.01$							
Note. P-value and confidence intervals adjusted for comparing a family of 3 estimates (confidence intervals corrected using the Tukey method).							

Couto et al. (2021) shows the treatment of common wheat seeds with bio-products based on *Trichoderma* spp., bacteria and mycorrhizae gives good results in comparison with the chemical treatments. With all of these, there can be seen differences depending by the species *Trichoderma* used and the applied doses. In their study (Couto et al., 2021) *Trichoderma asperellum* has inhibited the growth of the fungi on common wheat seeds in all the treated varieties, while in case *T. harzianum* only in a single variety was noticed the efficiency of the treatment. The rate of seeds without fungi has increased linearly with the increase of the doses of *T. harzianum*, the most efficient proved to be the dose of 2 x 10^{12} CFU (Couto et al., 2021).

In our research, the efficiency of the bio-product based on mycorrhizae, bacteria and *T. harzianum* 2 x 10^8 CFU wasn't the expected one, the difference between non-treated and treated being not significant from statistical point of view. *Fusarium* spp. grew on the spelt wheat seeds, the lowest incidence of the seeds with mycelia being determined in the variant non-treated but sterilized with alcohol (Figure 2). In the other two variants the incidence passed over 70%. Such results were reported by other authors too which have highlighted that spelt wheat can be colonized by numerous fungi, but predominant is *Fusarium* spp. (Haliniartz et al., 2020). In contrast, in the tests carried out on common wheat seeds, Sinkevičienė and Pekarskas (2019) show that some bio-products have diminished the contamination with *Fusarium* spp. up to 50%.

Our opinion is that the obtained result in the present study was influenced by at least to factors: the presence of the hulls adhered on the spelt wheat grains which haven't allowed to the bio-product to be in direct contact with the grain and the bio-fungicide applied dose. These aspects are making difficult the control of the pathogens from the seed mostly in the case of the ecological crops, increasing the susceptibility of the plants to disease during the growing season. On the other hand, if the seeds are not infected, the coating hulls provide some protection against the pathogens and pests (Chrpová, 2021). According with Vinale et al. (2009) the capacity of the *Trichoderma* species to control the pathogens can be oscillating. Even there are numerous studies which highlight the resistance of spelt wheat to the fungal pathogens of the seeds given by the hulled seeds (Suchy et al., 2018), however, the seeds of the variety Rokosz used in this research were contaminated with *Fusarium* spp. in a very high rate. Chrpova et al. (2021) say that most of the modern varieties of spelt wheat are susceptible to be infected with *Fusarium* spp. The introduction of spelt wheat in ecological agriculture system brings in attention the biological measures designated to limit the fungal infections. In this way the choice of the variety an of the bio-products used for seeds treatment is very important. According with the literature (Podolska et al., 2015; Gaweda et al., 2019) the variety Rokosz can be successfully cultivated in ecological cropping system due to its nutritional qualities, due to the content in gluten and to the resistance to the attack of the pathogens and pests.

CONCLUSIONS

The contamination index with *Fusarium* spp. of the spelt wheat seeds was different from a variant to other. The lowest contamination index was registered in V2 where the seeds were sterilized previously with alcohol. In V2 non-treated and sterilized the fungal contamination index reached to 73%. In V3 treated with the bio-product Micover WP the contamination index was 80%. The difference between the treated variant (V3) and non-treated (V1) was insignificant from statistical point of view and significant in the case of the variant sterilized with alcohol. The high contamination index with *Fusarium* spp. of the treated variant can be determined by the seed coating that hasn't allowed the product the adhere at the seed epiderma. There are necessary more laboratory and field researches to demonstrate the efficiency of the inefficiency of a certain bio-fungicide.

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INFLUENCE OF SUNFLOWER SATURATION ON PRODUCTIVITY OF SHORT-TERM CROP ROTATIONS

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Abstract

The place of sunflower in crop rotation is determined by its special requirements for the frequency of return to the previous place of cultivation. Without this requirement, there are insufficient guarantees to obtain a high yield of this crop. For efficient sunflower cultivation, crop rotations with a small set of crops and a short rotation period are recommended. Studies on the possibility of increasing the share of sunflower in crop rotations of short-term crop rotations and determining the impact on the productivity of the entire crop rotation were conducted in the Left Bank Forest-Steppe of Ukraine. It is established that increasing the saturation of sunflower in crop rotation leads to a decrease in its yield and productivity of the entire crop rotation.

***Key words**: sunflower, short-term crop rotations, yield, productivity.*

INTRODUCTION

It is known that crop rotations are the basis system of farming (Boiko et al., 2014; Kaminskyi & Boiko, 2013). They are being developed in compliance with the norms of alternation in rotation, adaptability of crops to specific soil and climatic conditions and specialization of the economy (Boiko et al., 2007; Boiko, & Kovalenko, 2008). Rational crop rotations provide conditions for the systematic application of technologies in each field, increasing soil fertility and productivity of each crop and, accordingly, the productivity of crop rotation itself. The level of productivity of crops that are part of crop rotation is the result of all technological measures of their cultivation (Dorozhko et al., 2011). The higher the impact of predecessors, tillage systems, organic and mineral fertilizers, plant protection products and plant growth regulators, the higher the level of yield of each individual crop and crop rotation productivity in general (Boiko & Kovalenko, 2003; Brazhenko & Brazhenko, 2005). Thus, productivity can be considered one of the main indicators that characterizes the adaptation of crop rotations to specific soil and climatic conditions (Ryzhuk et al., 2002; Litvinov & Tovstenko, 2010). This is especially true at present, when most agricultural formations have a narrow production direction, which necessitates the widespread introduction of crop rotations with a short period.

Productivity of crop rotations depends on different saturation, ratio and location of crops. Modern market conditions of production in Ukraine require such a placement of crops that would meet the needs, lead to increased productivity of crops, contribute to the stabilization of soil fertility (Kovalenko, 2014; Litvinov, 2015; Yurkevych et al., 2011) and ecological balance of the environment (Shuvar, 1998). In modern agriculture of Ukraine new agricultural enterprises with different areas of land tenure, land use and areas of specialization have been created. In this regard, there is a need to develop and improve the optimal forms of organization of the territory and innovation of short-term crop rotations with the optimal combination of different levels of intensification (Boiko et al., 2012; Dehodiuk & Boiko, 2008; Lebid, 2006; Saiko, 2002; Kaminskyi, 2012; Cherenkov et al., 2012).

Sunflower is the main oil crop of Ukraine. In recent years, there has been increased demand (in the domestic market and abroad) for sunflower seeds and products of its processing. Growing sunflowers has become quite profitable due to rising prices for its products. This is an important incentive to increase the area under this strategic crop in the forest-steppe zone of Ukraine. The high potential productivity of modern sunflower hybrids is not fully realized in production conditions. This is due to insufficient supply of nutrients to the soil. In some regions of Ukraine, sunflower is an unalterable crop for most producers. They return this culture every 2-3 years. In the northern part of the Steppe and Forest-Steppe zone, farmers manage to return sunflower to its previous place in 4-5 years (Beliakov et al., 2008; Boiko & Borodan, 2000; Boiko et al., 2005).

There is no unequivocal opinion among scientists and producers about the maximum saturation of crop rotations with sunflower. The vast majority of scientists who touch on this problem believe that sunflowers should return to their previous location no more than 8-10 years later (Dolgova, 1986; Inshin, 1985). At the same time, some scientists argue that this interval may be shorter (Lebid & Boiko, 2000; Pastushenko, 1972). Of great importance is the correct location in the crop rotation of sunflower. When developing crop rotations with this crop, the minimum allowable return period should be considered. However, in the literature, the authors estimate this interval differently, it ranges from 5 to 10 years (Boiko et al., 2005).

MATERIALS AND METHODS

Field research to determine the effect of saturation of short-term crop rotations with sunflower was conducted on the basis of the chair of agriculture named after O. M. Mozheiko of the research field of KhNAU named after V. V. Dokuchaev. This place is located in the eastern part of the Kharkiv district of the Kharkiv region of the territory of Ukraine. The soil cover of the experimental field is represented by typical chernozem heavy loam on loess-like loam. This soil is characterized by good physico-mechanical, agrochemical and physico-chemical properties, fairly high reserves of nutrients available to plants, high humus content and intensive biological activity (Tykhonenko & Dehtiarov, 2016).

Scheme of experiment and alternation of crops in five-field crop rotations of the Left-Bank Forest-Steppe of Ukraine:

- proportion of sunflower sown area in crop rotation 20%: 1. Pea. 2. Winter wheat. 3. Corn. 4. Winter rye. 5. Sunflower;
- proportion of sunflower sown area in crop rotation 40%: 1. Pea. 2. Winter wheat. 3. Sunflower. 4. Winter rye. 5. Sunflower;
- proportion of sunflower sown area in crop rotation 60%: 1. Sunflower. 2. Winter wheat. 3. Sunflower. 4. Winter rye. 5. Sunflower.

Sunflower hybrid - Cruiser LG59580.

In the conditions of Richland Invest Limited Liability Company (LLC) of Balakliia district of Kharkiv region the productivity of four-field crop rotation with grain crops saturation by 75%, sunflower by 25% was studied: winter wheat - corn - spring barley - sunflower, which is based on three tillage systems: traditional, minni-till, strip-till. In this territory of Ukraine, the soil cover is represented by ordinary chernozem. Repetition in the experiment is four times, the placement of plots is consistent. The sown area is 1800 m^2, the total area of the experiment is 12.8 ha.

Agrometeorological conditions for growing field crops, including wintering conditions, have changed along with climatic changes. Despite a certain increase in precipitation, the snow cover became unstable. Significant temperature fluctuations - from abnormally high to abnormally low - cause abiotic stress of plants. Sometimes the mild, warm nature of winter contributes to the intensification of pests and diseases of crops (Tsykov, 1984; Shapoval et al., 2008). Therefore, it is now important to assess the impact of sunflower depending on its location in short-term crop rotations on productivity and gross harvest of crops.

According to the KhNAU meteorological post, the average annual rainfall is 529 mm, the average annual air temperature is +7.2°C. Analyzing the weather conditions for 2020-2021, we can conclude that the indicators of heat and moisture significantly affected the length of the sunflower growing season, its growth and development, and ultimately the yield of sunflower and seed quality. In 2020-2021, the amount of precipitation during the sunflower growing season was 208.2 mm, which is 70.8 mm lower than the long-term data.

Richland Invest LLC is located in the territory of insufficient humidification of the Northern Steppe of Ukraine. During the study period, there was a significant deviation of the average daily temperature and rainfall from the average long-term values. The temperature regime confirms the trend of warming in the Northern Steppe of Ukraine. The largest deviations of air temperature from the average long-term indicators were observed in the spring and summer. There was an acute shortage of moisture throughout the growing season. In general, compared to long-term indicators, the decrease in precipitation at this time was 66.3 mm or about 24%. During the years of research, there were drought periods, which had a negative impact on the conditions of growing crops.

Comparative assessment of the productivity of short-term crop rotations in studies was calculated by the volume of production per 1 ha of crop rotation area, which was converted into feed and feed protein units and digestible protein (Grevtcov, 1991). By-products were not taken into account in determining these indicators.

To find out the possibility of scientifically substantiated expansion of sunflower crops and to determine the impact on the productivity of the crop itself and other crops in field crop rotations.

RESULTS AND DISCUSSIONS

There are many factors that determine the efficiency of agriculture, and crop rotation is one of the most important. With the increase in the diversity of cultivated crops, the efficiency of crop rotation increases. The leading factor in the high productivity of crops is their placement after the best predecessors in compliance with the norms of rotation. Highly productive are short-term rotation grain, grain-row, grain-fallow-row, row, fodder with a wide range of grain saturation - from 33.3-50.0-66.3% to 70-80-100%. In particular, cereals, row crops, legumes (pea, soy), as well as annual herbs (oats) and perennial legumes (sainfoin, clover, alfalfa). Realization of all the advantages of proper crop rotation increases crop yields, reduces the density of weeds, diseases, pests and reduces the cost of their control, ensures environmental balance, soil protection. Trends in the biologization of agriculture are intensifying in the world, starting with the improvement of crop rotations, which include grasses, legumes (pea, soy), intermediate and green crops, use non-commodity (by-products) of crops and increased doses of organic fertilizers. There is a direct relationship between the length of rotation of crop rotations and productivity of crops: with decreasing length of rotation, their productivity decreases.

According to the obtained results, the most promising option is crop rotation with a share of 20% vapors, grain crops - 50 (including food group from 20 to 40%) and industrial crops - 30% (including 10% of sunflower). There is an opinion that in the structure of field crop rotation it is necessary to reduce the share of sunflower to the level of scientifically sound standards. This is possible by replacing part of its sown area with corn and rapeseed (respectively 10 and 20%), which will expand the group of profitable industrial crops in short-rotation crop rotations to 30% (Shevchenko et al., 2015).

All types of field short-term crop rotations are rational. With the observance of the technology of growing field crops in such crop rotations the yield of pea is provided - 4.05-4.28 t/ha, winter wheat - 5.16-6.63, winter rye - 5.49–5.69, corn grain - 7.48-8.88, spring barley - 5.03-5.78, sunflower - 4.14-4.26, rape - 3.59, corn for green fodder - 43.82-44.82, hay of perennial grasses - 6.60 t/ha. Estimation of the total productivity of short-term crop rotations shows that the yield of grain crops in crop rotations is in the range of 4.61-6.15 t/ha, and the harvest from 1 ha of arable land was: grain - 3.00-6.00, fodder units - 6.73-11.18, digestible protein - 0.60-1.08 t/ha (Kokhan et al., 2015).

Kokhan et al. (2015) determined the highest yield of sunflower (2.82 t/ha) in the seven-field crop rotation, where its share was 14.3%. At saturation of crop rotation with sunflower to 20%, 25%, 33.3%, 50% its productivity gradually decreases. Particularly sharp decline occurred in the two-field crop rotation - by 0.54 t/ha and the three-field crop rotation - by 0.28 t/ha. In seven-field, five-field and four-field crop rotations with a share of sunflower, respectively 14.3%, 20% and 25%, the yield of sunflower fluctuated slightly - 2.82-2.67 t/ha. The increase in the sown area under sunflower in crop rotations does not affect the yield of other field crops, in particular corn, winter wheat, pea. Regardless of the degree of saturation of crop rotations with sunflower, the difference in yield does not exceed 0.29 t/ha, or 4.6%.To some extent, this also applies to winter wheat. Its yield in crop rotations with a share of sunflower from 14.3% to 33.3% at the level of 4.59-4.65 t/ha. Crop rotation differs little in terms of pea yield - 1.76-1.89 t/ha. Only in the five-field crop rotation, where the share of sunflower is 20% and the predecessor is spring barley, pea grains were harvested by 0.023 t/ha or 13% more. If you place crops in crop rotations after the best predecessors and adhere to their alternation, you can ensure high yields of winter wheat - 4.0-6.17 t/ha, spring wheat - 3.1-4.0 t/ha, spring barley - 3, 4-5.48 t/ha, oats - 3.26-4.8 t/ha, pea - 3.2-4.2 t/ha, corn for grain - 7.38-10.0 t/ha, sugar beet roots - 43.0-67.2 t/ha, sunflower seeds - 2.46-3.82 t/ha, green mass of annual and perennial grasses - 24.7-48.0 and 28.3-54.8 t/ha, green mass of winter green manure - 45.8-52.0 t/ha (Boiko et al., 2015).

To increase the overall productivity of crop rotations, tillage is also of great importance. Today's conditions require a rational self-healing system of agriculture with the involvement of non-traditional sources of mineral nutrition of plants and the use of moderate doses of fertilizers. This is possible in combination with the post-harvest residues of the predecessor for the expanded reproduction of fertility and restoration of natural soil formation of chernozems in agrocenoses. The distribution of crop residues on the field surface is regulated primarily by improving the methods of basic tillage, which are the foundation of any technology for growing field crops in different farming systems (Saiko & Maliienko, 2007).

In the conditions of Research Enterprise «Research Economy» (RE«RE») «Dnipro» of the Institute of Agriculture of the steppe zone (Dnipropetrovsk region) it was found that in the three-field crop rotations the highest productivity (grain yield, sunflower seeds, grain and feed units, digestible protein) depends primarily on recruitment and yields of field crops in crop rotations. This indicator is determined by the combined effect of environmental factors, as well as technological features and differences of different tillage systems. It was found that in grain-fallow-row crop rotation with sunflower field, productivity indicators do not depend on the cultivation system. However, there may be an increase in grain yield - by 0.06 t/ha and grain yield - by 0.02 t/ha of crop rotation area due to the shallow (subsoil tillage) system compared to the ploughing. Replacement of sunflower in crop rotation with spring barley leads to a decrease in crop rotation productivity in general by 2.9-5.9%, as well as to a decrease in the efficiency subsoil tillage system compared to the ploughing (Lebid & Tsyliuryk, 2014). It is proved that ploughing and differentiated tillage do not have a significant impact on crop rotation productivity. But with ploughing and disk plowing, compared with ploughing, it is significantly reduced (Prymak et al., 2018).

Analyzing the data obtained in the period 2020-2021, it is seen that the correct alternation of crops improves the conditions of growth and development of plants, which in turn affects the level of yield. Winter wheat was the most sensitive to the increase in the sown area of sunflower in crop rotation. Crop rotations, in which the share of sunflower was 20 and 40% provided the maximum level of winter wheat yield: 5.83 (Figure 1) and 5.54 t/ha (Figure 2), respectively.

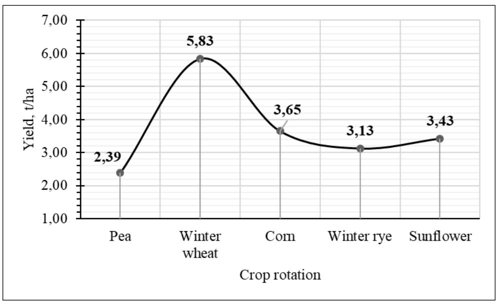

Figure 1. Yield of crops depending on the share of sunflower 20% in crop rotation

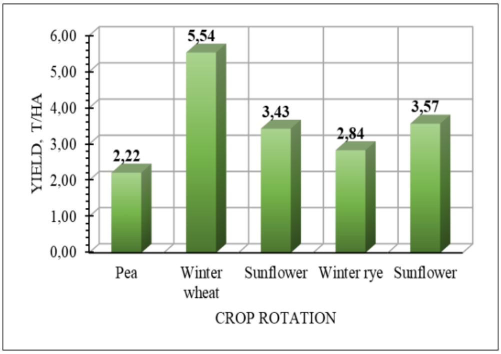

Figure 2. Yield of crops depending on the share of sunflower 40% in crop rotation

Winter wheat reacted negatively to increasing the saturation of crop rotation with sunflower up to 60%. In such crop rotation, the yield of this crop was reduced by 1.02-0.73 t/ha (Figure 3). The yield of winter rye also depended on the share of sunflower in crop rotation. The yield of this crop varied from 3.13 t/ha to 2.70 t/ha. In the crop rotation with a share of sunflower of 20% among the predecessors of winter rye, corn had an advantage, after which the yield was 3.13 t/ha. Placement after sunflower in crop rotations with shares of 40 and 60% led to a decrease in winter rye yield by 0.29 and 0.43 t/ha.

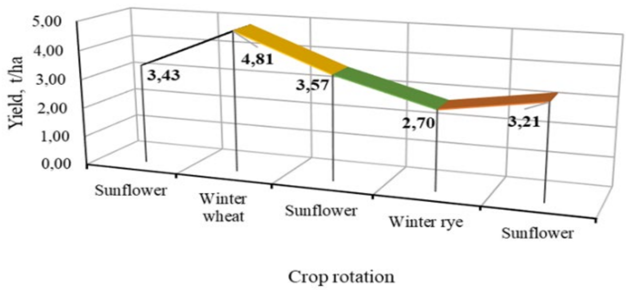

Figure 3. Yield of crops depending on the share of sunflower 60% in crop rotation

The highest yield of sunflower (3.57 t/ha) was obtained in the five-field crop rotation, where its share was 40%. At saturation of crop rotation with sunflower up to 20% there was a slight decrease in its yield by 0.14 t/ha. Saturation of crop rotation with sunflower up to 60% led to a significant reduction in its yield - 3.21 t/ha.

The highest yield of grain crops was obtained in the five-field crop rotation with grain saturation by 80% and sunflower by 20% - 3.75 t/ha. In this crop rotation, the food output per hectare of forage and fodder protein units was 3.37 and 4.56 t/ha, digestible protein - 0.52 t/ha (Table 1). In this variant, the dependence of the total productivity of crop rotation on the cultivation of corn in it, where it was: fooder - 0.73 and fodder protein units - 2.01 t/ha, digestible protein - 0.04 t/ha. When replacing corn with sunflower, the yield of grain crops was 3.53 t/ha, which is 0.22 t/ha less than the previous version.At the same time, to gather from 1 ha of crop rotation area increased by 0.21 t fooder and 0.67 t fooder protein units, digestible protein by 0.17 t.

When using the five-course crop rotation, where sunflower was grown for two years, the yield of fodder units was the highest (3.58 t/ha). The option with 60% sunflower saturation provided a lower yield of fooder units in crop rotation by 0.23 t/ha. In the short crop rotation with 40% grain crops saturation and 60% sunflower, the yield of the first was 3.76 t/ha, and the yield of fooder units was 3.35 t/ha, digestible protein - 0.75 and fooder protein units - 5.45 t/ha. The best precursor for winter wheat is peas. In the first variant of crop rotation after this predecessor, the total productivity of winter wheat was the highest and amounted to 7.00; 7.87 and 0.87 t/ha of fooder, fooder protein units and digestible protein, respectively. Saturation of crop rotation with sunflower by 40% reduced the productivity of winter wheat, which was placed after peas by 0.36 t/ha fooder units, digestible protein by 0.05 t/ha and 0.40 t/ha fooder protein units. Growing sunflower as the first crop in crop rotation ensured the productivity of winter wheat at the level of 5.77 t/ha of fodder units, 0.72 t/ha of digestible protein and 6.49 t/ha of fodder protein units.

Table 1. Total productivity of crop rotations with different saturation of sunflower

Crop rotations	Yield from 1 ha of crop rotation area		
	fooder units	fooder protein	digestible protein
1. Pea	2.80	0.47	3.73
2. Winter wheat	7.00	0.87	7.87
3. Corn	0.73	0.04	2.01
4. Winter rye	3.69	0.26	3.16
5. Sunflower	2.62	0.95	6.05
Average in crop rotation	**3.37**	**0.52**	**4.56**
In general, in crop rotation	**16.83**	**2.58**	**22.82**
1 Pea	2.59	0.43	3.46
2. Winter wheat	6.64	0.82	7.47
3. Sunflower	2.62	0.95	6.05
4. Winter rye	3.35	0.24	2.86
5. Sunflower	2.72	0.99	6.30
Average in crop rotation	**3.58**	**0.69**	**5.23**
In general, in crop rotation	**17.92**	**3.43**	**26.14**
1. Sunflower	2.62	0.95	6.05
2. Winter wheat	5.77	0.72	6.49
3. Sunflower	2.72	0.99	6.30
4. Winter rye	3.18	0.22	2.72
5. Sunflower	2.45	0.89	5.66
Average in crop rotation	**3.35**	**0.75**	**5.45**
In general, in crop rotation	**16.74**	**3.77**	**27.23**

Proper placement of pea in short crop rotations is of particular importance. It helps to improve the physical properties of the soil, reduce weediness. In 2020-2021, the yield of pea grain depended on the saturation of crop rotations with sunflower and ranged from 2.59 to 2.80 t/ha. In two variants of crop rotation, pea were grown after its worst predecessor - sunflower. The high level of productivity of this leguminous crop was manifested in the five-field crop rotation, where sunflower was grown one year. In this embodiment, the yield of fooder units of pea was 2.80 t/ha, digestible protein - 0.47 and 3.73 t/ha of fooder protein units. A slight decrease in the total productivity of pea (by 0.21, 0.04 and 0.27 t/ha) occurred during its cultivation in crop rotation with a share of sunflower 40%.

Over the years of research, the dependence of winter rye productivity on the saturation of short-term crop rotations with sunflower has been observed. Crops of winter rye in crop rotation with a share of sunflower 20% provided the largest collection of fooder, fooder protein units and digestible protein: 3.69, 0.26 and 3.16 t/ha. In the second variant, the yield of fooder units per 1 ha was 3.35 t, digestible protein - 0.24 t and fooder protein units - 2.86 t. The negative impact of increasing the saturation of crop rotation with sunflower to 60% on the total productivity of winter rye was revealed: 3.18 t fooder units, 0.22 t digestible protein and 2.72 t fooder protein units.

The overall productivity of sunflower depended largely on its yield. Placement of sunflower in the chain wheat - peas - winter wheat - sunflower - winter rye - sunflower contributed to the formation of the highest productivity: fooder units - 2.72, fooder protein - 6.30, digestible protein - 0.99 t/ha.

Not the last place in the formation of the productivity of short-term crop rotations is given to tillage systems. In the four-year crop rotation, the highest productivity indicators (yield of fooder units, digestible protein and fooder protein units) depended on sunflower saturation, yield of field crops and tillage systems (Table 2).

Table 2. Total crop rotation productivity depending on tillage

Crop rotation culture	Productivity by main tillage systems, t/ha								
	Plowing, 25-27 cm			TopDown, 25-27 cm			Strip-till, 27-30 cm		
	fooder units	digestible protein	fooder protein units	fooder units	digestible protein	fooder protein units	fooder units	digestible protein	fooder protein units
1	2	3	4	5	6	7	8	9	10
1. Winter wheat	7.19	0.89	8.09	7.45	0.93	8.38	6.94	0.86	7.80
2. Corn	0.66	0.03	1.83	0.75	0.04	20.6	0.73	0.04	2.01
3. Barley spring	6.41	0.54	6.24	6.64	0.56	6.47	6.50	0.55	6.33
4. Sunflower	1.69	0.62	3.92	1.66	0.60	3.85	1.75	0.63	4.04
Average in crop rotation	**3.99**	**0.52**	**5.02**	**4.13**	**0.53**	**5.19**	**3.98**	**0.52**	**5.04**

The productivity of Strip-till technology at 27-30 cm and plowing to a depth of 25-27 cm were equivalent: digestible protein yield - 0.52 t/ha, fooder units (3.99-3.98 t/ha), fooder protein units (5.02-5.04 t/ha). The Minni-till system had the advantage over all productivity indicators due to better loosening, thorough mixing of the soil and crop residues to a depth of 30 cm. The use of the combined assembly TopDown, 25-27 cm increased the productivity of crop rotation in terms of feed yield - 4.13 t/ha and forage protein units - 5.19 t/ha of crop rotation area. The tillage technologies under study ensured the yield of digestible protein in the range of 0.52-0.53 t/ha. Therefore, in short-term crop rotations (at least four fields) it is possible to place sunflower of modern varieties and hybrids under conditions of high level of agricultural technology.

CONCLUSIONS

It is proved that increasing the share of sunflower in short-term crop rotations leads to a decrease in the yield of the crop by 0.22-0.36 t/ha. The yield of sunflower seeds is at the same level with a saturation of 20% and 40% (3.43 and 3.57 t/ha). In the zone of unstable moisture of the Left-Bank Forest-Steppe the most productive were short-term crop rotations with sunflower saturation of 40 and 60%. The increase in the share of sunflower in crop rotations is negatively reflected in the yield of cereals. But this oil crop provides a high yield of fooder protein units (5.23-5.45 t/ha) and digestible protein (0.69-0.75 t/ha). In order to increase the productivity of short-term crop rotations, it is necessary to take into account the tillage system. The productivity of crop rotation with a share of sunflower of 25% was best influenced by the system of surface tillage using the TopDown assembly to a depth of 25-27 cm. In this crop rotation, the yield of feed and feed protein units was: 4.13 and 5.19 t/ha.

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PRODUCTIVITY OF DUO SYSTEM AND CONVENTIONAL GRAIN MAIZE (*Zea mays* L.) BY INFLUENCE OF SOME HERBICIDES AND HERBICIDE TANK MIXTURES

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Abstract

The research was conducted during 2018-2020 on pellic vertisol soil type. Under investigation was cycloxydim-tolerant grain maize hybrid Trilogi duo (Zea mays L.), FAO 350. A total of 22 variants were investigated. They included untreated control, 7 soil-applied herbicides by conventional technology: Sulcotrack (sulcotrione + terbuthylazine), Successor TX (petoxamide + terbuthylazine), Acris (dimethenamid-P + terbuthylazine), Deflexo mix (S-metolachlor + terbuthylazine), Click duo (terbuthylazine + pendimethalin), Bismarck KS (clomazone + pendimethalin), Pledge 50 VP (flumioxazine); 6 foliar-applied herbicides by conventional technology: Sovereign OD (nicosulfuron + sulcotrione), Mistral plus (dicamba + nicosulfuron), Spandis (prosulfuron + dicamba + nicosulfuron), Arigo WG (mesotrione + nicosulfuron + rimsulfuron), Collage 64 OD (thiphensulfuron-methyl + nicosulfuron), Capreno SC (tembotrione + thiencarbazone-methyl); 8 herbicide tank mixtures by Duo system technology: Starane gold + Focus ultra (fluroxypyr + florasulam + cycloxydim), Kabadex extra + Focus ultra (mesotrione + florasulam + cycloxydim), Callisto plus + Focus ultra (mesotrione + dicamba + cycloxydim), Magneto top 464 SL + Focus ultra (2.4-D + dicamba + cycloxydim), Peak 75 WG + Focus ultra (prosulfuron + cycloxydim), Permit + Focus ultra (halosulfuron-methyl + cycloxydim), Bentador + Focus ultra (bentazone + cycloxydim), Onyx + Focus ultra (pyridate + cycloxydim). The highest grain yields are obtained by use of herbicide tank mixtures by technology Duo system Kabadex extra + Focus ultra, Callisto plus + Focus ultra, Magneto top + Focus ultra, Starane gold + Focus ultra and Permit + Focus ultra. High grain yields are also obtained by use of foliar herbicides by conventional technology Spandis, Arigo and Mistral plus. The use of soil-applied herbicides Sulcotrack, Successor, Acris, Deflexo mix, Click duo, Bismarck and Pledge in maize crops leads to lower grain yields due to their inefficacy against perennial graminaceous and broadleaved weeds and against the annual broadleaved weed Xanthium strumarium L. Increase in grain yield is due to the greatest degree of increase in indexes grains number per cob, grain weight per cob and 1000 grains weight.

Key words: *grain maize, herbicides, herbicide tank mixtures, seed yield, structural elements.*

INTRODUCTION

In order to obtain high maize yields, it is important not only to have favourable climatic conditions, but also to apply appropriate cultivation technology. Starting with tillage, going through fertilization and seeds and reaching plant protection, these are all important elements of the overall production process.

Soil-applied and foliar-applied herbicides are used to control weeds, the choice of which must take into account the characteristics of each field, weed species, agro-climatic conditions. A number of authors in their research have established the positive influence of the correct weed control on the yield of maize grain (Soukup et al., 2004; Dragičević et al., 2012; Delchev, 2020).

The use of herbicides in the early stages of maize development is essential to achieve high yields (Simic et al., 2012). Soil-applied herbicides ensure clean and well-garnished sowing in the earliest stages of maize development, because most of the germinating weeds are destroyed (Malidza et al., 2009; Matić et al., 2011).

Soil-applied herbicides act for about 40-50 days, and then secondary weed infestation begins, which requires vegetative spraying (Asadi et al., 2009; Delchev, 2018, 2021). Foliar-applied herbicides are weakly dependent on soil moisture as opposed to soil-applied herbicides. This has its advantages - safe action and selection of the most suitable product for the weeds that have appeared (Kopmanis and Gaile, 2008; Vancetovic et al., 2010)

The purpose of this study was to establish the changes in the grain yield and structural elements of yield by influence of some herbicides and herbicide tank mixtures in Duo system and conventional grain maize under different meteorological conditions.

MATERIALS AND METHODS

The research was conducted during 2018 - 2020 on pellic vertisol soil type. Under investigation was cycloxydim-tolerant grain maize hybrid Trilogi duo (*Zea mays* L.), FAO 350. It was carried out a field experiment as a block method in 4 repetitions, on a 20 m^2 harvesting area, after durum wheat predecessor. A total of 22 variants were investigated. They included untreated control, 7 soil-applied herbicides by conventional technology: Sulcotrack, Successor TX, Acris, Deflexo mix, Click duo, Bismarck KS, Pledge 50 VP; 6 foliar-applied herbicides by conventional technology: Sovereign OD, Mistral plus, Spandis, Arigo WG, Collage 64 OD, Capreno SC; 8 herbicide tank mixtures by Duo system technology: Starane gold + Focus ultra, Kabadex extra + Focus ultra, Callisto plus + Focus ultra, Magneto top 464 SL + Focus ultra, Peak 75 WG + Focus ultra, Permit + Focus ultra, Bentador + Focus ultra, Onyx + Focus ultra. Active substances of herbicides, their doses and treatment periods are shown in Table 1. Soil-applied herbicides were treated during the period after sowing before emergence. Foliar-applied herbicides were treated during 5-7 maize leaf stage. All of herbicides and herbicide tank mixtures were applied in a working solution of 300 l/ha. Due to of low adhesion herbicide Spandis was used in addition with adjuvant Dash HC - 1 l/ha, herbicide Arigo WG - with adjuvant Trend 90-0.1%, herbicide Capreno SC - with adjuvant Mero 80 EC - 2 l/ha, herbicide Kabadex extra - with adjuvant Dasoil 26-2N - 500 ml/ha and herbicide Peak 75 WG - with adjuvant Atplus - 0.2 %.
At grain maize maturity all plots were evaluated for grain yield and yield components - cob length, grain number per cob, the grain weight per cob and 1000 grain weight, to evaluate the influence of the herbicides and herbicide tank mixtures on maize grain yield and yield components. It was investigated and changes who made of the tested factors in the plant height.
The statistical analysis of the data was done according to the analyses of variance method (Shanin, 1977; Barov, 1982; Lidanski, 1988).

RESULTS AND DISCUSSIONS

The weed flora present during the 3-year experiment was quite varied.
The dominant weeds that determine weed infestation in maize crops are mainly late spring annual broadleaved species - *Amaranthus retroflexus* L., *Amaranthus albus L.*, *Xanthium strumarium* L., *Chenopodium album* L., *Solanum nigrum* L., *Polygonum aviculare* L., *Portulaca oleracea* L., *Datura stramonium* L., *Abutilon teophrasti* Medic., a lesser amount *Amaranthus blifoides* W., *Tribulus terrestris* L., *Hibiscum trionum* L. Early spring annual broadleaved weeds are mainly *Falopia convolvulus* Leve and *Sinapis arvensis* L.
Annual graminaceous weeds are represented by *Panicum sanguinale* L., *Echinochloa crus-galli* L., *Setaria viridis* Beauv., *Setaria glauca* Beauv. In a lesser amount are *Setaria verticilata* Beauv. and *Echinochloa coarctata* Vas.
Perennial species in experiment are broadleaved weeds *Cirsium arvense* Scop. and *Convolvulus arvensis* L. and graminaceous weeds *Sorghum halepense* Pers., *Cynodon dactylon* Pers. and less often *Agropyrum repens* L.
Sunflower self-sown plants (*Helianthus annuus* L.) are from Clearfield and ExpressSun sunflower hybrids grown two years ago as predecessor. In the previous year, durum wheat (*Triticum durum* Desf.) was grown as predecessor before maize.
The data on the influence of herbicides and herbicide tank mixtures included in the experiment on the grain yield of cycloxide-tolerant maize by Duo system technology (Table 2) show that there is a positive correlation between their biological efficacy against weeds and grain yields.
The lowest grain yields are obtained by the untreated control, as a result of the strong weed infestation with broadleaved and graminaceous weeds and self-sown plants of Clearfield and ExpressSun sunflower (*Helianthus annuus* L.).

Table 1. Investigated variants

№	Variants	Active substance	Doses	Treatment period
1	Control – untreated	-	-	-
		Conventional technology		
		Soil-applied herbicides		
2	Sulcotrack	sulcotrione + terbuthylazine	2.6 l/ha	ASBE
3	Successor TX	petoxamide + terbuthylazine	4 l/ha	ASBE
4	Acris	dimethenamid-P + terbuthylazine	3 l/ha	ASBE
5	Deflexo mix	S-metolachlor + terbuthylazine	3.5 l/ha	ASBE
6	Click duo	terbuthylazine + pendimethalin	4 l/ha	ASBE
7	Bismarck KS	clomazone + pendimethalin	2 l/ha	ASBE
8	Pledge 50 VP	flumioxazine	80 g/ha	ASBE
		Foliar-applied herbicides		
9	Sovereign OD	nicosulfuron + sulcotrione	2 l/ha	5-7 leaf
10	Mistral plus	dicamba + nicosulfuron	1.2 l/ha	5-7 leaf
11	Spandis	prosulfuron + dicamba + nicosulfuron	500 g/ha	5-7 leaf
12	Arigo WG	mesotrione + nicosulfuron + rimsulfuron	330 g/ha	5-7 leaf
13	Collage 64 OD	thiphensulfuron-methyl + nicosulfuron	1 l/ha	5-7 leaf
14	Capreno SC	tembotrione + thiencarbazone-methyl + isoxadifen-ethyl (antidote)	290 ml/ha	5-7 leaf
		Duo system technology		
		Herbicide tank mixtures		
15	Starane gold +	fluroxypyr + florasulam	1.2 l/ha	5-7 leaf
	Focus ultra	cycloxydim	2 l/ha	5-7 leaf
16	Kabadex extra +	mesotrione + florasulam	300 ml/ha	5-7 leaf
	Focus ultra	cycloxydim	2 l/ha	5-7 leaf
17	Callisto plus +	mesotrione + dicamba	2 l/ha	5-7 leaf
	Focus ultra	cycloxydim	2 l/ha	5-7 leaf
18	Magneto top 464 SL +	2.4-D + dicamba	1 l/ha	5-7 leaf
	Focus ultra	cycloxydim	2 l/ha	5-7 leaf
19	Peak 75 WG +	prosulfuron	15 g/ha	5-7 leaf
	Focus ultra	cycloxydim	2 l/ha	5-7 leaf
20	Permit +	halosulfuron-methyl	50 g/ha	5-7 leaf
	Focus ultra	cycloxydim	2 l/ha	5-7 leaf
21	Bentador +	bentazone	2 kg/ha	5-7 leaf
	Focus ultra	cycloxydim	2 l/ha	5-7 leaf
22	Onyx +	pyridate	500 ml/ha	5-7 leaf
	Focus ultra	cycloxydim	2 l/ha	5-7 leaf

Herbicide Spandis was used in addition with adjuvant Dash HC – 1 l/ha, herbicide Arigo WG – with adjuvant Trend 90 – 0.1 %, herbicide Capreno SC – with adjuvant Mero 80 EC – 2 l/ha, herbicide Kabadex extra – with adjuvant Dasoil 26-2N – 500 ml/ha and herbicide Peak 75 WG – with adjuvant Atplus – 0.2 %.
ASBE – after sowing, before emergence

The highest grain yields are obtained when using the herbicide tank mixtures by the technology Duo system Kabadex extra + Focus ultra, Callisto plus + Focus ultra,

Table 2. Influence of some herbicides and herbicide tank mixtures on maize grain yield (2018-2020)

Variants	2018		2019		2020		Mean	
	kg/ha	%	kg/ha	%	kg/ha	%	kg/ha	%
Control – untreated	6060	100	5680	100	6666	100	6135	100
Conventional technology								
Soil-applied herbicides								
Sulcotrack	6951	114.7	6435	113.3	7533	113.0	6973	113.7
Successor	6914	114.1	6515	114.7	7406	111.1	6945	113.2
Acris	6921	114.2	6532	115.0	7526	112.9	6993	114.0
Deflexo mix	7024	115.9	6475	114.0	7566	113.5	7022	114.5
Click duo	6987	115.3	6452	113.6	7533	113.0	6991	113.9
Bismarck	6902	113.9	6452	113.6	7499	112.5	6951	113.3
Pledge	6866	113.3	6407	112.8	7466	112.0	6913	112.7

Foliar-applied herbicides								
Sovereign	7193	118.7	6759	119.0	8000	120.1	7317	119.3
Mistral plus	7375	121.7	6873	121.0	8086	121.3	7445	121.3
Spandis	7411	122.3	6901	121.5	8133	122.0	7482	122.0
Arigo	7393	122.0	6873	121.0	8146	122.2	7471	121.8
Collage	7314	120.7	6873	121.0	7873	118.1	7353	119.9
Capreno	7260	119.8	6771	119.2	8066	121.0	7366	120.1
Duo system technology								
Herbicide tank mixtures								
Starane gold + Focus ultra	7502	123.8	7009	123.4	8246	123.7	7586	123.6
Kabadex extra + Focus ultra	7569	124.9	7123	125.4	8333	125.0	7675	125.1
Callisto plus + Focus ultra	7587	125.2	7100	125.0	8326	124.9	7671	125.0
Magneto top + Focus ultra	7533	124.3	7072	124.5	8259	123.9	7621	124.2
Peak + Focus ultra	7096	117.1	6680	117.6	7666	115.0	7147	116.5
Permit + Focus ultra	7575	125.0	7134	125.6	7559	113.4	7423	121.0
Bentador + Focus ultra	7108	117.3	6612	116.4	7893	118.4	7204	117.4
Onyx + Focus ultra	7084	116.9	6549	115.3	7646	114.7	7093	115.6
LSD 5 %	370	6.1	256	4.5	340	5.1		
LSD 1 %	442	7.3	307	5.4	393	5.9		
LSD 0.1 %	485	8.0	352	6.2	440	6.6		

Magneto top + Focus ultra, Starane gold + Focus ultra and Permit + Focus ultra. The differences between these variants are small and have not been mathematically proven. These herbicide tank mixtures have very high herbicide efficacy against all annual and perennial broadleaved and graminaceous weeds and against sunflower self-sown plants.

High grain yields are also obtained by use of foliar-applied herbicides by conventional technology Spandis, Arigo and Mistral plus. They are lower than those for herbicide tank mixtures by Duo system technology. The reason for this is that these herbicides cannot control perennial graminaceous weeds *Cynodon dactylon* Pers. and *Agropyrum repens* L. Grain yields by foliar-applied herbicides Capreno, Collage and Sovereign are lower. These herbicides, in addition to not being able to control perennial graminaceous weeds *Cynodon dactylon* Pers. and *Agropyrum repens* L., are less efficacy against perennial graminaceous weed *Sorghum halepense* Pers., as well as against perennial broadleaved weeds *Cirsium arvense* Scop. and *Convolvulus arvensis* L.

Grain yields by herbicide tank mixtures Bentador + Focus ultra, Peak + Focus ultra and Onyx + Focus ultra are even lower. The reason for this is that these herbicide tank mixtures are poorly efficacy against perennial broadleaved weeds *Cirsium arvense* Scop. and *Convolvulus arvensis* L.

Low grain yields are obtained by use of soil-applied herbicides Sulcotrek, Successor, Akris, Deflexo mix, Click duo, Bismarck and Pledge.

Table 3. Influence of some herbicides and herbicide tank mixtures on structural elements of the yield (mean 2018-2020)

Variants	Cob length, cm	Grains per cob, number	Grain weight per cob, g	1000 grains weight, g	Plant height, cm
Control – untreated	18.5	607.4	124.72	211.3	218.8
Conventional technology					
Soil-applied herbicides					
Sulcotrack	18.1	624.1	144.36	226.2	246.0
Successor	18.1	624.2	140.54	225.6	243.5
Acris	18.7	629.0	145.32	228.7	250.2
Deflexo mix	18.5	649.2	146.54	234.0	250.5
Click duo	17.9	625.1	144.57	226.4	246.8
Bismarck	18.1	624.8	142.62	226.4	255.0
Pledge	18.1	629.8	138.00	230.0	250.1
Foliar-applied herbicides					
Sovereign	18.9	626.8	148.00	223.3	243.7
Mistral plus	19.3	650.2	148.12	232.3	250.5
Spandis	19.5	623.7	148.72	237.2	249.9

Arigo	19.3	642.3	148.54	234.0	250.0
Collage	18.1	623.7	144.22	226.0	246.5
Capreno	19.1	636.7	148.14	229.4	249.9
Duo system technology					
Herbicide tank mixtures					
Starane gold + Focus ultra	19.4	624.8	148.67	237.6	250.7
Kabadex extra + Focus ultra	19.7	646.3	149.29	237.3	250.8
Callisto plus + Focus ultra	19.6	638.7	148.79	236.4	250.6
Magneto top + Focus ultra	19.5	643.3	148.71	233.8	250.4
Peak + Focus ultra	18.2	629.8	144.00	230.0	246.2
Permit + Focus ultra	19.5	649.2	148.18	233.3	250.6
Bentador + Focus ultra	18.8	623.9	147.80	237.3	249.8
Onyx + Focus ultra	18.1	626.9	143.70	225.9	245.6
LSD 5%	1.1	8.7	11.1	13.5	7.9
LSD 1%	2.2	12.1	17.4	19.0	11.3
LSD 0.1%	5.2	16.3	23.6	25.5	15.3

These herbicides are inefficacy against perennial graminaceous weeds *Sorghum halepense* Pers., *Cynodon dactylon* Pers. and *Agropyrum repens* L., against perennial broadleaved weeds *Cirsium arvense* Scop. and *Convolisulus arvensis* L., as well as against the annual broadleaved weed *Xanthium strumarium* L. Only herbicide Successor has a low efficacy of 10 % against *Cirsium arvense* Scop. and 15 % against *Convolvulus arvensis* L., but on the other hand this herbicide shows low phytotoxicity against maize plants. However, grain yields by use of the seven soil-applied herbicides are higher than with weed infested, untreated control.

To explain changes in grain yields obtained by Duo system and conventional technologies were investigated some of the structural elements that determine it (Table 3). Differences in the efficacy and selectivity of the studied herbicides and herbicide tank mixtures lead to changes in the values of the indicators cob length, grain number per cob, the grain weight per cob and 1000 grain weight. The differences are mathematically proven. The greatest increase in the grain number per cob, the grain weight per cob and 1000 grain weight compared to untreated control is obtained by herbicide tank mixtures by Duo system technology Kabadex extra + Focus ultra, Callisto plus + Focus ultra, Magneto top + Focus ultra, Starane gold + Focus ultra and Permit + Focus ultra, followed by foliar-applied herbicides by conventional technology Spandis, Arigo and Mistral plus.

It was established an increase in the cob length in the variants of both grain maize cultivation technologies - Duo system and conventional. The increase in this index is less, but also has been proven mathematically. The cob length has a lesser influence on the yield value. More importantly for grain maize, the cobs are to have many grains, with well-fed and well ripened grains.

Studied herbicide combinations and combined herbicides have an influence on plant height. It is lowest in the untreated control. This is due to competition between existing in the control weeds and maize plants. Eliminate the negative effect of weeds leads to an increase in plant height in all variants of both technologies for maize cultivation. The highest values of the indicator plant height are at herbicide tank mixtures by Duo system technology Kabadex extra + Focus ultra, Callisto plus + Focus ultra, Magneto top + Focus ultra, Starane gold + Focus ultra and Permit + Focus ultra, followed by the foliar-applied herbicides by conventional technology Spandis, Arigo and Mistral plus. At soil-applied herbicide Successor and foliar-applied herbicide Sovereign plant heights are lower. As this reduction in height is accompanied by an increase in grain yield as a result of the high herbicide efficacy, these herbicides by conventional technology have a retardant effect rather than a phytotoxic effect. This is a further positive effect of their use, as it reduces the risk of pulling down or breaking of the plants in a storm and downfall of the yield.

CONCLUSIONS

The highest grain yields are obtained by use of herbicide tank mixtures by technology Duo system Kabadex extra + Focus ultra, Callisto plus + Focus ultra, Magneto top + Focus ultra, Starane gold + Focus ultra and Permit + Focus ultra.

High grain yields are also obtained by use of foliar herbicides by conventional technology Spandis, Arigo and Mistral plus.

The use of soil-applied herbicides Sulcotrack, Successor, Acris, Deflexo mix, Click duo, Bismarck and Pledge in maize crops leads to lower grain yields due to their inefficacy against perennial graminaceous and broadleaved weeds and against the annual broadleaved weed *Xanthium strumarium* L.

Increase in grain yield is due to the greatest degree of increase in indexes grains number per cob, grain weight per cob and 1000 grains weight.

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THE GENETIC DISTANCE OF ADVANCED LINES COMMON WINTER WHEAT BY IMPORTANT ECONOMIC TRAITS

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Abstract

The study was conducted in the period 2019-2021 on the experimental field of IRGR "K. Malkov" Sadovo. Twenty advanced breeding lines and four common winter wheat varieties were studied according to important economic traits. Grain yield, plant height, thousand grain weight and test weight were reported. To assess the genetic similarity and distance between the different genotypes, cluster analysis and analysis of the main components were applied. Based on the results of the cluster analysis, the studied genotypes were divided into five large cluster groups. The applied analysis of the main components shows that the components PC 1 and PC 2 explain 67.9% of the total variation of all traits by genotypes. The line MX 270/86 and the Enola variety, located in the most distant parts of the coordinate system, can be mentioned as a source of strong variation and genetic difference.

Key words: *common winter wheat, breeding lines, genetic distance, cluster analysis, PC analysis.*

INTRODUCTION

In the modern world, common wheat is of paramount importance to human nutrition and is widespread in almost all latitudes. (Rodomiro et al., 2008). Wheat is the main food cereal crop in Bulgaria. It is of great economic importance for the national economy. Its cultivation is favored by the appropriate soil and climatic conditions in the country. It occupies about 35% of the arable land in the country (between 11.5 and 12.5 million decares). As of the beginning of December 2021, the sown areas with wheat for the harvest of 2022 are by 1.1% more on an annual basis than the reported area for the previous year (https://www.mzh.government.bg/media/filer_public/2021/12/15/operativen_analiz_2021-12-15.pdf).

The wide application and the growing demand on a global scale are a prerequisite for new scientific endeavors and continuous development of selection programs, as it is the subject of large-scale research work (Chamurliiski, 2019). By determining the genetic distance for the correct selection of parental forms, significant progress can be made in the potential for recombinant genotypes (Islam, 2004). The success of any breeding program depends on the use of diverse genetic material (Pevicharova & Todorov, 2001; Todorov & Pevicharova, 2002; Markovic et al., 2002; Strano et al., 2011). Genetic diversity in plants determines their potential for achieving breeding advance, when applying the method of hybridization, according to the available genetic distance of genotypes. The more genetically distant the parental forms, the greater the potential for gene interaction in the form of dominance and epistasis leading to an increase in the potential for heterosis and transgression (Falconer, 1989). Estimation of genetic distance between genotypes can be based on the phenotypic manifestation of quantitative and qualitative traits (Kennedy et al., 1991; Souza & Sorells, 1991; Stoyanova, et al., 2019; Yanev, et al., 2021), molecular markers (Cao et al., 1998) or on the relationship coefficient (Mercado et al., 1996). Most often, genetic distance is measured as phenotypic distance (Anjani, 2005; Bose & Pradhan, 2005; Arriel et al., 2007; Debnath et al., 2008; Gashaw et al., 2007; Kabir et al., 2009; Dragov et al., 2019). The grouping of breeding materials using cluster analysis has been successfully used by various researchers

such as Devesh et al. (2019); Degewione & Alamerew (2013) and Baranwal et al. (2013).
The aim of the present study is to carry out an investigation of advanced breeding lines common winter wheat by important economic traits and determine their genetic distance with a view to their use in the breeding program as sources of starting material for creating new highly productive wheat varieties.

MATERIALS AND METHODS

The experiment was conducted in the experimental field of IRGR - Sadovo in the period 2019-2021. The common technology for growing common wheat was used. The field varietal experiments were carried out according to a randomized block diagram in three replications, with the size of the experimental plot of 10 m^2. The studied genotypes were compared with the complex standard for the country variety Sadovo 1. Twenty-four genotypes of common winter wheat were studied according to the following economic indicators: grain yield (kg/da), plant height (cm), 1000 grains weight (g) and test weight (kg/hl). The evaluation of the quality traits was performed in a technological laboratory at the Institute. The degree of variation of the studied traits was determined by calculating a coefficient of variation. It is accepted that variation is considered weak if the coefficient of variation is up to 10%, on average - when it is greater than 10% and less than 20%, strong - when it is above 20% (Dimova & Marinkov, 1999). On the results for mean of genotypes was conducted Duncan`s test for multiple comparison between the means at the detected significant differences ($p < 0.05$) (Duncan, 1955) over all studied traits. Statistica 10 software program was used for the two analyzes performed above. Hierarchical cluster analysis by the method of Ward (1963) and Principal Component Analysis (Kim & Mueller, 1978) was used to determine the genetic distance between the individual genotypes, based on the mean values for the study period. Mathematical analysis of the results was performed using the statistical processing programs SPSS 19 and Microsoft EXCEL 10 for Windows.

RESULTS AND DISCUSSIONS

On the Table 1 are presented the results of the surveyed economic traits for the three-year survey period. According to Duncan's test, it was found that there were significant differences between the genotypes in the studied traits, only for the yield trait the differences are very small and most genotypes are in one group. The data in the table show that the highest average yield was achieved by the lines RU 129/3053 (784.3 kg/da), MX 270/50 (762.6 kg/da) and MX 258/3353 (756.4 kg/da), and low was reported for lines MX 270/86 (639.7 kg/da) and MX 274/717 (625.3 kg/da). Nineteen wheat genotypes fall above the level of the Sadovo 1 standard, nine of which have achieved yields of over 700.0 kg/da.
According to the plant height, the values of the studied samples are in the range from 86.7 cm (Enola) to 110.0 cm (MX 276/3616). In ten breeding lines the reported plant height is less than 100 cm. The lines MX 274/717 (49.5 g), MX 270/3463 (49.3 g) and MX 270/86 (48.8 g) are characterized by a high value in terms of 1000 grains weight, and by line RU 48/2553 (39.6 g) is the lowest. In 54.2% of the total number of studied samples the measured 1000 grains weight is over 45.0 g.
The test weight of the examined materials ranges from 68.2 kg/hl (MX 270/86) to 79.7 kg/hl (MX 286/1759). Exceeding the standard trait was observed in twelve wheat genotypes. On fourteen samples the reported test weight is over 75.0 kg/hl.
The calculated coefficient of variation shows that the variation of the studied traits is assessed as weak (CV<10.0%), with the lowest variation in the traits test weight (CV=3.3%) and the highest in the plant height of the rations. Grain yield has a coefficient of variation (CV=6.0%) (Table 1).
To determine the genetic similarity and distance between the studied breeding materials, a cluster analysis based on the studied economic traits was applied. The study of genotypes through cluster analysis allows breeders to plan and make more effective decisions for the development of their breeding programs. With the help of cluster analysis, the samples can be divided by genotype, depending

on its phenotypic manifestation by a certain trait (based on different environments) or a group of traits. The results of the hierarchical cluster analysis are presented as a dendrogram on Figure 1. It can be seen from the figure that the studied breeding materials are grouped into five main cluster groups. The first group consists of four wheat genotypes.

Table 1. Results of biometric measurements of economic indicators in genotypes of common winter wheat for the period 2019-2021

№	Genotype	Yield, kg/da	Plant height, cm	1000 grains weight, g grains weight	Test weight, kg/hl
1	Sadovo 1 – st.	656.8ab	98.3abc	47.1abcd	75.8b
2	MX 270/24 (Nany) nnnnnbbbNNany	754.3ab	89.3bde	42.3bcdef	72.0bc
3	MX 270/28	681.0ab	97.3ef	44.2bcdef	72.9bcde
4	MX 270/27	648.9ab	101.3def	44.4efgh	75.1bcd
5	MX 270/50	762.6a	99.0def	46.8h	73.3a
6	MX 270/86	639.7ab	100.3bcde	48.8efgh	68.2bcde
7	MX 268/1008 (Sashez)	725.4ab	97.3fg	47.1defgh	74.6cdef
8	Ayilzla	732.6ab	106.7ef	45.8abc	77.0def
9	Nadita	689.9b	101.3ef	41.6abc	77.3bcdef
10	RU 129/3053	784.3ab	101.7g	41.7fgh	75.9ef
11	MX 276/3616	692.6ab	110.0fg	48.0efgh	78.4bcdef
12	RU 33/3244	712.5ab	106.3a	46.8bcdef	76.2bcde
13	MX 258/3353	756.4ab	88.3ef	44.3efgh	75.0def
14	MX 260/1175	743.9ab	102.0bdef	46.5efgh	77.3bcdef
15	Enola	676.3ab	86.7a	40.6ab	77.7ef
16	MX 265/3430	668.3ab	101.3ef	47.1efgh	76.4bcdef
17	MX 270/3461	675.5ab	97.3bde	48.1fgh	75.9bcdef
18	MX 270/3462	693.0ab	99.3def	48.6gh	74.5bcde
19	MX 270/3463	735.3ab	98.3bdef	49.3h	74.9bcde
20	MX 274/717	625.3a	106.0fg	49.5h	78.8ef
21	MX 286/1759	658.9ab	92.3abcd	44.8cdefg	79.7f
22	MX 286/1777	704.3ab	89.0a	42.5abcd	77.8ef
23	RU 48/2553	681.4ab	90.7abc	39.6a	74.5bcde
24	MX 215/3	691.5ab	88.0a	43.2abcde	72.7bc
	Mean	699.6	97.8	45.4	75.5
	Minimum	625.3	86.7	39.6	68.2
	Maximum	784.3	110.0	49.5	79.7
	Coef. var., %	6.0	6.7	6.4	3.3
	Standard error	8.6	1.3	0.6	0.5

Mean values (in each column), followed by the same letters are not significantly different at $p < 0.05$ according to Duncan's multiple range test (DMRT).

The lines MX 270/24 (Nany), MX 258/3353 and MX 270/50 form a separate subgroup, to which line RU 129/3053 joins at a higher Euclidean distance. The characteristic of this group is that the high yielding selection materials are united here. The results obtained are confirmed by the studies of Ajmal et al. (2013) who point out that high-yielding genotypes are grouped into a separate cluster, thus facilitating the process of selecting appropriate genotypes.

A second main cluster group is represented by the Ayilzla variety and the lines MX 270/3463, MX 260/1175, MX 268/1008 (Sashez). Representatives of this group are characterized by relatively high yields and at the same time have achieved the highest value in terms of mass per 1000 grains.

The third cluster includes five breeding materials. The standard Sadovo 1 and the lines MX 286/1759, MX 270/27, MX 270/86 are separated into a separate subgroup to which line MX 274/717 is connected. The genotypes forming this group had the lowest average yield compared to the other cluster groups.

The fourth cluster group includes the variety Enola and the lines RU 48/2553, MX 270/28, MX 270/3461, MX 265/3430. Samples from this group are characterized as low yields, with a high value of test weight and relatively low plant height.

The fifth cluster group, represented by six samples, is the most numerous. The lines MX 286/1777 and MX 215/3 form an independent subgroup. An independent subgroup is also observed between the variety Nadita and the lines MX 270/3462 and MX 276/3616. The line RU 33/3244 joins the two subgroups at a higher Euclidean distance. The representatives of this group have achieved the highest value of the traits test weight.

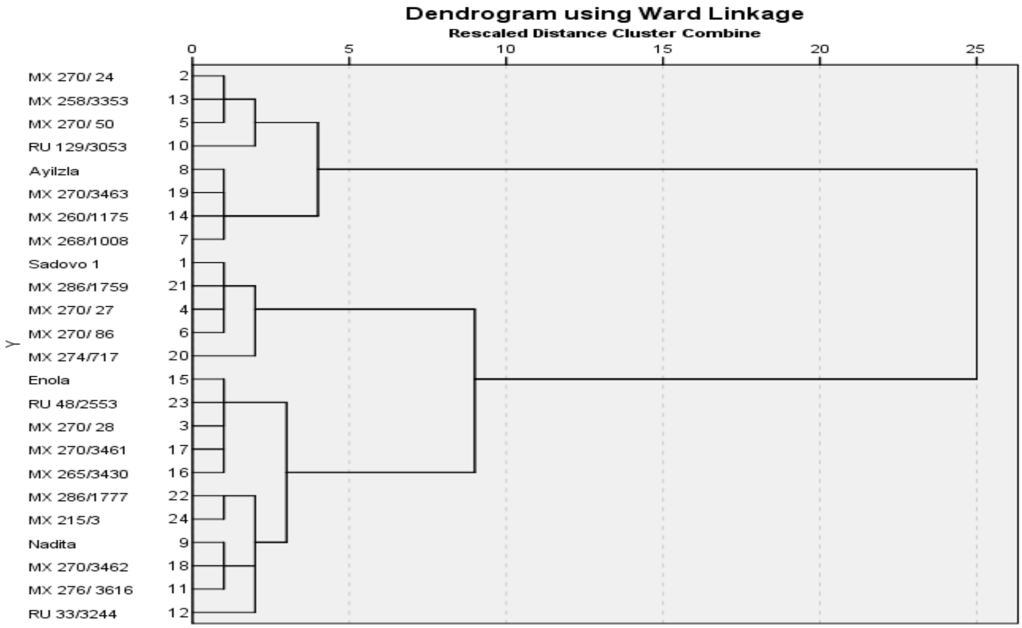

Figure 1. Dendrogram of hierarchical cluster analysis for 24 genotypes of common winter wheat

Dividing breeding materials into groups by using cluster analysis has been successfully applied by various researchers. For example, Devesh et al. (2019) examines sixty wheat lines on agronomically important traits, which are grouped into five cluster groups. Degewione & Alamerew (2013) reported the identification of six cluster groups in the twenty-six wheat genotypes they studied. Baranwal et al. (2013) grouped twenty-four wheat samples into four clusters.

Table 2 presents the genetic proximity and remoteness of the studied breeding materials based on the coefficient at which the individual cluster pairs are formed. The higher the value of the coefficient, the greater the differences between the studied samples. The results of the table show that the line MX 270/24 with line MX 258/3353 (2.145) is characterized by the greatest genetic similarity, followed by the variety Enola with line RU 48/2553 (5.794). In terms of genetic distance, there are significant differences between the lines RU 129/3053 compared with MX 274/717 (159.276) and MX 270/86 compared with RU 129/3053 (137.615).

According to several authors (Fang et al., 1996; Khodadadi et al., 2011; Siahbidi et al., 2013), it can be generally accepted that cluster analysis gives the best assessment of the genetic distance of genotypes and therefore, cluster analysis is preferably used in genetic diversity research. Pooja & Binewal (2018) and Dragov et al. (2019) revealed that results of cluster analysis could be exploited in planning and execution of future breeding improvement program in wheat.

The analysis of the main components is a supplement to the cluster analysis. Principal component analysis (PCA) reflects the importance of the largest contributor to the total variation at each axis of differentiation (Sharma et al., 1998).

Table 2. Genetic similarity between the studied triticale genotypes

№	Genotype	Genotype	Coefficient	Similar/Distant
1	MX 270/24	MX 258/3353	2.145	genetically similar
2	Enola	RU 48/2553	5.794	genetically similar
3	MX 270/28	MX 270/3461	9.484	genetically similar
4	Sadovo 1	MX 286/1759	13.386	genetically similar
5	Nadita	MX 270/3462	17.583	genetically similar
6	MX 258/3353	MX 274/717	132.446	genetically distant
7	MX 270/ 27	RU 129/3053	135.43	genetically distant
8	MX 270/ 50	MX 274/717	137.615	genetically distant
9	MX 270/86	RU 129/3053	144.986	genetically distant
10	RU 129/3053	MX 274/717	159.276	genetically distant

The results of the conducted PC analysis (Table 3) show that the two main components PC 1 and PC 2 explain 67.9% of the total variation of the studied traits and genotypes, which is large enough.

Similar results in determining the general variation are mentioned by other authors. Analyzing the genetic diversity of twenty-two bread wheat genotypes, Fouad (2020) reported that three main components accounted for 79.6% of the total variation. Boshev et al. (2016) point out that the overall variation in their study is 71.4% and is due to the three main components.

Table 3. Component analysis of the variance in the studied traits

Component	Total	% of Variance	Cumulative %
1	1.68	42.0	42.0
2	1.04	25.9	67.9
3	0.94	23.6	91.5
4	0.34	8.5	100.0

Table 4 shows the location of the studied economic traits to the two main components. According to Chahal & Gosal (2002) characters with the largest absolute value closer to unity within the first principal component influence the clustering more than those with lower absolute value closer to zero.

In our study, the first component included the traits yield, plant height and 1000 grains weight, with the yield negatively related to PC 1, and the other two traits were positively related to the component. In PC 2 falls the sign hectoliter mass, positively connected component.

Table 4. Explained significant components by indicators by wheat samples

№	Traits	Component	
		1	2
1	Yield	-0.396	-0.228
2	Plant height	0.861	-0.023
3	1000 grains weight	0.847	-0.36
4	Test weight	0.254	0.924

The selected breeding materials relate differently to the two main components (Table 5).

Table 5. Explained significant components by wheat genotypes

№	Genotype	Component	
		1	2
1	Sadovo 1 – st.	0.533	0.293
2	MX 270/24- Nany	-1.304	-1.584
3	MX 270/28	-0.081	-0.737
4	MX 270/27	0.280	0.325
5	MX 270/50	0.243	-1.267
6	MX 270/86	1.454	-2.365
7	MX 268/1008	0.255	-0.610
8	Ayilzla	0.562	0.465
9	Nadita	-0.545	1.012
10	RU 129/3053	-0.786	-0.111
11	MX 276/3616	1.341	1.156
12	RU 33/3244	0.848	0.243
13	MX 258/3353	-1.127	-0.677
14	MX 260/1175	0.291	0.359
15	Enola	-1.819	1.017
16	MX 265/3430	0.688	0.489
17	MX 270/3461	0.584	0.121
18	MX 270/3462	0.836	-0.485
19	MX 270/3463	0.722	-0.687
20	MX 274/717	1.577	1.571
21	MX 286/1759	-0.578	1.691
22	MX 286/1777	-1.373	0.793
23	RU 48/2553	-1.585	-0.013
24	MX 215/3	-1.016	-1.001

The first component is represented by fifteen wheat genotypes, six of which are located in the positive values of PC1, and the remaining samples are located in the negative values. Eight samples fall into component two, four of which are positively related to the component and the other four fall into the negative parts of the component.

On the other hand, genotypes located on the periphery are characterized by a more pronounced specific trait. Those in the middle are more balanced in terms of the studied traits. According to Khodadadi et al. (2011) genetic diversity of plants determines their potential for improved efficiency and hence their use for breeding, which may eventually result in enhanced food production. In this sense, the genotypes MX 270/86, Enola, MX 286/1759 and RU 48/2553, located in the most remote parts of the factorial plane, can be mentioned as sources of variation in order to create a variety of starting material and enrich the gene pool in common winter wheat. The above mentioned samples can be used as parent pairs in hybridization for selective improvement work in common wheat. They can be expected to produce recombinant ones with higher yields and the creation of new varieties of common wheat is possible.

From the graphical representation of the analysis of the main components by genotypes (Figure 2) we can get a clearer idea of the location of the studied materials in the coordinate system. The more distant location a genotype has in the coordinate system, the more it is genotypically and phenotypically different from other samples.

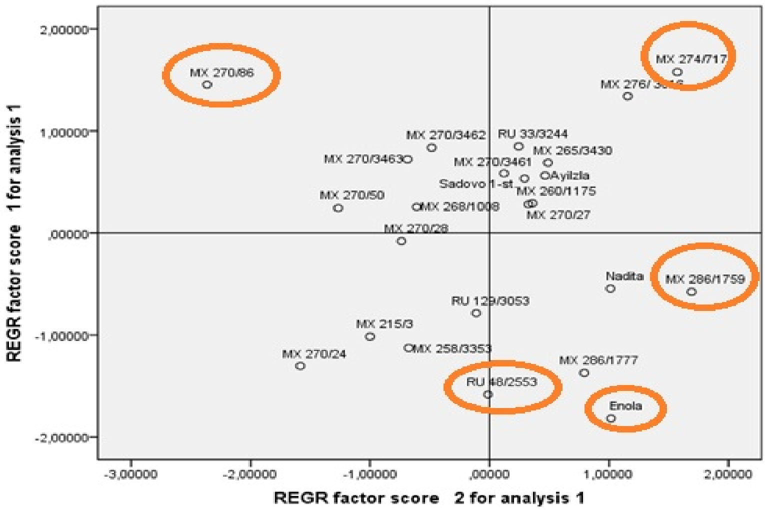

Figure 2. Projection of the studied genotypes by main components

CONCLUSIONS

Significant differences were found between genotypes on all studied traits.
The studied breeding materials are divided into five main cluster groups, with different degrees of genetic distance. The lines MX 270/24 and MX 258/3353 are characterized by the greatest genetic proximity, and the strongest genetic distance is observed between the lines MX 274/717 and RU 129/3053.
The analysis of the main components shows that the components PC 1 and PC 2 explain 67.9% of the total variation of all traits and genotypes. Component one includes fifteen genotypes, and component two includes nine.
The following genotypes can be determined as sources of variation: MX 270/86, Enola, MX 286/1759 and RU 48/2553
Genetically distant breeding materials falling into different cluster groups and components can be used as sources of starting material to increase genetic diversity in the selection process and create new lines and varieties of common winter wheat.

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GENOTYPE × ENVIRONMENT INTERACTION AND GRAIN YIELD STABILITY IN DURUM WHEAT GENOTYPES

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Abstract

The aim of this study was to establish the genotype by environment interaction for grain yield and the phenotypic stability of 27 durum wheat genotypes. The study was conducted on the experimental field of the Field Crops Institute - Chirpan. The studied genotypes were set in a randomized block design in four replications with replication size of 15 m². The trait yield for 27 varieties has been observed during a three-year period (2015-2017). The local growing technology for durum wheat was applied. Analysis of variance, stability analysis and cluster analysis were used. Significant influence of genotype, environment(year) and genotype by environment interactions on the grain yield was established. The environment(year) has the greatest influence on the expression of grain yield. According to the simultaneous assessment for high yield and stability by Kang, genotypes were ranked as follows: D-8159, D-8148, Reyadur, Saya, D-8032, D-8031, D-8036, D-8040 and D-8091. From the obtained results it is possible to create a strategy for increasing the yield of durum wheat and create new stable varieties.

Key words: *durum wheat, genetic distance, genotype by environment, grain yield, phenotypic stability.*

INTRODUCTION

Agricultural products and especially cereals provide about 20% of human calories and protein worldwide. Durum wheat products are used entirely for human nutrition and are suitable for people with various dietary needs. The yield has a complex structure of different components, all of which show quantitative inheritance due to polygenic systems (Vaezi et al., 2000; Foroozanfar & Zeynali, 2013). The increasing wheat productivity is an important step in feeding a rapidly growing population (Rizkalla et al., 2012). This can be achieved by creating new high-yielding varieties and applying new technologies in their cultivation. The new varieties should show higher values of yield and its components. The breeding for stable yields is also important, it allows genotypes to be grown more widely in different conditions. The purposeful breeding activity for the improvement of durum wheat in Bulgaria began in the 30s of the last century at the Field Crops Institute - Chirpan. Since then, a large number of varieties have been created, through which the yield potential of the culture in our country has been constantly increased.

Studies of wheat genotypes in different weather conditions is the main method for determining their stability and adaptive potential. The development and creation of genotypes with high adaptive potential is a major goal of breeding programs. When changing the growing conditions, it is possible for phenotypic traits to change their values in different directions. Phenotypic traits of genotypes do not need to show the same values in different agroecological conditions (Ali et al., 2003). Some genotypes perform well in one or two years, but in others they do not perform as well (fail). This is due to the genotype-environment interaction, which affects the stability of the genotype under different conditions (Arshaf et al., 2001). The genotype-environment interaction is important because the environment has a significant role in the manifestation of yielding genotypes under different growing conditions. Shah et al. (2009) found highly significant differences for genotypes on all studied traits, and also noted the interaction of genotypes with location, genotypes with year and genotypes with year and location. The genotype-environment interaction is an important factor in the variation of economic traits (Nurminiemi et al., 2002). The response of different yield genotypes to changing environmental conditions is essential to determine their economic value and their further use as varieties or donors in different breeding programs (Sinebo, 2005).

The assessment of phenotypic stability makes sense only in the presence of a significant genotype-environment interaction (Hussein et al., 2000). There are several types of methods for assessing phenotypic stability, which are mainly divided into variance, regression, nonparametric and parametric. Many of them have been applied to durum wheat in the world and in our country (Rharrabti et al., 2003; Mohamed et al., 2013; Dragov & Dechev, 2015). Some researchers emphasize that the interaction of the genotype with the conditions of the year in terms of yield in durum wheat is most pronounced. According to Mustatea et al. (2009) new high-yielding varieties must have high yields and high stability. Many studies have been conducted to establish the stability of wheat genotypes in different years (Rasul et al., 2006; Parveen et al., 2010; El-Ameen, 2012). Different parameters are known for assessing phenotypic stability (Eberhart & Russell, 1966; Shukla, 1972), but the Kang (YSi) parameter has emerged as the reliable method for simultaneously assessing yield and stability (Kang, 1993).

The present study aims to establish the genotype-environment interaction in grain yield and the phenotypic stability of 27 durum wheat genotypes. Certain parameters for the stability of genotypes will allow the select more stable and better adapted varieties.

MATERIALS AND METHODS

The study was conducted in three consecutive years (2015-2017). In terms of meteorology, 2015 is characterized by higher temperatures and significantly more precipitation than the multi-year norm. The second year of testing 2016 is characterized by higher temperatures and below-normal precipitation compared to the multi-year period. The third year of testing 2017 is characterized by temperatures around the norm and less precipitation compared to the multi-year period. The experiments were based on soil type Pellic Vertisols in field conditions in the experimental field of the Field Crops Institute - Chirpan. The studied genotypes were set by a randomized block desing in four replications with large ones on the experimental plot of 15 m^2. The accepted local technology for growing durum wheat has been applied, and the predecessor is spring peas. The main fertilization is with 10 kg/da of active substance phosphorus and feeding in spring with 10 kg/da of active substance nitrogen. To control wheat and deciduous weeds, a herbicide treating with a combination of two herbicides was carried out.

Explored genotypes with old and new varieties created in FCI - Chipran and the most promising breeding lines: Zvezditsa, Progres, Deyana, Tserera, Beloslava, Vazhod, Deni, Predel, Elbrus, Trakiets, Victoriya, Kehlibar, Raylidur, Saya, Reyadur, D-8161, D-8159, M-674, D-8040, D-8091, D-7763, D-8036, D-8148, D-7553, D-8032, D-8159 and D-8031. All varieties and breeding lines are created in FCI - Chirpan. Some of the varieties were created by the method of experimental mutagenesis, and others by combining breeding. Advanced breeding lines are created by the method of combined breeding.

Grain yield in kg/da was monitored on all genotypes and the obtained results were included in statistical analysis. Analysis of variance (ANOVA) was performed and various stability parameters were calculated: σ^2_i - (Shukla, 1972), S^2_i - (Shukla, 1972), W_i - (Wricke, 1962), YS_i - (Kang, 1993). For the last two analyzes, the Stable program developed by Kang & Magari (1995) was used. The cluster and PC analysis was performed using the software product Statistica 10. The cluster analysis was performed according to Ward (1963).

RESULTS AND DISCUSSIONS

The yield is a major quantitative trait complex formed by all other traits related to his expression. It is a leading trait in breeding programs and its breeding improvement is of paramount importance. The main goal of breeding programs is to obtain varieties with high yield potential (Petrovich et al., 2012).

Yields by year and average for the three years are presented in Table 1. The highest yield in the first year of the study has the line D-8031, the average yield in 2015 was 533.3 kg/da. The highest yield in the second year of research is D-8159, the average value in 2016 was 298.2 kg/da. In the third year of the study, the highest yield was achieved by the line D-8159, and the average yield in 2017 was 586.4 kg/da. The genotypes D-8031, D-8159, D-8032, Reyadur, Saya, D-8148, D-8036 and D-8091 have high yields over 500 kg/da on average for the three years (Table 1).

Table 1. Yield by years and average for three years (2015-2017)

Genotypes	Yield 2015 kg/da	Yield 2016 kg/da	Yield 2017 kg/da	Average yield kg/da
Zvezdtitsa	380.7	206.4	529.3	372.1
Progres	452.9	183.5	512.5	382.9
Deyana	474.0	220.6	562.5	419.0
Tserera	422.7	276.2	599.2	432.7
Beloslava	499.8	179.9	649.7	443.1
Vazhod	501.6	180.7	593.8	425.4
Deni	504.4	225.7	505.5	411.9
D-8161	510.9	357.9	477.8	448.9
Predel	522.0	248.2	584.7	451.6
Elbrus	489.6	256.6	625.3	457.2
D-8195	548.4	321.8	461.7	443.9
Trakiets	547.8	258.8	584.3	463.6
M-674	538.2	302.1	564.0	468.1
Viktoriya	594.4	287.2	505.8	462.5
Kehlibar	542.2	310.9	594.3	482.5
Raylidur	534.9	279.7	659.5	491.4
D-8040	528.7	379.7	592.3	500.2
D-8091	524.9	364.7	666.2	518.6
D-7763	536.9	270.5	632.5	479.9
D-8036	579.3	331.1	604.2	504.9
D-8148	607.3	376.4	646.3	543.3
D-7553	592.7	368.7	535.7	499.0
Saya	588.8	336.7	636.4	520.6
Reyadur	603.5	370.4	626.2	533.4
D-8032	562.7	364.9	626.8	518.1
D-8159	589.1	408.5	681.2	559.6
D-8031	621.8	382.9	576.5	527.1
Mean	533.3	298.2	586.4	472.6
Mean error	11.1	13.4	11.4	9.27

The standard variety Predel has an average value of three years of 451.6 kg/da. The genotypes realized yields over 500 kg/da are the new lines created in FCI-Chirpan and the two relatively new varieties Reyadur and Saya. It is noteworthy that the advanced lines for the most part exceed the standard varietie Predel and are a good basis for creating new durum wheat varieties. Compared to the average yield per year, the third year of testing is the most appropriate, where the genotypes have achieved the highest yields expressed by the average of all of them.

The results of the analysis of variance are represented in Table 2. The calculated F criteria show the presence of significant influence of the environment (781.1**), as well as the genotype - environment interaction (4.38**). Genotypes also have significant influence (2.04**). The environment has the greatest influence on the expression of grain yield with 77% of the total. Genotypes and genotype - environment interactions have an approximately equal share - about 11%. Genotypes have a greater influence. Genotype – environment interaction is significant for the trait grain yield of durum wheat (Akcura et al., 2005; Nsarellah et al., 2011). The presence of genotype - environment interaction makes it particularly difficult to conduct an effective selection of a genotype by phenotype for this trait. This result proves the urgent need for a long-term study of productivity or the statistical method of phenotypic stability of yield in durum wheat genotypes. A similar conclusion has been reached by other researchers in durum wheat (Nsarellah et al., 2011; Mohamed et al., 2013).

Table 2. Analysis of variance (ANOVA) for yield in durum wheat

Source	df	Sum of squares	Mean squares	F	η^2 %
Total	80	4767474			
Genotypes (G)	26	550080	21156.92	2.04 **	11.54
Environ-ments (E)	2	3680610	1840305	781.1 **	77.20
Interaction (G x E)	52	536784	10322.77	4.38 **	11.26
Heterogenity	26	263083.5	10118.6	0.96 n.s.	
Residual	26	273700.5	10526.9	4.47 **	5.74
Pooled error	156		2356		

* - $P \leq 0.05$; ** - $P \leq 0.001$; n.s. – no significant

The yield stability parameters are presented in Table 3. It should be noted that the Shukla stability variances σ^2_i and S^2_i and the Wricke ecovalence W_i estimate the variation over the years. Their higher (and significant) values indicate lower stability, and conversely, small nonsignificant values indicate high stability. The values of σ^2_i and S^2_i according to Shukla and W_i according to Wricke in our study are low and nonsignificant for M-674, Kehlibar, D-8148 and Saya, which evaluates them as stable. The Kang (YS_i) stability parameter was calculated for a complex assessment of yield and stability. It combines favorable values of yield and stability, with higher values marked with a plus being both stable and valuable. The Kang test evaluates both yield and stability, so it is not just a parameter for assessing stability. Its values are of non-parametric type, i. e. of rank type. In this case, not only the yield as a value, but also its stability in the given period is of great importance. According to Kang's YS_i, in our study, the lines with the best combination of high yield value and stability, i. e. high rank, are: D-8159, D-8148, D-8032, D-8031, D-8036, D-8040 and D-8091 and the varieties Reyadur and Saya (Table 3). Lines D-8159 and D-8032 are recognized as new varieties of durum wheat by the Exclusive Agency of Variety Testing, Seed Control and Approbation, Bulgaria. The D-8032 line is recognized as a new durum wheat variety under the name Heliks (Dragov et al., 2019). The D-8159 line is recognized as a new durum wheat variety under the name Deyche. Another line D-7763 is recognized as a new durum wheat variety under the name Viomi. Although it does not have a stable and high yield, it has a high resistance to diseases and high yellow pigments. The three varieties are entered in the variety list of Bulgaria and Europe. In view of the overall assessment, the D-8148 line is valuable. With regard to these results, it is possible to offer the D-8148 line for a new durum wheat variety. The varieties Saya and Reyadur were recognized in 2016 and are included in the variety lists of Bulgaria and Europe and at that time are included in the system of seed production and the institute had seeds from them. These results are prerequisites for the inclusion of the above-mentioned varieties in intensive hybridization and obtaining new genotypes with their participation, which exceed the standard in biological and economic qualities.

Table 3. Stability parameters for yield in durum wheat

Genotypes	σ^2_i	S^2_i	W_i	YS_i
Zvezditsa	8259.6 *	16886.5 **	16060.2	-6
Progres	1571.7 n.s.	-351.93 n.s.	3675.3	-1
Deyana	2763.7 n.s.	1605.6 n.s.	5882.7	2
Tserera	14030.9 **	28392.3 **	26747.8	-2
Beloslava	28590.8 **	9700.76 *	53710.7	-1
Vazhod	14156.6 **	750.0 n.s.	26980.6	-5
Deni	1683.7 n.s.	3280.1 n.s.	3882.6	1
D-8161	20588.1 **	4769.5 n.s.	38890.8	1
Predel	2216.3 n.s.	-302.4 n.s.	4869.0	10
Elbrus	8125.4 *	10329.97 *	15811.7	7
D-8195	19830.5 **	22050.9 **	37487.8	0
Trakiets	2269.3 n.s.	86.98 n.s.	4967.2	13+
M-674	-3.47 n.s.	108.96 n.s.	758.2	14+
Viktoriya	14222.7 **	28493.9 **	27103.1	4
Kehlibar	-379.2 n.s.	-353.76 n.s.	62.3	18+
Raylidur	8445.3 *	6977.1 n.s.	16404.2	15+
D-8040	6126.6 n.s.	1139.64 n.s.	12110.2	20+
D-8091	7788.7 *	15538.0 *	15188.2	20+
D-7763	5008.0 n.s.	2105.3 n.s.	10038.8	17+
D-8036	-55.0 n.s.	294.524 n.s.	662.6	21+
D-8148	-313.2 n.s.	-375.8 n.s.	184.6	28+
D-7553	102345.2 **	118331.8 **	190292	-4
Saya	-66.10 n.s.	-418.54 n.s.	642.2	25+
Reyadur	215.62 n.s.	250.19 n.s.	1163.9	27+
D-8032	720.3 n.s.	444.96 n.s.	2098.7	23+
D-8159	2395.9 n.s.	3851.8 n.s.	5201.5	30+
D-8031	8182.7 *	10640.6 *	15917.9	22+

* - $P \leq 0.01$; ** - $P \leq 0.001$; n.s. – no significant

Figure 1 represent the dendrogram from the hierarchical cluster analysis of the studied lines and varieties in terms of grain yield per da based on the results of the studied period. Initially, the genotypes studied were divided into two clusters. One includes the old (old and modern varieties) and new varieties (new varieties and some breeding lines) coming from the breeding program of FCI-Chirpan. The other cluster includes the advanced breedings lines and the two newest varieties Saya and Reyadur created by the method of sexual hybridization (advanced breedings lines and the latest varieties). At a sufficient level of reliability, the cluster of varieties is divided into two subclusters and essentially those subclusters represent the two strands of the FCI-Chirpan breeding program (experimental mutagenesis and combinatorial breeding). Figure 1 shows three clusters genetically distant from each other. When cluster analysis is performed on the basis of data obtained from different environments (years), to a large extent its values include the stability of the values of the trait. The new varieties created in the FCI fall into one cluster, while the standard variety Predel falls into the subcluster of the new varieties. The figure shows that the promising genotypes (advanced lines and latest varieties) of durum wheat fall into a separate cluster. This shows that they are genetically distant from previous varieties. Probably the new durum wheat breeding lines, created in recent years under changed weather/meteorological conditions, are better adapted to obtain high results. The results of the cluster analysis and the distribution of genotypes in the dendrogram can serve for the correct use of the genotypes in the hybridization scheme of the breeding program. Both genotypes D-8148 and Saya identified as stable fall into the same cluster. This suggests that hybridization between them would lead to faster equalization but less breeding advance in terms of yield. On the other hand, these two varieties are in a different cluster with the proven variety Predel standard in terms of biological and economic qualities. Crossing the two stable genotypes with the Predel variety would lead to greater breeding advance, but it will have a longer decay time. They are enough far away and in the decaying generations of these hybrid combinations it is possible to obtain heterosis and a longer time to conduct a selection in order to select more diverse forms. In conducting the breeding advance, we should take into account the genetic distance of the genotypes included in the combining breeding. Genetically closer parents need to be combined to achieve faster success. In order to achieve greater breeding advance in economically important qualities, it is advisable to cross genetically more distant parents (from different clusters). The authors Khodadadi et al., 2011 reach the same conclusion in the breeding strategy. Upon closer examination of the dendrogram, it can be seen that genotypes defined as both stable and yielding are in the same cluster. This shows that cluster analysis can also be used to group genotypes by stability, but it is important that stability is determined in advance by standard methods.

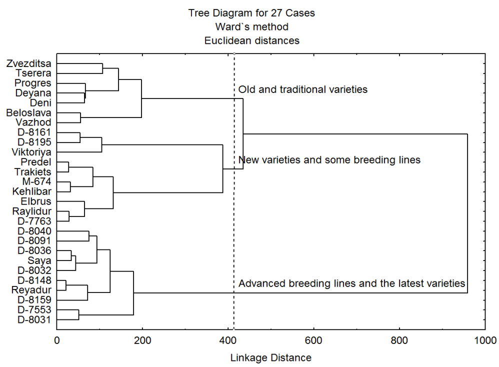

Figure 1. Dendrogram of cluster analysis for 27 durum wheat genotypes by grain yield

In the analysis of experimental results, especially for an important trait such as yield, PC analysis is also applied. The results of this analysis are presented in Figures 2 and 3. The graphical expression of PC genotype analysis is shown in Figure 2. According to Valkova & Dechev (2012), the most stable genotypes are in the quadrant of the positive values of the two main components, which largely coincides with our results for the Shukla (1972) stability assessment. It is accepted that PC1 is related to the linear effects of genotype variation and PC2 to the nonlinear part of the variation. At the same time, it is known that the stability parameters of Shukla - σ^2_i and S^2_i - are accepted in a similar way.

Logically, we come to the construction of Figure 3 with the location of the points of the genotypes in the coordinate system PC1 to grain yield. The genotypes located in the upper right (positive) quadrant of the coordinate system are of the greatest interest for the breeding. As can be seen from the data in Figure 3, the most valuable in terms of breeding, combining high yield and high phenotypic stability are the genotypes D-8159, D-8148, D-8032, Saya, D-8091 and others.

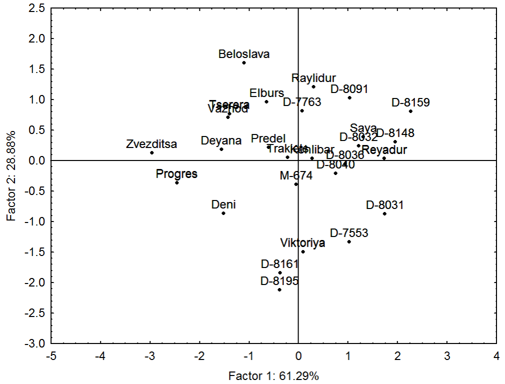

Figure 2. PC analysis for 27 durum wheat genotypes

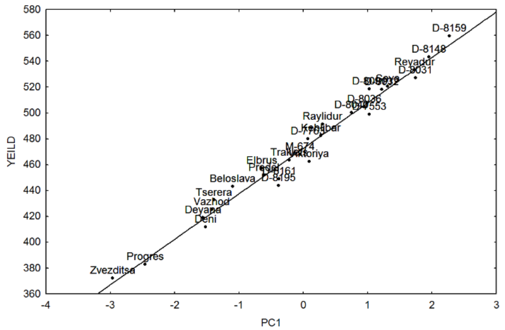

Figure 3. Relation of PC1 to yield in coordinate system

This almost completely coincides with the results of the yield - stability (YS_i) parameter of Kang and the corresponding group in the cluster analysis. Therefore, PC analysis can be used successfully to assess the phenotypic stability of genotypes on a given trait and to draw conclusions about their breeding value.

CONCLUSIONS

Significant influence of genotypes, environment (year) and genotype - environment interaction in the expression of the grain yield has been established. The greatest importance is due to the environment (year) as it occupies 77.20 % of the total variation in grain yield. The significant influence of the genotype-environment interaction allows for stability analyzes and adequate interpretation of the results. According to the Kang (YS^i) stability parameter, lines D-8159, D-8148, D-8032, D-8031, D-8036, D-8040 and D-8091 combine stability and high yield. These lines are of interest to the breeding program. The D-8159 line has the highest average yield and the highest rank. It is the latest variety created in FCI-Chirpan under the name Deyche. Cluster and PC analyzes can be used for preliminary stability assessment, but stability must be determined in advance by standard methods. Cluster analysis can be used to create a hybridization scheme according to the distance of the genotypes.

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IMPROVING THE PRODUCTIVITY AND QUALITY OF RYE PRODUCTION, BY APPLYING FOLIAR FERTILIZERS WITH A HIGH CONTENT OF MICROELEMENTS, IN SANDY SOIL CONDITIONS

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Abstract

*The research was carried out in the period 2019-2021 on the autumn rye crop, located in the conditions of sandy soils in southern Oltenia, Romania and aimed at involving foliar fertilizers with a high content of microelements on plant productivity and quality of grain production. The obtained results showed that the highest production of rye grains, of 3566.25 kg / ha, was achieved by foliar fertilization with the product Basfoliar 36 Extra, applied in a dose of 8 l / ha, on an agrofund of $N_{150}P_{80}K_{80}$, in the phase forming the first internode of the plant. Grain production was significantly positively correlated with the number of grains in the ear (r = 0.859**) and with the weight of one thousand grains (r = 9.914**). From the point of view of grain quality, foliar fertilization with Polyactiv Mn product, applied in a dose of 2.5 l/ha, on the $N_{150}P_{80}K_{80}$ agrofound (Crude Protein = 13.23%; Gluten = 28.48%; Zeleny index = 48.67 ml), foliar fertilizer that increased rye production by 524.35 kg/ha, significant difference from non-fertilized foliar.*

***Key words**: fertilization, rye, productivity, quality.*

INTRODUCTION

Due to the low organic matter content of sandy soils, the success of most crops requires large amounts of chemical fertilizers, which can often lead to pollution of groundwater with nitrates, due to poor hydrophysical properties in terms of chemical retention (Gheorghe et al., 2003). Under the conditions of a sustainable agriculture, obtaining high and stable yields for most plants cannot be conceived without the controlled application of fertilizers with macro and microelements, as a means of restitution in soil of mineral elements extracted at harvest (Rosculete & Rosculete, 2018; Jansone & Gaile, 2015). Rye (*Secale cereale* L.) is a cereal, whose grains are used mainly for human consumption, but also in animal and bird feed. Therefore, the content of micronutrients and macronutrients in cereals is as important as production (Kowieska et al., 2011). In the agronomic practices of cereals, the main factors that allow to obtain a high production with favorable qualitative properties, include both the habitat conditions and the genetic determinants of the varieties (Beáta et al., 2008; Ruzgas & Plycevaitiene, 2005; Smatas & Gaurilcikiene, 2005; Cioromele & Contoman, 2015). The literature mentions that the production and nutritional value of cereals are largely determined by the satisfaction of nutritional needs through fertilization (Stępień & Wojtkowiak, 2015; Kipling et al., 2018). In intensive agriculture, which requires high yields, in order to maintain the health of the soil, the importance of using inputs (pesticides, fertilizers) is undeniable (Matei et al., 2021; Paraschivu & Cotuna, 2021). The choice of a market economy production technology should be preceded by economic calculations of technology inputs (Jankowskik et al., 2003). Thus, in Poland the increase in rye production resulting from more intensive production methods did not fully cover the increase in direct costs. Oltenia is an important agricultural region where drought occurs frequently, only two out of ten years being favorable to agricultural crops (Bonea, 2020a; Bonea, 2020b; Nicolescu et al., 2008). From the point of view of ensuring the nutrients necessary for the nutrition of rye plants, sands and sandy soils are characterized by low natural fertility, determined by the low content of organic matter and fertilizers (Matei et al., 2009;

Gheorghe et al., 2009; Bonea & Urechean, 2020). In order to preserve and increase soil fertility, and to prevent soil and groundwater contamination with nitrates, it is necessary for fertilization to be carried out in a controlled manner so as to ensure the optimal use of nutrients by cultivated plants (Bonea, 2016; Hera, 2002; Paraschivu et al., 2015; López et al., 2019). In this regard, in the agricultural years 2019/2020 and 2020/2021 research was initiated on rye culture, which aimed at foliar fertilization with some environmentally friendly products to promote sustainable agriculture in the area of sandy soils.

MATERIALS AND METHODS

The researches were carried out in the period 2019-2021 for the Suceveana rye variety, by sowing it in autumn, between October 10-20 at RDSPCS Dabuleni, located in southwestern Oltenia, Romania. The experiment was organized in field conditions, according to the method of plots subdivided with 2 factors, on a sandy soil, which on the soil profile 0-50 cm was poorly supplied with total nitrogen (0.045-0.05%) and organic carbon (0.44-0.46%), had a good supply of extractable phosphorus (63.8-67.5 ppm), medium in exchangeable potassium (69.4-78 ppm), and showed a reaction of neutral soil with a pH = 7.1-7.2. The factors studied were:

Factor A: Root fertilization:

a_1 - $N_{75}P_{40}K_{40}$ (1/2 of the technological dose NPK);

a_2 - $N_{150}P_{80}K_{80}$ (technological dose NPK).

Factor B: Foliar fertilization:

b_1 - Unfertilized foliar;

b_2 - Basfoliar 36 Extra, at a dose of 8 l/ha;

b_3 - Maturevo 3.35.35 + ME, at a dose of 3.5 kg/ha;

b_4 - Biohumussol Liquid, in concentration of 1%;

b_5 – Polyactiv Mn, at a dose of 2.5 l/ha.

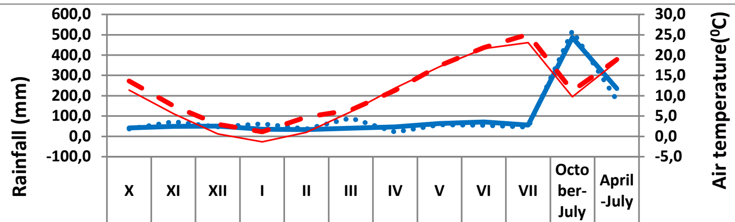
Root fertilization with $N_{40}P_{40}K_{40}$ (a_1) and $N_{80}P_{80}K_{80}$ (a_2) was applied in autumn to prepare the germination bed, and the difference in nitrogen dose, respectively N_{35} (a_1) and N_{70} (a_2), was applied in early spring, at the beginning of March, which coincides with the end of the twinning phase of rye twinning, the BBCH 29 vegetation stage (according to the BBCH scale for coding vegetation for straw cereals). Foliar fertilization was applied to the formation of the first internode in rye culture (BBCH 31). In the flowering phase of the plant, vegetation stage BBCH 65-69, leaf samples were collected to assess the supply status of plants in macroelements, respectively the total nitrogen content, determined by the Kjeldahl method, the total phosphorus content, determined by the colorimetric method and the total potassium content, determined by the method of dosing by flame emission photometry. During the vegetation period (BBCH 87-89), determinations were made of biometrics (plant height, spike length) and plant productivity (number of spikes / m^2, number of grains in spike). At harvest, it was determined: grain production, weight of one thousand grains (WTG), hectolitre weight (HW) and grain quality (Crude Protein, Wet Gluten, Zeleny Sedimentation Index), by spectrophotometric method, with NIR analyzer, INFRAMATIC model 9200 - Perten. The results were calculated and analyzed by the method of analysis of variance (ANOVA) and using mathematical functions.

RESULTS AND DISCUSSIONS

Analyzing the climatic conditions recorded in the period 2019-2021 at the weather station of RDSPCS Dabuleni (Figure 1), they were favorable for the growth and development of rye plants, within the limits of the biological requirements of the plant (minimum seed germination temperature of 1- 2^0C, the sum of temperatures during the vegetation of 1800-2000 ^{0}C, resistance in winter to minimum temperatures of minus 20^0C, without being covered by snow).

During the vegetation period of the rye crop (October-July), an average air temperature of 11.2^0C was registered, with 1.5^0C higher, compared to the multiannual average, thus noticing the accentuation of the arid climate in the area of sandy soils. Although the rainfall recorded exceeded the multiannual average by about 32.7 mm, they were unevenly distributed over the vegetation period of the rye, being necessary to supplement the water deficit in the soil during the critical periods for water (at sunrise and the phase of sprouting the plant).

Between April and July, compared to the multiannual average, there was a moisture deficit of 57.7 mm, which combined with the increase in air temperature accentuated the drought, which required water supply by irrigating the crop. Adverse weather conditions (especially droughts) in recent years, which often last a long part of the growing season, have a negative effect on plant yield, but not only on susceptible species, but also on resistant ones, such as rye (Czyczyło & Myśków, 2017).



	X	XI	XII	I	II	III	IV	V	VI	VII	October-July	April-July
Rainfall (2019-2021) (mm)	36,2	71,6	46,8	61,6	36,1	89,5	21,1	57,1	54,4	44,9	519,2	177,5
Multiannual rainfall (1956-2021), (mm)	42,2	49,3	50,8	35,1	33,4	40,5	46,4	62,7	70,3	55,7	486,5	235,2
Deviation rainfall from the multiannual average (mm)	-6,0	22,3	-4,0	26,5	2,7	49,0	-25,3	-5,6	-15,9	-10,8	32,7	-57,7
Average air temperature (2019-2021) (0C)	13,6	7,5	3,0	1,1	4,8	6,5	11,3	17,4	21,9	25,1	11,2	18,9
Multiannual average temperature (1956-2021), (0C)	11,4	5,6	0,6	-1,3	1,0	6,0	11,9	17,1	21,6	23,1	9,7	18,4
Deviation temperature from the multiannual average (0C)	2,2	1,9	2,4	2,5	3,8	0,5	-0,6	0,3	0,2	2,0	1,5	0,5

Figure 1. Evolution of climatic conditions recorded at the weather station of RDSPCS Dăbuleni

The results regarding the biometry of the rye plant showed higher values at the fertilization of the crop with the technological dose of $N_{150}P_{80}K_{80}$, compared to the fertilization with ½ from the technological dose (Table 1).

Table 1. Influence of root and foliar fertilization on rye plant biometrics and productivity in sandy soil conditions

Root fertilization	Foliar fertilization	Plant height (cm)	No. of spikes/ m^2	Spike length (cm)	No grains / spike	WTG (g)	HW (kg/hl)
$N_{75}P_{40}K_{40}$ (½ from the technological dose of NPK)	Unfertilized foliar	147.0	472	10.4	46	29.8	68.8
	Basfoliar 36 Extra (8 l/ha)	148.9	499	11.4	53	36.0	70.8
	Maturevo 3.35.35 + ME (3.5 kg /ha)	153.2	502	11.0	51	36.3	71.5
	Biohumussol Lichid (1 %)	154.9	495	11.1	51	30.5	71.2
	Polyactiv Mn (2.5 l/ha)	151.8	490	10.3	54	31.7	70.7
Average		151.1	491	10.8	51	32.9	70.6
$N_{150}P_{80}K_{80}$ (the technological dose of NPK)	Unfertilized foliar	163.3	494	10.7	53	30.0	70.8
	Basfoliar 36 Extra (8 l /ha)	170.3	550	11.9	60	37.7	75.0
	Maturevo 3.35.35 + ME (3.5 kg /ha)	168.0	540	11.6	57	37.2	75.4
	Biohumussol Lichid (1 %)	168.0	544	12.0	60	36.5	74.7
	Polyactiv Mn (2.5 l / ha)	165.0	516	11.2	56	36.5	72.7
Average		166.9	528.7	11.4	57.4	35.6	73.7

Thus, compared to fertilization with $N_{75}P_{40}K_{40}$, fertilization of rye crop with $N_{150}P_{80}K_{80}$ led to an increase of 15.8 cm in plant height, by 37.7 spikes/square meter of plant density, by 0.6 cm of spike length, by 6.4 grains in spike, with 2.7 g of WTG and with 3.1 kg/hl of HW. Nitrogen fertilization is one of the most important factors in the growth and development of cereal crops. The availability of nitrogen for the plant is indispensable because it is a basic component of the organic molecules involved in plant growth and development (Salas, 2003). Analyzing the effect of foliar fertilization, it was noticed the increase of the values of the productivity traits of the plant, compared to foliar non-fertilizer, on both agro-funds of root fertilization. The best results were obtained in foliar fertilization with the product Basfoliar 36 Extra, applied at a dose of 8 l/ha in the formation phase of the first internode, which, compared to non-fertilized foliar, caused increases of 11.3-25.6% on the productivity elements, respectively the number of spikes/m^2, the length of the spike, the number of grains in the spike, the WTG and the HW. The growth is due to the high content of microelements in foliar fertilizers, which are very quickly absorbed by the leaves and do not turn into compounds inaccessible to plants.

The results obtained on the state of supply of plants in macroelements (N, P, K) are shown in Figure 2.

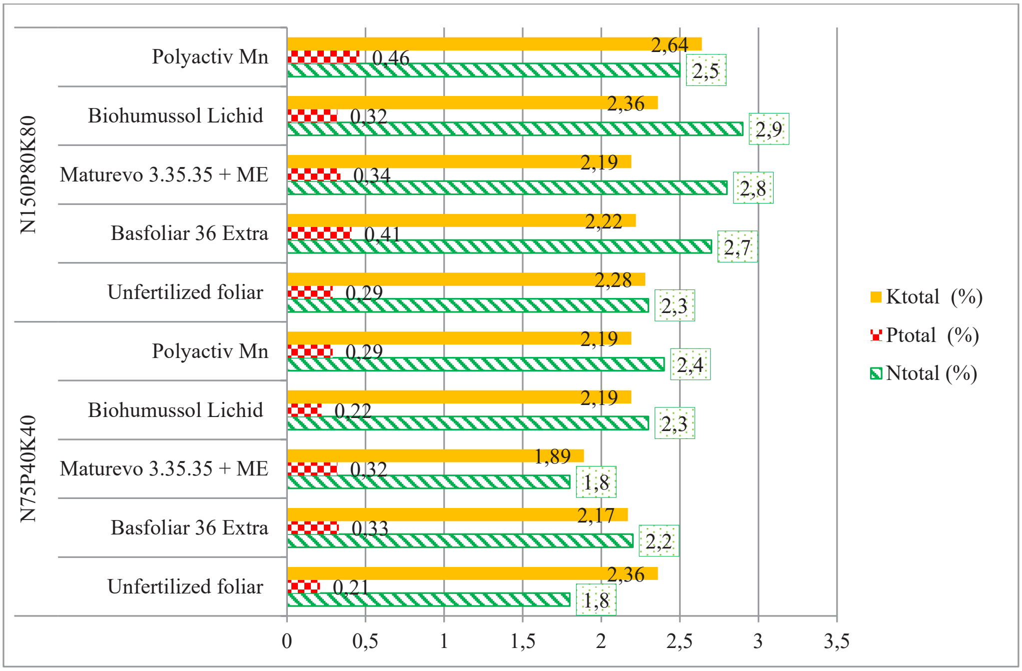


Figure 2. State of supply of rye plants in nitrogen, phosphorus and potassium according to the fertilization system

The content of rye plants in nitrogen was between 1.8% in the fertilized version with ½ of the technological dose and non-fertilized foliar and 2.9% in the version fertilized with the technological dose and foliar fertilized with the liquid Biohumussol product, in a dose of 1%. The values obtained indicate a reduced state of supply of plants in total nitrogen, with a tendency to increase the nitrogen content with increasing doses of fertilizers. The supply status of rye plants in total phosphorus indicates optimal values between 0.21%, in the fertilized version with ½ of the technological dose and non-fertilized foliar and 0.46%, in the version fertilized with the technological dose and foliar fertilized with the product Polyactiv Mn (2.5 l/ha). Also, the state of supply of plants in potassium has highlighted values in the optimal field of supply of plants.

Analyzing the interaction of the two factors studied on the production results obtained in rye, it was highlighted the foliar fertilization with Basfoliar 36 Extra, in a dose of 8 l/ha, on an agrofund of $N_{150}P_{80}K_{80}$, with a maximum production of 3566.25 kg/ha, ensuring a production difference of 1172.65 kg / ha, very statistically significant compared to non-fertilized foliar (Table 2). Statistically assured production differences, compared to foliar non-fertilizer, at the same level of root fertilization were registered for the other foliar products applied, respectively: Maturevo 3.35.35 + ME, Biohumussol Lichid and Polyactiv Mn. Similar results were obtained in Poland for rye grown on clay loam soil with an organic carbon content of 0.79%, where production increases due to foliar fertilization with microelements Cu, Zn, Mn, applied alone or in combination on an agrofund of mineral fertilization with NPK, were 980-1480 kg/ha, compared to non-fertilized (Stępień et al., 2016). Research conducted in Romania (Brăila), in the conditions of a chernozem soil with an alkaline pH, showed that the production results obtained from rye were differentiated by variety and fertilization regime (Cioromele & Contoman, 2015). Under these conditions, the Suceveana variety achieved the maximum production (4147 kg/ha) when applying the dose of N_{50}, and the Ducato variety achieved the maximum production (4013 kg/ha) at fertilization with N_{100}, the differences compared to non-fertilized being very significant for both varieties.

Table 2. Significance of rye crop yields under the influence of root and foliar fertilization

Fertilization variant		Grain Yield		Difference from the unfertilized (kg/ha)	The significance
Root fertilization	Foliar fertilization	(kg/ha)	(%)		
$N_{75}P_{40}K_{40}$ (½ from the technological dose of NPK)	Unfertilized foliar	1744.20	100.00	Unfertilized	Unfertilized
	Basfoliar 36 Extra (8 l/ha)	2547.20	146.04	803.00	***
	Maturevo 3.35.35 + ME (3.5 kg/ha)	2509.95	143.90	765.75	**
	Biohumussol Lichid (1%)	2216.75	127.09	472.55	*
	Polyactiv Mn (2.5 l/ha)	2032.55	116.53	288.35	-
$N_{150}P_{80}K_{80}$ (the technological dose of NPK)	Unfertilized foliar	2393.60	100.00	Unfertilized	Unfertilized
	Basfoliar 36 Extra (8 l/ha)	3566.25	148.99	1172.65	***
	Maturevo 3.35.35 + ME (3.5 kg/ha)	3344.00	139.71	950.40	***
	Biohumussol Lichid (1%)	3305.75	138.11	912.15	***
	Polyactiv Mn (2,5 l/ha)	2917.95	121.91	524.35	*
			LSD 5%	404.55	
			LSD 1%	557.2	
			LSD 0.1%	767.05	

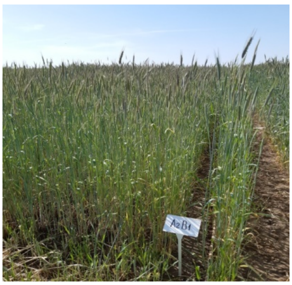


Photo 1. Foliar unfertilized rye crop
Source: Original

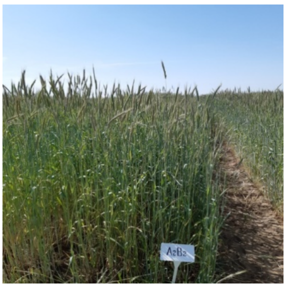


Photo 2. Foliar fertilized rye culture with *Basfoliar® 36 Extra SL*
Source: Original

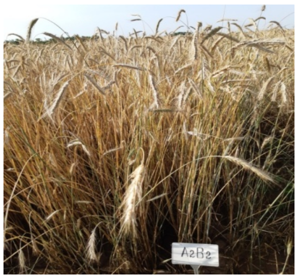


Photo 3. Foliar fertilized rye culture with *Basfoliar® 36 Extra SL*
Source: Original

Analyzing the functional link between grain production and the productivity elements of the plant (number of grains in spike and weight of one thousand grains) showed distinctly significant positive correlations (r = 0.859 **, r = 0.914 **), which emphasized the increase in production as the productivity of the plant increased (Figure 3).

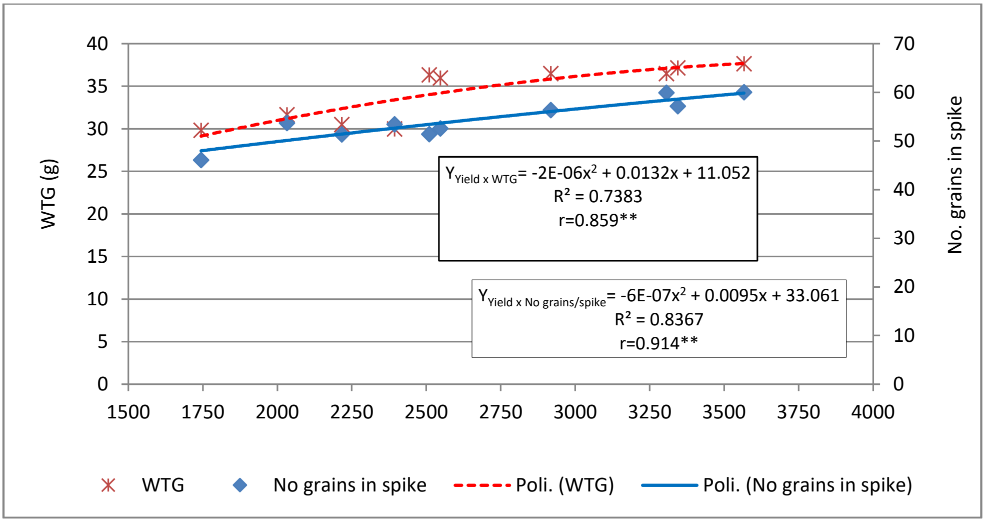


Figure 3. Correlations between the productivity elements of the plant and the production obtained from rye in different fertilization variants

The quality of rye grains was influenced by both root fertilization and foliar fertilization (Table 3). The protein content of rye grains was between 8.25% in the fertilized version at ½ of the technological dose and non-fertilized foliar and 13.23% in the version fertilized with the technological dose of NPK and foliar fertilized with the product Polyactiv Mn (2.5 l/ha). In all variants fertilized with the technological dose of NPK and with different foliar products, the amount of protein in the grains showed higher values compared to the variants fertilized at ½ in the technological dose. Similar results were obtained for rye grown in north-western Mexico, which showed that the yield and quality of production increased significantly by fertilization by 150 kg/ha N, compared to unfertilized with nitrogen (López et al., 2019). The results obtained by Stępień et al. (2016), also highlighted the role of mineral fertilization with NPK in increasing by 5% the protein content of the grain, compared to unfertilized. Gluten in rye grains was between 14.05% in the fertilized version at ½ of the technological dose and non-fertilized foliar and 28.48% in the variant fertilized with the technological dose of NPK and foliar fertilized with the product Polyactiv Mn, in a dose of 2.5 l/ha. However, the protein and gluten content is not sufficient for a complete characterization of the quality of cereal flour, so it is very useful to determine the value of the sedimentation index. The value of the Zeleny Sedimentary Index depends on the composition of the proteins, but it is also correlated with the protein content (Marinciu & Şerban, 2018). The content of wet gluten grains and the Zeleny Sedimentary Index are very important quality indicators for the technological process, contributing to the characterization of the dough, especially its processing capacity and its baking potential (Banu, 2003). The results obtained in our experiment also showed that the high values of protein and gluten content, recorded in the fertilized variants with the technological dose of NPK and foliar products, were also reflected in the high values of the Zeleny Index in the same variants (28.67-48.67 ml).

Table 3. Nutritional quality of rye grains according to fertilization system

Foliar fertilization	Root fertilization					
	$N_{75}P_{40}K_{40}$			$N_{150}P_{80}K_{80}$		
	Crude protein (%)	Gluten (%)	Zeleny index (ml)	Proteina (%)	Gluten (%)	Zeleny index (ml)
Unfertilized foliar	8.25	14.05	15.00	10.44	20.17	22.33
Basfoliar 36 Extra (8 l/ha)	9.04	16.03	13.97	11.77	24.45	30.00
Maturevo 3.35.35 + ME (3.5 kg /ha)	9.42	14.12	17.00	11.12	21.94	28.67
Biohumussol Lichid (1%)	9.04	16.39	23.67	11.94	24.74	32.67
Polyactiv Mn (2.5 l/ha)	8.87	18.65	22.33	13.23	28.48	48.67

CONCLUSIONS

Fertilization with Basfoliar 36 Extra, carried out in the formation phase of the first internode of the plant, with a dose of 8 l/ha, on an agrofund of $N_{150}P_{80}K_{80}$, determined the obtaining of the maximum production for rye cultivation (3566.25 kg/ha).

Grain production was significantly positively correlated with the number of grains in the spike (r = 0.859**) and with the weight of one thousand grains (r = 9.914**).

From the point of view of the quality of the grains, the best results showed the foliar fertilization with the Polyactiv Mn product, applied in a dose of 2.5 l/ha, on the agrofund of $N_{150}P_{80}K_{80}$ (Crude Protein = 13.23%; Gluten = 28.48%; Zeleny index = 48.67 ml), foliar fertilizer that increased rye production by 524.35 kg/ha, a significant difference from non-fertilized foliar.

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AGRONOMIC PERFORMANCE OF SOME WHEAT VARIETIES UNDER CONVENTIONAL AND ORGANIC FIELD CONDITIONS

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Abstract

In this study we tested an assortment of eight Romanian wheat varieties in conventional and organic field conditions at Agricultural Research and Development Station Şimnic, Craiova. The results for the yield showed that the varieties exhibited a significant interaction only with the organic field conditions. In these conditions of the organic field, the Litera variety was significantly inferior to the control (Glosa variety) in terms of yield. Overall, the varieties grown under organic field conditions had a lower yield (-42.6%), with a lower thousand grains weight (-6.8%) and a lower hectoliter weight (-1.6%) compared to conventional field conditions. The varieties of wheat that showed minimal loss under organic field conditions were Glosa for yield; Glosa and Ursita for thousand grains weight, and Ursita and Zamfira for hectoliter weight, hence these varieties could be used as parents for organic breeding programs in this region. Only in conventional field conditions, the correlation between yield and hectoliter weight was significant, 64.5% of the yield variability being associated with the variability of this character.

***Key words**: conventional, organic, hectoliter weight, thousand grains weight, yield, wheat.*

INTRODUCTION

Most wheat production is produced using the conventional crop system, a system that contributes substantially to ensuring global food security.

In 2020, global wheat production was 760 million tons (FAO, 2020). According to Grote et al. (2021), more than two-thirds of global wheat is used for food and one fifth is used for livestock feed.

In recent years, organic wheat production has increased significantly in many countries due to consumer demand.

Organic farming is accepted as an effective alternative to overcome the effects of chemical pollution in conventional agriculture (Gevrek & Atasoy, 2012).

An organic farming system is based on the use of organic fertilizers and non-chemical crop protection strategies, which often involves a reduction in yields compared to a conventional system, but this reduction can be offset by higher prices for organic products (Tamis & Van den Brink, 1999).

To overcome concerns about limiting production in organic farming systems, better adapted genotypes that use nitrogen efficiently are needed (Kubota et al; 2018; Chen et al., 2020). Also, a major constraint factor for organic farming is weed infestation, so competitive genotypes are needed. A competitive genotype for organically grown wheat must have agronomic traits: rapid growth at the beginning of the season, taller plants, early maturity and elevated fertile tillers number (Mason et al., 2007).

In addition to the crop system, the yield of wheat is also influenced by the interaction of other factors: cultivar, soil, climate (Jonczuk & Stalenga, 2016).

Wheat is a crop sensitive to prevailing weather conditions, such as rainfall during grain filling and temperatures in July (during the ripening period of cereals) (Jansone & Gaile, 2013).

In many previous studies, it is mentioned that Oltenia is a region of agricultural crop where drought and heat frequently occur limiting the yield of agricultural crops (Bonea, 2016; 2020a, 2020b; 2020c; Urechean & Bonea, 2012; Urechean et al., 2019; Bonea & Urechean, 2020; Dunăreanu et al., 2021), therefore organic agriculture needs varieties that can cope with different levels of abiotic stress and have a stable yield over the years (Dunăreanu & Bonea, 2022).

This feature, respectively drought tolerance is another important issue for both conventional and organic farming. Organic farmers can give higher priority to this feature because they want an organic system that is less dependent on inputs (Lammerts van Bueren et al., 2011).

The main objective of the study is to evaluate the performance of an assortment of wheat varieties in conventional and organic field conditions to identify the most suitable varieties.

MATERIALS AND METHODS

The study was conducted in the agricultural year 2020-2021 in two field conditions: conventional and organic (Figure1, Figure 2).

Conventional cultivated plots were fertilized in autumn with doses of NPK 18-46-0 and in spring ammonium nitrate in two doses: 200 kg/ha in February and 150 kg/ha in April. No organic pesticides were used in the organically grown plots and no weed control was performed.

The analyzed wheat assortment was represented by 8 Romanian varieties obtained at NARDI Fundulea. This assortment was analyzed in terms of average yield, as well as thousand grains weight (TGW) and hectoliter weight (HW).

Figure 1. View from the organic field

TGW and HW was determinate with Seed counter - Sadkiewicz instruments and Perten AM 5200-A. The data provided in this study is the average of three replicates.

ANOVA to analyze all data for randomized block design was used.

The differences between the varieties were compared based on the least significant difference (LSD P ≤ 0.05; 0.01 and 0.001).

Relationships between studied characters were examined using Pearson correlation coefficients ($p \leq 0.05$). Use Microsoft Excel 2010 for data calculations.

Figure 2. View from the conventional field

RESULTS AND DISCUSSIONS

Yield is the main determinant of the economic value of wheat.

In our study, under conventional field conditions, all tested varieties performed at the control variety (Glosa), the differences being statistically non-significant.

The maximum yield was recorded for the Pitar variety (8929 kg/ha), and the minimum yield for the Litera variety (6911 kg/ha).

Favorable climatic conditions in the study year led to an average production of 7489 kg/ha (Tables 1 and 3).

Table 1. Yield of wheat in conventional field conditions

Variety	Yield (kg/ha)	Differences to control (kg/ha)	Signif.
Glosa (Ct)	7396	Control	-
Pitar	8929	+1533	ns
Boema 1	5955	-1441	ns
Litera	6911	-485	ns
Ursita	7827	+431	ns
Semnal	7942	+546	ns
Voinic	7880	+484	ns
Zamfira	7071	-325	ns

LSD 5% = 2267.7 kg/ha; LSD 1% = 3112.8 kg/ha; LSD 0.1% = 4300.2 kg/ha: ns = non-significant

In organic field conditions, ANOVA showed significant differences between varieties, but only Litera variety recorded a significant decrease in production compared to the control variety (-1698 kg/ha). For the rest of the varieties, the differences from the control were non-significant; the average production obtained being of 4295 kg/ha (Tables 2 and 3).

Table 2. Yield of wheat in organic field conditions

Variety	Yield (Kg/ha)	Differences to control (Kg/ha)	Signif.
Glosa (Ct)	4573	Control	-
Pitar	4235	-338	ns
Boema 1	4147	-426	ns
Litera	2875	-1698	0
Ursita	4649	-76	ns
Semnal	4836	+263	ns
Voinic	5437	+864	ns
Zamfira	3605	-968	ns

LSD 5%= 1336.6 kg/ha; LSD 1%=1840.9 kg/ha; LSD 0.1% = 2534.5 kg/ha; 0 or ns = significant or non-significant at LSD 5%

The classification of the varieties (ranking) based on the studied characters (yield, thousand grains weight and hectoliter weight) was made according to the minimum and maximum differences between the organic and the conventional field conditions (Tables 3-5).

Because nutrient intake in organic field conditions is a limiting factor in production, all varieties tested had lower yields in organic field compared to conventional field condition.

On average, the difference was -3194 kg/ha or -42.6% (Table 3).

Thus, the difference in yield between the two types of cropping systems is largely determined by the rainfall in the year of study.

According to Urechean & Bonea (2017), the Oltenia area is often affected by drought and heat only two years out of ten are favorable to agricultural crops.

Table 3. Ranking of the varieties for yield based on the differences between the conventional and organic management systems (a-b=c)

Variety	CONV[a]	ORG[b]	Difference[c]	Rank
Boema 1	5955	4147	1808	1
Voinic	7880	5437	2443	2
Glosa	7396	4573	2823	3
Ursita	7827	4649	3178	4
Semnal	7942	4836	3293	5
Zamfira	7071	3605	3466	6
Litera	6911	2875	4036	7
Pitar	8929	4235	4694	8
Mean	7489	4295	3194 (42.6%)	-

COV - conventional; ORG - organic

Compared to conventional field conditions, the smallest decrease in organic yield was recorded in the Boema 1 variety (-1808 kg/ha) which ranked first, and a maximum decrease in yield was recorded in the Pitar variety (-4694 kg/ha) which ranked last (eighth place) (Table 3).

The grains weight is a highly heritable trait and has made significant contributions to yield potential in modern wheat breeding.

Thousand grains weight (TGW) and yield has proved to be the preferable criteria to screen for heat-tolerant wheat in field (Cheng et al., 2015).

Wheat varieties capable of making a TGW higher under thermal stress, it has a higher tolerance to warm environment (Mohtasham, 2012).

In our study, with one exception (Zamfira variety in organic conditions) all varieties had TGW values of over 40 g.

The Glosa variety was the only variety that recorded a higher TGW value (49.6 g), respect-tively an increase of value (+2.9 g) in organic culture compared to conventional culture (46.7 g). On average, the difference between the fields was -3.1 g or -6.8% (Table 4).

The smallest decrease in TGW in organic conditions was recorded in the Ursita variety (0.5 g) and a maximum decrease was recorded in the Boema 1 variety (8.7 g) compared to conventional conditions (Table 4).

Table 4. Ranking of the varieties for thousand grains weight based on the differences between the conventional and organic field conditions (a-b=c)

Variety	CONV[a]	ORG[b]	Difference[c]	Rank
Glosa	46.7	49.6	+2.9	1
Ursita	46.0	45.5	0.5	2
Voinic	42.9	41.5	1.4	3
Semnal	42.7	41.0	1.7	4
Zamfira	40.9	38.1	2.8	5
Pitar	48.0	43.0	5.0	6
Litera	47.1	40.1	7.0	7
Boema 1	49.3	40.6	8.7	8
Mean	45.5	42.4	3.1 (6.8%)	-

COV - conventional; ORG – organic

Hectoliter weight (HW) is another determining factor in the economic value of wheat. The grading manual for consumption seeds in Romania, establishes for wheat a minimum value of 78 kg/hl for Grade 1quality, 75 kg/hl for Grade 2 and 72 kg/hl for Grade 3 quality (Dunăreanu & Bonea, 2022).

In our study, in conventional conditions, Pitar and Voinic varieties met the requirements for Grade 1 quality and the rest of the varieties for Grade 2 and 3 of quality.

In organic conditions only Voinic variety was classified in Grade 1 of quality. Also, only

Glosa variety registered values below the limit of 72 kg/hl, respectively 70.2 kg/hl (with non-bakery value) in organic conditions.
Thus, the largest decrease for HW in organic conditions compared to conventional conditions was recorded in the Glosa variety (4.1 kg/hl) which ranked last, and the smallest decrease of 0.3 kg/hl in the Ursita and Zamfira varieties who took the first places (Table 5).

Table 5. Ranking of the varieties for hectoliter weight based on the differences between the conventional and organic field conditions (a-b=c)

Variety	CONV[a]	ORG[b]	Differences[c]	Rank
Ursita	77.4	77.1	0.3	1
Zamfira	75.1	74.8	0.3	2
Boema 1	73.1	72.7	0.4	3
Voinic	79.7	79.0	0.7	4
Semnal	76.9	75.9	1.0	5
Litera	74.9	73.8	1.1	6
Pitar	78.0	76.6	1.4	7
Glosa	74.3	70.2	4.1	8
Mean	76.2	75.0	1.2 (1.6%)	-

COV - conventional; ORG - organic

Under conventional field conditions, the only significant correlation was observed between yield (Y) and HW (r = 0.803*), indicating that 64.5% of the wheat yield variability could be explained by the variability of this character (Figure 3). The rest of the correlations were non-significant (Table 6).

Table 6. Pearson's correlation coefficients between studied characters under conventional field conditions

Characters studied	Yield	Thousand grains weight	Hectoliter weight
Yield	1	0.191^{ns}	0.803*
Thousand grains weight		1	-0.378^{ns}
Hectoliter weight			1

*; ^{ns} - significant; non-significant at 0.05 level of probability

In organic field conditions, all correlations between the studied characters were non-significant (Table 7), probably due to the small number of variants tested, the correlations studied were mostly non-significant.

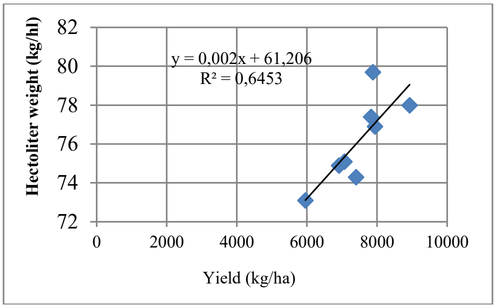

Figure 3. Dependence between yield and hectoliter weight in conventional field conditions

Table 7. Pearson's correlation coefficients between studied characters under organic field conditions

Characters studied	Yield	Thousand grains weight	Hectoliter weight
Yield	1	0.381^{ns}	0.431^{ns}
Thousand grains weight		1	-0.345^{ns}
Hectoliter weight			1

ns – non-significant at 0.05 level of probability

CONCLUSIONS

The yield of the varieties tested in the organic system was, on average, by 42.6% lower than in the conventional system. Also, thousand grains weight was smaller by 6.8% and hectoliter weight by 1.6%.
The wheat varieties that registered a minimal decrease in the value of the characters studied in organic conditions compared to the conventional conditions were: Glosa for yield; Glosa and Ursita for thousand grains weight, and Ursita and Zamfira for hectoliter weight.
These varieties are recommended for organic farming in the study area, depending on the purpose of the farmers (production or quality), but can also be used as parents in the breeding program for organic farming.
In general, all correlations between the characters studied were insignificant in both field conditions, except for the correlation between yield and hectoliter weight in organic field conditions.

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EFFECT OF THE ORGANIC AND BIODYNAMIC FERTILIZATION ON THE PRODUCTIVITY OF SUGAR, FODDER AND TABLE BEETS

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Abstract

The use of organic fertilizers in the ecological production of sugar, fodder and table beets increases significantly the volumes of organic raw material for production of forages and food. The influence of variants of treatment with the organic fertilizers Free N 100, Raim Zolfo, Heliosulfure, and the biodynamic preparations 500 and Fladen, on the productivity and dry matter content of the sugar beet variety Diex, fodder beet variety Sasha and Radost table beet variety has been tested on the Experimental ecology field (carbonate black earth) of AI-Shumen during the period 2019-2020. The test was conducted using the long plots method in 4 repetitions with 8.2 sq. meters area of the experimental plot, in crop rotation of wheat-beet-sorghum, without any use of conventional pesticides and fertilizers. The productivities of the treated with biological preparations variants exceed that of the control in the more favorable for the development of the crops 2019, as well as in the extremely dry for the vegetation 2020.

***Key words**: organic fertilizers, biodynamic preparations, sugar, fodder, table, beet.*

INTRODUCTION

The organic farming as a form of sustainable production is an important priority in the agricultural development policy of Bulgaria. There is a significant increase in organic production on world markets (Lukyanova, 2003; Bozhanska, 2019). Organic farming strengthens agro-ecosystems, preserves biodiversity, promotes healthy food production and creates more employment in rural areas. The production of clean food from chemically contaminated food becomes fundamental for the health status of the population (Kulaeva and Kuznetsov, 2004, Balezentiene and Sampietro, 2009; Georgiev et al., 2019; Bozhanska et al., 2020).

To achieve this goal, the regulation of crop life processes without the use of chemicals is studied (Kerin and Berova, 2001; Mihova et al., 2015). A number of companies have appeared offering various ecological fertilizers and biostimulants. The experimental study of the complex use of organic preparations provides valuable information to farmers - producers of organic products (Enchev and Kikindonov, 2016; Dochev et al., 2019).

The main indicator of soil fertility is the humus content. Excessive use of pesticides in Bulgaria threatens the deterioration of natural fertility, pollutes groundwater and the environment, increases the acidification of usable areas (Yakimov, 2013). Biodynamic agriculture, as a form of organic farming, aims to revive soil fertility. Based on many years of experience, the effect of biodynamic preparations on soil and plants by stimulating humus content and biological activity has been reported (Schauman, 1987; Raupp, 2001). According to agrochemical studies, the activity of biodynamic preparations is significantly higher compared to fertilizer material. This shows that in biodynamic agricultural practices, the stimulation is towards achieving the right natural values and balance of soil agrochemical components, which leads to more intensive carbonate cycle and efficient biological turnover,

ensuring sustainable fertility with respect to the nitrogen cycle (Naydenova et al., 2015).
The sugar, fodder and table beets are crops with high potential to expand the raw material base for production of forages, food and biofuels. The increased demand for organic products is reviving interest in sugar beet for the production of sweet syrups. The Shumen Agricultural Institute conducts researches on the use of organic preparations in beet production (Enchev et al., 2017, 2018). The aim of the present study is to study the productive potential of different forms of beets in the conditions of organic agriculture in the region of Northeastern Bulgaria.

MATERIALS AND METHODS

The experimental study was conducted in 2019-2020 at the Agricultural Institute - Shumen, Northeastern Bulgaria. The experimental ecological field has a five-year period without use of any chemical pesticides and mineral fertilizers, on carbonate black earth, with a scheme of crop rotation of wheat - sorghum - beet. The field experiment is based on the method of fractional plots with quadruple repeatability of the variants, with an area of the harvest plot of 8.2 sq.m. The sowing was carried out at the end of April, at a distance of 70 cm between rows and with in-row density of 12 plants per square meter.
The variants include 3 varieties: Diex - sugar beet, Sasha - fodder beet, Radost - table beet, all from the selection of Agricultural institute, listed in the State Variety List of the Republic of Bulgaria, with 3 treatment options: controls without treatment, fertilization with biodynamic and biological preparations.
The biodynamic treatment is with the simultaneous use of the preparations 500 and Fladen, applied in a formed rosette phase with 1.5% solution. Free N 100 and Reim Zolfo were imported as biological complex treatment. The first, applied in a dose of 0.05 l/da, enriches the soil and helps the absorption of atmospheric nitrogen, and the second preparation, in addition to being a fungicide, also acts as a stimulant for plant growth applied in a dose of 250 ml/100 l water. Later, the biological fungicide Heliosulfur was applied at a dose of 500 ml/da.
The roots were harvested at the end of October. The weight of each harvest plot of each variant was measured by the root yield indicator, the dry matter content was determined refractometrically. The results were statistically processed with the XLSTAT program for proof and accuracy of the experiments.

RESULTS AND DISCUSSIONS

The agrometeorological conditions at the beginning of the vegetation in 2019 are characterized as favorable, with good soil moisture and high enough temperature for the normal germination and formation of garnished crops. The rainfalls in July allowed for intensive crop development. From mid-August to the end of October, there was a drought, which reduced the accumulation of biomass. 2020 is characterized as extremely unfavorable, with record water deficit. Winter rainfalls are half the norm. March and April were practically without any rainfalls, and the whole of May is one third of the normal precipitation. The prolonged extreme drought in July and August had an irreversible impact on record low productivity levels (Table 1).
The results of 2019 test of organic preparations effect on the productivity of three varieties of beet are shown on Table 2. In the more favorable 2019 the productivity of the three varieties in their control variant has relatively high for organic farming levels of 2 tons - from the table beet, 3.4 tons - from sugar beet, and up to 4.5 tons from the fodder beet.

Table 1. Agrometeorological conditions for the vegetation period, 2019-2020

Year Month	Rainfalls - mm					Temperature Mean for the month
	Decades			Sum	Norm	
	I.	II.	III.			
IV 2019	7.7	45.9	-	53.6	41.0	10.1
V	24.8	16.0	8.4	49.2	64.0	16.7
VI	28.8	10.6	31.2	70.6	75.0	22.2
VII	8.0	24.5	9.1	41.6	60.0	21.9
VIII	22.1	3.7	1.6	27.4	42.0	22.9
IX	-	4.2	11.9	16.1	28.0	18.7
X	16.2	-	7.1	23.3	53.0	13.3
IV.2020	0.0	0.6	1.0	1.6	41.0	12.0
V	12.3	0.0	14.1	26.4	64.0	16.8
VI	4.9	71.1	2.4	78.4	75.0	21.4
VII	0.5	1.1	13.2	14.8	60.0	24.7
VIII	0.0	21.1	0.3	21.4	42.0	24.4
IX	21.7	0.0	9.4	31.1	28.0	21.1
X	17.7	18.9	11.3	47.9	53.0	15.6

The treatment with organic preparations dramatically increases the root yield by 20 to 30% compared to the control. The effect on fodder beet is weaker. The increase in root yield is associated with a slight decrease of the dry matter content, which is expected having in mind the inverse correlation of these traits. The resulting dry matter yield is a demonstration for the ability of organic treatments to largely compensate for intensive factors such as pesticides and mineral fertilization in the conventional sugar and table beet production.

The extreme water deficit conditions in 2020 have a strong impact on productivity. The reduction in root yield is half of the results obtained in 2019 for all three forms of beets. The processes of accumulation of nutrients in the beet root are sensitive to water deficiency, in which nutrients are redirected to maintain the physiological balance of the leaf apparatus.

Table 2. Effect of the treatment with organic preparations on the productivity and the dry matter content of varieties of sugar beet - Diex, fodder beet – Sasha, table beet - Radost 2019

Variants	Root Yield		Dry matter content		Dry matter Yield	
	t/ha	Rel. to control (%)	%	Rel. to control (%)	t/ha	Rel. to control (%)
Sugar beet - Diex						
Control	33.9	100.0	14.8	100.0	5.02	100.0
Biodynamic fertilization	41.9	123.3	14.2	95.9	5.94	118.3
Biological fertilization	44.4	130.8	14.0	94.6	6.22	123.9
Fodder beet Sasha						
Control	45.3	100.0	15.8	100.0	7.15	100.0
Biodynamic fertilization	47.9	105.7	15.7	99.4	7.52	105.3
Biological fertilization	49.9	110.2	15.2	96.2	7.59	106.1
Table beet Radost						
Control	21.1	100.0	12.3	100.0	2.60	100.0
Biodynamic fertilization	25.4	120.4	12.4	100.8	3.15	121.1
Biological fertilization	26.8	127.0	12.3	100.0	3.30	126.8
GD 1%	3.56	6.72	1.72	3.52	1.89	5.08
P %	3.52		4.08		3.84	

The effect of treatment with biodynamic and biological preparations in these extreme conditions is also decreasing compared to that in 2019 (Table 3). The trend of stronger impact of treatment on the productivity of sugar and table beets compared to fodder beet productivity is repeated. The effect of biological preparations is stronger, as the influence of biodynamic stimulants on the humus content is suppressed in conditions of severe water deficiency. The significant increase of the dry matter content is normal, making it impressive to keep the lower dry matter levels in the table beet. As a result, the increase in dry matter yield when treated with biostimulants is statistically proven only for sugar beet.

Table 3. Effect of the treatment with organic preparations on the productivity and dry matter content of varieties of sugar beet - Diex, fodder beet - Sasha and table beet - Radost, 2020

Variants	Root yield		Dry matter content		Dry matter yield	
	t/ha	Rel. to control %	%	Rel. to control %	t/ha	Rel. to control %
Sugar beet - Diex						
Control	12.4	100.0	20.0	100.0	2.48	100.0
Biodynamic fertilization	13.2	106.5	21.0	105.0	2.77	111.8
Biological fertilization	13.8	111.3	21.5	107.5	2.97	119.6
Fodder beet - Sasha						
Control	19.6	100.0	20.5	100.0	4.02	100.0
Biodynamic fertilization	20.2	103.1	20.5	100.0	4.14	103.0
Biological fertilization	20.4	104.1	21.0	102.4	4.28	106.6
Table beet - Radost						
Control	12.5	100.0	13.8	100.0	1.73	100.0
Biodynamic fertilization	13.7	109.6	13.0	94.2	1.78	102.9
Biological fertilization	14.6	116.8	12.5	90.6	1.83	105.5
GD 1%	4.81	5.21	3.20	4.41	1.58	5.52
P %	5.72		5.43		4.78	

CONCLUSIONS

The results of the test in conditions of organic farming without use of pesticides and mineral fertilizers show a significant variation in yields depending on the agro-climatic conditions.

The extreme deviations from the norm sharply reduce the yield and the effect of treatment with organic preparations. Ensuring optimal water balance is crucial for efficient ecological beet production.

For the application of organic production, tests of a larger range of preparations are needed, as well as selection of more adapted varieties. The sugar beet has a greater potential for organic production than fodder and table beet. The effect of biological preparations is stronger, as the influence of the biodynamic stimulants on the humus content is suppressed in severe water deficiency conditions.

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INFLUENCE OF NUTRITION BACKGROUND ON THE PRODUCTIVITY OF *Carthamus tinctorius* IN THE CONDITIONS OF SOUTHERN STEPPE OF UKRAINE

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Abstract

The article presents the results of studies conducted in 2017-2019 years on the southern chernozem in the southern Steppe of Ukraine, the studies found that the optimization of nutrition increased the field germination of safflower seeds compared to the control by 1.3-6.2%, due to the maximum indicators for the background of application of $N_{60}P_{60}$ and $N_{60}P_{60}$ + "Organic D-2M" (90.2-91.4%). For optimizing the nutrition much more intense it was the growth of vegetative mass, leaf area, larger formed mass of 1000 seeds, while the seed increases the accumulation of protein and fat. It was found that for cultivation of crops without optimized nutrition, it formed yields in the range of 1.0-1.1 t / ha. With the application of mineral fertilizers in half and full doses, the yield increase was 0.23-0.55 t / ha. Additional treatment of seeds and planting with organic fertilizer "Organic D-2M" on these fertilizer backgrounds provides yields at the levels of 1.55-1.63 t / ha. The maximum yield (1.63 t/ha) was formed due to seed treatment and foliar fertilization with "Organic D-2M" organic fertilizer on the background of application before sowing $N_{60}P_{60}$, its level was slightly lower when using only $N_{60}P_{60}$ – 1.53 t/ha. The conducted studies showed the economic feasibility of using seed treatment and sowing of safflower plants with "Organic D-2M" – organic fertilizer in the rosette phase on the background of applying full $N_{60}P_{60}$ mineral fertilizer.

Key words*: safflower, nutrition background, yield, seed quality, profitability.*

INTRODUCTION

The growing consumption of vegetable fats, the increase in world prices for oilseeds has led to an increase in the area of sunflower cultivation in Ukraine – 6.1 million hectares, which significantly exceeds the scientific standards and causes a decrease in the content of humus, macro-and microelements in soils, and a deterioration of the environmental situation (Melnyk et al., 2017; Zavorotniy and Bilyk, 2017; Kuzmenko et al., 2016).

There is a need to search for new drought-resistant and less demanding crops as a biological mechanism for diversifying production. One of these plants is safflower, which is an oil and dye crop being resistant to extreme conditions and has been widely used in global production in recent years (Ozturk et al., 2008; Faten et al., 2019; Ali et al., 2019; Wood et al., 2018; Oguz et al., 2019, Wei B. et al., 2019). This crop has a great potential: it can be grown in various natural and climatic zones of Ukraine, it is resistant to drought, shedding and lodging of crops, it has phytosanitary properties, it is a good precursor for winter and spring crops, it can provide high profitability of production due to unpretentiousness in cultivation and significant demand for grown products on the world market (Shevchenko et al., 2017; La Bella et al., 2019).

Today, safflower is grown in 60 countries, but the main global producers of raw materials are Mexico, India, Argentina, Kazakhstan and the United States (FAO, 2018). In Ukraine, the area of its crops is still not significant - about 5 thousand hectares in the Kherson region. There are prospects for increasing the acreage to 1 million hectares in Ukraine, since safflower grows even on saline and saline soils in the conditions of steppes and semi-deserts, whose areas grow annually (Shevchenko et al., 2017).

Under favorable growing conditions, the crop forms up to 2.0 t/ha of seeds or more due to the content of up to 40% of oil, which is not inferior to sunflower oil in terms of fatty acid composition (Salvatore et al., 2019). Taking into account the trends of changes in the modern climate with frequent extreme weather anomalies and a gradual increase in average annual temperatures, which negatively affect the yield of most field crops, such qualities of safflower as having drought resistance and unpretentiousness to growing conditions favorably distinguish it from traditional for the zone and well-known for producers of oilseeds (Leus, 2016; He et al., 2018; Sajjad Ali et al., 2017).

The analysis of literary sources has determined that in recent years, mainly, the issues of agricultural techniques for growing safflower on gray forest, chestnut soils of the Kherson region and in the Crimea are covered (Fedorchuk and Filipov, 2013; Vozhehova et al., 2018; Vozhehova et al., 2019; Homina et al., 2017).

The problem of determining the biological productivity of safflower for growing on southern Chernozem depending on the optimization of nutrition conditions remains unexplored.

It is known that one of the most important elements of increasing the yield of agricultural crops, including oilseeds, is the use of fertilizers. Researchers determined that safflower reacted positively primarily to phosphoric and potash fertilizers. Safflower uses 30-35 kg of nitrogen, 20-25 kg of phosphorus, and 35-45 kg of potassium to form 1 ton of seeds and an appropriate amount of vegetative mass. A greater amount of nitrogen and phosphorus is used by the plant in the beginning of stemming, and less potassium is used by the plant during this period. From stemming to flowering, the need to use nitrogen almost does not change, phosphorus decreases, and potassium increases. On southern chernozems, it is recommended to apply mineral fertilizers at a dose of N_{30-45} P_{40-60} K_{15-45} for cold weather, on dark chestnut soils it is recommended N_{45-60} P_{30-45}, and on irrigated lands it is recommended N_{60-90} P_{60-90} (Mohammad et al., 2017; Vozhehova et al., 2019).

At the same time, it was determined that intensive use of mineral fertilizers can cause a number of negative environmental consequences associated with the accumulation of fluorine, heavy metals, radioactive elements and other toxicants in the soil, which leads to eutrophication of the latter, deterioration of the habitat conditions of the ichthyofauna, deterioration of water quality indicators, etc. (Chandini et al., 2019; Savci, 2012; Atikur and Zhang, 2018, Nosheen, 2018).

Foliar nutrition is an integral part of modern crop production technology and the key to obtaining a high yield of good quality (Abo-Sedera et al., 2016; Hamaiunova et al., 2019). The use of organic-mineral fertilizer "Organic D-2M", made on the basis of organic acids, allows you to ensure optimal nutrition of crops, reduce the harmful effects of high doses of NPK, pesticides, pesticides and radionuclides, increase crop yields, including and many oilseeds, indicators of their quality, improve soil fertility and ensure environmental safety (Panfilova & Mohylnytska, 2019; Panfilova & Hamayunova, 2018; Dvoretsky & Glushko, 2016; Gamayunova, 2019).

Therefore, the purpose of the research was to determine the effect of the nutrition background on the level of yield and quality of seeds of safflower for growing on the southern Chernozem in the southern Steppe zone of Ukraine.

MATERIALS AND METHODS

The research was carried out during 2017-2019 yrs in LLC "Zolotoy Kolos" of the Vitovsky district of the Mykolaiv region using generally accepted methods. The object of research was the process of forming the productivity of safflower on the basis of patterns of growth and development of plants in the southern Steppe of Ukraine. Subject of the research was plants of safflower varieties Lagidny, which is entered in the Register of plant varieties of Ukraine since 2011yr, mineral fertilizers (ammonium nitrate, double superphosphate) and organic-mineral fertilizer "Organic D-2M" (presowing treatment of seeds in the rate of 1 l/t and fertilizing of plants in the rosette phase in norm 1 l/ha using a working solution of 200 l/ha sowing Area of the plot is 108 m^2, accounting - 35,0 m^2. The experience was repeated three times.

"Organic D-2M" is organo-mineral fertilizer containing N as 2.0-3.0%, P_2O_5 as 1.7-2.8%, K_2O as 1.3-2.0%, total calcium as 2.0-6.0%, organic matter as 65-70% (in terms of carbon). The variants were placed in the experiment by the method of split plots, the repetition of the experiment was fourfold. Soil of research areas was southern black soil humus, light clay-loam soil on wide slightly drained loess on the watershed plateau, typical for the area of Southern Steppe. The reaction of the soil solution was neutral (pH 6.8-7.2). Their arable layer contains an average of 2.4% humus, light-hydrolyzed nitrogen as 16 mg/kg, mobile phosphorus as 160 mg/kg and exchanged potassium as 187 mg/kg of soil.

The experiment scheme included the following variants:

1. Control (without fertilizers);
2. Treatment of seeds and seeding plants with "Organic D-2M"
3. $N_{30}P_{30}$;
4. $N_{30}P_{30}$ + "Organic D-2M";
5. $N_{60}P_{60}$;
6. N_{60} P_{60}+ "Organic D-2M".

RESULTS AND DISCUSSIONS

During the years of research, weather conditions differed both in temperature and in the amount of precipitation during the growing season of plants. Sowing was carried out in the second decade of April, seedlings appeared after 12-15 days, depending on weather conditions and nutrition background. Higher indicators of field germination of safflower seeds were determined on fertilized sites and for processing seeds before sowing with organic-mineral fertilizer "Organic D-2M". The density of standing plants was close to the normal seeding rate (Table 1).

Table 1. The influence of nutrition background on the seed germination of safflower, %

№ п/п	Variant	Years of research			average for 2 yrs
		2017	2018	2019	
1.	Control*	87.2	83.1	85.3	85.2
2.	treatment of seeds and seeding plants with "Organic D-2M"	88.4	85.5	87.0	87.0
3.	N_{30} P_{30}	89.7	86.7	87.9	88.1
4.	N_{30} P_{30}+ "Organic D-2M"	90.8	87.1	88.7	88.9
5.	N_{60} P_{60}	90.9	89.5	90.1	90.2
6.	N_{60} P_{60}+ "Organic D-2M"	92.3	90.4	91.3	91.3
The least significant difference (LSD) at $p<0.05$		2.1	1.9	1.8	

*Control (without fertilizers, treatment of seeds and seeding plants with water)

On average, for three years of research, field germination in the control of seed treatment with water was 85.2%, and organic-mineral fertilizer "Organic D-2M" against the background of $N_{60}P_{60}$, it increased to 91.3%, which exceeded the control by 6.1%. Plants of these variants also had the highest survival rates. The plants of the fertilized areas used their genetic potential to a greater extent and were characterized by a more developed habit and a longer vegetation period. Also, safflower plants formed a much larger number of baskets compared to the crops of the control variant, in which the interphase periods of vegetation were shorter.

During the years of research at the seedling stage, a significant acceleration of root growth and a slow increase in the leaf mass of safflower were noted, which provided better plant survival during dry periods of vegetation. Before the appearance of 10-12 true leaves, low growth rates were observed, after which the formation and lengthening of the stem and branching of plants occurred more intensively.

Due to branching (from 3 to 18 branches, depending on the variant), the plants formed a shrub with a diameter of 20-45 cm, a height of 85-95 cm in less moisture-rich year 2018, in a more favorable year 2017, respectively, 27-53 and 100-110 cm. In 2017, the later stages of budding phases (I decade of June), flowering (III decade of June), and fruiting were observed (Figure 1).

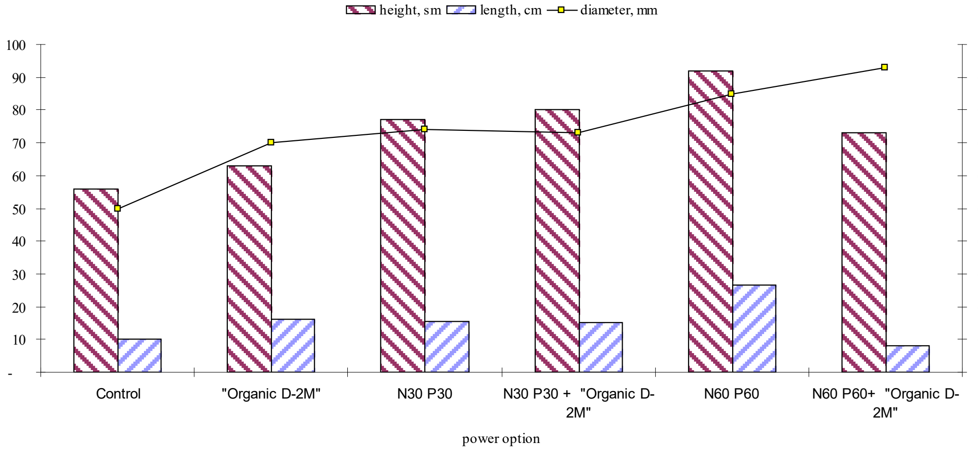

Figure 1. Biometric indicators of the leaf depending on the nutrition background at the beginning of budding (average for 2017-2019), mm

Studies determined that the nutrition background significantly affected the size of the leaves of safflower. Thus, the length of the leaves of this crop when grown on $N_{60}P_{60}$ and $N_{60}P_{60}$+"Organic D-2M" backgrounds increased by 4.1% and 6.8%, respectively, compared to the control

The maximum values of the assimilation area of plants reached in the flowering phase with the joint application if $N_{60}P_{60}$+"Organic D-2M" and amounted to 18.9 thousand m^2/ha, which is more than control by 6.1 thousand m^2/ha (Table 2).

Table 2. The dynamics of growth of leaf area of plants of safflower dye depending on the background of nutrition (average for 2017-2019), thousand m^2/ha

Variant	Phases of growth and development		
	Rosette	budding	flowering
Control*	0.07	7.7	12.8
treatment of seeds and seeding plants with "Organic D-2M"	0.09	9.6	14.6
N_{30} P_{30}	0.11	11.0	16.9
N_{30} P_{30}+ "Organic D-2M"	0.12	11.9	17.3
N_{60} P_{60}	0.13	12.9	17.9
N_{60} P_{60}+ "Organic D-2M"	0.15	14.8	18.9
The least significant difference (LSD) at $p<0.05$	0.03-0.04	0.80-1.40	0.90-1.30

*Control (without fertilizers, treatment of seeds and seeding plants with water)

The area of the leaf surface in the socket phase, depending on the nutrition supply background, was the largest for the use of $N_{60}P_{60}$ and $N_{60}P_{60}$+"Organic D-2M" (0.13 and 0.15 thousand m_2/ha, respectively), which is 0.06 and 0.08 thousand m_2/ha more than the asymmetric surface of plants in the control variant.

During the budding phase, the area of the leaf surface of fertilized plants was determined in the range of 12.9-14.8 thousand m_2 / ha, which exceeded the control by 30.6-31.2%.

We determined the experimental and direct trend lines and the value of the accuracy of the approximation relative to the influence of the nutrition background on the formation of the leaf surface area of plants of safflower. As in the rosette phase, as well as budding and flowering, there was a close relationship between these components: R2 = 0.923; 0.984 and 0.982.

Optimization of nutrition had a positive effect on the number of formed leaves and inflorescences on the plant (Figure 2).

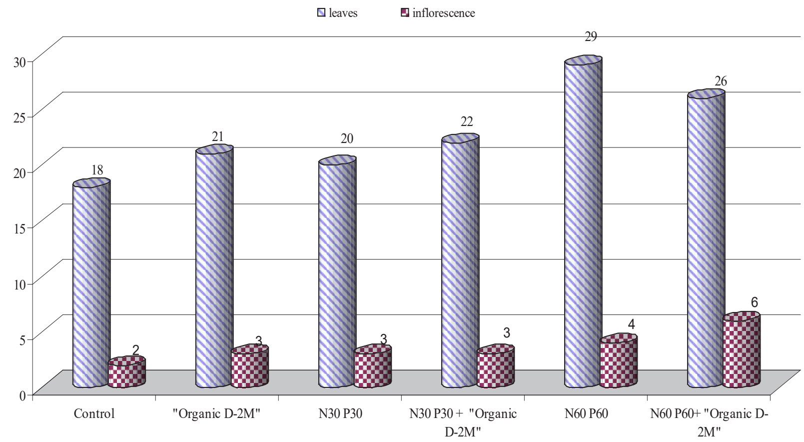

Figure 2. Influence of the nutrition background on the number of leaves and inflorescences on one plant of safflower (average for 2017-2019), PCs.

With a similar dependence, under the influence of the studied factors, there was an increase in the biomass of plants of safflower.

As determined in the course of biometric measurements, the increase in biomass depended on the weather conditions of the year that developed during the growing season of the crop, but it changed significantly under the influence of the nutrition background.

In addition, this dependence was observed not only in the intensity of growth of aboveground plant biomass, but also in the mass of roots (Figure 3).

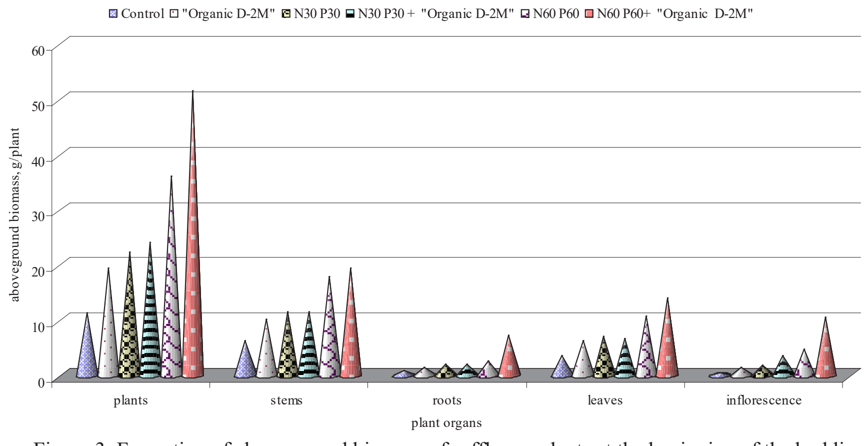

Figure 3. Formation of aboveground biomass of safflower plants at the beginning of the budding phase, depending on the nutrition background (average for 2017-2019), g/plant

The accumulation of dry matter occurred according to the growth of green biomass, the largest amount of it was formed during the flowering-fruiting period and fluctuated within 1.1-2.0 t/ha depending on the variant. On average, over the years of research, it was found that the crops of plants of the control variant, compared with the introduction of mineral fertilizer in a dose of $N_{60}P_{60}$, both separately and together with a biological product ($N_{60}P_{60}$+ "Organic D-2M"), dry biomass accumulated by 0.52 t/ha and 0.65 t/ha, respectively.

Structural analysis of safflower plants was determined by the following indicators: plant height, number of baskets, number of seeds in a basket, weight of seeds per plant (Table 3).

Table 3. Influence of nutrition optimization on indicators of the structure of the safflower crop (average for 2017-2019)

Factor A (variants of nutrition)	Height of plants, cm	Mass of one plant, g	Nuvber of baskets per plant, pcs.	Number of seeds in a basket, pcs.	Mass of seeds from one plant, g
Control *	83.0	46.65	7.0	12.0	3,1
treatment of seeds and seeding plants with "Organic D-2M"	89.0	62.32	10.0	16.0	6,1
N_{30} P_{30}	97.0	72.37	13.0	17.0	8,5
N_{30} P_{30}+ "Organic D-2M"	100.0	77.24	13.0	18.0	9,1
N_{60} P_{60}	111.0	81.91	13.0	23.0	11,7
N_{60} P_{60}+ "Organic D-2M"	114.0	111.74	14.0	25.0	14,0
The least significant difference (LSD) at $p<0.05$	3.0-8.0	2.7-5.3	1.0-2.0	3.0-4.0	1,3-1,7

*Control (without fertilizers, treatment of seeds and seeding plants with water)

The optimal combination of mineral fertilizers and plant growth regulators is an important factor in improving the yield and quality of safflower seeds (Yerenenko O. et al., 2018).

On average, for 2017-2019, the largest values of such structure indicators as the number of baskets per plant, the size of baskets, the weight of 1000 seeds, the weight of seeds in a basket and the weight of seeds from 1 plant were determined when $N_{60}P_{60}$ was used together with the «Organic D-2M» organo-mineral fertilizer. These indicators of the structure of the safflower crop affected the level of crop yield (Table 4).

Table 4. Influence of weather conditions and nutrition background on the yield of safflower seeds in the years of cultivation, t/ha

Factor A (variants of nutrition)	Years of research			Average for 3 yrs
	2017	2018	2019	
Control *	1.20	0.84	0.93	0.99
treatment of seeds and seeding plants with "Organic D-2M"	1.25	0.97	1.08	1.10
N_{30} P_{30}	1.54	1.14	1.26	1.31
N_{30} P_{30}+ "Organic D-2M"	1.69	1.25	1.37	1.44
N_{60} P_{60}	1.73	1.37	1.50	1.53
N_{60} P_{60}+ "Organic D-2M"	1.79	1.47	1.63	1.63
The least significant difference (LSD) at $p<0.05$	0.12	0.11	0.12	

*Control (without fertilizers, treatment of seeds and seeding plants with water)

On average, over three years of research, the yield of safflower seeds was formed as follows: low yield as 0.99 t/ha. it was determined in the control without fertilizers when processing seeds and sowing only with water.

The use of organic-mineral fertilizer "Organic D-2M" for processing and fertilizing without adding mineral fertilizers provided a yield of 1.10 t/ha, which was by 11.1% more than the control. Significantly higher yields were obtained when applying mineral fertilizers to safflower for sowing in half and full recommended doses for this crop, namely on the background of $N_{30}P_{30}$ as 1.31 t/ha, and $N_{60}P_{60}$ as 1.53 t/ha of seeds. The yield increased even more if the pre-sowing treatment of seeds and foliar nutrition with organic-mineral fertilizer "Organic D-2 M" in the rosette phase was carried out on the specified fertilizer backgrounds. On average, over three years, these variants collected 1.44 and 1.63 t/ha, respectively, which indicates an increase in crop yield from the preparation "Organic D-2M" at the level of 0.13 t/ha and 0.10 t/ha compared to the studied variants with doses of mineral fertilizers and within 0.45–0.64 t/ha relative to the control.

Thus, when using mineral fertilizers and Organic D-2M together, the seed yield was significantly higher, and the total dose of $N_{60}P_{60}$ was the maximum, where the average for 2017-2019 it was 1.63 t/ha of seeds, which was by 64.6% higher than the control.

It should be noted that the studied factors significantly affected the main indicators of the quality of safflower seeds. So, plants of fertilized variants, on average, formed something weighty grain over the years of research, the weight of 1000 seeds in them prevailed by 1.0-2.9 g. The highest value of this indicator was determined by the combined use of the full dose of mineral and organic-mineral fertilizer "Organic D-2M", where the weight of 1000 seeds on average over the years of research was 40.1 g (Table 5).

Table 5. Influence of nutrition background on the main indicators of quality of safflower seeds (average for 2017-2019)

Factor A (variants nutrition)	Mass of 1000 seeds, g	Content of protein, %	Content of fat, %
Control *	37.2	19.1	38.1
treatment of seeds and seeding plants with "Organic D-2M"	38.2	20.2	38.5
N_{30} P_{30}	38.6	20.4	39.6
N_{30} P_{30}+ "Organic D-2M"	39.1	20.5	40.2
N_{60} P_{60}	39.0	20.6	39.4
N_{60} P_{60}+ "Organic D-2M"	40.1	20.6	39.9
The least significant difference (LSD) at p<0.05	1.3-1.8	0.2-0.3	0.3-0.6

*Control (without fertilizers, treatment of seeds and seeding plants with water)

We determined that the protein content in the seeds of safflower was dependent on the weather conditions of the growing year and the nutrition background. More protein 20.2-20.6% was contained in the seeds of the fertilized variants, while in the control-19.1 %, it was by 5.5-7.3% less percentage points.

More fat in safflower seeds as 38.5 up to 40.2% also accumulated in order to optimize nutrition and exceeded the control by 0.4-2.1%. We defined a conditional collection (yield) of oil that could be removed from safflower seeds collected from a unit area. On average, over the years of studies with wind control, this indicator was 0.38 t/ha, when processing seeds and sowing plants with organic-mineral fertilizer "Organic D-2M" it was 0.42 t/ha; when growing crops on the background of $N_{30}P_{30}$ application it was 0.52 t/ha; on the background of $N_{60}P_{60}$ it was 0.60 t/ha, and the joint application of these backgrounds of fertilizer also processing seeds and sowing plants of safflower preparation "Organic D-2M", respectively, 0.58 t/ha and 0.65 t/ha of oil, which exceeded the control by 52.6% and 71.1%, or the conditional yield of oil for the combination of mineral fertilizers with organo-mineral fertilizer "Organic D-2M" significantly increased. The positive effect of the combined use of mineral fertilizers with growth-regulators on the main indicators of the quality of oilseeds is important in their cultivation, as the seeds are usually used for the production of oil. Moreover, it is desirable that it is of high quality.

CONCLUSIONS

Thus, the conducted researches found that the optimization of nutrition increases the field germination of the seeds of safflower dye compared with the control by 1.3-6.2%, with the maximum indicators against the background of application of $N_{60}P_{60}$ and $N_{60}P_{60}$ + "Organic D-2M" (90.2-91.4%). With the optimization of nutrition, the vegetative mass of plants, the area of the leaf surface is much more intense, the mass of 1000 seeds is formed, while the accumulation of protein and fat increases in the seeds. The maximum yield (1.63 t/ha) was formed by seed treatment and foliar feeding of "Organic D-2M" organic-mineral fertilizer on the background of $N_{60}P_{60}$ sowing, slightly lower than its level when using only $N_{60}P_{60}$ - 1.53 t/ha. The conducted studies have proved the economic feasibility of using the treatment of seeds and plants of safflower dyestuff organo-mineral fertilizer "Organic D-2M" in the phase of the socket against the background of the introduction of complete mineral fertilizer $N_{60}P_{60}$.

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VISUALISATION OF PLANT PROTECTION PRODUCTS PROPERTIES VIA TABLEAU DESKTOP SOFTWARE

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Abstract

The paper present visualization techniques of properties of plant protection products via Tableau Data Visualization software for the purposes of safe and effective selection of pesticides towards different abiotic, biotic and antropogenic conditions. Although one plant protection product has many and different properties which determine its application, via Tableau was able all of these properties to be presented (showed) in the only one visualization, which make the process of selection of the right plant protection product extremely fast, easy and effective. Tableau Desktop is interactive data visualization software which is based on spreadsheets and relational databases. During the recent years this software founded in 2003 from Christian Chabot, Pat Hanrahan and Chris Stolte, researchers at the Department of Computer Science at Stanford University, became one of the most popular solution in the world from this type, used widely in all human areas for creation of high level graph-type data visualizations via easy to be used graphical user interface. In 2008 Tableau received award for "Best Business Intelligence Solution" by the Software and Information Industry Association.

***Key words**: data visualization, Tableau Desktop Software, plant protection products, agriculture, pest management.*

INTRODUCTION

During recent years, data science and visualization became extremely popular in all scientific areas (Rettberg, 2020; Burch et al., 2021). The software tools as Tableau Desktop (Tableau Software, 2020), Power BI (Microsoft PowerBI, 2021; Becker & Gould, 2019), R language for Statistical Computing (R Core Team, 2020; Ihaka & Gentleman, 1996) Google Data Studio (Google Data Studio, 2021; Aan, 2022) and other continue to gain more and more popularity after each day, especially in world COVID-19 pandemic where an enormous number of data must be possessed and analyzed (Chen et al., 2020; Iliinsky & Steele, 2011; Bowe et al., 2020). Although the agriculture is not among the sphere where computer modeling and graphics pay significant roles, there is increasing number researches in this aspect (Řezník et al., 2020; Kushwaha et al., 2020; Zhai et al., 2020). Plant protection products are a substantial part of modern day agriculture. However, nevertheless that pesticides are associated with industrial age and present day pest management, there application dates back even from the ancient times when people used various natural, non-organic and organic substances like salts, plant extracts and soaps to defeat pests which threatening cultural crops (Costa, 1987).

Plant protection products for a long time ago are not simple products - actually they are extremely complex having numerous properties which determine their effective and safe application in the field. These products p especially during recent years are under enormous pressure and critics due to their harmful and dangerous effects on humans and the environment. Therefore the application of pesticides requires significant knowledge and strategically approach - there are numerous pesticides/plant protection products on the market with many different properties. The purpose of present day agricultural specialist is to secure as safe as possible application of the pesticides towards humans and environment from one hand and as effective as possible - from the other, taking into consideration extremely variable abiotic, biotic and anthropogenic conditions of the terrain.

That is why, data analysis and visualizations can be critical and extremely essentials for choosing the right pesticides/plant protection products for a given application. The purpose of this paper is to present a study for evaluation of the best possible way for visualization of plant protection properties data in order maximal and comfortable information delivery to the pest management specialist for best safe and effective pesticides selection.

MATERIALS AND METHODS

The properties (data) for the plant protection products were taken from various sources: the websites of the producers, lists of approved for application in the territory of Republic of Bulgaria plant protection products (Bulgarian Food Safety Agency, 2021), Pesticides Properties Database (PPDB, 2007), EU Pesticides Database of approved plant protection products on territory of EU member states (EU Pesticides Database, 2021). The data initially was inserted into MS Excel sheet.

In this study as an example was used strawberry as cultural crop. The plant protection products can be 3 basic types: fungicides - used to defeat fungal pests; insecticides - used to defeat insect pest and herbicides - used against weeds.

The one plant protection product has these major properties which determine its application in practice (Akamatsu, 2011):

Trade name - string variable

Producer - string variable

Active Substance i.e. pesticide - string variable

Percent Active Substance into given plant protection product - decimal number variable

Formulation type of the given plant protection product - string variable

Dose (kg or l per ha) - string variable

BBCH for the initial applications - BBCH for the final applications - the fenophase interval for application of the given plant protection product - whole numbers varaibles

PHI - post harvest interval - whole numbers varaibles

Category of usage - whole numbers varaibles

Mode of action - string variable

Major group - string variable for fungicides; whole number - for insecticides and herbicides

Type major group - string variable (only for for insecticides and herbicides)

Target group - string variable (only for fungicides)

Chemical group - string variable

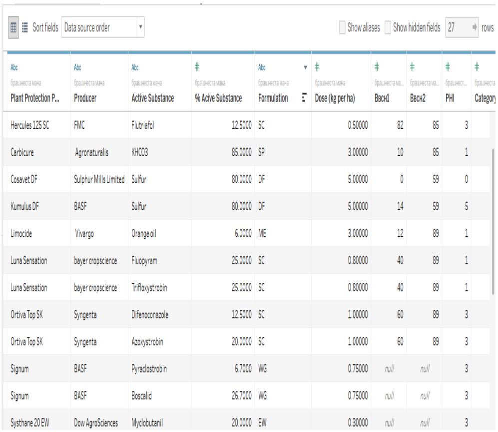
log p (octane - water coefficient) - decimal number variable

Vapor pressure - decimal number variable

GUS (Groundwater Ubiquity Score) - decimal number variable

RESULTS AND DISCUSSIONS

The list above clearly shows the complexity of the one plant protection product - 17 different properties which must be taken into account during the process of choosing the right one. Without specialized software for data analysis and visualization, this is completely impossible. The need of visualization of these properties is more necessary due to the fact that selection of the right plant protection product is often done under pressure of time and need of urgent taken of the measurement. Treatments with pesticides against giving pest/pests and the increasing international and national requirements for safe use of pesticides (Marer, 1988). One of the most popular and usable data visualization tool in the world is Tableau Desktop. The software provide very intuitive and user friendly interface, similar to Ms Excel Pivot Tables but with much more improvements and capabilities (Hamersky, 2016; Murphy, 2013) In the graphic below (Figure 1) is presented the initial data import from Excel to Tableau - in the given case - fungicides used against powdery mildew on strawberries


Sort fields Data source order · Show aliases · Show hidden fields 27 rows

Plant Protection P...	Producer	Active Substance	% Acive Substance	Formulation	Dose (kg per ha)	Bbch1	Bbch2	PHI	Category
Hercules 125 SC	FMC	Flutriafol	12.5000	SC	0.50000	82	85	3	
Carbicure	Agronaturalis	KHCO3	85.0000	SP	3.00000	10	85	1	
Cosavet DF	Sulphur Mills Limited	Sulfur	80.0000	DF	5.00000	0	59	0	
Kumulus DF	BASF	Sulfur	80.0000	DF	5.00000	14	59	5	
Limocide	Vivargo	Orange oil	6.0000	ME	3.00000	12	89	1	
Luna Sensation	bayer cropscience	Fluopyram	25.0000	SC	0.80000	40	89	1	
Luna Sensation	bayer cropscience	Trifloxystrobin	25.0000	SC	0.80000	40	89	1	
Ortiva Top SK	Syngenta	Difenoconazole	12.5000	SC	1.00000	60	89	3	
Ortiva Top SK	Syngenta	Azoxystrobin	20.0000	SC	1.00000	60	89	3	
Signum	BASF	Pyraclostrobin	6.7000	WG	0.75000	null	null	3	
Signum	BASF	Boscalid	26.7000	WG	0.75000	null	null	3	
Systhane 20 EW	Dow AgroSciences	Myclobutanil	20.0000	EW	0.30000	null	null	3	

Figure 1. Importing the plant protection products properties data in Tableau Desktop from MS Excel Sheet

The conducted different variations of presenting (visualizing) of the data reveal that the most appropriate and effective way is this presented on graphic below (Figure 2)

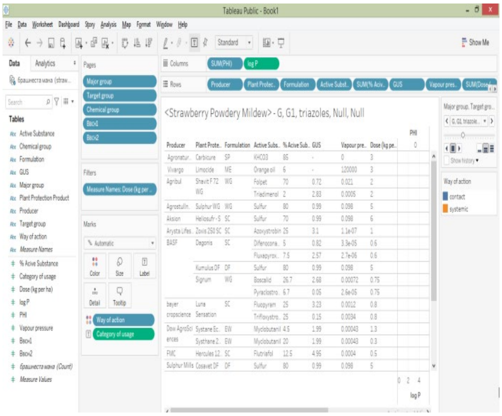


Figure 2. Designing the plant protection properties visualization in Tableau Desktop

In this way, all of listed properties of the plant protection products used against giving pest can be seen in one visualization. On the row as string variables are: producer, plant protection product name, formulation, active substance. The variables: Percent Active Substance, GUS, Vapour Pressure and Dose are also put on the row of visualization, but their properties were changed to "Dimension" and "Discrete". The columns present properties of PHI (post-harvest interval) and log p (octane-water coefficient). PHI has the same properties "Dimension" and "Discrete" like Percent Active Substance, GUS, Vapour Pressure and Dose in the rows, but log p –" Dimension" and "Continuous"

In the section of "Marks" are listed properties of "Way of action" and "Category of usage". There are two ways of action of one pesticide (plant protection product): systemic and contact and the best possible way is this property to be presented as colour visualization. Category of usage is a whole number – there are 3 types: first (1), second (2) and third (3) category of usage of the plant protection products. This property is also placed in the "Marks" but as text. In the "Pages" section is placed properties concerning the mode of action of the active substances of the plant protection products (Major group, Target group and Chemical group) and BBCH interval (the time period between the BBCH stages for the initial and the final plant protection products applications).

In the graphics below (Figure 3 and Figure 4) is presented how the visualization looks like

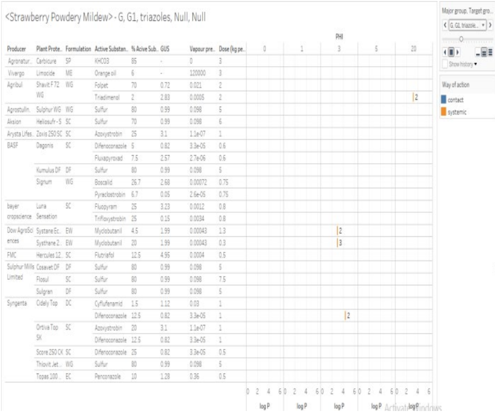


Figure 3. Final look of the plant protection properties visualization in Tableau Desktop towards fungicides used to defeat powdery mildew on strawberries

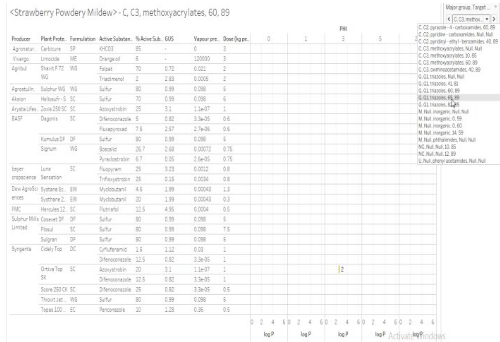


Figure 4. Final look of the plant protection properties visualization in Tableau Desktop towards fungicides used to defeat powdery mildew on strawberries

In the graphics below (Figure 5 and Figure 6) is presented visualization towards pesticides for defeat aphids infected strawberries:

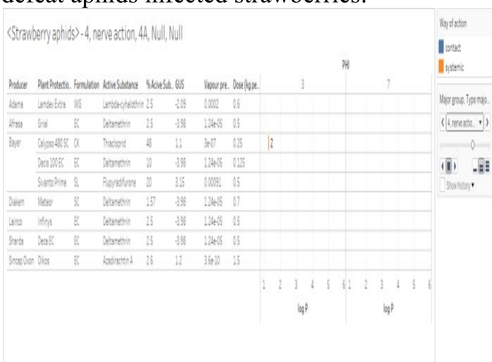


Figure 5. Final look of the plant protection properties visualization in Tableau Desktop towards insecticides used to defeat aphids on strawberries

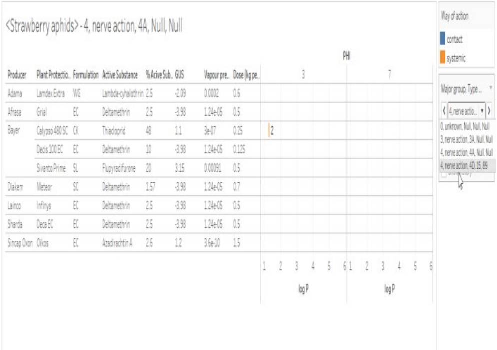


Figure 6. Final look of the plant protection properties visualization in Tableau Desktop towards insecticides used to defeat aphids on strawberries - second part

The only one difference is that in the "Pages" Section, instead Target group, there is Major group type.

CONCLUSIONS

The presented way of data visualization shows that such approach can be extremely useful and applicable in the area of agriculture, in particular – pest management. Tableau Desktop software has user friendly interface which make process of creation and use of visualization fast and easy to be done with minimal education endeavours. Although one plant protection product has many and different properties which determine its application via Tableau was able all of these properties to be presented (showed) in the only one visualization, which make the process of selection of the right plant protection product extremely fast, easy and effective.

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NEW DATA CONCERNING THE EVOLUTION OF THE EUROPEAN SUNFLOWER MOTH (*Homoeosoma nebulellum* Den. & Schiff.) IN SUNFLOWER CROPS IN THE SOUTH-EAST OF ROMANIA

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Abstract

The European sunflower moth [Homoeosoma nebulellum (Den. & Schiff.)] is a pest that can sometimes significantly damage sunflower crops in the south and southeast of Romania. Many studies reveal that the pest attack on cultivated crops, including sunflower, can be higher because of global warming. Also, global warming can have consequences in increasing the pest generation's number in one year or the area in northern latitudes. This study has monitored the fly of the European sunflower moth in sunflower crops from NARDI Fundulea, Călărași County, southeast of Romania, between 2019 and 2021. It has used Delta traps with atraNeb pheromones, produced at "Raluca Ripan" Institute for Research in Chemistry, Cluj-Napoca, Romania. The evolution of the European sunflower moth in sunflower crops at NARDI Fundulea differed in this three-year study. The monitoring of this pest in sunflower crops reveals that first captures were recorded at the beginning of May in 2019 and 2021 and the end of April in 2020. In climatic conditions of the year 2019, at NARDI Fundulea, it has recorded three fly peeks of this pest on 28 May, 26 July, and 19 Augusr. In 2020 the maximum fly peek was registered on 9 June, and a secondary lower peek on 2 September. Similar to 2019, in 2021, it registered three fly peeks on 11 June, 19 August, and 13 September. Higher captures recorded at NARDI Fundulea in September 2019 and 2021 weren't reported in Romanian literature before and are possible consequences of global warming, but further studies are necessary to elucidate these aspects.

Key words: *sunflower, moth, fly peek, monitoring.*

INTRODUCTION

Sunflower is one of the most important crops for Romanian agriculture. In the last seven years, the area cultivated with this crop was higher than 1 million hectares (except in 2017), while average production ranged from 1765 to 3041 kg/ha (Romanian Statistical Yearbook, 2021; MADR, 2022). According to the Eurostat database, Romania occupies first place in EU27 with the highest area cultivated with sunflower (Eurostat, 2022). However, according to the same agricultural statistics, only in some years did Romania have the highest sunflower production in Union Europe. The main reason for lower sunflower yield in Romania, compared with other countries in the EU, is draught, broomrape, weeds, diseases or pests (Bărbulescu et al., 2001a,b; Petcu et al., 2001; Popov, 2002; Ciucă et al., 2004; Popov et al., 2007; Saucă et al., 2010, 2018; Petcu et Păcureanu, 2011; Anton et al., 2015; Rîșnoveanu et al., 2016; Csép, 2018; Hussain et al., 2018; Trotuș et al., 2019; Škorić et al., 2021). In Romania, sunflower crop, in first vegetation stages (from plants emergence BBCH 10 until four leaves stage, BBCH 14) is attacked from several pests, that can produce high yield losses such as maize leaf weevil (*Tanymecus dilaticollis*), darkling beetle (*Opatrum sabulosum*) wireworms (*Agriotes* spp.) or turnip moth (*Agrotis segetum*) (Popov et Bărbulescu, 2007; Georgescu et al., 2018; Trașcă et al., 2019; Trașcă et al., 2021). However, before and after the flowering stage, sunflower can be attacked by several pests, such as black bean aphid (*Aphis fabae*), leaf-curling plum aphid (*Brachycaudus helichrysi*), European corn borer (*Ostrinia nubilalis*), corn earworm (*Helicoverpa armigera*) and birds (Čamprag et al., 1981; Linz et Hanzel, 1997; Van Denberg et al., 1997; Reddy et al., 2004; Trotuș et Buburuz, 2015; Truzi et al., 2017; Demenko et al., 2019; Sausse, 2021). In Romania and neighboring countries, European sunflower moth [*Homoeosoma nebulellum* (Den. & Schiff.)] is a common pest of sunflower (*Helianthus annuus*) and creeping thistle (*Cirsium arvense*) (Boguleanu et al., 1980; Lemetayer et al., 1993; Szaruká et al., 1996; Perju, 1999; Roșca et Istrate, 2009). The same authors mentioned that this pest presents two generations per year (G1 May-June; G2 Jully-April). The first generation develops on wild hosts from the Asteraceae family, such as creeping thistle (*Cirsium arvense*), while the second generation develops on sunflower crop. Recent studies reveal that, in the North-East of Hungary, the European sunflower moth presents three generations per year (Szabó et al., 2009). A possible explication for this is the increase in the temperatures resulting from global warming (Olesen et al., 2011; Bebber et al., 2014; Choudhary et al., 2019). European sunflower moth larva developed in sunflower caladium, consuming inflorescences and seeds (Perju, 1999; Szabó et al., 2007; Roșca et Istrate, 2009). In Azerbaijan, average sunflower yield losses from this pest attack arrive at 460 kg/ha (Ismayilzade et al., 2015). According to Szabó et al. (2009), in the Nyírség region (north-east of Hungary), a traditional sunflower variety (Kisvárdai) is attacked by European sunflower moth larva because the shells don't contain a phytomelan layer. In Romania, the larva produced more severe damage in the third stage in old sunflower varieties (Roșca and Istrate, 2009). In the last decades, the National Agricultural Research and Development Institute (NARDI) Fundulea has created sunflower hybrids with shells with a phytomelan layer (Vrânceanu et Stoenescu, 1978, 1988; Păcureanu et al., 2007; Csép, 2018). As a result, European sunflower moth larva can't drill the seeds, and the damages are lower. However, in the last decade, the Ecological Agriculture system has used older sunflower varieties with shells not resistant to larva attacks (Brumă, 2021). Also, in our country, it wasn't recent research concerning European sunflower moth biology in the conditions of the climate changes. This study aims to monitor seasonal fly patterns of this pest in the sunflower crop, using pheromone traps in the climatic conditions in southeast Romania.

MATERIALS AND METHODS

The flight of the European sunflower moth was monitored at the experimental field of the Plant Protection Collective from Agrotechnics Laboratory, National Agricultural Research and Development Institute Fundulea, Călărași County, Romania (latitude: 44°46' N; longitude: 26°32' E; alt.: 68 m a.s.l.), between 2019 and 2021. At this experimental site, soil type is chernozem with medium texture, humus content of 2,8-3,2 %, pH of 6,4-6,8, nitrogen content of 0,17-0,18 %, potassium content of 135-170 ppm and phosphorus content of 10-25 ppm. Also, the multiyear average temperature registered at NARDI Fundulea in the last 60 years is 11,0 °C, while the average rainfall amount registered in the last 60 years is 571 mm. In 2019 and 2020, this study used the Performer sunflower hybrid, while in 2021, it used the FD15E27 hybrid. Both were created at NARDI Fundulea and have the same vegetation period (Păcureanu et al., 2007; 2019).

- In 2019, the sunflower was sowed on 25 April, plants emerged on 4 May, and the harvest was on 2 September.
- In 2020, the sunflower was sowed on 9 April, plants emerged on 21 April, and the harvest was on 16 September.
- In 2021 the sunflower was sowed on 28 April, plants emerged on 7 May, and the harvest was on 24 September.

For monitoring the seasonal fly patterns of the European sunflower moths in the sunflower field, it has placed three Delta traps with atraNeb sexual pheromones, produced at "Raluca Ripan" Institute for Research in Chemistry, Cluj Napoca, Romania (Vasian et al., 2018). The traps were placed at 50 m one from each other, according to a methodology developed by Ghizdavu et Roșca (1984) cited by Roșca et al. (1986). At the same time, the minimum distance between traps and sunflower crop margins was 15-20 m. The traps were placed in the sunflower field from the beginning of April until the first ten days of October (Figure 1). The height of the traps depends on sunflower crop vegetation stages. The pheromones were replaced after 4-6 weeks. At each reading, for moths counting, adhesive plates from Delta traps were photographed with Panasonic TZ200 compact camera with Leica Vario-Elmar lens (1;3.3-6.4/8.8-132 ASPH).

Figure 1. Pheromonal (AtraNeb) Delta trap used for monitoring seasonal fly of the European sunflower moth at NARDI Fundulea (7.05.2020)

The images with captures from Delta traps were downloaded to the computer, then the images were magnified, and the moths were counted (Figure 2). The purpose of using a photo camera is to increase the accuracy of insect identification and counting. Monitoring results are presented as absolute and mean values of the male moth's capture per trap and average moth's capture per month. During this study, the seasonal fly patterns of the European sunflower moth at NARDI Fundulea are presented graphically on Microsoft Excel charts.

Figure 2. Captures of the European sunflower moth, photographed with Panasonic TZ200 photocamera, at NARDI Fundulea (7.05.2020)

Meteorological data were collected from an automatic weather station from NARDI Fundulea experimental field, located 100 m from the experimental site. It monitors daily air temperature and rainfalls from April to October during the monitoring period.

RESULTS AND DISCUSSIONS

At the experimental site, located at NARDI Fundulea, in Călărași County (south-east of Romania), the average year temperature was higher than expected values for this region (Figure 3). The highest deviation of the year temperature from the last 60 years' averages it has registered in 2021 (T = 13.45°C). In all three years of this study (2019-2021), the temperature was higher than usual, with a positive deviation from 1.18 to 2.45°C.

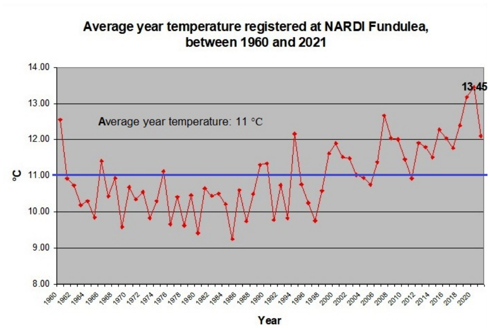

Figure 3. Average year temperature registered at NARDI Fundulea, between 1960 and 2021

Regarding rainfalls amount registered at NARDI Fundulea, data from the meteorological station reveal a high variability from one year to another (Figure 4).

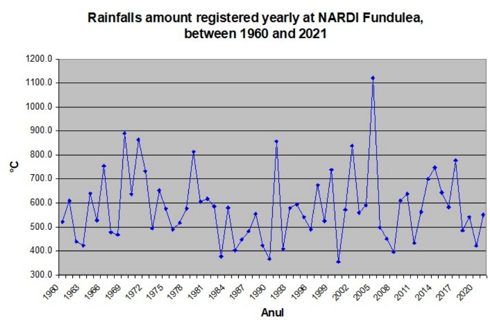

Figure 4. Rainfalls amount registered yearly at NARDI Fundulea, between 1960 and 2021

However, during this study, the rainfall amount registered at the experimental site was lower than 60 years average, with a negative deviation ranging from 19.6 (in 2019) to 149 mm (in 2020).

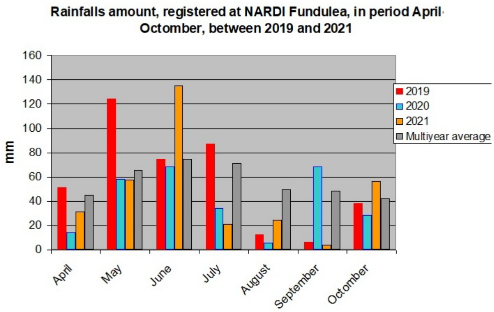

Figure 5. Rainfalls amount registered at NARDI Fundulea in April-Octomber, between 2019 and 2021

During this monitoring, between 2019 and 2021, rainfalls were higher than average in May 2019, with a positive deviation of 59 mm, and in June 2021, with a positive variation of 60.1 mm (Figure 5). In 2020, rainfall registered from April to September was bellowing the average, except for September. It is essential to mention that in September 2020, more than 80 % of the rainfalls amount were registered on only one day (4 September).

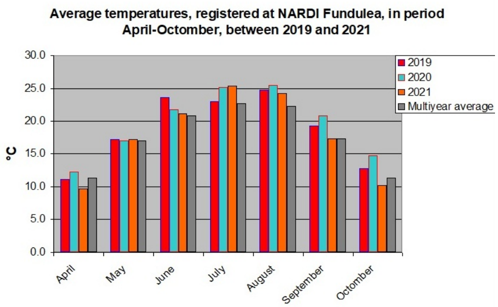

Figure 6. Average temperatures registered at NARDI Fundulea in April-October, between 2019 and 2021

Temperatures registered during this study were over multiyear average in the summer months in all three years (Figure 6). In April, the average temperature was higher than average in 2022, slightly lower than average in 2019, and lower than the multiyear average in 2021, with a negative deviation of 1.6°C. In May, the average temperature was close to average in all three years, while in September and October, temperatures were higher than the multi-year average in 2019 and 2020. Weather conditions during this study were warmest than average, although, in some spring or autumn months, temperatures were lower than average. At the same time, rainfalls amount have a positive deviation from the average in some months, but in many months were quieter than usual. Many types of research prove that in Central and Eastern Europe, including Romania, temperatures increased and rainfalls decreased (Olesen et al., 2011; Bebber et al., 2014; Choudhary et al., 2019). The same authors mentioned that it could register higher rainfalls amount for short periods (one day or a few hours).

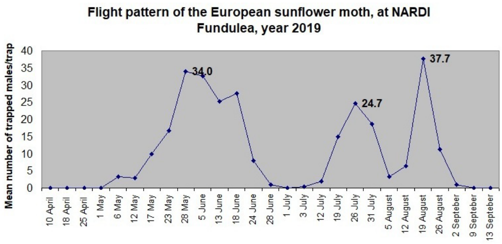

Figure 7. Flight pattern of the European sunflower moth, at NARDI Fundulea, year 2019

The captures from pheromone traps show the variability of the fly of the European sunflower moth during the three years of this study. In 2019, the first captures were recorded on 6 May. Then it has a constant increase in the capture number until 28 May, when it has registered the first fly peek, with an average of 34.0 captures/trap (Figure 7).

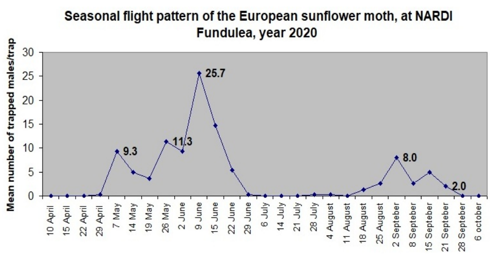

Figure 8. Flight pattern of the European sunflower moth, at NARDI Fundulea, year 2020

Between 3 July and 2 September, it has registered continuous flight of European sunflower moth, with two peeks on 26 July (24.7 captures/trap) and 19 August (37.7 captures/trap). From all three flight peeks registered in 2019 at NARDI Fundulea, the highest fly peek was in the second part of August.

In 2020, the first capture was recorded on 29 April, with a fly peek on 9 June (25.7 captures/trap). This year it has recorded two fly peeks, compared with the previous year (Figure 8). Also, the second fly peek in autumn was lower (8.0 captures/trap). The last catch in the pheromone traps was recorded on 21 September. A possible explication for the lower number of captures from the second generation is because of draught from the summer.

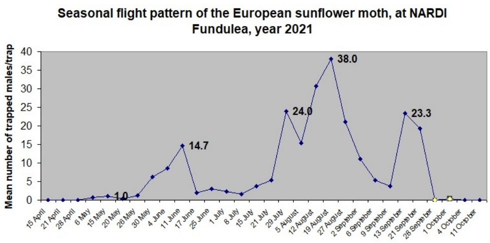

Figure 9. Flight pattern of the European sunflower moth, at NARDI Fundulea, year 2021

Perju (1999) mentioned that in the years with low rainfalls during the summer, many larvae from the first generation remain in diapauses in the soil and then continue with winter hibernation. As a result, the insect number from the second generation is lower. In 2020, the rainfall amount recorded in July and August was below the multi-year average, while June was slightly lower.

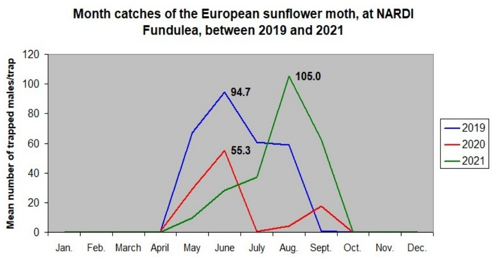

Figure 10. Moth catches of the European sunflower moth, at NARDI Fundulea, between 2019 and 2021

In 2021, the first capture was recorded on 6 May. Like 2019, it was three fly peeks of the European sunflower months (Figure 9). The highest fly peek registered on 19 August (38.0 captures/trap). The last capture was recorded on 1 October, although it was a continuous flight from 6 May!

Summarising the data from this study, it can conclude that in 2019 and 2020, most of the captures from the pheromone traps were recorded in May and June, while in 2021, the majority of the captures were recorded in August and September (Figures 10 and 11).

The result of this study is quite similar to those obtained by Szabó et al. (2009) in northeast Hungary. The author mentioned that the second and the third generation of the European sunflower moths could not be clearly distinguished due to seasonal flight patterns. A similar situation was observed during monitoring this pest, at NARDI Fundulea, in 2019 and 2021. At the same time, the case reported by Szabó et al. (2009) in Hungary in 2007 was similar to those recorded at NARDI Fundulea in 2020. However, in the Romanian literature, it wasn't referenced to the higher-flying peek of the European sunflower moth, recorded in August or the first half of September.

Figure 11. High captures of the European sunflower moth, at NARDI Fundulea, 6 Seotember, 2021

Olesen et al. (2011) mentioned that global warming has consequences in increasing the generation numbers of the insect species in one year (including sunflower pests). As a result, pest pressure on crops increases.

Regard as atraNeb pheromone, the results of this study reveal high selectivity of this compound, used in the monitoring of the European sunflower moth. The pheromone traps have recorded accidental captures of the green lacewing adults (*Chrysoperla carnea*), especially in June, and corn earworm (*Helicoverpa armigera*), in July and August. However, the differences between these accidental captures and monitored sunflower pests are apparent. Further studies are necessary for the main areas cultivated with sunflower in Romania, using an automatic monitoring system, to assess better the impact of global warming concerning the evolution of the main pest species of this crop. Also is necessary to see the possibility of the increasing pressure of the European sunflower moth on sunflower crops and the behaviour of the new sunflower hybrids to this pest in global warming conditions.

CONCLUSIONS

This study reveals new information about the evolution of the European sunflower moth (*Homoeosoma nebulellum*) in climatic conditions in southeast Romania.

In 2019 and 2021, it was three fly peeks of this pest, while in 2020, it had two fly peeks, although the second fly peek was reduced.

In 2019 and 2021, it has observed more captures in August and September.

AtraNeb pheromone is very selective for European sunflower moths

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YIELD AND GRAIN QUALITY OF SOFT WINTER WHEAT DEPENDING ON THE FERTILIZATION IN THE NORTHERN STEPPE OF UKRAINE

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Abstract

The results of the long-term researches on determination of the influence of mineral fertilizers on the soft winter wheat yield and grain quality after black fallow and after spring barley in the conditions of Northern Steppe of Ukraine are presented. According to the research in 2012-2014 it is established that application of spring-summer nitrogenous top-dressing at sowing after black fallow provided (according to the quality indicators set regulated by the current national standard for wheat DSTU 3768: 2019) formation of grain of the second class of quality at winter wheat varieties Lytanivka, Zamozhnist, Antonivka and Rozkishna and for the most part the first class - at variety Sonechko by the yielding capacity within 6.19-6.60; 6.25-6.74; 5.60-6.08; 5.89-6.37 and 5.38-5.71 t/ha respectively. The expediency of double top dressing of winter wheat sowings after spring barley is scientifically proved: ammonium nitrate in dose N_{30} early in the spring on frozen-melted soil and in the end of tillering stage of plants, that provided the obtainment of yielding capacity of 4.70-5.28 t/ha with grain quality of the second and third class in the favorable moisture years. Studies conducted in 2016-2018 found that the highest yields in varieties Kokhanka, Missiya Odeska and in Pylypivka grown after black fallow were formed by plant feeding with ammonium nitrate locally in the late tillering phase, dose of 60 kg/ha, active substance. In this feeding mode increase in yield compared with the control (without feeding) was, depending on variety, 0.58-0.64 t/ha. The highest yield (7.23 t/ha) was formed by Pylypivka variety. When growing winter wheat after spring barley, the increase in grain yield, compared with the control (without feeding) in variety Kokhanka, on average for three years depending on feeding option, was 0.48-1.20 t/ha; in Missiya Odeska - 0.36-1.15; and in Pylypivka - 0.51-1.16 t/ha. The highest increase in yield was provided by the application of nitrogen fertilizer (a dose of 60 kg/ha) on frozen-melted soil and in two terms: spreading N_{60} on frozen-melted soil and local application of N_{30} at the end of tillering. The Kokhanka variety yield under these feeding mode was 5.31 and 5.46 t/ha, respectively, Missiya Odeska - 4.78 and 5.03 t/ha, and Pylypivka - 5,47 and 5.62 t/ha. The highest grain yield (5.62 t/ha) was formed by winter wheat variety Pylypivka with application of ammonium nitrate N_{60} on frozen-melted soil and local application of N_{30} at the end of tillering. Experimental data analysis and generalization showed that application of nitrogen fertilizers in spring-summer growing season after both predecessors, as a rule, facilitated improved grain quality, namely: grain nature, vitreousity, protein and crude gluten content, flour sedimentation.

***Key words**: winter wheat, variety, mineral fertilizers, predecesor, yield, grain quality.*

INTRODUCTION

Stable demand for food in the world opens up prospects for expanding the market for Ukrainian agricultural products. Among other crops, the leading place belongs to winter wheat, the main food crop. In recent years, quantitative indicators of the yield for soft winter wheat (*Triticum aestivum* L.) fully cover domestic demand for food wheat and allow to increase its exports, which contributes to strengthening the country's economy (Kernasiuk, 2020; Procopenko, 2019).

Among the most important factors influencing the formation of winter wheat yield and quality are the weather conditions during the growing season, variety, predecessor and crops fertilizer.

Modern varieties should be characterized by adaptability to growing conditions, resistance to environmental stressors, especially in the area of insufficient and unstable moisture - conditions of Ukraine's Steppe Zone (Netis, 2008; Remeslo & Saiko, 1981; Sobolev, 1979). Winter wheat is a crop demanding to nutritional conditions.

From this point of view, it is desirable to sow after the best predecessors, with sufficient essential nutrients reserves necessary for optimal plants growth and development, nitrogenous substances accumulation in the vegetative mass; all this is a guarantee of good yields of high quality grain (Likhochvor, 2016; Maathus & Diatloff, 2013; Romheld & Kirkby, 2010; Solodushko, 2016). To form 1 ton of winter wheat, grain the following is required: 25-35 kg of nitrogen, 11-13 kg of phosphorus, 20-27 kg of potassium, as well as a number of other elements such as calcium, magnesium, sulfur and others. As yield increase, so does the nutrients removal from the soil by wheat plants (Karasiuk et al., 1995).

However, regardless of the planned harvest, available varieties, predecessors and the effective soil fertility level, the use of mineral fertilizers on standard black soil has its own peculiarities. Phosphorus and potassium fertilizers in full ($P_{45-60}K_{30-45}$) are applied with the main tillage or with the pre-sowing cultivation. After non-fallow predecessors, where the mobile nitrogen compounds content is bordering low and medium supply (7-13 mg/kg) there is a need to apply nitrogen fertilizers in the pre-sowing period in doses 45-60 kg/ha of acting substance. However, the final calculation of the fertilizers amount is adjusted according to the soil diagnostics results (Buka, 2000; Cherenkov et al., 2021).

Based on the previous studies analysis, it is proved that the nitrogen nutrition optimization for winter wheat growing season has a significant impact on the formation of yield and grain quality of this crop. Early spring fertilization is particularly appropriate for weakened crops (especially the ones not fertilized in the autumn). Such fertilization promotes plant regeneration after winter, enhances tillering and the new shoots formation (Vaguseviciene et al., 2012). Grain quality is improved by application of later feedings - at the end of the tillering phase, in the earing phase and at the milk ripeness beginning. In the context of the introduction of new high-yielding winter wheat varieties against the background of climate change, studies of the fertilizers impact on yield and grain quality for these varieties after various predecessors continue to remain relevant (Zhemela & Musatov, 1989).

MATERIALS AND METHODS

The research experimental part was conducted on the research farm "Dnipro" (State Enterprise "Institute of Grain Crops of NAAS of Ukraine") located in the central part of Ukraine's Northern Steppe. The experimental fields soil cover is represented by ordinary low-humus full-profile black soil. The soil mechanical composition is medium loamy. The zone climate is temperate-continental with insufficient and unstable moisture. Field experiments were performed after black fallow and after spring barley. For pre-sowing cultivation after black fallow the background fertilizer was applied in doses $N_{0-30}P_{60}K_{30}$, and after the stubble predecessor - $N_{60}P_{60}K_{30}$. Wheat seeds were sown with a CH-16 seeder with a row spacing - 15 cm, seed wrapping depth - 5-6 cm. Harvesting was carried out separately on different plots by "Sampo - 500" combine.

Experiments were laid down by the successive plots method, in a systematic way. The accounting plot area was 30-35 m^2, the repetition of experiments - three times. In different years, were studied the grain yield and quality dependence on nitrogen fertilization for soft winter wheat varieties Lytanivka, Zamozhnist, Antonivka, Sonechko, Rozkishna, Kokhanka, Missyia Odeska and Pylypivka. According to variety testing results the varieties Zamozhnist and Kokhanka are classified as valuable in terms of grain quality, other varieties are classified as strong. Grain quality indicators were determined according to the methodology provided by current national regulations. The distribution of winter wheat grain into classes was carried out in accordance with Ukraine's grain standard DSTU 3768: 2019.

RESULTS AND DISCUSSIONS

Agro-meteorological conditions during the research years were different and significantly affected the winter wheat plants growth and development, and thus the formation of yield and grain quality. The vegetation period of 2011/12 was extremely dry. The precipitation amount for the year, starting from August 2011 and ending in July 2012, was lower by 122.9

мм compared to the average long-term data. The autumn period of 2011 was very unfavorable for moisture, the lack of precipitation was about 75%. It should be noted that under such conditions more damage was seen in crops after non-fallow predecessors, while after fallow crops were in satisfactory condition. In experiments after spring barley at autumn vegetation end crops were liquefied and heterogeneous, the plants were in the 3rd leaf appearance phase and the tillering beginning. December warm spells weakened the plants hardening before winter process, and very cold and dry weather, which settled in late January and lasted until the end of the second decade of February, also worsened the winter crops condition. During the spring-summer vegetation of plants, abnormally hot, with a lack of precipitation weather was observed in the period from April 24 to June, which led to delayed grain filling, premature ripening and reduced yields. In subsequent years, the weather conditions were more favorable for winter wheat growth, development and yield formation.

Comparing the winter wheat yield in different weather conditions, it can be noted that on average for varieties Lytanivka, Zamozhnist, Antonivka, Sonechko and Rozkishna depending on the experiment variant with growing after black fallow this indicator value in 2012 was 3.87-4.27 t/ha, in 2013 - 6.67-7.40, and in 2014 - 6.77-7.23 t/ha. After spring barley the yield varied in 2012 between 2.24 and 2.39 t/ha, in 2013 and 2014 it was significantly higher and varied from 4.16 to 4.70 and from 4.73 to 5.28 t/ha, respectively.

In all years after black fallow and in favorable for moisture 2013 and 2014 after spring barley there were increases in yields when nitrogen feedings were applied. The highest values were established after fallow in the experiment option where at the spring tillering phase end ammonium nitrate was applied locally: dose N_{60}; and after spring barley - for two step application of this fertilizer:N_{30} on two dates: on permafrost soil and locally. In 2012, nitrogen feedings after the stubble predecessor was ineffective and in most experiment variants did not increase yields. On average, in 2012-2014, winter wheat cultivation after black fallow for varieties Lytanivka, Zamozhnist, Antonivka, Sonechko and Rozkishna in the variants with feedings formed the yield in the range of 6.10-6.60; 6.25-6.74; 5.60-6.08; 5.89-6.37 and 5.38-5.71 t/ha, respectively.

In the growing season 2011/12 in dry weather conditions, low yields of winter wheat were noted. But studied varieties both after black fallow and after spring barley, formed high-protein grain, which according to current national regulations (DSTU 3768: 2019) corresponded mainly to the first class quality (protein content in grain more than 14%, crude gluten - more than 28%). In 2013 after black fallow, on average in all experiment variants the protein content in grain, depending on the variety, was 12.7-14.0%, gluten - 23.4-27.6% (the second class), in 2014, respectively, 11.2-13.4 and 23.7- 27.7% (the second and third class). After spring barley, in 2013 the amount of protein in grain was 11.0-12.4%, and gluten - 19.0-23.0% (the third class), in 2014, respectively, 11.6-13.4 and 24.0-30.3% (the second and third classes).

The grain protein content of winter wheat varieties depended on nitrogen feedings. On average, in 2012-2014, in the experiment variants where such feedings were applied, the highest protein and crude gluten content in wheat grain after black fallow was in variety Sonechko (14.0-14.5 and 27.5-30.2% respectively), while in the control group these indicators were 13.4 and 27.2%, respectively. In other varieties, after nitrogen feedings the protein content varied between 12.8 and 13.9%, gluten - 25.4-27.3%; in the control group - between 12.3-12.8% and 24.4-24.9%, respectively. The highest indicators of protein and gluten content in winter wheat grain of different varieties were formed with two-step nitrogen feedings of crops: at the tillering phase end the with ammonium nitrate (a dose of 30 kg/ha of acting substance), and urea in the earing phase (Table 1). According to the set of quality indicators in variety Sonechko with different fertilizer options, excluding feedings with urea-ammonia mixture (UAN-32), the first class quality grain was formed, in other varieties - the second class quality grain.

Table 1. The grain protein and gluten content in winter wheat varieties depending on the nitrogen feedings after black fallow, 2012-2014

Nitrogen fertilizer	Grain protein content, %					Grain gluten content, %				
	1*	2	3	4	5	1	2	3	4	5
No feeding - control (background $P_{60}K_{30}$)	12.4	12.7	12.8	13.4	12.3	24.4	24.4	24.8	27.2	24.9
N_{30} at the end of plants tillering, ammonium nitrate	13.0	13.4	13.4	14.1	12.9	25.8	25.7	26.0	28.5	26.4
N_{30} at the end of plants tillering, UAN-32	13.0	13.3	13.2	14,0	12.9	25.8	25.4	25.7	27.5	26.5
N_{30} in the earing phase foliar, urea	12.8	13.3	13.3	14.0	13.0	25.6	26.0	25.5	28.4	26.5
N_{60} at the end of plants tillering, ammonium nitrate	13.0	13.6	13.5	14.4	13.2	26.6	26.2	26.1	29.9	26.7
N_{30} at the end of plants tillering, ammonium nitrate + N_{30} in the earing phase foliar, urea	13.3	13.9	13.6	14.5	13.5	26.8	26.3	27.0	30.2	27.3

1 - Lytanivka; 2 - Zamozhnist; 3 - Antonivka; 4 - Sonechko; 5 - Rozkishna

After spring barley, like after black fallow, the highest amount of protein and crude gluten in wheat grain, on average for three years of research, was in the variety Sonechko. With different nitrogen feedings, in the grain of this variety the protein content was in the range of 13.1-14.3%, gluten - 26.3-30.1% (in the control, respectively 13.3 and 26.7%). In other varieties with spring-summer fertilization of crops these indicators varied between 11.8-13.7 and 23.3-26.5% respectively. In the control group, grain protein content depending on the varieties, was 11.9-12.7%, and crude gluten - 23.6-24.6%. The best grain quality was obtained with two-step nitrate feeding of winter wheat varieties: ammonium nitrate (dose 30 kg/ha of acting substance) in early spring on frozen-thawed soil and at the tillering phase end; ammonium nitrate (dose 30 kg/ha of acting substance) at the tillering phase end and urea N_{30} in the earing phase (Table 2).

According to the set of quality indicators in variety Sonechko with above variants of nitrogen feedings the first class grain was formed. With different variants of feedings - the second class grain was formed.

Table 2. The grain protein and gluten content in winter wheat varieties depending on the nitrogen feedings after spring barley, 2012-2014

Nitrogen fertilizer	Grain protein content, %					Grain gluten content, %				
	1*	2	3	4	5	1	2	3	4	5
No feeding - control (background $N_{60}P_{60}K_{30}$)	12.0	12.7	12.5	13.3	11.9	24.1	24.6	24.1	26.7	23.6
N_{30} at the end of plants tillering, ammonium nitrate	12.4	13.0	12.9	13.6	12.2	25.8	24.9	25.7	28.3	23.9
N_{30} at the end of plants tillering, UAN-32	12.2	12.6	12.4	13.1	11.8	24.0	24,0	23.7	26.3	23.3
N_{60} at the end of plants tillering, ammonium nitrate	12.3	13.2	13.0	13.4	12.4	25.9	25.3	26.0	28.2	24.8
N_{30} in early spring on frozen-thawed soil + N_{30} at the end of plants tillering, ammonium nitrate	13.3	13.4	13.7	14.0	12.4	27.6	27.3	26.5	29.0	25.7
N_{30} at the end of plants tillering, ammonium nitrate + N_{30} in the earing phase foliar, urea	12.5	13.1	12.9	14.3	12.7	25.7	26.5	26.1	30.1	26.1

1 - Lytanivka; 2 - Zamozhnist; 3 - Antonivka; 4 - Sonechko; 5 - Rozkishna

According to 2016-2018 research results with winter wheat varieties Kokhanka, Missiya Odeska and Pylypivka, it was found that after black fallow among the nitrogen feedings options the higher yield was obtained with applying ammonium nitrate locally (a dose - N_{60} at the end of spring tillering). This feeding option provided an increase in grain yield 0.58-0.64 t/ha depending on the variety. We would like to note the tendency to increased yields with foliar feedings with urea in the plants earing phase. However, significant difference compared to the control group (only pre-sowing application of complete fertilizer $N_{30}P_{60}K_{30}$) was noted with combination of urea and "Falcon" fungicide in dispencing container. Among the studied varieties higher yield in all experiment variants was formed by variety Pylypivka with the highest indicator (7.23 t/ha) in the variant with N_{60} application locally (Table 3.).

Table 3. Influence of nitrogen feedings on yield, grain protein and gluten content for different varieties of winter wheat after black fallow, 2016-2018

Nitrogen fertilizer	Yield, t/ha			Grain protein content, %			Grain gluten content, %		
	1*	2	3	1	2	3	1	2	3
No feeding – control (background $N_{30}P_{60}K_{30}$)	6.43	6.30	6.59	11.8	11.9	12.0	20.8	19.9	21.2
N_{30} at the end of plants tillering, ammonium nitrate	6.78	6.64	6.98	12.0	12.1	12.5	21.4	20.6	23.0
N_{60} at the end of plants tillering, ammonium nitrate	7.01	6.91	7.23	12.3	12.3	12.7	22.0	22.0	23.5
N_{30} in the earing phase foliar, urea	6.54	6.42	6.72	12.6	12.4	12.7	22.7	22.0	24.1
Mixture of urea (N_{30}) + fungicide Falcon (600 ml/ha) in the earing phase foliar	6.68	6.51	6.84	12.9	12.3	12.4	23.8	21.9	22.4
**1 - Kokhanka; 2 - Missiya Odeska; 3 - Pylypivka*									

As for the winter wheat grain quality it should be noted that the nitrogen fertilizers use in the spring-summer growing season after black fallow, as a rule, helped to increase the grain protein and crude gluten content. For varieties Kokhanka and Missiya Odeska, the best options were those where winter wheat crops had feedings with ammonium nitrate at the tillering phase end (dose 60 kg/ha of acting substance) and foliar feedings with urea (simultaneously with fungicide). In winter wheat variety Pylypivka for protein compounds accumulation the most effective were feedings at the tillering phase end locally (N_{30-60}) and foliar N_{30} in the earing phase.

In winter wheat cultivation after spring barley (against the background of $N_{60}P_{60}K_{30}$) nitrogen feedings at different times and with different doses (ammonium nitrate was always used) had a positive effect on the grain yield.

The yield increase compared to the control in variety Kokhanka was 0.48-1.20 t/ha, Missiya Odeska - 0.36-1.15 t/ha, and in variety Pylypivka - 0.51-1.16 t/ha.

The most effective was N_{60} application in early spring on frozen-thawed soil, as well as its combination with subsequent feeding with N_{30} locally at the tillering end. With such feeding options Kokhanka variety yield was 5.31 and 5.46 t/ha respectively, for Missiya Odeska - 4.78 and 5.03 t/ha, for Pylypivka - 5.47 and 5.62 t/ha (Table 4.).

It was established that the higher grain protein and gluten content in winter wheat varieties after spring barley was formed, as a rule, in cases where the total nitrogen dose for crops feeding was 60-90 kg/ha.

The largest amount of grain protein compounds was with two-step plants feeding: N_{60} in early spring on frozen-thawed soil and N_{30} locally at the tillering phase end. Depending on the variety with such fertilizing system the grain protein content varied between 11.7-12.5%, and crude gluten - 19.0-23.1%; the highest rates were in the varieties Pylypivka and Kokhanka, and lower - in variety Missiya Odeska.

It should be noted that during the research years nitrogen feedings of winter wheat crops after both predecessors helped to increase not only the grain protein and gluten content, but in most cases it improved such indicators as grain nature and vitreousity, flour sedimentation rate.

Table 4. Influence of nitrogen feedings on yield, grain protein and gluten content for different varieties of winter wheat after spring barley, 2016-2018

Nitrogen fertilizer	Yield, t/ha			Grain protein content, %			Grain gluten content, %		
	1*	2	3	1	2	3	1	2	3
No feeding - control (background $N_{60}P_{60}K_{30}$)	4.26	3.88	4.46	11.4	11.4	11.4	19.3	16.3	18.3
N_{30} in early spring on frozen-thawed soil	4.91	4.45	5.08	11.4	11.4	11.4	19.3	16.9	19.4
N_{60} in early spring on frozen-thawed soil	5.31	4.78	5.47	11,8	11,8	11,8	21.0	18.0	21.5
N_{30} at the end of plants tillering	4.74	4.24	4.97	11.6	11.6	11.6	21.0	17.2	20.4
N_{30} in early spring on frozen-thawed soil + N_{30} at the end of plants tillering	5.16	4.60	5.32	12.0	12.0	12.0	22.5	19.2	21.7
N_{60} at the end of plants tillering	5.08	4.54	5.25	11.9	11.9	11.9	22.7	18.9	22.0
N_{60} in early spring on frozen-thawed soil + N_{30} at the end of plants tillering	5.46	5.03	5.62	12.3	12.3	12.3	22.9	19.0	23.1

**1 - Kokhanka; 2 - Missiya Odeska; 3 - Pylypivka*

CONCLUSIONS

During the research, a significant decrease in winter wheat yield was revealed. It was a result of abnormally adverse weather during the growing season 2011-2012.The average grain yield by variety depending on experiment option after black fallow amounted to 3.87-4.27 t/ha, after spring barley - 2.24-2.39 t/ha. In other years with more favorable weather the above indicators values after fallow, as a rule, exceeded 6-7 t/ha, and after the stubble predecessor - 4-5 t/ha. The grain protein and crude gluten content in the arid year 2012 was the highest among the research years and amounted at least 14 and 28%, respectively, which was at the first class quality level. In other years these quality indicators were formed at significantly lower levels.

Winter wheat crops spring-summer feedings with nitrogen fertilizers were more effective in favorable years for moisture. After black fallow (against $N_{0\text{-}30}P_{60}K_{30}$) the highest yield increases were observed in the variant where ammonium nitrate was applied locally at spring tillering phase end - dose N_{60}. After spring barley (against $N_{60}P_{60}K_{30}$) - with two-step feedings: $N_{30\text{-}60}$ on frozen-thawed soil and N_{30} locally at the tillering end. Winter wheat crops nitrogen feedings after both predecessors helped to improve grain quality indicators such as protein and gluten content, grain nature, vitreousity and flour sedimentation rate.

Higher yields in 2012-2014 were formed by winter wheat varieties Zamozhnist, Lytanivka and Rozkishna, grain quality - Sonechko variety; in 2016-2018, the most productive variety was Pylypivka, the best grain quality was in varieties Kokhanka and Pylypivka.

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EFFICACY OF SOME HERBICIDES ON WEED GROWTH AND YIELD OF POTATO IN CLIMATIC CONDITIONS OF BARSA COUNTY

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Abstract

Weed control is an important factor for a successful potato crop. The objectives of current study were to assess the effect of herbicides and their rates of application on weeds and the crop. Test results come from a field experiment conducted between 2020–2021 to the National Institute of Research and Development for Potato and Sugar Beet Brasov, Romania. Two factors were tested: factor I - potato variety: Brasovia; factor II - five herbicides to control weeds and a control one variant (V1: Control; V2: clomazone+pendimenthalin 2.0 l/ha; V3: clomazone+ pendimenthalin 1.8 l/ha; V4: Sencor 0.9 l/ha; V5: Proman 3 l/ha; V6: Challenge 4 l/ha). The experiment was laid out in randomized complete block design with three replications. Herbicides were applied as preemergence. The weed community included Chenopodium album, Amaranthus spp., Echinochloa crus-galli, Abutilon theophrasti, Polygonum spp., Falloppia convolvulus. In both years the reported effectiveness for all registered weeds was good and very good, over 85-90% of the control and all variants treated by herbicides significantly influenced the increase in potato yield in comparison with the control variants.

Key words: *efficacy, herbicide, potato, weed control, yield.*

INTRODUCTION

Potato (*Solanum tuberosum* L.) is one of the most important food crops in the world. In volume of crop production, potato ranks fourth following wheat, maize, and rice in the world. It is regarded as a high-potential food security crop because of its ability to provide a high yield of high-quality product per unit input with a shorter crop cycle (mostly < 120 days) than major cereal crops, like maize, sorghum etc. (Adane et al., 2010; Kebede et al., 2016).
Weed infestation decrease the quality and quantity of potato tubers via decreasing size, weight and number of tubers (Arnold et al., 1998). Competition affects considerably the shape, size and function of competing species (Mondani et al., 2011).
Competition between potatoes and weeds should be minimized from planting to the time of canopy closure, 6 to 7 weeks later. Weeds that emerge after row closure usually will not compete with the potato crop so long as the canopy is uniform and dense. Crop uniformity and density is determined by the stature of the variety and the uniformity of plant spacing (Hermeziu et al., 2020).
Jan et al. (2004) reported that chemical weed control increased potato yield significantly and was found to be the least expensive giving the highest marginal rate of return (14.17%) compared to other weed control measures.
Among weed management practices, chemical weed control is easy, effective and time saving method. Labor cost has increased tremendously during the last few years, which has made the manual weeding almost impracticable (Khan et al., 2009).
Substantial scientific reports are now available that show that the time of weed control is as important as the weeding itself. Delayed weeding until late stages could result in irreversible damage due to weed competition (Zimdahl 1987; Karimmojeni et al., 2014).

MATERIALS AND METHODS

Experiments were carried out at the National Institute of Research and Development for Potato and Sugar Beet Brasov, Romania, in 2020-2021. The soil was cambic chernozeum with 6.6 pH, humus 4.68% and clay 27%. The pre-crop in both years was wheat.

The field experiments each year were set up in random block, 3 replicate plots with 4 rows each with 11 plants. The size of elementary plot was 9 m^2, with the distance 75/30 cm. Fertilizer, NPK 15-15-15, was applied at 1000 kg/ ha rate in both years before potato planting.
A Romanian potato variety Brasovia was planted in 2020, April 6 and in 2021, May 3.
Herbicide used were: V1: Control (untreated); V2: clomazone+pendimethalin - 2.0 l/ha; V3 clomazone+pendimethalin) - 1.8 l/ha; V4: Sencor (metribuzin 70%)) - 0.9 l/ha; V5: Proman (500 g/l metobromuron - 3.0 l/ha; V6: Challenge (600 g/l aclonifen) 4.0 l /ha. Herbicides were applied on 30 April 2020 and 19 May 2021 respectively and assessments were made 20,37 and 54 days after application. Herbicides were applied with a knapsack sprayer with 10 l capacity (nozzle type TJ 11002). The weeds species, growth stages and population level were recorded by counting the number of individual species in 4 x 0.25 m^2. Statistical analysis was done using factorial analysis of variance (ANOVA), the statistical and rating differences between mean values was performed by LSD test.
The harvest was performed in 2020, September, 10 and respectively 2021, October 4.

RESULTS AND DISCUSSIONS

In 2020 during the vegetation period (April - August) the average monthly temperatures were close to normal, only 0.7°C higher than MAA. Between April 1 and August 31, the total rainfall was less with 8.6 l/m^2 than the MAA but the distribution of precipitation was very uneven. A very low volume in April but an excess of rainfall in May made it difficult to carry out the activities in good conditions. In 2021 in the same period the average monthly temperatures were much close to normal, only 2.2°C higher than MAA but the rainfalls was less with 36.9 l/m^2 than the MAA.
The weather conditions in particular years had a significant impact on weed infestation (Table 1). The highest number of weeds, before row closure as well as before tuber harvest, was found in 2020 which was characterized by uneven distribution of rainfall and temperatures (Figure 1).

Table 1. Weeds present in the field
to NIRDPSB Brasov (2021-2022)

Common name	Scientific name	EPPO code
Fat-hen	*Chenopodium album*	CHEAL
Pigweeds	*Amaranthus* spp.	AMARE
Cockspur	*Echinochloa crus-galli*	ECHCG
Velvetleaf	*Abutilon theophrasti*	ABUTH
Knotweed	*Polygonum* spp.	POLG
Wild buckweed	*Falloppia convolvulus*	POLCO

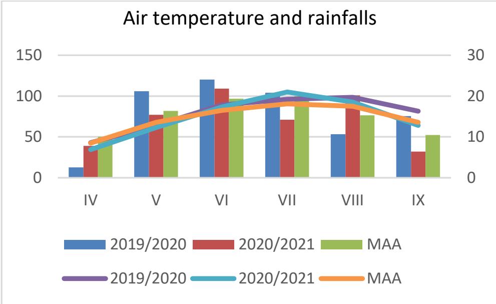

Figure 1. Air temperature and rainfalls during the experiment

Chenopodium album (CHEAL) evaluated in experience reached a population of 23.2 ind./m^2 at the first assessment in 2020 and 22.3/m^2 at the first assessment in 2021 in the untreated variant (control).
There were statistically significant differences between variants. The lowest values were observed in the Challange variant (1.2 kg/ha). In the case of *Amaranthus* spp. (AMARE) the control variant reached a population of 16.7 ind./m^2 at the first assessment in 2020 and 15.5 ind./m^2 at the first assessment in 2021 and *Echinochloa crus-galli* (ECHCG) 14.9 ind./m^2 at the first grading in 2020 and 12.7 ind./m^2 at the 2021 assessment.
Abutilon theophrasti (ABUTH) was assessed as reaching a population of 50 ind./m^2 in the control variant in 2020 and 5.8 ind./m^2 in 2021 and *Fallopia convolvulus* (POLC) recorded 11.6 ind./m^2 at the first assessment in 2020 and 11.2 ind./m^2 at the assessment in 2021. In the case of *Polygonum* spp. (POLG), the control variant reached a population of 11.3 ind./m^2 at the first assessment in 2020 and 12.7 ind./m^2 at the first assessment in 2021. There are statistically significant differences between variants (Table 2).

Table 2. Effectiveness of different herbicides in potato weeds control (I assessment)

Weeds	CHEAL	CHEL	AMARE	AMARE	ECHCG	ECHCG	ABUTH	ABUTH	POLCO	POLCO	POLG	POLG
Data	20,05.20	8.06.21	20,05.20	8.06.21	20,05.20	8.06.21	20,05.20	8.06.21	20,05.20	8.06.21	20,05.20	8.06.21
Control (untreated)	23.2a	22.3a	16.7a	15.5a	14.9a	12.7a	5.0a	5.8a	11.6a	11.2a	11.3a	12.7a
Clomazone+ pendimenth 2.0	2.0c	3.8b	1.9bc	2.7b	1.7bc	0.7bc	2.1b	1.8b	2.1bc	2.3bc	2.2b	2.9b
Clomazone+ pendimenth .1.8	3.8b	2.0c	2.5b	2.1b	2.2b	1.9b	2.7b	2.6b	2.9b	2.2bc	2.0bc	1.9bc
Sencor	1.8cd	1.3cd	1.4bc	1.7b	0.9cd	2.6b	1.7b	1.1b	1.9bcd	1.1cde	1.4bc	0.7d
Proman	1.3cd	1.3cd	1.1bcd	0.4c	1.2bcd	1.1bc	0.4c	0.2c	1.2cde	0.9de	1.2bcd	1.2cd
Challange	1.3cd	0.8cd	0.9cd	0.2c	0.6d	0.5bc	0.2c	0.0c	0.9de	0.4e	1.0cd	1.1cd
LSD (P =.05)	1.73	1.49	0.25	0.25	0.17	0.20	0.21	0.19	0.20	0.20	0.19	0.18
Standard Deviation	1.19	1.69	0.17	0.19	0.12	0.10	0.14	0.15	0.14	0.12	0.13	0.11
CV	3.2	1.97	4.28	3.48	8.96	7.45	9.82	8.8	8..82	7.9	9.88	8.9

Means followed by same letter do not significantly differ (P =.05, Student-Newman-Keuls)

To the second assessment *Chenopodium album* (CHEAL) reached a population of 21.7 ind./m^2 at in 2020 and 22.3 ind./m^2 in 2021 in the untreated variant (control).

There were statistically significant differences between variants.

In the case of *Amaranthus* spp. (AMARE) the control variant reached a population of 9.8 ind./m^2 in 2020 and 11.8 ind./m^2 in 2021 and *Echinochloa crus-galli* (ECHCG) 10.8 ind./m^2 in 2020 and 11.0 ind./m^2 at the 2021 assessment. *Abutilon theophrasti* (ABUTH) was assessed as reaching a population of 10.0 ind./m^2 in the control variant in 2020 and 8.9 ind./m^2 in 2021.and *Fallopia convolvulus* (POLC) recorded 8.9 ind./m^2 in 2020 and 9.3 ind./m^2 in 2021.

In the case of *Polygonum* spp. (POLG), the control variant reached a population of 11.8 ind./m^2 in 2020 and 9.5 ind./m^2 in 2021. There are statistically significant differences between variants (Table 3).

Table 3. Effectiveness of different herbicides in potato weeds control (II assessment)

Weeds	CHEAL	CHEAL	AMARE	AMARE	ECHCG	ECHCG	ABUTH	ABUTH	POLCO	POLCO	POLG	POLG
Data	6.06.20	25.06.21	6.06.20	25.06.21	6.06.20	25.06.21	6.06.20	25.06.21	6.06.20	25.06.21	6.06.20	25.06.21
Control (untreated)	21.7a	22.3a	9.8a	11.8a	10.8a	11.0a	10.0a	8.9a	8.9a	9.3a	11.8a	9.5a
clomazone+ pendimenth 1.8 l	2.5bc	2.1b	2.0b	1.5b	0.0b	1.7b	0.0b	0.0b	1.9cd	2.5b	0.0b	0.0b
clomazone+ pendimenth 2.0 l	3.2b	1.4bc	2.0b	1.5b	0.0b	1.4bc	0.0b	0.0b	2.9b	2.0bc	0.0b	0.0b
Sencor	1.5cd	0.7cd	1.3bc	0.8bc	0.0b	0.4de	0.0b	0.0b	1.6bc	1.7bc	0.0b	0.0b
Proman	1.2cd	0.4d	0.8cd	0.5bc	0.0b	0.0e	0.0b	0.0b	1.0cd	0.4e	0.0b	0.0b
Challange	0.5de	0.7d	0.8cd	0.5bc	0.0b	0.2de	0.0b	0.0b	0.7d	0.6de	0.0b	0.0b
LSD (P =.05)	3.28	2.73	0.97	0.47	0.73	1.22	1.43	1.01	0.19t	6.59	1.34	4.60
Standard Deviation	2.25	2.25	0.67	0.32	0.50	0.83	098	0.69	0.13t	4.51	0.92	3.15
CV	30.09	28.8	34.29	26.72	31.86	29.77	28.32	25.74	13.09	5.65	7.31	3.77

Means followed by same letter do not significantly differ (P =.05, Student-Newman-Keuls)

Chenopodium album (CHEAL) to the last assessment reached a population of 21.7 ind./m^2 in 2020 and 22.2 ind./m^2 in 2021 in the untreated variant (control). There are statistically significant differences between variants. The lowest values were observed in Challange (1.2 kg/ha) and Proman (3.0 l/ha) variants. In the case of *Amaranthus* spp. (AMARE) the control variant reached a population of 11.8 ind./m^2 in 2020 and 12.2 ind./m^2 in 2021 and *Echinochloa crus-galli* (ECHCG) 10.8 ind./m^2 in 2020 and 10.0 ind./m^2 at the 2021 assessment. *Abutilon theophrasti* (ABUTH) was assessed as reaching a population of 9.5 ind./m^2 in the control variant in 2020 and 8.2 ind/m^2 in 2021. *Fallopia convolvulus* (POLC) recorded 10.5 ind./m^2 in 2020 and 8.2 ind./m^2 at the assessment in 2021. In the case of *Polygonum* spp. (POLG), the control variant reached a population of 10.8 ind./m^2 in 2020 and 7.7 ind./m^2 in 2021. To the last assessment *Echinochloa crus-galli, Abutilon theophrasti, Polygonum* spp. in treated variants were not present. There are statistically significant differences between variants (Table 4).

Table 4. Effectiveness of different herbicides in potato weeds control (III assessment)

Weeds	CHEAL	CHEAL	AMARE	AMARE	ECHCG	ECHCG	ABUTH	ABUTH	POLCO	POLCO	POLG	POLG
Data	23.06.20	12.07.21	23.06.20	12.07.21	2.06.20	12.07.21	23.06.20	12.07.21	23.06.20	12.07.21	23.06.20	12.07.21
Control (untreated)	21.7a	22.2a	11.8a	12.2a	10.8a	10.0a	9.5a	8.2a	10.5a	8.2a	10.8a	7.7a
Clomazone + pendimeth. 1.8 l	1.5bc	1.5b	1.5b	1.0b	0.0b	0.0b	0.0b	0.0b	1.4bc	0.0b	0.0b	0.0b
Clomazone+ pendimeth 2.0 l	1.9b	1.5b	1.5b	1.0b	0.0b	0.0b	0.0b	0.0b	2.1b	0.0b	0.0b	0.0b
Sencor	0.6c	0.5b	0.8bc	1.0b	0.0b	0.0b	0.0b	0.0b	0.7cd	0.0b	0.0b	0.0b
Proman	0.1d	0.0c	0.5bc	0.1bc	0.0b	0.0b	0.0b	0.0b	0.4d	0.0b	0.0b	0.0b
Challange	0.1d	0.0c	0.5bc	0.1bc	0.0b	0.0b	0.0b	0.0b	0.7d	0.0b	0.0b	0.0b
LSD (P =.05)	2.73	2.28	1.14	1.18	1.22	0.89	1.01	0.91	0.16	0.51	0.47	0.75
Standard Deviation	1.87	1.55	0.78	0.80	0.83	0.60	0.69	0.62	0.11	0.51	0.32	0.62
CV	13.8	11.56	11.46	18.8	19.77	11.6	15.74	11.6	12.46	10.5	16.72	11.6

Means followed by same letter do not significantly differ (P =.05, Student-Newman-Keuls)

No potato injury was observed with any herbicide treatments at NIRDPB Brasov in 2020 and 2021.

In 2020 to the control variant was the lower yield of tubers in the largest size (50-60 mm) category (17.06 t/ha) compared to herbicide-treated plots (differences being between 7.32 and 11.78 t/ha). To the medium category (40-50 mm) the highest yield was to the Sencor variant (21.98 t/ha) and the lowest to Challange variant (17.03 t/ha) (Table 5).

Table 5. Influence of herbicides on yield 2020

Product	YLDCAT1 50-60 mm size tubers (t/ha)	Dif. (t/ha)	Sign.	YLDCAT2 40-50 mm size tubers (t/ha)	Dif. (t/ha)	Sign.	YLDCAT3 28-40 mm size tubers (t/ha)	Dif. (t/ha)	Sign.
Untreated ckeck	17.06	-	-	19.18	-	-	1.30	-	-
Clomazone +pendimeth. 1.8 l	26.39	9.33	ns	19.02	-0.16	ns	1.39	0.09	ns
Clomazone+ pendimeth 2.0 l	24.38	7.32	ns	19.23	0.21	ns	1.71	0.32	ns
Sencor	28.83	11.78	ns	21.98	2.74	ns	1.90	0.19	ns
Proman	26.42	9.37	ns	20.70	-1.28	ns	2.10	0.20	ns
Challange	28.36	11.30	ns	17.03	- 36.67	ns	2.12	0.02	ns

DL5% = 14.93 t/ha; DL5% = 8.16 t/ha; DL5% = 1.27 t/ha;
DL1% = 20.56 t/ha; DL1% = 11.19 t/ha; DL1% = 1.74 t/ha;
DL0.1% = 27.99 t/ha; DL0.1%= 15.23 t/ha; DL0.1% = 2.37 t/ha.

Regarding the yield, in 2021, highest value was obtained to V6 (Challange) (24.78 t/ha) and the lowest to the V5 (Proman) variant (22.2 t/ha). To the control variant was the lower yield of tubers in the largest size (50-60 mm) category (4.89 t/ha) compared to herbicide-treated plots To the medium category (40-50 mm) the highest yield was to the Control variant (16.19 t/ha) and the lowest Clomazone + pendimethalin 1.8 l variant (14.66 t/ha) (Table 6).

Table 6. Influence of herbicides on yield 2021

Product	YLDCAT1 50-60 mm size tubers (t/ha)	Dif. (t/ha)	Sign.	YLDCAT2 40-50 mm size tubers (t/ha)	Dif. (t/ha)	Sign.	YLDCAT3 28-40 mm size tubers (t/ha)	Dif. (t/ha)	Sign.
Untreated ckeck	4.89	-	-	16.19	-	-	1.73	-	-
Clomazone +pendimeth . 1.8 l	6.12	1.23	ns	14.66	-1.53	ns	1.92	0.19	ns
Clomazone +pendimeth 2.0 l	4.94	0.06	ns	16.12	-0.07	ns	1.90	0.17	ns
Sencor	6.18	1.29	ns	15.20	-0.99	ns	2.16	0.42	ns
Proman	6.03	1.14	ns	14.73	-1.46	ns	1.46	-0.28	ns
Challange	7.83	2.94	ns	15.41	-0.78	ns	1.54	-0.19	ns

DL5% = 3.88 t/ha; DL5% = 4.39 t/ha; DL5% = 0.74 t/ha;
DL1% = 5.32 t/ha; DL1% = 6.02 t/ha; DL1% = 1.02 t/ha;
DL0.1% = 7.24 t/ha; DL0.1% = 8.19t/ha; DL0.1% = 1.38 t/ha.

The productions obtained in 2021 are lower than in 2020. The spring precipitations determined a later planting and the temperatures during the vegetation period (July-August) negatively influenced the development of the plants.

CONCLUSIONS

The results showed that no phytotoxic effect of any herbicide was observed on the potato crop. The tuber yield was influenced due to different treatments. The yield of potato tuber in 2020 was recorded highest (52.71 t/ha) under Sencor 0.9 l/ha treatment. The lowest tuber yield

(37.53/ha) was obtained in control variant. In 2021 the yield of potato tuber was recorded highest (28.8 t/ha) under mixture Clomazone+pendimethalin 2.0 l/ha treatment. The lowest tuber yield (22.2 t/ha) was obtained in Proman 3 l/ha. The weather conditions in the studied years influenced the weeds infestation degree and the obtained yield.

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COMPARATIVE RESEARCH WITH SEVERAL DH MUTANT/RECOMBINANT WHEAT LINES CULTIVATED UNDER THE SOUTH ROMANIA CONDITIONS

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Abstract

This research was carried out in 2017-2019 period under the soil-climate conditions of Agricultural Research and Development Station - ARDS Caracal and included several DH mutant/recombinant winter wheat lines. The experiment was set up after randomized blocks method in three replications. The main goal of the research was to identify new competitive winter wheat lines with improved resistance for the new specific conditions of the South Romania. During the research observations, determinations and measurements concerning morphological, productivity and quality characters were made. The analysis of the average data indicated that DH mutant/recombinant winter wheat lines can easily adapt to the cultivation conditions from experimented areal. Regarding productivity, experimented material presented superiority in terms compared with the average of known varieties used as control. The obtained results also showed genetic value of some mutant/recombinant wheat lines, which in addition to productivity present high quality.

Key words*: Triticum aestivum L., DH mutant/recombinant lines, yield, quality.*

INTRODUCTION

Diversification of genetic variability obtained as a result of mutations is an important factor in genetic progress of cultivated species. In plants, mutations have played a key role in their formation and adaptation to various areas and environmental conditions.

After the discovery of the mutagenic effect of X-rays in the early twentieth century and later of other physical and chemical mutagens, the natural genome of potentially useful variability of cultivated species was completed with artificially induced variability. Its inclusion in selection programs has made it possible to obtain valuable forms in a relatively short period of time. Many of these mutant forms have been and are used directly in cultivation as new varieties and others have been shown to be important sources of genes in various breeding programs.

The integration of the novel techniques and methods into wheat breeding programs is necessary to accelerated progress in producing of new wheat genotypes (Panita et al., 2020).

To National Agricultural Research and Development Institute - NARDI Fundulea, mutagenesis research has been initiated in order to diversify genetic variability for a number of agronomic traits. Mutant cultivars obtained so far are relatively few compared to those obtained by classical breeding, but interest in mutagenesis is growing, at least in some species, given the possibilities offered by the progress of genomics research to identify new genes produced under the action of factors mutagens (Giura, 2011). Also, by applying a specific mutagenic protocol at two wheat genotypes noted for superior agronomic properties and two irradiation cycles application, hybridization and DH technology (Barbu (Dobre) et al., 2018a) it were obtained new DH lines of wheat which proved to be more adapted than the existing genotypes in cultivation and climatic changes.

Mutagenic experiments carried out at NARDI Fundulea with traditional varieties, as well as with more modern cultivars of various sources, have led to hundreds of mutant lines. The better ones were included in a nationwide network of trials, with the aim of evaluating their agronomic potential.

The current perspective of increasing global temperature needs progress in breeding for heat tolerance and this is dependent on identification of more diverse gene sources (Giura et al., 2019).

Considering the great economic interest of wheat to all regions of the country, the average yield per hectare in Romania has the lowest level in the EU, even it is on a nationwide upward trend in the last years (Medelete et al., 2018). For this reason it is necessary to obtain new genotypes with high productive potential and increased adaptability to various environmental conditions. In this purpose the best mutant/recombinant lines were further tested in a series of trials conducted under a wide range of environments. They were compared with two standard genotypes: "Izvor" and "F00628-34". The trials started in 2015 and were carried out for three years at 6 locations. Izvor is a variety cultivated in the South part of Romania being known as drought tolerant and with high yielding ability in dry years because is carrying or recessive allele (controlling osmotic adjustment) on 7A chromosome (Banica et al, 2008), while improved line F00628-34 has a higher yield potential in areas without water stress and carries 1AL/1RS translocation (Saulescu et al., 2011).

In the South areas of Romania climate is drier in last years and the new wheat genotiypes has to perform in these condition and be able to offer a good answer to fertilizers applied. The new mutant/recombinant lines of wheat which were studied the gradual increase of doses of nitrogen fertilization is reflected by the increases in all grain yield components (Iancu et al., 2019).

The aim of this paper was to evaluate some quantitative characters of some DH mutant/recombinant wheat lines cultivated in South area in order to identify new genotypes or an interesting breeding material.

MATERIALS AND METHODS

Thirteen mutant/recombinant wheat lines developed at NARDI Fundulea were evaluated along two wheat genotypes for some quantitative and qualitative characteristics in the South Romania climatic conditions. DH lines obtained via maize hybridization are the most useful for research studies and for the breeding of new wheat cultivars (Ciulca et al., 2020).

These were sown in the field on a chernozem soil, medium rich in nutrient and with a humus content which varied between 3-4% (Matei et al., 2020), in the last decade of October after randomized blocks method in three replicates. Determinations were made during vegetation period and after harvesting. The interpretation of the results was based on variance analysis and Pearson corelation. Protein, starch and fibers content were determined using a Perten Infrared Analyzer. TKW and seeds weight was measured by an electronic caliper (100 randomly grains of each wheat line).

Data were statistically analyzed and means were compared by least significant differences (LSD), P = 0.05%.

RESULTS AND DISCUSSIONS

The climatic conditions during this research could be characterized as almost normal for the South region with values of temperatures higher than multiannual (Table 1) and precipitations which totaled 448 mm in 2017-2018 and 387.5 mm in 2018-2019 (Table 2).

The results concerning the rising density varied from 480 pl./m^2 (Bi II 40) to 600 pl./m^2 (Ai II 233) comparative with 496 pl./m^2 (Izvor variety) and 528 pl./m^2 (F00628-34 line) while harvest density presented values between 640 pl./m^2 (Bi I 40) and 800 pl./m^2 (Bi II 111) comparative with 680 pl./m^2 (Izvor) and 780 pl./m^2 (F00628-34) or 540.80 pl./m^2, respectively 706,40 pl./m^2 average of the experiment (Table 3).

For the DH mutant/recombinant lines taken under study, stem length presented values from 80.5 cm (Bi II 69) to 92 cm (Bi II 127). This higher limit was also registered for one control, F00628-34 line, while the other control, Izvor variety registered a smaller values of 88 cm.

The results concerning the spike length varied from 5.5 cm (Bi II 110) to 9.5 cm (Ai II 212) which emphasized a clear superiority comparative both with other lines, control and average of the experiment.

Analyzing yield potential of the mutant/recombinant wheat lines, it can be noticed the superiority of Bi II 40 line (7154 kg/ha) compared with Bi II 110 (4742 kg/ha) or average of the experiment (5945.27 kg/ha) and even the two controls Izvor (6437 kg/ha) and F00628-34 (6358.5 kg/ha).

Table 1. The variation of the temperatures and deviations from the multiannual values

Year \ Month		Oct.	Nov.	Dec.	Jan.	Feb.	March.	Apr.	May	June	July	Average
2017-2018	Value	12.1	6.5	3.1	0.8	1.00	3.8	16.1	19.6	22.1	21.9	10.70
	Deviation	0.9	1.2	2.9	-0.1	-0.4	-2.2	4.6	2.1	0.8	-1.3	0.85
2018-2019	Value	13.8	5.1	0.2	0.5	3.20	9.1	12	17.1	22.8	23.1	10.69
	Deviation	2.6	-0.2	0	-0.4	1.8	3.1	0.5	-0.4	1.5	-0.1	0.84
Multianual		11.2	5.3	0.2	0.9	1.40	6	11.5	17.5	21.3	23.2	9.85

Table 2. The variation of precipitation and deviations from the multiannual values

Year \ Month		Oct.	Nov.	Dec.	Jan.	Feb.	March	Apr.	May	June	July	Sum
2017-2018	Value	56	48	14	6.8	12.4	53	54	84.8	17.6	101.4	448.00
	Deviation	15.6	-4.4	-32.7	-31.3	-25.5	12.2	2.1	21.1	14.7	46.9	18.70
2018-2019	Value	7.4	46.8	53.4	38.6	14.2	25.2	44.4	69	28.5	60	387.50
	Deviation	-33	-5.6	6.7	0.5	-23.7	-15.6	-7.5	5.3	25.6	5.5	-41.80
Multianual		40.4	52.4	46.7	38.1	37.9	40.8	51.9	63.7	2.9	54.5	429.30

Table 3. Average data for the analyzed characteristics (2017-2019)

Genotype	Rising density (pl./m^2)	Harvest density (spike/m^2)	Stem length (cm)	Spike length (cm)	Yield (kg/ha)
Ai II 212	548cde	712efg	88.5abc	9.5a	5978.5bcd
Ai II 233	600a	688gh	84.5defg	8.5b	5535.0def
Ai II 236	536ef	664hij	85.5cdef	8.5b	5687.0def
Bi I 40	504gh	640j	88.5abcd	8.5b	5894.0cde
Bi II 40	480h	640j	83.0fg	7.5c	7154.0a
Bi II 57	572bc	664hij	84.5defg	9.5a	5880.5cde
Bi II 58	544def	728def	84.0efg	7.5c	6350.5bc
Bi II 69	548cde	752bcd	80.5g	7.5c	6448.5b
Bi II 82	536ef	696fgh	92.0a	8.5b	6402.5b
Bi II 109	572cd	768abc	91.5ab	8.5b	5324.0f
Bi II 110	584ab	736cde	85.5cdef	5.5d	4742.0g
Bi II 111	556cd	800a	86.0bcdef	6.5d	5458.5ef
Bi II 127	508g	648ij	92.0a	8.5b	5528.5def
Izvor (Ct.)	496h	680ghi	88.0abcde	8.5b	6437.0b
F00628-34 (Ct.)	528fg	780ab	92.0a	8.5b	6358.5bc
Average	540.80	706.40	87.07	8.10	5945.27
Std. deviation	33.81	52.37	3.64	1.06	596.87
C%	6.25	7.41	4.19	13.03	10.04
Min	480.00	640.00	80.50	5.50	4742.00
Max	600.00	800.00	92.00	9.50	7154.00
LSD 5%	27.11	35.01	4.18	0.89	501.57

So, in the rather fertile and dry soils of the Southern area (350-500 mm rainfall), DH mutant/recombinant wheat lines have to manage lately, so that often these present relatively short straw (80-90 cm), early maturing, rapid waxless.

Thousand grain weight (TGW) as the main physical indices of the quality were lower in some lines compared to the two controls and average of the experiments but it was also lines with higher values (Table 4). Thus, TGW varied between 37.45 g (Bi II 109) and 47.55 g

(Bi II 40). Similar values of those mentioned in this experiment reported Dobre (2016) in a set of 85 mutant/recombinant DH lines of winter wheat, and Ciulca et al. (2020).

The HW of grains for the DH mutant/ recombinant lines recorded values between 70.85 kg/hl (Bi II 127) and 73.35 kg/hl (Ai II 236). In the case of controls, Izvor variety presented 71.95 kg/hl while F00628-34 line proved superiority, registering the highest value 73.50 kg/hl. Average of the experimented presented a value of 72.21 kg/hl.

Table 4. Average data for the analyzed characteristics (2017-2019)

Genotype	TGW (g)	HW (Kg/hl)	Protein (%)	Starch (%)	Fibers (%)
Ai II 212	40.85de	72.15bc	12.80e	73.6c	15.50fg
Ai II 233	43.20b	72.35b	12.95d	73.2f	15.95de
Ai II 236	43.35b	73.35a	13.05cd	74.3b	14.20i
Bi I 40	44.75ab	73.15a	12.50f	74.9a	15.30gh
Bi II 40	47.55a	71.95b	13.05cd	73.4d	15.45fgh
Bi II 57	40.15def	72.15bc	12.50f	73.4df	16.85ab
Bi II 58	43.60b	71.85bc	13.10c	72.7h	15.30gh
Bi II 69	42.65bcd	73.15a	12.45f	74.2b	17.00a
Bi II 82	39.65ef	72.05bc	13.40b	74.1b	15.70efg
Bi II 109	37.45f	71.85bc	13.65a	73.0g	16.40bcd
Bi II 110	39.75def	71.15d	13.50b	72.2i	15.85ef
Bi II 111	42.75bc	71.75c	12.95d	72.7h	15.40fgh
Bi II 127	40.10def	70.85d	13.10c	72.0j	16.10de
Izvor (Ct.)	41.00cde	71.95bc	12.40f	73.3ef	14.95h
F00628-34 (Ct.)	40.05def	73.50a	11.90h	74.9a	16.35cd
Average	41.79	72.21	12.89	73.46	15.75
Std. deviation	2.52	0.77	0.47	2.26	0.73
C%	6.03	1.07	3.64	5.28	4.63
Min	37.45	70.85	11.90	72	14.20
Max	47.55	73.50	13.65	74.9	17.00
LSD	3.02	0.52	0.11	0.19	0.49

In terms of protein content it was identified lines with higher content such as: Bi II 109 (13.65%), Bi II 110 (13.50%), Bi II 58 (13.10%). These lines overcome the control and the average of experiment and confirm the genetic potential for high quality.

As concern starch content, minimum value was 72%, registered by Bi II 127 line while the maximum value was 74.9%, registered by Bi I 40 and F00628-34 lines. Izvor variety registered 73.3% while the average of the experiment was 73.46%. Panita et al., (2020) sustain that lines with higher grain protein contents presented lower starch percent.

Fibers content varied between 14.20 (Ai II 236) and 17.00% (Bi II 69), with 14.95% Izvor variety, 16.35% F00628-34 and 15.75% average of the experiment.

For all analyzed characteristics C% presented values under 10% which means small variability, an exception making spike length which recorded 13%.

Evaluation of DH mutant/recombinant forms is necessary in order to speed the advancement of those who is carrying superior traits (Dobre et al., 2018b). Selection of new genotypes with desirable traits from the genetic diversity is crucial for the adaptability and survival of wheat under climate fluctuations, which are expected to become a major constraint for plants potential in the future. Lines such as Bi II 40, Bi II 58 and Bi II 82 combine well yield capacity with protein and even starch content.

It was also establish the correlations between the analyzed characteristics, knowing these can streamline the selection process to improve plant performance (Table 5). According to Taulemesse et al. (2016), the quality and productivity are negatively correlated, but this association is often caused by the influence of environmental conditions. This experiment indicates this negative correlation with protein (-0.535), but not in starch content (0.659). Also, starch content presented a positive correlation with HW (0.926). Yield is positive correlated with rising density (0.659) and harvest density (0.643).

Table 5. Correlations between the analyzed characteristics (2017-2019)

Characters	Rising density (pl./m^2)	Harvest density (pl./m^2)	Stem length (cm)	Spike length (cm)	Yield (kg/ha)	Harvest humidity (%)	TGW (g)	HW (kg/hl)	Protein (%)	Starch (%)
Harvest density (pl./m^2)	0.465**									
Stem length (cm)	-0.181^{ns}	0.062^{ns}								
Spike length (cm)	-0.142^{ns}	-0.405**	0.360*							
Yield (kg/ha)	0.659**	0.643**	-0.181^{ns}	0.476**						
Harvest humidity (%)	0.362*	-0.373*	-0.165^{ns}	-0.162^{ns}	-0.572**					
TGW (g)	-0.431**	-0.407**	-0.613**	-0.183^{ns}	-0.492**	-0.056^{ns}				
HW (kg/hl)	-0.489**	0.486**	-0.141^{ns}	0.322*	0.346*	-0.019^{ns}	0.573**			
Protein (%)	0.308*	0.003^{ns}	0.086^{ns}	-0.343*	-0.535**	0.143^{ns}	-0.581**	-0.619**		
Starch (%)	-0.270^{ns}	-0.077^{ns}	0.069^{ns}	0.417**	0.659**	-0.090*	0.212^{ns}	0.926**	-0.587**	
Fibers (%)	0.377*	0.312*	-0.020^{ns}	0.071^{ns}	-0.053^{ns}	0.049^{ns}	-0.418**	-0.059^{ns}	-0.163^{ns}	-0.058^{ns}

P 5% = 0.310; P 1% = 0.400

In ARDS Caracal conditions it can ensure high production capacity and quality of grain in other species like sorghum, which is proving to be a species with real capacities of extension due to its adaptability in this area (Matei et al., 2020).

Meteorological data sustain that the average air temperature has risen by 2-3^{0}C, in the case of summer, in regions in the south of the country. The mutant/recombinant lines should be earliness and also the control genotypes so that the ideal type for Southern conditions to be rather early than late in order to better cope with the environmental characteristics and provide the necessary duration of time for optimal yield.

The assessment of quantitative and qualitative components of mutants/recombinant lines that overcome the control varieties is obvious even in the different environment conditions from the experiment period.

Under the South conditions, some tested DH mutant/recombinant lines (Bi II 40, Bi II 58, Bi II 69, Bi II 82) proved to be able to adapt and the obtained data for the agronomic characteristics analyzed, as assessed in several years of field evaluation indicate a common, remarkable feature which is the much improved resistance to higher temperature, a slight-to-highly improved yielding ability in altered heating time. DH mutant/recombinant lines taken into study proved a stable and high genetic potential, significantly superior comparative with controls and could be considered as an interesting material for future breeding programs. Exploitation and utilization of superior genes and multiple variations can be helpful approaches for improving wheat production (Daniel et al., 2018).

CONCLUSIONS

The experimental results obtained for the mutant/recombinant wheat during the experimental period 2017-2019 showed that best yield were established to Bi II 40 (7154 kg/ha), Bi II 69 (6448.5 kg/ha) and Bi II 82 (6402.5 kg/ha) lines. First two overcome the average of the controls, 6437.0 kg/ha Izvor variety and 6358.5 kg/ha F00628-34 line.

Best protein content in the DH mutant/recombinant lines was established to Bi II 109, Bi II 110 and Ai II 236 with values higher than 13%.

Under the South of Romania conditions, some of tested DH mutant/recombinant lines proved to be able to adapt to these, registering superior values of TGW, HW, protein content and improved yield capacity. These lines can be used as valuable genetic material in wheat breeding.

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YIELD OF CRUDE PROTEIN AND RATE OF ACCUMULATION IN THE DRY MATTER IN A NATURAL GRASS ASSOCIATION USED IN PASTURE AND HAYMAKING REGIME IN THE CONDITIONS OF THE CENTRAL BALKAN MOUNTAIN

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Abstract

The experiment was conducted on a natural meadow type Chrysopogon gryllus - Agrostis capillaris, widespread in the mountainous regions of Bulgaria. Two regimes of use (PR-pasture and HR-haymaking) of grassland in the following variants concerning the harvesting period were studied: PR1 (Control: 31 May - 09 June); PR2 (10 June - 19 June); PR3 (20 June - 29 June) and HR1 (Control: 30 June - 9 July 9); HR2 (10 July - 19 July); HR3 (20 July - 31 July). It was found that the method and period of harvest in the natural mountain association affects the increase in yield and crude protein content. In the pasture and haymaking regime of use, the growth rate of the indicators was the highest, respectively, the highest crude protein production was registered during the harvesting period on 10-19 June (67.42%) and 20-30 July (129.16%), while the highest crude protein content was registered on 20-29 June (55.07%) and 20-30 July (69.95%). The highest increase in dry matter yield was registered in the second decade of June (10-20) for pasture use (14.42%) and at the end of July (20-31) for haymaking (35.77%).

Key words: *natural grassland, Chrysopogon gryllus - Agrostis capillaris, pasture and haymaking regime of use, crude protein yield.*

INTRODUCTION

Natural plant communities in the mountain regions of Bulgaria are an important feed resource for farm animals. The monitoring of bioproductive potential of natural grasslands related to meadow and pasture ecotypes, which are an essential natural fodder reserve, is directly related to the animal breeding for agriculture. Various measure on the surface are applied such as restorative mowing (Huhta et al., 2001). Mowing at different stages, different ways and systems of fertilizing and regrowth (Cosentino et al., 2002; Kulakov et al., 2015) in these areas stimulate the development of valuable species and increase the beneficial effects on grass vegetation (David et al., 2002). Properly applied management practices, including environmentally friendly ones (Kulakov & Sedova, 2013), as well as combined measures such as lawn cleaning and fertilizing with organic or mineral fertilizers (Kozhouharov & Lingorsky, 2012) are essential and have a direct impact on the chemical composition of grasslands (Popescu and Churkova, 2015; Mrázková et al., 2020).

The careful and purposeful approach among them is a prerequisite for better distribution of components in plant communities and production of feed biomass with high economic value (Vîntu et al., 2011; Fattahi & Ildoromi, 2011; Zziwa et al., 2012). The choice of an appropriate mowing date and the technology for the utilization of the aboveground mass has a beneficial effect on the botanical composition, productivity and longevity of meadow and pasture vegetation (Stevanovıć et al., 2008; Pellegrini et al., 2010).

The sharp reduction in the number and types of perennial meadow grasses requires a purposeful and regulated selection of agrotechnical events for the maintenance and implementation of systems of use. In pasture and haymaking, the time of grazing and mowing affects the yield and variability in the floristic composition of the grassland (Kemp & Michalk, 2005). Knowledge of these patterns aims to create conditions for better development of more valuable species in different botanical groups (Bovolenta et al., 2008) and increase the quality of fodder biomass. Grass communities respond to changes in the environment both through species turnover and through intraspecific biological and morphological changes (Volf et al., 2016). Species of local origin form highly productive and long-lasting grasslands (Naydenova & Mitev, 2008). The mode of use may be associated with their limited distribution or create conditions for their more stable share in the grassland over the years. Pasture harvesting stimulates lower-growing species (Li et al., 2013), and haymaking of grass cover provides more favorable conditions for the development of high-growing species from the group of grasses and some legumes.

The aim of the experiment was to monitor the rate of accumulation in the crude protein yield, in the natural mountain grass association, in pasture and haymaking regime of use.

MATERIALS AND METHODS

The experiment was conducted in the period 2013-2017, on a meadow of *Chrysopogon gryllus-Agrostis capillaris* type, at the foot of the Central Balkan Mountains (latitude N – 42° 54' 37', longitude E – 24° 41' 31'' and 515 m), Bulgaria. The change in crude protein yield was monitored in two main modes of use and three harvest periods (early, medium-early and late with corresponding dates). The design of the selected experimental site covers a total area of 300 m^2 and includes a model by the block method in 4 replications for with a size of the experimental (randomized) plot of 10 m^2.

The experiment includes the following variants:

I. Pasture harvesting (PH):

PH1 - Pasture (Control) from 31st May to 9th June

PH2 - Pasture from 10th June to 19th June

PH3 - Pasture from 20th June to 29th June

II. Hay-making harvesting (HH):

HH1 - Mowing (Control) from 30th June to 9th July

HH2 - Mowing from 10th July to 19th July

HH3 - Mowing from 20th July to 31st July

The periods of pasture and hay-making harvesting were conducted in the phenophase of tasseling/ear formation and in the phenophase of flowering of bunch grasses and common bentgrass until the initial phases of insemination at the edificators of the grass community.

After harvesting in stages at each of the periods/dates of study, the grass samples (each weighing 1 kg) were collected and dried in laboratory conditions at 105°C, and recalculated for an area of 1 ha based on the dry matter content. The crude protein yields were obtained by grass samples, who had been pre-prepared by drying and grounding in an electro-mechanical grinder. The samples were taken from each of the studied variants/harvesting dates.

The crude protein content (CP, %) was determined by the *Kjeldahl* method (according to BDS - ISO-5983).To decompose the organic matter, the sample was boiled with H_2SO_4 in the presence of a catalyst. The acidic solution was alkalified with sodium hydroxide solution (NaOH). The ammonia was distilled and collected in a certain amount of sulfuric acid (H_2SO_4), the excess of which was titrated with a standard solution of sodium hydroxide NaOH. Alternatively, the separated ammonia was distilled off in excess of H_3BO_3 solution and then titrated with HCl or H_2SO_4 solution.

Crude protein yield (kg/ha) was calculated as the product of dry matter yield (kg/ha) and crude protein content in (g/kg).

Botanical changes in grassland (%) were determined by: analysis of fresh grass samples prepared by weight method, taken immediately before mowing the experimental randomized plots, establishing the percentage of the main botanical groups (grasses and legumes) and motley grasses (total).

The experimental area (natural mountain meadow) was used without management, so in the autumn of the third experimental year we applied stockpile combine fertilizing with $P_{120}N_{80}$.

The data processing to track the dynamics of crude protein on two bases (chain and constant) is with the program *StatSoft Inc.* (2010). STATISTICA (*data analysis software system), version 10.* Retrieved from statsoft.com.

Agroclimatic characteristics in the area of the experiment.
The climate in the studied region (The Central Balkan Mountain region) part of the mountain range of the Balkan Mountains is humid continental. During the experimental years, it has an impact on the development of natural grass communities, which manage to form one regrowth of grass mass per year. In 2014, the vegetation and autumn-winter precipitation marked the highest amount (1164.9 mm) compared to the other experimental years, but this did not significantly affect the growth of legumes in the studied grassland (Figure 1). The relative difference in the precipitation amount in 2015 (922.7 mm) and 2017 (983.2 mm), as well as in 2013 (807.3 mm) and 2016 (837.0 mm) compared to the maximum value of the feature varied from 18.5 to 26.2% and from 39.2 up to 44.3%, as the distribution of precipitation was most favorable for sustainable growth of grass species during the last two experimental years (2016 and 2017).

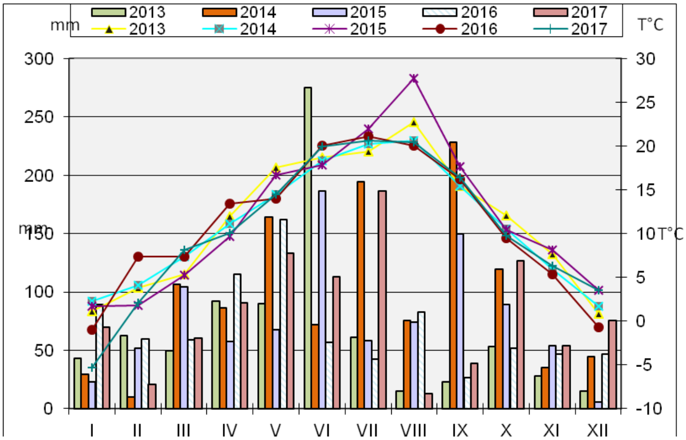

Figure 1. Average monthly temperatures (°C) and monthly precipitation amounts (mm) of 2013-2017

For the experimental period, in 2015 were registered the highest average air temperature (11.9°C) and the highest average temperature for July, August and September (22.4°C), which did not have a significant impact on the productivity of the plant community. The relative difference in average air temperatures for 2013 (11.4°C), 2014 (11.0°C) and 2016 (11.1°C) varied from 0.9 to 3.6%. The temperature regime data show that the lowest average annual temperature (10.5°C) was in 2017, which in turn favorably affects the growth and development of more unstable protein component in grass communities (legumes stimulate their growth more intensively in combination from lower air temperature and higher humidity in late spring and summer months). The study of the data shows that in the fifth experimental year, the active vegetation of plants in the grasslands begins at the highest average temperature in March (8.1°C) compared to other experimental years and this in combination with abundance and distribution of precipitation provoked good quality of grass vegetation.

RESULTS AND DISCUSSIONS

Yield and increase rate in the amount of crude protein.
Crude protein yield is an aggregate indicator important in assessing natural grass associations and systems to improve and maintain them. It combines the two main indicators of productivity and quality of biomass produced, mainly through the amount of crude protein produced, which is very important for animal husbandry and determines the quality of grass biomass.
On average over the five-year experimental period, haymaking yields resulted in a higher yield of crude protein (278.0 kg/ha) compared to pasture (240.7 kg/ha) (Table 1). Among the haymaking variants, the most productive is the

one with harvesting/mowing in the period from 10-19 July (323.0 kg/ha). In pasture use, the highest yield of crude protein (287.0 kg/ha) was obtained in the variant with the latest harvesting of grassland in the period of 20th June - 29th June.

Table 1. Yield of crude protein (kg/ha) in pasture and hay-making harvesting, over the years and average for the period

Variants	2013	2014	2015	2016	2017	2013-2017
PH1	192.2	78.3	82.1	144.6	341.3	159.3
PH2	176.0	194.9	218.2	269.8	496.1	275.8
PH3	201.8	170.8	268.5	314.9	442.7	287.0
Average	**190.0**	**148.0**	**189.6**	**243.1**	**426.7**	**240.7**
HH1	172.4	120.4	135.8	524.5	323.0	259.0
HH2	278.4	222.9	203.1	462.6	436.9	323.3
HH3	125.5	305.4	221.8	424.8	198.2	251.6
Average	**192.1**	**216.2**	**186.9**	**470.6**	**319.4**	**278.0**

The maximum amount of crude protein for the first year was found in the second period (HH2) of hay-making harvest with 278.4 kg/ha, while the lowest yield of 125.5 kg/ha was obtained in the third hay-making period (HH3). In the pasture regime, the lowest yields were obtained in the second year of the study (2014) with 78.3 kg/ha in variant PH1, as the average for the year of the three terms of pasture harvesting was 148 kg/ha.

In the third experimental year (2015), the most significant quantitative accumulation of crude protein was in the third period of pasture mowing (PH3) – 268.5 kg/ha. The first period of pasture harvesting (PH1) had the slightest accumulation rate with 82.1 kg/ha. The average annual yield of crude protein in the third experimental year (189.6 kg/ha) obtained during the pasture harvesting periods (PH1, PH2 and PH3) was 1.4% higher than the hay harvesting periods (186.9 kg/ha).

A sharp positive reversal in the dynamics of the amount of crude protein (CP) was obtained in the fourth experimental year (2016). The quantitative accumulation of protein was significant in both pasture and hay-making periods of mowing. The results show that the peak of the quantitative indicator during the first three periods for pasture harvesting reached 314.9 kg/ha, obtained in the time frame of harvesting 20.06-29.06 (PH3).

Table 2. Increase rate (%) on the amount of crude protein (on a constant basis), by years and average for the period

Variants	2014	2015	2016	2017	**Average increase rate**
PH1	-59.23	-57.27	-24.75	77.63	-15.91
PH2	10.69	23.94	53.27	181.78	67.42
PH3	-15.34	33.05	56.06	119.38	48.29
Average	**-22.10**	**-0.21**	**27.95**	**124.58**	**32.56**
HH1	-30.17	-21.20	204.25	87.38	60.07
HH2	-19.94	-27.04	66.15	56.95	19.03
HH3	143.37	76.76	238.55	57.97	129.16
Average	**12.56**	**-2.69**	**145.00**	**66.27**	**55.29**

This is confirmed by the relative values in the increase of crude protein calculated on a constant basis (model tracking the dynamics of change in relative values of crude protein in subsequent experimental years compared to the first year), where according to the values of the attribute the indicated variant (PH3) exceeded the first year by 56.06% and 17.30% in a direct comparison on the model year compared to year (chain basis). On average for the fourth year of the pasture harvesting period, the quantitative indicator (crude protein yield) registered a positive difference on a constant basis compared to the first year by 27.95%, while on a chain basis the increase reached 28.23% (Tables 2 and 3). The upward trend continues with regard to the periods of hay-making (HH1, HH2), where crude protein yields reached maximum values (HH1 on June 30-July 9) with 524.5 kg/ha and the increase on a constant basis was 204.25% compared to the first year, and on a chain basis with 286.09%.

On average for the fourth year, the increase of constant and chain bases was from 145.0% to 151.77%.

In the last (fifth) experimental year (2017) the tendency for progressive increase of crude protein yields compared to the previous one was preserved. The yield of crude protein was 33.6% higher in the variants with pasture harvesting than hay harvesting. The average yield for the year was 426.7 kg/ha, as the largest increase (496.1 kg/ha) of the indicator was measured in the second period of pasture harvesting (PH2 - 10.06. - 19.06.). The increase in crude protein yield on a constant basis was 181.78%, and on a chain basis it was 83.4%. In the haymaking regimes, the most significant increase rate of crude protein was in the first hay-making regime (HH1 - June 30-July 9). On a constant basis, the increase rate was 87.38%. The values are negative (-38.41%) compared to the previous year when calculating the chain basis.

Table 3. Increase rate (%) of the amount of crude protein (on a chain basis), over the years and average for the period

Variants	2014	2015	2016	2017	**Average increase rate**
PH1	-59.23	4.81	76.11	136.07	39.44
PH2	10.69	11.97	23.67	83.84	32.54
PH3	-15.34	57.15	17.30	40.58	24.92
Average	-22.10	28.09	28.23	75.52	27.43
HH1	-30.17	12.86	286.09	-38.41	57.59
HH2	-19.94	-8.87	127.72	-5.54	23.34
HH3	143.37	-27.37	91.53	-53.34	38.55
Average	12.56	-13.55	151.77	-32.13	29.66

During the study period, the increase in crude protein yield, calculated on a constant basis, marked significant differences depending on the harvesting method. The average value of the indicator for the variants of pasture harvesting (32.56%) is a positive value, lower by 69.8% compared to hay-making of grasslands (Table 4). For PH1 (May 31-June 9) the average value is negative (-15.91). The highest increase rate of yield was in PH2 (June 10-June 19) (67.42%).

The results obtained on a chain basis are completely opposite (Table 3), where the average value of the indicator in the variants with pasture harvesting is negative (-22.10), and in hay-making harvesting is positive (12.56). The reason for this is the negative values (-59.23 and (-15.34) of the indicator for the pasture variants at the beginning (PH1 - 31 May - 9 June) and at the end of June (PH3 - 20 June - 29 June).

Regarding the crude protein content, the average value (27.30%) calculated on a constant basis was lower compared to the protein yield (32.56%), where in PH1 increase values are negative (-9.80%).

The percentage increase in protein on a chain basis (23.81%) was significantly higher compared to the negative value of protein yield (-22.10).

In terms of dry matter yield, the increase calculated on a constant basis (0.79%) and on a chain basis (15.65%) is less significant compared to the increase in protein content and protein yield.

In **hay-making harvesting** the average increase in protein yield (55.29%) was higher by 22.73% compared to pasture harvesting. The values for all variants are positive as the highest values were registered in the grasslands of variant HH3 (July 20-July 31). This is significantly influenced by the higher increase in crude protein content in the specific harvesting regime.

The increase in the dry matter yield in hay-making harvesting, calculated on a constant basis with 13.76%, was significantly higher compared to that in pasture harvesting. The results obtained on a chain basis are completely opposite, where the values in the increase of the dry matter yield are about 2 times lower. There was a proven accumulation of crude protein in a direct comparison (each against each other) of the experimental years.

In conclusion, the comparison in the increase of indicators, such as crude protein yield, crude protein content and dry matter yield shows that during hay-making the increase in the values of these quality traits is significantly higher compared to pasture harvesting.

The higher increase in crude protein yield is due to the higher increase in crude protein content in biomass, determined by the higher share of legume grass species in the botanical composition of the grassland.

Table 4. Average increase (%) of crude protein yield, crude protein content and dry matter yield, as a percentage of constant basis (compared to the first year) and chain basis (compared to previous years)

Variants	Crude protein yield		Crude protein content		Dry matter yield	
	Constant basis	Chain basis	Constant basis	Chain basis	Constant basis	Chain basis
Pasture harvesting						
PH1	-15/91	-59.23	-9.80	20.01	-12.15	18.64
PH2	67.42	10.69	50.55	29.30	14.42	18.36
PH3	48.29	-15.34	55.07	26.23	-1.60	14.95
Average	**32.56**	**-22.10**	**27.30**	**23.81**	**0.79**	**15.65**
Hay-making harvesting						
HH1	60.07	-30.17	56.15	65.78	4.62	8.57
HH2	19.03	-19.94	12.94	24.48	6.55	8.20
HH3	129.16	143.37	69.95	20.89	35.77	8.91
Average	**55.29**	**12.56**	**42.63**	**31.03**	**13.76**	**6.63**

Significantly lower increase in dry matter yield shows that the yield of crude protein (as a total indicator combining productivity and quality indicators) is more significantly influenced by quality indicators, such as crude protein content and the share of legume species in the established grasslands.

The data in Figures 2 and 3 follow the increase dynamics of the legume component. Legume species significantly dominate the botanical composition of the final experimental years (2016 and 2017), both in pasture and hay-making harvesting periods. In the first year of pasture harvesting (for PH1, PH2 and PH3) the share of legumes was respectively 2.0%, 0.0%, 0.0%, while in the second 0.0%, 6.7% and 5.4%. In the fourth experimental year (2016), the amount of legumes increased to 22.6%, 44.8% and 45.0%, respectively. These values of legumes, to some extent, explain the sharp rise in the amount of crude protein.

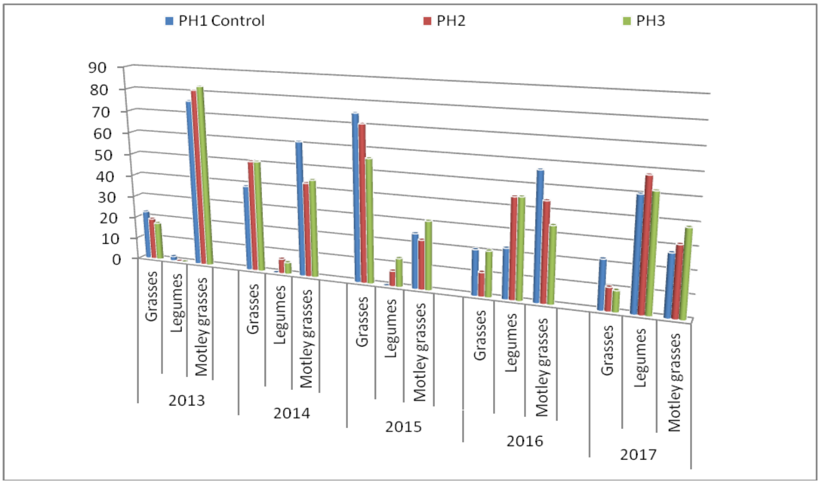

Figure 2. Botanical composition over the years and main plant groups on natural grassland of *Chrysopogon gryllus* L.-*Agrostis capillaris* L. type in pasture harvesting periods

The high content of legumes in the grass mass is directly related to the high content of crude protein (Nilsdotter-Linde et al., 2016; Kovtun et al., 2020) and minerals (P, K, Ca, Mg) in the forage mass.

In the first three experimental years, grasses dominated both in pastures and hayfields. After additional fertilizing (combined mineral fertilizing), the increase, quantity and species diversity of legumes increased and affected the content of crude protein in biomass.

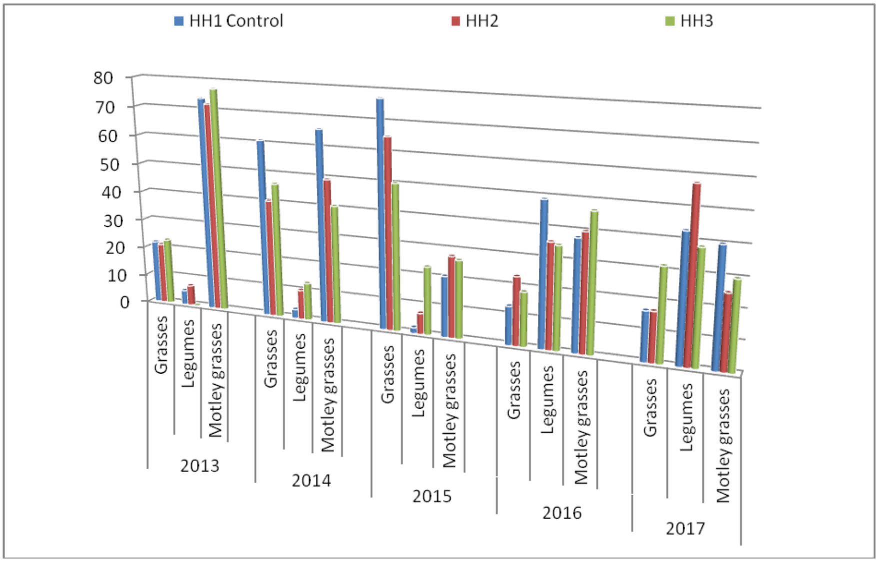

Figure 3. Botanical composition over the years and main plant groups on natural grassland of *Chrysopogon gryllus* L.-*Agrostis capillaris* L. type in pasture harvesting periods

A similar increase rate can be observed in the hay-making regime (Figure 3), where in the periods (HH1, HH2 and HH3) the content of legumes in the first year was 5%, 7.0% and 0.0%, respectively. After the applied agrotechnical events and regimes of use, the increase of the protein component (the group of legumes) in the last year of the experiment (2017) was 43.1%, 57.7% and 38.5%, respectively. The third hay-making variant (HH3 from July 20 to July 31) is particularly impressive, where the most harmonious increase in the relative amount of legumes was found throughout the experimental period. For this variant, the results in the years are: 2013 (0.0%), 2014 (12.9%), 2015 (23.3%), 2016 (34.8%) and 2017 (38.5%). Legumes significantly increase the quality of grass biomass.

CONCLUSIONS

It was found that the method and period of harvesting in the natural mountain association affected the increase in **the crude protein yield**. The value of the indicator in pasture harvesting (32.56%) is a positive value (on a constant basis) and lower by 69.8% in hay-making. On a chain basis, the production of CP, in biomass on 31.May-09.June (-59.23) and 20.June-29. June (-15.34) was negative, which determines the low value of the indicator (-22.10%) in pasture harvesting. Hay-making harvesting of grasslands (in the period July 20-July 31) had a positive effect on the increase in the yield of CP (12.56%).

The increase in **the content of CP** in the regimes of use on a constant basis is respectively 19.3% (27.30-IP) and 29.7% (42.63-CP) lower than that of CP yield. The rate of increase in the content of CP in pasture harvesting, on a chain basis (23.81%) is significantly higher compared to protein yield. The hay-making regime allows a more balanced ratio in the values of the indicators of yield and content of CP (12.56: 31.03).

In pasture harvesting of the grassland, the increase in **dry matter yield** established on a constant basis (0.79%) is significantly lower compared to haymaking (13.76%). The opposite trend is observed when established on a chain basis. The values of the indicator are higher in pasture (15.65%) compared to hay-making harvesting of grassland.

The increase in the studied indicators shows that the increase in crude protein yield during hay-making harvesting is significantly higher compared to pasture harvesting. The increased share of legumes is a prerequisite for higher protein content and higher quality biomass.

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NEW SOYBEAN VARIETIES VARIABILITY BY PLANTS MORPHOLOGY FROM ECOLOGICAL WHITE LUVIC SOIL CONDITIONS

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Abstract

Recent studies have shown that the analysis of morphological traits in soybeans could provide new directions in the breeding process. Having a rich genetic diversity, the plant manifest itself in close connection with the concrete conditions in the crop environment. In the present study, two early soybean varieties were compared: Cristina TD and Onix, which are recommended by their performance in farm conditions. In both varieties, some new directions have been found, these being recently improved, namely through improved morphological characters. In the comparison between the two varieties, the plants had a height of 69 cm in Cristina TD and 65 cm in Onix. In the same order the wieght of the average plant was 24 g to 27 g, with a number of about 4 branches. The number of pods on a plant was 31 (Cristina TD) to 40 (Onix), weighing 12 g and 15 g. The number of beans on an average plant was 67 to 85, weighing 6.9 g at 8.5 g, the number of grains in a pod was approximately equal to 2.13-2.15. the grain had the length in favor of the Cristina TD variety, 7.1 mm to 6.7 mm for Onix, and the grain thickness ranged between 5.3 and 5.5 mm. The mass of one thousand grains exceeded 100 g in Cristina TD (104.5 g) and was below 100 g in Onix (98.4 g). The number of grains and their weight were positively correlated with the other characters in both varieties, while the mass of one thousand grains depended more on the weight of the grains and their thickness in the Cristina TD variety. The study of the morphological characters of the two new soybeans varieties demonstrated a good adaptability in the conditions of the white luvicsoil from the south of the territory.

Key words: *branches, grains, pods, soybeans, variability.*

INTRODUCTION

Known for a very long time (Lee et al., 2011), soybean [*Glycine max* (L.) Merrill, pro syn *G. angustifolia* Miq., *G. gracilis* Skvort., *G. hispida* (Moench) Maxim] proves very favorable agronomic (Conner et al., 2004; Mureșanu et al., 1999; Mureșanu et al., 2016) and culinary qualities (Riaz, 2006; Shekhar et al., 2016; Heuzé et al., 2017; Hu et al., 2019). Thus, the plant in a relatively long period of vegetation, namely in the first three seasons, fixes atmospheric nitrogen (N_2) (common feature of all species in the family *Fabaceae*), structures and enriches the soil in nitrates (NO_3), directly assimilable and ensures proper crop rotation. Atmospheric nitrogen fixation is based on the activity of symbiotic bacteria of the *Bradyrhizobium* type, with which the conversion of N_2 into ammonia takes place, by a path of the type: a) $N_2+8H^++8e= 2NH_3+H_2$ and then in assimilable form expressed by the ammonium ion: b) $NH_3+H^+= NH_4^+$). In nodules the bacterium produces amino acids, with which protei are formed (Endres, 2001). After harvesting the plants, the nodules left in the soil decompose, and the acumulated amino acids are also converted biologically into nitrates (NO_2^-). They become available mainly for wheat plants that usually follow in crop rotation. Soybeans are rich in protein and oil which together represent 56% of the total: 36% protein and 20% oil. The differences is 30% carbohydrates, 9% water, and the remaining 5% ash (Hu et al., 2019). At the same time, soybeans contain significant amounts of phytic acid, a wide range of minerals and B vitamins (Riaz, 2006; Shekhar et al., 2016). From a genetic point of view, soy manifest a high polymorphism (Singh et al., 2006; Schmutz et al., 2020). Of these, *Glycine max* (L.) Merrit has characteristic of 2n = 2x = 40. From botanical point of view, soybeans produce 2-4 grains in the pod,rarely more, these having a globular shape, 5-11 mm in diameter, and the colors have various shades between green, yellow, brown and black. To study the variability of morphological traits in new cultivated soybean varieties, the following were determinated: height, number of branches, plant weight, number and weight of pods, number and weight of beans, number of beans in a pod, grain size and mass of thousand grains (MTG).

MATERIALS AND METHODS

The determinations were made during September in the last two years. Plants were chosen from experiments located in the specific field of research. He cultivation technology was the one recommended by the resort. At maturity, 25 plants were hervested in 4 replicates (a total of 100 plants). The cultivated varieties were *Onix* and *Cristina TD*, which has the following characteristics: they are new varieties, with improved characters, from the semi-early category (00), with determined growth and which form yellow, spherical flattened grains, with an absolute mass over 100 g. The plants harvested in the field were brought to the laboratory and dried for a few days to obtain the lowest possible humidity (equilibrium). The height and weight of the whole plant were measured, the brances formed on the stem, the number and weight of pods formed, the number, weight and thickness of the grains were counted, then the absolute mass of the grains in the form of a thousand grains. The results obtained represent the average of the two years of crop. The obtained morphological characters were analyzed by the method of histograms (frequency polygons). Both class intervals and absolute values were used in the method. The study highlighted several aspects, namely: modal values (MV), the limits od the intervals of variability of the studied characters and the specifics of each character of the varieties in the analyzed area. Simple causal links were established between the determined characters, with the help of which some trends could be observed by comparing the two varieties. The testing of the vakues was done with the theoretical values for the transgression probabilities for 0.5%, 1% and 0.1%. expressing values was used with Excel. In the statistical calculation of all the determined characters, the analysis of variance (anova test) was used, namely on the variation strings. Statistical parameters were calculated using the formulas: $\bar{a} = \Sigma x/n$, where $\bar{a}$ = average of the determinations, and x = determined values, s^2 (variance) = $1/n\text{-}1[\Sigma x^2\text{-}(\Sigma x)^2/n]$, s (standard error) = $\sqrt{S^2}$, VC% (variation coefficient) = $s/\bar{a}.100$.

RESULTS AND DISCUSSIONS

Variability of some plant characters. In general, high-growth soybean varieties are characterized by relatively low plant heights. In absolute value, the waist can reach 75-110 cm. The positioning of the stem is vertical, which is an advantage for the total mechanization of the plant. The characteristics of the two varieties covered some specific aspects. Thus, from the determinations made, the varieties showed similar plant lengths between 50 and 85 cm (Figure 1). They dominated the plants between 65 and 70 cm for the *Onix* variety (26-27%) and 75 cm for the *Cristina TD* variety (25%). Plants with small lengths (50 cm) accounted for both 2%, and the largest (80 cm) accounted for 2-3% of the total.

The total weight of the plants was between wide values, namely between 10 g and 70 g. Both varieties dominated the plants with 25 g (23% and 30%, respectively) (Figure 2). In both varieties there was a tendency to form plants with total weights around 60-70 g.

Regarding the number of branches on a plant, it was between 2 and 12. Dominated the plants with 2 branches (31%) in the *Onix* variety and those with 4 branches per stem in the *Cristina TD* variety (Figure 3). And in the case of the branches formed on a plant, there is a tendency to amplify the branching on the stem towards 10-12 pieces. Among the varieties, *Onix* branched approximately similar to *Cristina TD* (Figure 4).

Variability of soybeans pods and beans. One of the improved characters obtained was the number of pods on a plant (Figure 5). The relatively wide range determined was between both varieties between 10 and 100. The modal value was for both 40 pieces on a plant, with frequencies of 32% for *Onix* and 39% for *Cristina TD*. From the obtained data it was found that there is a tendency of the *Onix* variety to form a relatively higher number of pods than *Cristina TD*.

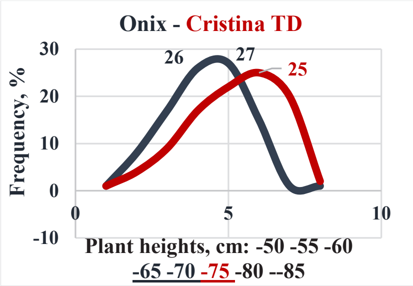

Figure 1. Frequencies of soya plants height

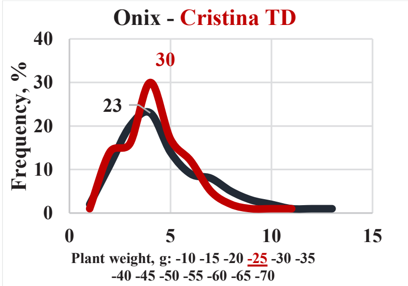

Figure 2. Frequencies of soya plants weight

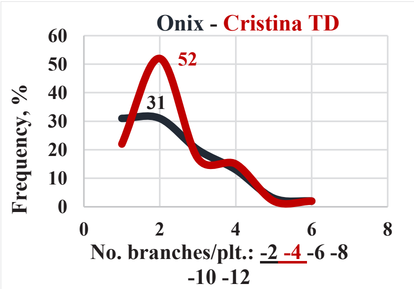

Figure 3. Frequencies of no. of branches/plant

Figure 4. *Onix* soybean variety

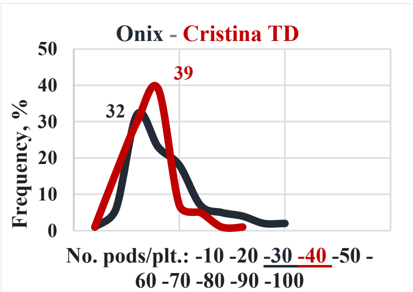

Figure 5. Frequencies of no. of pods/plant

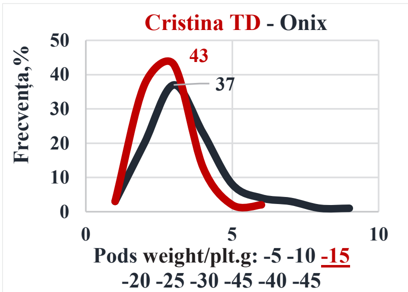

Figure 6. Frequencies of pods weight/plant

The weight of those pods on a soybean plant ranged from 5 to 45 grams. In both dominant varieties were plants that had a total pod weight of 15 g (Figure 6). At this modal value, the *Cristina TD* variety had a frequency of 43%, and the *Onix* variety at 37%. The weight of the pods on a plant shows the same tendency for the *Onix* variety to form pods with a higher total mass, i.e. around 40-45 g.

In these pods the plant forms a number of grains, depending on the genetic capacity of the variety, soil quality, climatic conditions and cultivation. In both varieties, between 30 and 250 grains of a plant were determined (Figure 7). The modal value was 70 grains similar to the two varieties, but with frequencies of 31% for *Cristina TD* and 29% for *Onix*. And in the case of the number of berries on a plant, the *Onix* variety showed a tendency to form more grains, namely over 200/plant. The density and appearance of *Cristina TD* plants are shown in Figure 8.

The weight of grains on a plant was generally between 2 g and 24 g in both varieties, however, the modal values were differentiated, namely at 6 g/plant in *Cristina TD* (31%) and at 8 g/plant in *Onix* (31%). The expression of the *Onix* variety also included plants with the total mass of the grains at slightly higher values, namely over 20 g (Figure 9).

The number of grains in a pod ranged from 1.8 to 2.8 (Figure 10). The pods dominated with

2.2 berries in both varieties, but with the modal values of 41 % in the *Cristina TD* variety and 31% in the *Onix* variety.

The size of the soybeans refer to the length and thickness/width. The data obtained showed differences between the two varieties. Thus, the grain length was generally between 4 and 8.5 mm (Figure 11). Dominant were the grains with 7 mm in the *Cristina TD* variety (27-28%) and those with 7.5 mm in the *Onix* variety (23%). Wider grain length ranges were observed in *Onix*, while the *Cristina TD* variety has slightly more grouped lengths.

The thickness of the grains was between 4 and 7 mm, with similar modal values, namely 5.5 mm: 35% for *Cristina TD* and 30% for *Onix* (Figure 12).

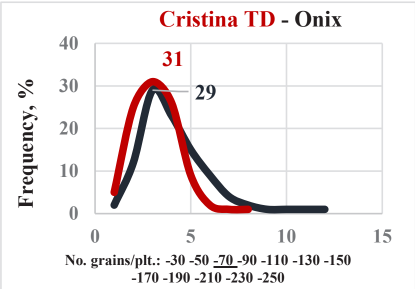

Figure 7. Frequency of no. grains/plant

Figure 8. *Cristina TD* soyabean variety

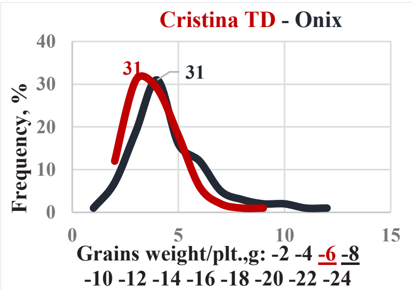

Figure 9. Frequency of grains weight/plant

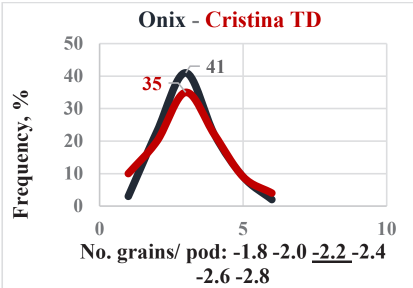

Figure 10. Frequency of no grains/pod

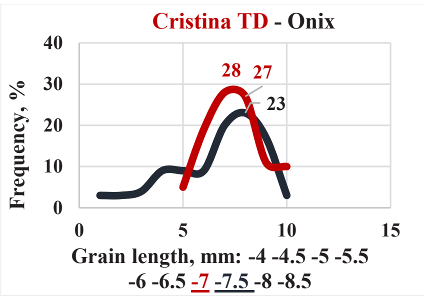

Fig. 11. Frequencies of grain length

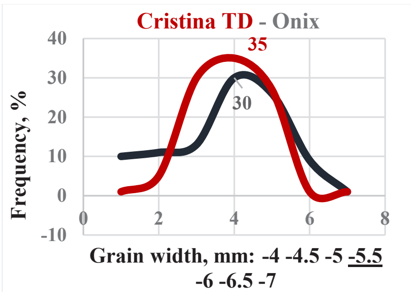

Fig. 12. Frequencies of grain width

The weight of soybeans expressed by the mass of one thousand grains was generally between 80 g and 160 g (Figure 13). In the *Cristina TD* variety the dominant weight of the grains was 100 g (32%), while in the *Onix* it was 110 g (41%). Between the two varieties, *Cristina TD* found an extension of the mass of one thousand grains to higher values, of over 140 g (Figure 14).

Correlations between the studied morphological characters. At the level of the whole set of correlations between all the characters analyzed for these soybean varieties,

statistically assured correlations were obtained in most cases. Of these, the positive correlations between the weight of the plant and the other characters related to it were noted, with correlation coefficients obtained between **.627** and **.916** for the *Cristina TD* variety and between **.657** and **.973** for the *Onix* variety.
Instead, insignificant links were obtained, either positive or negative, between the number of grains and their length with the other characters. It was generally found that the *Onix* variety had slightly more negative correlations compared to the *Cristina TD* variety. Instead, the mass character of a thousand grains correlated insignificantly, either positively or negatively with other characters in the *Cristina TD* variety, while in *Onix* this character was predominantly positive and even with statistical assurance with the other characters analyzed (Table 1).

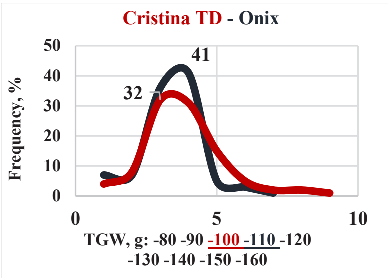

Figure 13. Frequencies of a thousand grain weight-TGW

Figure 14. Grains of Cristina TD variety

Table 1. Correlations between the main soyabean varieties characters

Indices	Plant weight	No. branch	No. pods	Pods weight, g	No. grains	No. Grains/ pod	Grains weight, g	Grain length mm	Grain width, mm	TGW g
Cristina TD variety										
Plant length, cm	**.386**	-.026	**.207**	**.272**	.181	-.140	**.221**	.007	-.066	.079
Plant weight, g	1	**.627**	**.865**	**.916**	**.880**	.089	**.875**	.001	.008	.061
No. branches		1	**.554**	**.511**	**.565**	.075	**.509**	.026	.072	.066
No. pods			1	**.912**	**.953**	-.089	**.886**	.005	-.061	-.085
Pods weight, g				1	**.946**	.155	**.974**	.022	.028	.164
No. grains/plant.					1	.193	.030	-.046	-.042	-.059
No. grains/pod						1	**.210**	-.135	.073	.065
Grains weight, g							1	-.014	.014	**.255**
Grain length, mm								1	**.336**	.092
Grain width, mm									1	**.218**
Onix variety										
Plant length, cm	**.385**	**.262**	**.324**	**.271**	**.297**	-.149	**.263**	.028	-.144	-.040
Plant weight, g	1	**.657**	**.967**	**.973**	**.962**	-.033	**.962**	.158	-.026	**.212**
No. branches		1	**.634**	**.595**	**.601**	-.117	**.581**	.052	-.137	.109
No. pods			1	**.977**	**.972**	-.123	**.962**	.101	-.066	.163
Pods weight, g				1	**.982**	.014	**.990**	.115	-.032	**.244**
No. grains/plant					1	.091	**.981**	.119	-.057	.155
No. grains/pod						1	.066	.084	.035	.042
Grains weight, g							1	.128	-.039	**.289**
Grain length, mm								1	**.646**	.130
Grain width, mm									1	.081
LSD 5 % = .190 LSD 1 % = .250 LSD 0.1% = .320										

Statistical analysis of morphological characters in soybean plants. The results obtained in the morphological analysis of some soybean characters showed specific aspects (Table 2). Thus, the length (height) of the plant measured in comparison *Cristina TD- Onix*, 69 to 65 cm. This character demonstrated greater variability in *Onix*. The weight of an average plant, at maturity, was 24 g for the first variety and 26 g for the second variety, both with high variability. Both stems formed 4 branches each, and the number of pods was 32 to 40. The weight of these pods was 11 g to 15 g. The number of grains was 67 to 85 in favor of *Onix*, and their weight was from 7 to 8.5 g. The grains had lengths of 7.1 mm to 6.7 mm, with thickness of over 5 mm. The mass of one thousand grains was 105 g for the first variety and 98 g for the second variety.

Table 2. Statistical indices of soybean plants and grains

Indices	Height cm	Plant weight	No. branches	No. pods	Pods weight	No. grains	No. grains/ pod	Grains weight/ plt., g	Grain lengtn, mm	Grain width, mm	TGW, g
Cristina TD variety											
Mean, ā	**69.2**	**24.4**	**3.91**	**31.5**	**11.6**	**66.5**	**2.13**	**6.9**	**7.13**	**5.33**	**104.5**
Variance, s^2	59.30	56.67	5.21	123.9	7.126	650.6	0.056	7.74	0.423	0.27	231.9
Std. deviation, s	7.70	7.53	2.28	11.13	2.67	25.51	0.237	2.78	0.65	0.52	15.23
Var. coef., s%	**11.1**	**30.1**	**58.4**	**35.3**	**23.1**	**38.4**	**11.2**	**40.2**	**9.1**	**9.8**	**14.6**
Onix variety											
Mean, ā	**65.2**	**26.5**	**4.23**	**39.7**	**15.0**	**85.1**	**2.15**	**8.52**	**6.73**	**5.483**	**98.4**
Variance, s^2	1016	123.6	7.896	231.6	51.49	2520	0.520	16.94	0.781	1.106	397.34
Std. deviation, s	31.82	11.13	2.810	15.22	7.176	50.20	0.721	4.116	0.884	1.052	19.933
Var. coef., s%	**48.9**	**41.1**	**66.4**	**38.3**	**48.0**	**59.0**	**33.5**	**48.3**	**13.1**	**19.2**	**20.2**

CONCLUSIONS

The morphological characteristics of soybeans, *Cristina TD* and *Onix* varieties, had new and specific aspects. The cultivation of these varieties was due to the fact that they have recent genetic improvements, especially for the higher productive potential. Being varieties with a relatively small size, the stem had lengths of 65-70 cm. This may be an increasingly important condition for maximizing production, when superior, intensive agrotechnics can be used. The plants had a total mass of 25-27 g, and the stem formed 4 branches each.

The number of pods obtained was between 32 and 40 per plant, and their biomass was between 12 g and 15 g. The number of grains was 67-85 per plant, and their weight was between 7 g and 8.5 g. The length of the grains was between 7.1 and 6.7 mm and the absolute mass of the grains was between 100 and 105 g.

Simple correlations were established between all the studied characters, with some differentiations. In general, these correlations obtained were both positive and statistically assured. Only the diameter of the grain and the mass of a trousand grains were insignificantly correlated with some characters.

The variability of the morphological characters studied in the two soybean varieties demonstrated high variability of the characters in the *Onix* variety and relatively low in *Cristina TD*.

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THE EFFECTIVENESS OF TREATMENTS IN THE CONTROL OF WHEAT DISEASES, MOARA DOMNEASCĂ LOCATION, ILFOV COUNTY

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Abstract

Our research aimed to determine the effectiveness of treatments in the control of wheat diseases between 2015-2019 at the Moara Domnească Didactic Resort, Ilfov County located in South Romania. Based on the data on monitoring the attack in the control and treated variants, the effectiveness of the treatments applied in the vegetation was determined. Observations were made on Glosa and Boema varieties in 2015-2017 and on Katou, Pitbul and Jaguar varieties in 2017-2019, for the pathogens Blumeria graminis f.sp. tritici, Zymoseptoria tritici, Septoria spp., (FA), Fusarium spp. and Puccinia recondita. The effectiveness of the applied treatments was 90.7% in powdery mildew control (Boema variety, 2015/2016), 90% in septoriosis control (Jaguar variety, 2018/2019, 73% Boema variety 2016/2017), 66.6% in fusariosis control (Boema variety, 2016/2017), 73.3% in brown rust control (Jaguar variety, 2028/20190).

***Key words**: wheat, pathogens, variety, degree of attack, effectiveness.*

INTRODUCTION

Wheat is the most important of the cultivated plants and one of the staple foods for the whole planet (Bîlteanu, 1991; Muntean et al., 2003; Figueroa et al., 2018), a main source of calories and plant proteins (Curtis et al., 2002). The main source for the preparation of bread, wheat is given special and permanent attention in agricultural research. The state of health of the wheat crop has preoccupied and continues to concern the fundamental and applied research, in order to obtain high, stable and high quality productions. The impact of treatments on the attack of pathogens and wheat production is one of the preventive and curative measures that ensure the stability of wheat production. Wheat is attacked by a significant number of pathogens, including micromycetes *Blumeria graminis* f. sp. wheat, fungi of the genus *Septoria* spp. (telemorphic forms *Zymoseptoria tritici* and *Parastagonospora nodorum*), *Fusarium* spp., *Puccinia recondita* can occur year after year in crops (Cristea, 2005). Important wheat diseases such as rust, fusariosis, spots caused by pathogenic fungi cause significant production losses every year, leading to better management (Figueroa et al., 2018). In the integrated control of these pathogens, chemical protection is an important measure, especially in years with favourable conditions or in the case of less resistant genotypes. The presence of pathogens such as *Fusarium* spp. and *Parastagonospora nodorum* on wheat caryopsis can affect the quality of quantitative and qualitative indicators of seeds. Also, the attack of some pathogens can have an impact on the wheat crop technology regarding the crop rotation, reason for which the research of seed pathogens is a goal in the research activity of wheat seed pathology (Raicu and Baciu, 1978). The application of chemicals in the control of wheat diseases is part of their integrated control strategy. The effectiveness of treatments in combating plant diseases is a concern in establishing schemes to combat plant diseases (Cioneag et al., 2015).

MATERIALS AND METHODS

The aim of the research was to calculate the effectiveness of treatments applied in vegetation in the control of pathogens *Blumeria graminis* f. sp. *tritici*, *Zymoseptoria tritici*, *Septoria* spp., *Fusarium* spp. and *Puccinia recondita*, in the period 2015-2019 at the Moara Domnească Didactic Resort, Ilfov County located in South Romania. The biological material was represented by the varieties Boema and Glosa in the agricultural years 2015/2016, 2016/2017, Katou and Pitbul in the agricultural year 2017/2018 and the varieties Jaguar and Pitbul in the year 2018/2019. Treatments were performed with: Artea 0.4 l/ha (8 04 2016) and Topsin 1.25 l/ha (15.05.2016). The seed was treated with Sponsor 0.5 l/to. In 2016/2017, fungicide treatments were applied as follows: Orius 0.4 l/ha (27.04.2017) and Acanto Plus 0.5 l/ha (19.05.2017) and the seed was treated with Yunta Quattro in a dose of 1.6 l/to. In 2017/2018 the seed was treated with Yunta Quattro in a dose of 1.6 l/to and in the vegetation treatments were applied with Tebucur 0.5 l/ha (11.04.2018) and Falcon Pro 0.8 l/ha (30.05.2018). In 2018/2019, Orius 0.4 l/ha (05.03.2019) and Amistar 2.3 l/ha (13.05.2019) were applied to the vegetation and the seed was treated with Austral Plus 5 l/to.

The frequency and intensity of the attack were calculated according to the formulas: Frequency (F%) = n x 100/N, where N= number of plants observed (%), n = number of plants specific symptoms (%). The intensity was noted in percentages and calculated according to the formula: Intensity (I%) = Σ (ixf)/n (%), where I = percentage given, f = number of plants/organs with the respective percentage, n = total number of attacked plants/ organs. Based on the data obtained in calculating the frequency and intensity, the degree of attack was calculated: GA = F x I/100 (%), where GA = attack degree (%), F = frequency (%), I = intensity (%). The efficacy of the treatments was determined according to the formula E = [Gam-Gav/Gam] x 100 (%) (Abbott 'formulas), in which: Gam- degree of attack on the control variant, Gav- degree of attack on the treated variant.

RESULTS AND DISCUSSIONS

The data in Table 1 show that, in the period 2015-2017, the wheat varieties grown at Moara Domneasca showed a powdery mildew attack, caused by the pathogen *Blumeria graminis* f. sp *tritici*, leaf *septoria* caused by *Zymoseptoria tritici* (2015-2016), septoriosis (*Septoria* spp.) and fusariosis caused by micromycetes of the genus *Fusarium* (*Fusarium* spp.) whose level and evolution of the attack in the control variant (untreated) have already been published (Iosub et al., 2021). The application of the treatments with the mixed products T1 (Artea 0.4 l/ha) and T2 (Topsin 1.25 l/ha) reduced the powdery mildew attack on the Glosa variety in 2015/2016 from 10.5% to 1.5%. There was a severe decrease in the frequency of the attack from 72% in the untreated control to 26% after the application of the two treatments. Also, the intensity of the attack was lower, calculating I = 5.5% compared to the control with I = 15%. In the conditions of this year, the presence of the attack of leaf septoria was observed, which reduced its attack to 3.1% after the administration of the treatments compared to the control variant in which the attack was 15%. In the case of the Boema variety, in the control variant GA = 13% and after the application of fungicides with the two treatments the attack decreased to 1.2%. Regarding the attack of *Zymoseptoria tritici*, in the Boema variety the level of the attack decreased to 2.7% after the application of the treatment scheme compared to the variant without treatments with GA = 17.5%. During the year 2016/2017, the cultivated varieties detected an attack of powdery mildew, septoria and fusarium on ears of wheat. The application of treatments with Orius 0.4 l/ha and Acanto Plus 0.5 l/ha was beneficial to the wheat crop. In the Glosa variety, the frequency of the powdery mildew attack reached 24% and the intensity reached 6.5%, resulting in an attack level of GA = 1.6%, compared to the control variant in which GA = 6.9%. Regarding the attack of micromycetes *Septoria* spp. there was a significant decrease in the incidence of the attack with F = 28%, compared to the control variant in which F = 56%. The level of attack was 2.4% after applying the treatments, compared to GA = 8.4% in the untreated plot. Micromycete attack *Septoria* spp. at the Boema variety was 3.4% after the application of the treatments, compared to the untreated variant in which the degree of attack was 12.7%. The value of the attack decreased so much, but especially its incidence, which was 32%, while in the untreated variant it was 75%. Chemical control, which often involves two or three sprays per season, remains the main mechanism for controlling leaf septoria and currently focuses on the use of alternative management strategies (Arraiano and Brown, 2017; Torriani et al., 2015).

Table 1. The influence of treatments on the attack of wheat pathogens, in the period 2015-2017

Variety	Variat	Pathogen/ year 2015-2016						Pathogen/ year 2016-2017						
	Treated (T) / Control (MT)	*Blumeria graminis* f. sp.*tritici*			*Septoria* spp.			*Blumeria graminis* f. sp. *tritici*			*Septoria* spp.			*Fusarium* spp.
		F (%)	and (%)	GA (%)	F (%)	and (%)	GA (%)	F (%)	and (%)	GA (%)	F (%)	and (%)	GA (%)	F (%)
Glosa	T1 T2	26	5.5	1.4	28	11	3.1	24	6.5	1.6	28	8.5	2.4	2
	MT	72	15	10.5	75	20	15	58	12	6.9	56	15	8.4	4
Boema	T1 T2	21	6	1.2	21	13	2.7	21	5	1.0	32	0.5	3.4	2
	MT	65	20	13	70	25	17.5	45	14	6.3	75	17	12.7	6

The frequency of the attack of *Fusarium* spp. on the ears was also reduced, which in the case of the Glosa variety reached 2% compared to the control and in the case of the Boema variety the frequency of the ears of wheat with fusariosis decreased from 6% to 2% (Table 1).
In the conditions of 2017-2018, the Katou and Pitbul varieties were found to have powdery mildew and septoria (Iosub et al., 2021). Compared to the control variant (MT), the attack was severely reduced following the applied treatment scheme (Orius 0.4 l/ ha and Acanto Plus 0.5 l/ ha). Thus, the frequency of the powdery mildew attack decreased to 43% and the intensity to 11.5%, which determined a value of the degree of attack of 4.9% compared to the control variant with GA = 16% for the Katou variety. In the case of the same variety, the attack of septoria on the leaves was reduced to 5.1% compared to 17%.
There was a significant decrease in the intensity of the attack. In the Pitbul variety, in the treated variant the powdery mildew attack reached half (GA = 7.5%) of the value of the attack in the control variant (GA = 15%).
A significant reduction of the attack was registered in the case of the attack of septoria in the Pitbul variety in which GA = 2.2% compared to 9.7% in the untreated variant, due primarily to the decrease of the value of the attack intensity which reached 5% compared to 15% (control) (Table 2).
The application of fungicide treatments is part of the control strategy of fusarium wilt, but McMullen et al. (2012) show that mixtures of triazoles can provide 30-60% control due to the resistance of the pathogen to these substances. *Septoria nodorum* is effectively managed through a combination of genotype, chemical control and cultural practices such as crop rotations (Francki, 2013).

Table 2. The influence of treatments on the attack of wheat pathogens, between 2017-2018

Variety	Variant	Pathogen/year 2017-2018					
	Treated (T) / Control (MT)	*Blumeria graminis* f. sp. *tritici*			*Septoria* spp.		
		F (%)	I (%)	GA (%)	F (%)	I (%)	GA (%)
Katou	T	43	11.5	4.9	54	9.5	5.1
	MT	80	20	16	85	20	17
Pitbul	T	17	7.5	1.3	44	5	2.2
	MT	45	15	6.7	65	15	9.7

In the conditions of 2018-2019 for the Pitbul and Jaguar varieties for the detected diseases, the attack had diminished values compared to the control variants.
In the case of the Pitbul variety, there was an attack of septoria in which both the frequency and intensity of the attack were reduced to 22% and 6.5%, resulting in an attack value of 1.4%, compared to the untreated variant in which the values of the incidence and intensity of the attack determined an attack rate of 5.8%. In the plots cultivated with the Jaguar variety, an attack of powdery mildew, septoria and brown rust was observed. In the case of the attack of these diseases, the values of the attack decreased after the application of the treatments (Tebucur 0.5 l/ha and Falcon Pro 0.8 l/ha) compared to the control variant.
The attack of powdery mildew reached 1.3% compared to 5.3%, the attack of septoria decreased to 3.5% compared to 13% (control) and the attack of brown rust to 1.2% compared to 4.5% (control) (Table 3).
In the case of fungicides against powdery mildew, the phenomenon of pathogen resistance must be monitored (Genet and Jawaroska, 2009).

Table 3. The influence of treatments on the attack of wheat pathogens, between 2018-2019

Variant		Pathogen / 2018-2019								
Variety	treated (T)/control (MT)	*Blumeria graminis* f. sp. *tritici*			*Septoria* spp.			*Puccinia recondita*		
		F (%)	and (%)	GA (%)	F (%)	and (%)	GA (%)	F (%)	and (%)	GA (%)
Pitbul	T	-	-	-	22	6.5	1.4	-	-	-
	MT	-	-	-	45	13	5.8	-	-	-
Jaguar	T	19	7	1.3	32	11	3.5	16	7.5	1.2
	MT	48	11	5.3	65	20	13	35	13	4.5

Strategies for controlling wheat rust include cultural practices, chemical and genetic control (Elis et al., 2014). The effectiveness of the treatments applied to the varieties cultivated in the period 2015-2019 was calculated (Table 4). The effectiveness of treatments is a concern in the strategy of combating diseases in cultivated plants (Toth and Cristea, 2020; Chireac and Cristea, 2021; Buzatu et al., 2018; Jaloba et al., 2019; Cioneag et al., 2016; Alexandru et al., 2019). The application of the two treatments in combating powdery mildew in 2015/2016 to Glosa and Boema varieties had efficiencies of 86.6% and 90.7%, respectively. Regarding the attack of leaf septoria, the efficacy had values of 79.3% for the Glosa variety and 84.5% for the Boema variety. It can be appreciated that the attack of powdery mildew and septoria of the leaves, in the conditions of the year and considering the genotype, by applying the treatments, the efficacy values were high, especially for the Boema variety. In the conditions of 2016/2017, the highest values of the effectiveness of the treatments were registered for the Boema variety, over 84% for powdery mildew and 73% for *Septoria* spp. The effectiveness in control the attack of *Fusarium* spp. was 66.6%. In the Glosa variety, the efficacy values were over 70% in the case of monitored foliar pathogens and 50% in the case of fusarium head blight.

Table 4. Effectiveness of treatments in combating wheat diseases (2015/2017)

Variety	Alternative	2015-2016				2016-2017					
		Blumeria graminis f. sp. *tritici*		*Zymoseptoria tritici*		*Blumeria graminis* f. sp. *tritici*		*Septoria* spp.		*Fusarium* spp.	
		GA (%)	E (%)	GA (%)	E (%)	GA (%)	E (%)	GA (%)	E (%)	GA (%)	E (%)
Glosa	T	1.4	86.6	3.1	79.3	1.6	76.8	2.4	71.4	2	50
	NT	10.5		15		6.9		8.4		4	
Boema	T	1.2	90.7	2.7	84.5	1.0	84.2	3.4	73.2	2	66.6
	NT	13		17.5		6.3		12.7		6	

In the conditions of 2017/2018 for the Katou and Pitbul varieties, the applied treatments had an effectiveness of about 69.4% against the powdery mildew attack of the Katou variety and of 80.6% for the Pitbul variety. Regarding the attack of septoria, the effectiveness of the treatments was 70% for the Katou variety and 77.3% for the Pitbul variety (Table 5)..

Table 5. Effectiveness of treatments in combating wheat diseases (2015/2017)

	Alternative	2017-2018				2018-2019					
		Blumeria graminis f. sp. *tritici*		*Septoria* spp.		*Blumeria graminis* f. sp. *tritici*		*Septoria* spp.		*Puccinia recondite*	
		GA (%)	E (%)	GA (%)	E (%)	GA (%)	E (%)	GA (%)	E (%)	GA (%)	E (%)
Katou	T	4.9	69.4	5.1		-	-	-	-	-	-
	NT	16		17	70	-	-	-	-	-	-
Pitbul	T	1.3	80.6	2.2		-	-	1.4	75.8	-	-
	NT	6.7		9.7	77.3	-	-	5.8		-	-
Jaguar	T	-	-	-	-	1.3	75.4	3.5	90.8	1.2	73.3
	NT	-		-		5.3		13		4.5	

Higher efficacy values were found for the Pitbul variety compared to the Katou variety under the same conditions of the year (Iosub et al., 2021). And the application of the treatments had an effectiveness of 75.8%. In the case of the Jaguar variety, the effectiveness of the applied treatments was 90.8% in control of septoria and 73.3% in the case of the brown rust attack

CONCLUSIONS

The application of treatments in control of wheat diseases to the varieties cultivated in the Moara Domneasca location in South Romania, in the period 2015-2019 led to a severe reduction of the attack and incidence of some pathogens (*Fusarium* spp.). The effectiveness of the treatment scheme in 2016/2016 had an effectiveness of 90.7% in combating powdery mildew and 84.5% in control of leaf septoria in the Boema variety. The treatments applied in 2016/2017 had a higher effectiveness against the attack of powdery mildew, *Septoria* spp. and fusarium wilt in the Boema variety compared to the Glosa variety and in 2017/2018 in the Pitbul variety there were values of 80.6% in control of powdery mildew and 77.3 % against *Septoria* spp. In 2018/2019, the Pitbul variety did not register a powdery mildew attack and the effectiveness in control of the attack of septoria was 75.8%. Brown rust was detected in the case of the Jaguar variety (2018/2019) with a treatment efficiency of 73.3%.

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THE USE OF AMMONIUM SULPHATE HAS AN ADJUVANT EFFECT ON THE PRODUCTIVITY OF OILSEED RAPE (*Brassica napus* L.)

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Abstract

Oilseed rape (Brassica napus L.) is the second most common oil crop grown in the world, after soybean. The aim of the study was to investigate the adjuvant effect of leaf treatment with ammonium sulphate together with a plant growth regulator (PGR) on the seed yield and quality of canola, cv. DK Implement CL. The experiment was set up in the region of Plovdiv, Bulgaria in the period October 2020 - June 2021. The test variants included: 1 - untreated control, 2 - Plant growth regulator (1 l/ha) + Ammonium sulphate (1 l/ha), 3 - Plant growth regulator (1.5) l/ha + Ammonium sulphate (2 l/ha), 4 - Plant growth regulator (1 l/ha), 5 - Plant growth regulator (1.5 l/ha), 6 - Tilmor (1.2) l/ha, and 7 - Carax (1.5 l/ha). It was established that the application of ammonium sulphate has a positive effect on the plant growth, grain yield, oil and moisture content, and 1000 kernel weight.

Key words: *adjuvant, ammonium sulphate, Brassica napus, oil content, rapeseed yield.*

INTRODUCTION

Winter rape (*Brassica napus*) is one of the most important oil-protein crops in the world (Sikorska et al., 2021). Oilseed rape is the main raw material which is used for producing edible oil and it is a high-protein source in animal nutrition (Ahmad et al., 2007; Malhi et al., 2006). The chemical composition of seeds depends mainly on the genetic factor, but it could also be affected by environmental and agrotechnical conditions (Sikorska et al., 2021). The application of foliar fertilizers has a positive effect on the content of crude fat (Ahmad et al., 2012; Chwil, 2016; Jankowski et al., 2016) and total protein (Ahmad et al., 2007; Malhi et al., 2006; Sattar et al., 2011) in oilseed rape.

According to Jankowski et al. (2016) the foliar application of micronutrients is particularly beneficial for the plant. Winter rapeseed shows a high demand for sulphur (Sienkiewicz-Cholewa & Kieloch, 2015). Sulphur is the fourth major plant nutrient after nitrogen, phosphorus and potassium and according to Havlin et al. (2004) this element is essential for synthesis of the amino acids like cysteine, and methionine, a component of vitamin A and activates certain enzyme systems in plants

Kotecki et al. (2005) emphasize that sulphur is responsible for the synthesis of chlorophyll and amino acids, it activates enzymes important in the metabolism of energy and fatty acids, increases the resistance of plants to diseases and pests, has a positive effect on other nutrients, mainly nitrogen, and also limits the lodging of plants.

According to Khan et al. (2011) canola has a higher sulphur requirement than most cereals and to meet that demand, additional sulphur may be needed in a balanced fertilizer program. Zao et al. (2003) showed that as a result of insufficient nutrition of plants with sulphur, the synthesis of sulphur amino acids is limited, which inhibits the process of protein formation and promotes the accumulation of non-protein forms of nitrogen. According to Muhammad et al. (2017) the foliar treatment with sulphur had a positive effect on the yield of rapeseed grown on a S-deficient soil.

Fertilizers that supply (S) in the sulphate form are immediately available to crops (Kandil & Gad, 2012). Sulphur requirement and metabolism in plants are closely related to N nutrition (Reuveny et al., 1980), and N metabolism is also strongly affected by the S status of the plant (Janzen and Bettany, 1984; Duke and Reisenauer, 1986).

This motivated us to investigate the effect of foliar application of ammonium sulphate on the growth and yield of oilseed rape, when it is applied together with a Plant growth regulator.

MATERIALS AND METHODS

Plant material

Oilseed rape cv. Implement CL is preferred as a test object because of its very fast initial development in the fall and yield stability year after a year, regardless of soil and meteorological conditions. It is resistant to cracking of the pods and this reduces yield losses before and during harvesting as well as decreases the number of self-seeding. The variety demonstrates a very good resistance at low temperatures and tolerance to virus diseases (TuYV). It has a very good production potential and excellent oil content.

Experimental design

The experiment was conducted on the field in the region of Plovdiv from October 2020 till June 2021. Oilseed rape was sown on 26 August 2020 with a row spacing of 25 cm and 10 cm spacing within the row. The experiment was laid out in randomized complete block, having four replications. The size of every plot was 24 m². The ammonium sulphate, a plant growth regulator (PGR) containing trinexapac-ethyl, and two reference products were applied two times during the vegetation via foliar spray. The first application was done on 18 October 2020, BBCH 16 (Majority), the second application was on 5 March 2021, BBCH 31 (Majority). Seven test variants were examined: 1 - untreated control; 2 - PGR (1 l/ha) + Ammonium sulphate (1 l/ha); 3 - PGR (1.5 l/ha) + Ammonium sulphate 2 l/ha; 4 - PGR1 (l/ha); 5 - PGR (1.5 l/ha); 6 - Tilmor (1.2 l/ha); 7 - Carax (1 l/ha). The plant regulator which was selected for the combined application with AS was Modus (250 g/l trinexapac-ethyl). As reference products, two PGRs with fungicidal properties were used. Tilmor contains tebuconazole (160 g/l) with the addition of prothioconazole (80 g/l). Carax® is an innovative combination of mepiquat chloride 210 (g/l) and metconazole (30 g/l).

Biometry and analysis of the yield

The analysis of the biometry of the treated plants was performed by measuring the height of 5 plants per a block plot 5 times during the vegetation (BBCH 16; BBCH 18; BBCH 31; BBCH 61; BBCH 69-71). The yield was harvested on 29 June 2021. The oil content was analysed in a certified laboratory according to BS EN ISO 659:2009 (Reference method). Seed moisture was measured with Pfeuffer HE 50 Grain Moisture Meter.

Statistical Analysis

The data were presented as means ± SD of 4 replicates. The experimental results were statistically processed with the SPSS program using a one-way ANOVA dispersion analysis using Duncan's comparative method, with the validity of the differences determined at a 95% significance level. The different letters (a, b, c, d) after the average show statistically significant differences between the analyzed variants.

RESULTS AND DISCUSSIONS

In order to analyse the effect of the tested substances on the plant growth 5 measurements of the plant height were done. The data are presented in Figure 1. The plants were with the same height on the day of the first measurement. One month later, the differences between the tested variants were obvious. The untreated plants were the highest followed by the plants treated with a PGR + AS in the lower doses. More than 3 months after the first application and measurement the plants treated with AS were as high as the control. At that time the second application was performed. On 5 March (before flowering), plants from variant 2 were shorter than the control plants by 17% and the plants from variant 3 - by 24% respectively. The reduction of the height in variant 4 was by 11%, and in variants 5, 6, and 7 - by 11%, 2%, and 6% respectively. The last measurement was on 16 April (after flowering). Plants treated with PGR 1 l/ha + AS 1 l/ha were shorter by 22% compared to the control. The plants, which were supplied with the higher dose of PGR and ammonium sulphate, were by 28% shorter. The other tested variant were also shorter than the control and higher than the ammonium sulphate supplied plants. According to Armstrong & Nicol (1991) when the plants are shorter and erect, they produce an even, compact pod canopy, and as a result, ripening is more uniform, pod shattering is reduced and harvesting is more efficient.

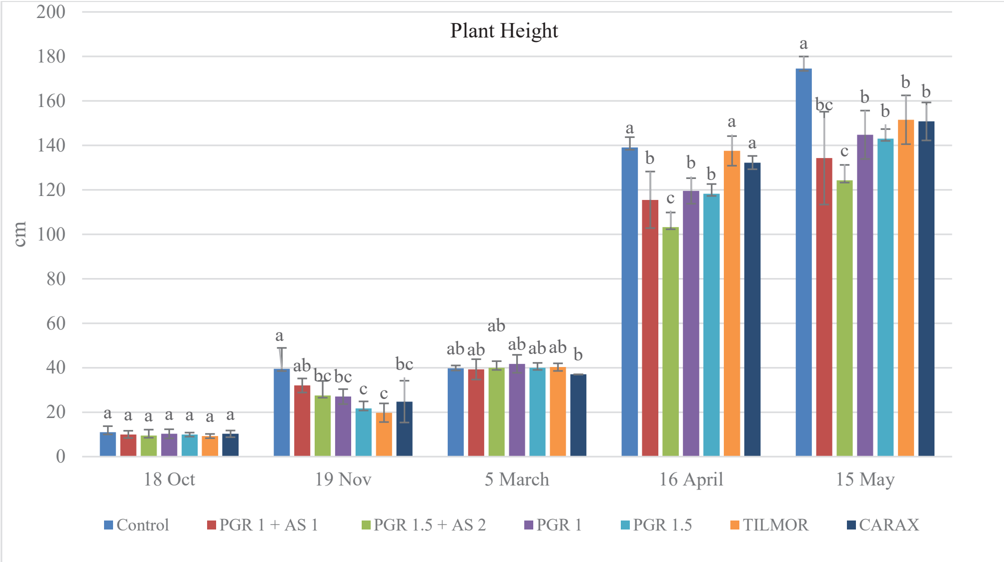

Figure 1. Plant height (cm) on the day of the first foliar spray with the test products and several times after that

In our experiment we use the Ammonium sulphate as an adjuvant - to improve the action of the PGR. Plant growth regulators are used worldwide in many crop species (Tidemann et al., 2020). Their application is followed by a variety of beneficial effects including increased yield, breaking of bud dormancy, fruit maturation prevention or initiation, and, of particular interest here, plant height management and lodging mitigation are observed (Dahnous et al. 1982; Green 1986; Rademacher, 2015).

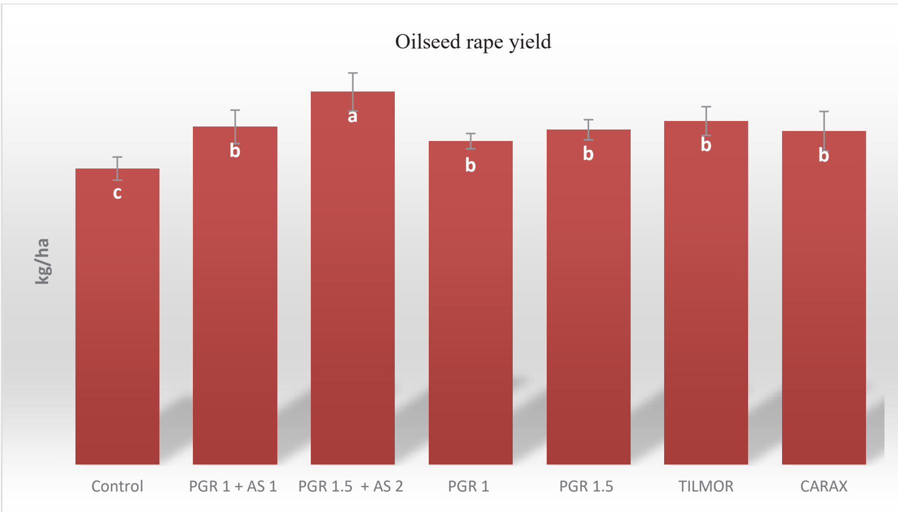

Figure 2. Oilseed rape seed yield (kg/ha)

The data regarding the grain yield of oilseed rape are presented in Figure 2. The yield from the plants treated with ammonium sulphate in the dose of 1 l/ha was 14% higher than the untreated control. The increase after the application of PGR + AS in dose of 2 l/ha was by 25%. The variants treated only with PGR provided 9% (in the dose of 1 l/ha) and 13%

(1.5 l/ha) more grain. The results obtained are in line with the data presented by Anjum et al. (2016). According to the authors, foliar application of 1% Ammonium sulphate water solution is able to increase the canola yield by 27%. Muhammad et al. (2017) also analysed the effect of Ammonium sulphate foliar application on oilseed rape yield. They examined three different concentrations (1%, 0.3%, and 0.2% solution) and declare that more grain yields were obtained with the application of 1% and 0.3% ammonium sulphate solution in comparison to the untreated control. They also observed that the number of leaves and branches generally increased with the increasing levels of Ammonium sulphate as foliar spray although there was no significant difference between the variants.

Our results about the oilseed rape yield are in line also with the achievements of Balik et al. (2006). They observed an increase of the yield in the nitrochalk treatment by 49% and by 60% in the ammonium nitrate + ammonium sulphate treatment respectively, compared to the untreated control.

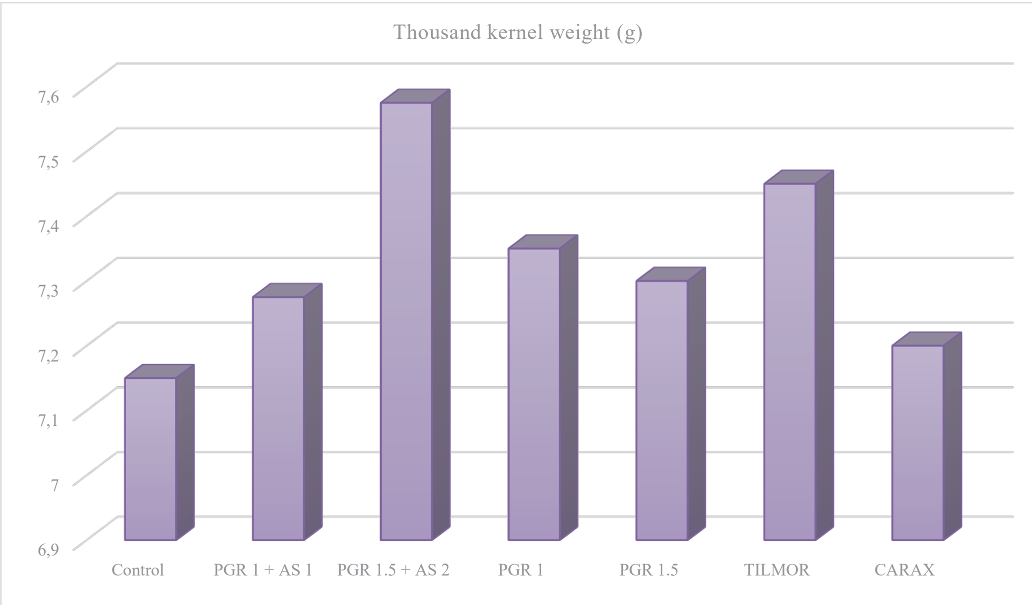

Figure 3. Thousand kernel weight (g) of oilseed rape grain

The data about the analysis of 1000 kernel weight is presented in Figure 3. Although the differences between the variants are not statistically significant, the plants treated with PGR + Ammonium sulphate in the dose of 2 l/ha, provided the heaviest seeds.

Anjum et al. (2016) also reported about the increased weight of 1000 seeds after foliar application of Ammonium sulphate. The results are also in agreement with the findings of Sharifi (2012) and Sattar et al. (2011). The authors reported that increasing levels of sulphur led to an enhancement of thousand grain weights. Canola is an oil seed crop and it response positively to sulphur application due to which its grain yield increases (Malik et al., 2004) (Figure 4).

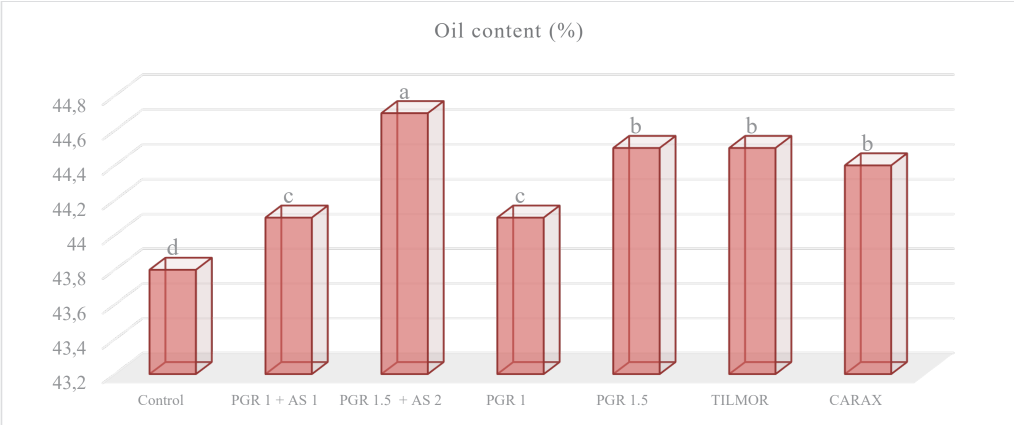

Figure 4. Oil content of oilseed rape grain (%)

In their research Ahmad et al. (2007) used a dose of 0, 10, 20, and 30 kg of S/ha. They observed that the oil content was significantly increased with the increasing doses of sulphur to 20 kg/ha but the application of 30 kg/ha of sulphur had no significant effect on the oil content. On the other hand, Subhani et al. (2003) reported, that the oil content is directly proportional to the doses of sulphur.

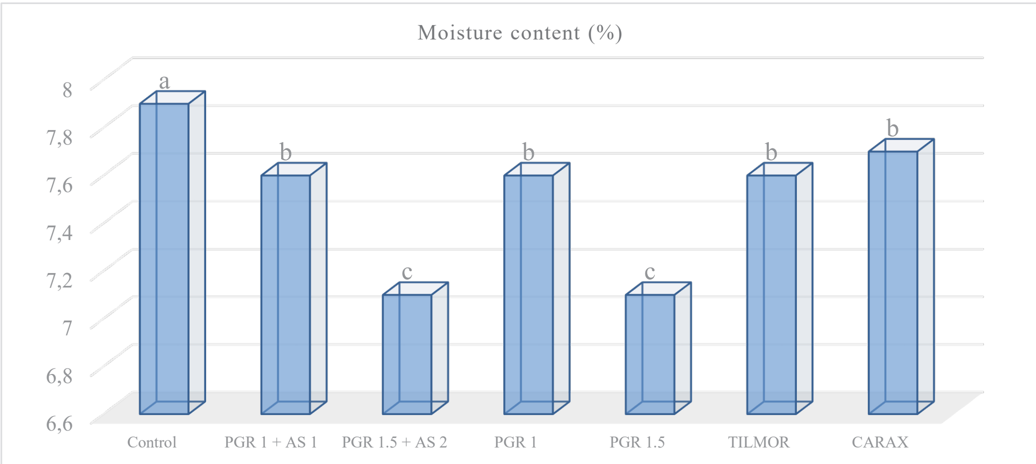

Figure 5. Moisture content of oilseed rape grain (%)

The moisture content of the oilseed rape grain was also measured (Figure 5). The results show that the moisture content was the highest in the seeds of the control plants. The moisture of PGR 1 + AS 1 was lower than the control by about 4%. Applied alone, the PGR led to the same reduction of the yield component. Both of the reference products had the same effect. The lowest value of that parameter was measured after the application of PGR 1.5 and PGR 1.5 + AS 2. Like other seeds, rapeseed is physiologically active and can be affected by moisture content, temperature and access to oxygen. The recommended storage moisture content of seeds ranges from 7 to 10 % in different countries. However, the process of drying could affect negatively the yield quality (Gawrysiak-Witulska et al., 2012).

CONCLUSIONS

The experiment aimed at investigating the adjuvant effect of ammonium sulphate applied together with a plant growth regulator product on the growth, yield and some yield components of oilseed rape. The results obtained make us believe that the application of 2 l/ha Ammonium sulphate in combination with a plant growth regulator has an adjuvant effect on the oilseed rape growth, yield, oil content and the 1000 kernel weight. We could recommend two foliar treatments (in autumn and in spring) together with a plant growth regulator to enhance the effects of the plant growth regulator and the fertilizers used and to improve the crop performance. The combination with Ammonium sulphate enhances the effect of the plant growth regulator regarding to the plant height, yield, oil and moisture content. The sole application of the PGR did has also positive effect on the crop growth and productivity but the results are more pronounced after the AS supplement, especially when the higher doses of PGR and AS were used.

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APPLICATION OF CLUSTER ANALYSIS AND PRINCIPAL COMPONENT ANALYSIS FOR THE STUDY OF AGRONOMIC CHARACTERISTICS OF *Virginia tobacco* HYBRIDS COMBINATION

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Abstract

Agro-morphological traits of five Virginia tobacco hybrid combinations and standard Virginia 0514 were analyzed. The aim of the study was to group and evaluate hybrid combinations by stem height (SH), leaf number (LN), length of 12th leaf (LL), width of the 12th leaf (WL), days to 50% flowering (D50F), dry leaf yield. Hierarchical cluster analysis and analysis of the main components were applied. The grouping of hybrids in clusters found that Hybrid 27, Hybrid 33 and Hybrid 126 with a common parent component Virginia 385 have larger leave size and higher dry leaf yield, which determines not only their differentiation into a separate cluster, but also their strong distance from the other two hybrids and the Virginia 0514 standard. The Hybrid 126 has the longest growing season. The studied traits were transformed into two factors. The first includes length of 12th leaf and width of the 12th leaf, days to 50% flowering and dry leaf yield and explains 42.8% of the total variance. The second main component consists of plant height and leaf number, explains 32.5%. As a result of the study it was proved that the most effective would be the selection activity, aimed at the selection in the population of the second cluster on the grounds - length and width of the 12th leaf, dry leaf yield and days to 50% flowering.

Key words: *Virginia tobacco, hybrid combinations, morphological traits, dry leaf yield, cluster analysis, Principal Component Analysis (PCA).*

INTRODUCTION

Tobacco (*Nicotiana tabacum* L.) is a crop that is important for the Bulgarian economy. There are four varietal groups of tobacco in our country: Oriental - Basma and Kaba Kulak and large-leaved - Virginia Flue-cured and Burley - Air Cured varieties.
Virginia Tobacco is a typical cigarette type and is the most significant ingredient in American and Virginia blend cigarettes (Campbell, 1989). High productivity is the ultimate goal of any selection program. Knowledge of the relation between plant characteristics is crucial for improving tobacco yield (Ahmed and Mohammad, 2017).Tobacco is produced for its vegetative parts. The value of the yield is determined by the yield of the leaves, the number of harvested leaves, the length, width and shape of the leaves (Butorac, 2004). The study of tobacco genetic diversity is of interest for the conservation of genetic resources, the expansion of the genetic base and practical applications in selection programs (Darvishzadeh et al., 2013).
There are a number of studies on the morphological traits of tobacco (Xiao et al., 2007; Maleki et al., 2011; Mitreski et al., 2018; Risteski I. and Karolina Kočoska, 2014; Ali et al., 2014, etc.). The cluster analysis can significantly increase the efficiency of the selection process (Rosseeva et al., 2012). Ivanov and Dimova (2015) perform analysis and evaluation of maize hybrids by joint application of cluster analysis and analysis of the main components as accompanying methods for more efficient breeing work. Jain S. K. and P. R. Patel (2016) report on the effectiveness of PCA analysis in deciding which agronomic traits should be emphasized in the breeding program.
Tobacco characteristics studies are important for the full utilization of tobacco germplasm resources (MeilingXu et al., 2013).

Darvishzadeh and Maleki (2012) apply a cluster analysis to assess genetic diversity for morphological and agronomic characteristics in the gene pool of oriental tobacco.

It was found that of the studied traits, days up to 50% flowering, dry tobacco yield and the number of leaves per plant are most important for distinguishing tobacco genotypes. Samizadeh Lahiji H. et al. (2013) studied the genetic remoteness of 89 varieties of flue-cured tobacco. A cluster analysis based on morphological features was performed. Ning et al. (2009) reported that two groups and four subgroups were formed after a cluster analysis of the agronomic characteristics of fifteen tobacco genotypes.

In the overall assessment of agronomic characteristics, the result shows that compared to group I, plant height, the distance between the nodes, length and width of leaves from the middle area in group II are greater, and the number of leaves and days from transplanting to flowering are less. Porkabiri et al. (2019) report that length, leaf width and leaf area are the effective criteria for creating high-yielding varieties in the selection for high yield tobacco.

Conducting cluster analysis with the help of modern computer programs makes it possible to determine those traits that contribute most to the resulting distribution of genotypes by class (Rachovska et al., 2002).

The aim of the study is to make a grouping and comparative evaluation of hybrid combinations by plant height, leaf number, leaf size - length of middle leaves, and width of middle leaves, dry leaf yield, days to 50% flowering.

MATERIALS AND METHODS

Five-year investigation was carried out in the experimental field of Tobacco and Tobacco Products Institute, Markovo. Five Virginia tobacco hybrid combinations and standard Virginia 0514 were included in a block design with four replications and 27 m^2 experimental plot (Table 1). Each genotype was analyzed according to the following characteristics: stem height (SH), leaf number (LN), leaf length (LL), leaf width (LW), days to 50% flowering (D50F), dry leaf yield (DLY).

A comparative evaluation of the hybrid combinations with the Virginia 0514 standard was performed on each of the traits at a level of statistical significance of 0.05. A variance analysis was applied, as a result of which the average values and standard error for each of the hybrid forms were calculated.

Table 1. F1 hybrid combinations

F1 hybrid combinations	Breeding method	Origin
H27 (Coker 254 x Virginia 385)	F1	Bulgaria
H33 (Virginia 0594 x Virginia 385)	F1	Bulgaria
H51 (Virginia 0594 x L 825)	F1	Bulgaria
H126 (Virginia 385 x L0543)	F1	Bulgaria
H135 (L 0543 x L 0842)	F1	Bulgaria
Virginia 0514 - standart	F1	Bulgaria

For the grouping of hybrid combinations, hierarchical cluster analysis was applied using the intergroup coupling method and measure of similarity the quadratic Euclidean distance. The result is presented by a dendrogram, visualizing the differentiation of hybrids by the degree of similarity in the studied indicators. The analyzed indicators were transformed into two factors by a Principal Component Analysis (PCA), and the rotation of the factors was performed using the Varimax method. It was found that the data meet the necessary prerequisites for its implementation. The data were standardized in advance. The IBM SPSS Statistics 24 software product was used for statistical processing of the experimental data.

RESULTS AND DISCUSSIONS

The data obtained as a result of the experimental activity, as well as the results of their mathematical processing are presented in Table 2.

The results of the single-factor analysis of variance and the comparative evaluation of the studied variants and the Virginia 0514 standard show that the hybrid combinations have no proven differences with the Virginia 0514 standard based on the indicators of plant height and leaf number.

The highest degree of variation is found in H27 on both indicators. On the basis of the length of the 12th leaf H27 (58.73 cm), H33 (61.16 cm) and H126 (63.64 cm) differ from Virginia 0514 (58.88 cm), which is due to the longer leaves compared to the standard. For the crosses H 51 (33.61 cm), H27 (34.64 cm), H33 (34.01 cm) and H126 (35.71 cm) proven wider leaves than the standard were reported.

On the basis of days to 50% flowering, only H126 proves longer days to 50% flowering (74.15 days). For the other hybrid combinations, the values are close to those of the standard, so there are no proven differences with it.

During the five-year study period at the Virginia 0514 standard, lower dry leaf yield was reported compared to H27 (334.55 kg da), H33 (329.15 kg/da) and H126 (320.25 kg/da), which determines the presence of proven differences between them at a level of statistical reliability of 0.05.

Table 2. Comparative evaluation of Virginia hybrid tobacco combinations by morphological characteristics, vegetation periods dry leaf yield

Cluster №	Hybrid	Stem height	Leaf number	Length of 12^{th} leaf	Width of 12^{th} leaf	Days to 50% flowering	Dry leaf yield
I	H51	160.86±2.02$^{n.s.}$	24.40±2.62$^{n..s.}$	58.73±1.01$^{n.s.}$	33.61±0.4*	69.25±1.43$^{n.s}$	295.25±7.26$^{n.s.}$
	Virginia 0514 st	164.50±3.30	25.58±2.05	58.88±0.96	32.12±0.5	67.65±1.79	296.55±4.49
	H135	157.66±1.85$^{n.s.}$	25.05±2.10$^{n.s.}$	57.10±0.92$^{n.s.}$	32.54±0.5$^{n.s.}$	69.3±0.75$^{n.s.}$	292.05±3.66$^{n.s.}$
II	H27	164.30±5.05$^{n.s.}$	25.12±3.65$^{n.s.}$	61.56±0.44*	34.64±0.3*	68.1±1.18$^{n.s.}$	334.55±3.54*
	H33	160.02±2.10$^{n.s.}$	25.73±2.51$^{n.s.}$	61.15±0.63*	34.01±0.5*	69.2±1.5$^{n.s.}$	329.15±3.61*
	H126	161.50±2.57$^{n.s.}$	25.65±1.82$^{n.s.}$	63.64±0.50*	35.71±0.4*	74.15±0.61*	320.25±5.22*
Average		161.47	25.25	60.18	33.77	69.61	311.3
SEM		1.07	0.210	0.970	0.540	0.950	7.710
P-Value		0.590	0.552	0.000	0.000	0.008	0.000

As a result of the conducted hierarchical cluster analysis, it was found that the studied hybrid combinations were grouped in two clusters according to the degree of similarity in the studied indicators (Figure 1).

The first cluster includes hybrid combinations with smaller leaf sizes (length and width of the 12th leaf) and lower yields of dry tobacco: H51, Virginia 0514, H135.

The H27, H33 and H126 hybrid combinations have larger leaf sizes, both 12th leaf length and width, and are more productive.

This determines their differentiation into a separate cluster, which joins the first at a maximum Euclidean distance of 25 units, proving the existence of large differences between the two groups.

All three hybrids have a parent component Virginia 385, which is absent in the other variants, which suggests the impact of this variety on the better characteristics of these hybrid combinations.

As the cluster analysis does not perform tests for statistical reliability of the obtained results, it is expedient to combine this method with another approach.

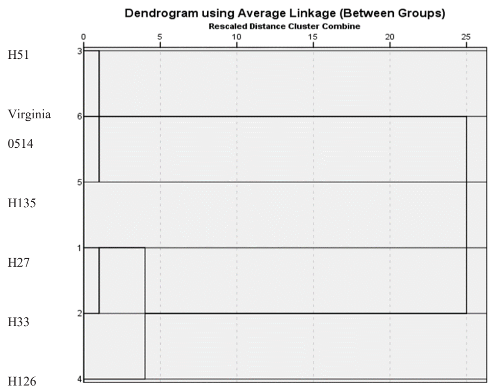

Figure 1. Grouping of hybrid forms of Virginia tobacco according to morphological characteristics, dry leaf yield and days to 50% flowering

For a qualitative description of the factors influencing the obtained clustering, a Principal Component Analysis (PCA) was applied. For this purpose, it was found that the experimental data meet the requirements for PCA: KMO-Test (0.631> 0.5) and Bartlett's test (0.000 <0.05), and the determinant of the correlation matrix is a positive number. The studied traits are transformed into two factors: F_1 and F_2.

The first includes: length and width of the 12th leaf, days to 50% flower and yield and explains 42.8% of the total variance. In this principal component, the width of the 12th leaf, the length of the 12th leaf, the yield of dry tobacco and days to 50% flowering have the strongest influence. The second principal component consists of: stem height and leaf number and explains 32.5%, with a cumulative percentage of variation of 75.3%. Here the number of leaves and the height of the plant have the highest correlation coefficient, which is evidenced by the maximum values of factor weights (Table 3, Figure 2).

Table 3. PCA for hybrid forms of *Virginia tobacco*

Indicator	Component	
	F_1	F_2
Stem height	0.002	0.892
Leaf number	-0.073	0.921
Length of middle leaves	0.874	-0.281
Width of middle leaves	0.912	-0.131
Days to 50% flowering	0.525	0.409
Dry leaf yield	0.832	0.213
% of Variance	42.8	32.5
Cumulative %	42.8	75.3

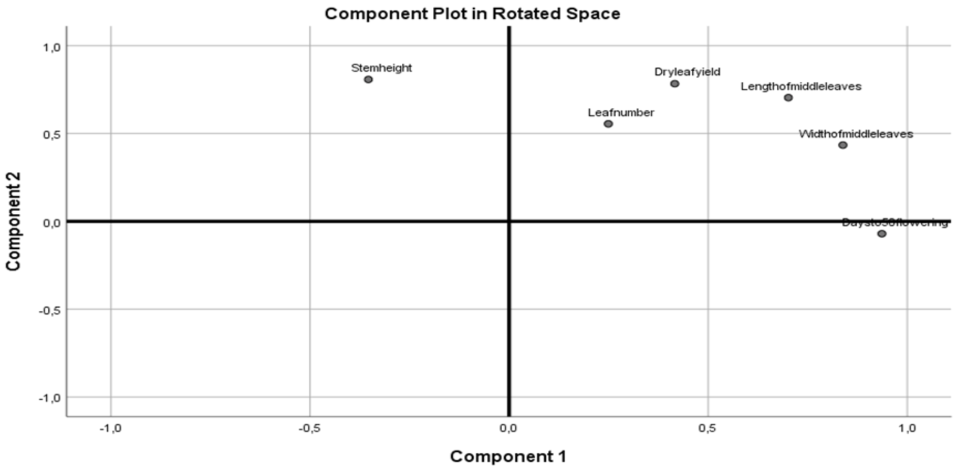

Figure 2. Component plot of the studied indicators on the factorial plane

CONCLUSIONS

The grouping of hybrids in clusters showed that H27, H33 and H126 with a common parent component Virginia 385 have larger leaves and are more productive, which determines not only their differentiation into a separate cluster, but also their strong distance from the other three hybrids in this study. Hybrid H126 has the largest 12th leaf, followed by H27. Hybrid H27 is the most productive. Hybrid H126 has the longest growing season. Hybrid H27 has not only the highest yield, but stands out as relatively stable in this respect, which makes it a recommended variety for cultivation by tobacco growers. The results of the combined application of cluster analysis and principal components analysis show that the most effective would be the selection activity aimed at the populations of the second group based on the traits: length and width of the 12th leaf, dry leaf yield and days to 50% flowering.

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AGROECOLOGICAL ASSESSMENT OF THE INFLUENCE OF MICROBIOLOGICAL FERTILIZER ON OIL FLAX VARIETIES

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Abstract

In a field stationary experiment and laboratory conditions, an assessment was made of the varietal responsiveness of oil flax plants to the effect of the microbiological fertilizer "Baikal EM-1" in the soil and climatic conditions of the Penza region. It has been established that in the technology of growing varieties of oil flax plants, the microbiological fertilizer "Baikal EM-1" used for seed inoculation before sowing + foliar treatment of flax plants in the "Christmas tree" phase + foliar treatment of flax plants in the budding phase, contribute to an increase in germination energy, field germination, as well as increasing the length of the seedling and germinal root. This leads to an increase in plant height in the herringbone phase of 14.2 cm, in the control variant 11.4 cm, in the flowering phase 49.1 cm, which is 10 cm higher than the control variant. Leafiness in the "herringbone" phase was 75.8%, in the control variant 64.8%. The seed yield of the Lirina variety was 19.3 c/ha and straw was 38.63 c/ha, while in flax plants of the Kinelsky 2000 variety, the seed yield was 18.4 c/ha and the straw was 36.8 c/ha.

***Key words**: oil flax, microbiological fertilizer "Baikal EM-1", grade, productivity and crop structure.*

INTRODUCTION

The processes of soil degradation that have been rapidly developing in recent years against the background of chemicalization of agriculture are forcing producers to switch to energy-saving production technologies. In addition, special attention was paid to the quality of products (Kulikova and Blinokhvatova, 2021; Chebotar et al., 2015).

Of particular importance is the biologization of agriculture both in open and closed ground. The use of microbiological fertilizers has shown high efficiency in many crops (Baldani, 2005; Chandra et al., 2019; Hogenhout et al., 2009; Koryagin et al., 2020).

Flax is a valuable oilseed crop suitable for cultivation in almost any agricultural zone. An important reserve for the growth of oilseed flax yield is intensive technology of its cultivation, including scientifically based application of microbiological fertilizers (Pukalova, 2016; Shaykova et al., 2018; Posypanov, 2007).

Obtaining environmentally friendly products is of great importance in flax growing. Therefore, the study of the use of a biological product in the technology of flax cultivation and its effect on the productivity of seeds and fiber is currently relevant and promising.

MATERIALS AND METHODS

The microbiological fertilizer "Baikal EM-1" used in our experiments is an aqueous solution containing a complex of beneficial microorganisms that actually live in the soil and their metabolic products. These microorganisms interact in the soil, while producing all kinds of enzymes, amino acids and other physiologically active substances that have both direct and indirect positive effects on the growth and development of plants. The main role in the preparation "Baikal EM-1" is played by photosynthetic and lactic acid strains of microorganisms. Photosynthetic strains of bacteria affect the direct growth of plants, and lactic acid strains of bacteria contribute to faster soil cleansing from harmful substances and pathogenic microorganisms.

The aim of the work is to study the responsiveness of varieties flax oil seed for microbiological fertilizer Baikal EM-1, on the

dynamics of its growth, development and productivity.
The varietal responsiveness of oil flax to the effect of the Baikal EM-1 microbiological fertilizer was studied in a small-plot experiment on light gray forest soil. The plot area is 1 m^2, the experiment is repeated four times. The width of the protective strips is 1 m. The placement of repetitions is sequential. With a solution of the drug "Baikal EM-1", at a concentration of 1:1000, seeds were inoculated directly on the day of sowing and subsequent foliar treatments of plants - in the phases of herringbone and budding.
Scheme of experience:
1. Inoculation of seeds with water before sowing (control);
2. Inoculation of seeds "Baikal EM-1" before sowing;
3. Inoculation of seeds "Baikal EM-1" before sowing + foliar treatment in the "herringbone" phase;
4. Inoculation of seeds "Baikal EM-1" before sowing + foliar treatment in the budding phase;
5. Inoculation of seeds "Baikal EM-1" before sowing + foliar treatment in the "herringbone" phase + in the budding phase.
Sowing was carried out with a row spacing of 15 cm to a depth of 3 cm, the seeding rate was 700 pcs/m^2.The crop was harvested in the phase of full ripeness.
The yield data obtained in the experiment were processed by the method of dispersion analysis.
Variety Lirina -Deutsche Saatveredelung AG, variety Kinelsky 2000 -Patentee GNU Povolzhsky Research Institute of Breeding and Seed Production. P.N. Konstantinov of the Russian Agricultural Academy (Figure 1).

RESULTS AND DISCUSSIONS

The study of the effect of the drug on the sowing qualities of flax showed that the germination energy of the studied varieties was higher in the variants with seed treatment before sowing with the microbiological agent Baikal EM-1 than in the control variant (treatment of seeds before sowing with water) (Table 1).

Table 1. Influence of inoculation of flax seeds with a biological product on the sowing qualities of oil flax seeds

Indicators	Linen variety			
	Lirina		Kinelsky 2000	
	1	2	1	2
Germination energy, %	85.6	89.8	84.1	87.6
Laboratory germination, %	91.3	95.5	88.5	93.7
Field germination, %	79.3	84.4	75.7	83.1
Spine length on day 3, cm	1.13	1.37	1.1	1.2
Spine length on the 6th day, cm	6.1	6.8	4.8	5.1

1 - Inoculation of seeds with water before sowing (control);
2 - Inoculation of Baikal EM-1 seeds before sowing.

The same can be said about the laboratory and field germination of the studied plant varieties. The inoculation of flax seeds "Baikal EM-1" ensured laboratory germination of plants of the Lirina variety - 95.5%, plants of the Kinelsky 2000 variety - 93.7%. Whereas in the control variant it was 91.3% and 88.5%, respectively. Field germination of the flax variety Lirina was 4.2% higher compared to the control variant; in the flax variety Kinelsky 2000 - by 5.2%. The length of the seedlings also increased markedly compared to the control.

The highest height of flax plants in the field was observed in the Lirina variety in the “herringbone” and flowering phases during seed inoculation + foliar treatment in the “herringbone” and budding phases. Plant height reached 14.2 cm in the herringbone phase and 49.1 cm in the flowering phase, while in the variant with seed treatment before sowing with water (control) it reached 11.4 cm in the herringbone phase, and in the flowering - 39.1 cm. A similar pattern was observed in flax varieties Kinelsky 2000 (Table 2).

Table 2. The effect of microbiological fertilizer on the biometric parameters of plants of oil flax varieties

Indicator	Development phases	Option				
		1	2	3	4	5
Flax variety Lirina						
Plant height, cm	"herringbone"	11.4	12.0	12.5	12.8	14.2
	bloom	39.1	42.4	45.3	46.8	49.1
Leafiness of plants, %	"herringbone"	64.8	71.4	72.1	72.9	75.8
	bloom	48.1	51.2	52.3	53.1	56.1
Plant biomass, g/m²	"herringbone"	299	310	349	411	454
	bloom	880	940	1100	1400	1770
Flax variety Kinelsky 2000						
Plant height, cm	"herringbone"	10.9	11.7	15.1	16.3	17.4
	bloom	48.5	51.4	55.4	59.2	60.4
Leafiness of plants, %	"herringbone"	63.6	70.0	71.2	72.3	73.7
	bloom	47.5	50.8	52.3	52.8	61.3
Plant biomass, g/m²	"herringbone"	221	297	330	375	423
	bloom	814	895	981	1212	1541

1 - Inoculation of seeds with water before sowing (control);
2 - Inoculation of seeds "Baikal EM-1" before sowing;
3 - Inoculation of seeds "Baikal EM-1" before sowing + foliar treatment in the "herringbone" phase;
4 - Inoculation of seeds "Baikal EM-1" before sowing + foliar treatment in the budding phase;
5 - Inoculation of seeds "Baikal EM-1" before sowing + foliar treatment in the "herringbone" phase + foliar treatment in the budding phase

The highest percentage of foliage, both in the Lirina variety and in the Kinelsky 2000 variety, was observed in the variants where the seeds were inoculated together with the processing of the vegetative mass "Baikal EM-1" in the "herringbone" and budding phases. In the “herringbone” phase, the Lirina variety had 75.8% foliage, which is 11% more than in the variant with seed treatment with water before sowing (control variant). In plants of the variety Kinelsky 2000, respectively, 73.7%, which is 10.1% more than in the control.

The degree of foliage of plants affects the net productivity of photosynthesis, which allows plants to accumulate more dry matter, which means that the largest economic yield can be predicted.

The biomass of flax plants in the “herringbone” phase increased by 155 g/m² during the inoculation of Baikal EM-1 seeds before sowing + foliar treatment in the “herringbone” phase + foliar treatment in the budding phase in flax plants of the Lirina variety compared to the control; in flax plants of the Kinelsky 2000 variety - by 201.4 g/m². In the flowering phase, the biomass of the Lirina variety in the variant with the inoculation of seeds "Baikal EM-1" before sowing + foliar treatment in the "herringbone" phase + foliar treatment in the budding phase was 1770.2 g/m^2, which is 890.2 g. more than in the control variant. In the flax variety Kinelsky 2000, in the variant, inoculation of seeds together with the treatment of the vegetative mass "Baikal EM-1" in the phases of "herringbone" and budding, the biomass during flowering was 1540.5 g/m^2, which is 726.5 g/m^2 more,

The study of the influence of microbiological fertilizer "Baikal EM-1" on the elements of the structure of the crop in different varieties of oil flax showed that both varieties showed high responsiveness to the use of microbiological fertilizer "Baikal EM-1". Compared to the control variant, the following increased: plant height, the number of bolls per plant, as well as the weight of 1000 seeds (Table 3).

Table 3. The effect of seed inoculation with fertilizer on the elements of the crop structure in different varieties of oil flax

Indicator	Development phases	Option				
		1	2	3	4	5
Flax variety Lirina						
Plant height, cm	General	44.6	50.1	52.5	52.8	55.6
	Technical	35.5	37.5	39.1	39.4	41.3
Quantity per 1 plant, pcs	Branches	2	2	2	2	2
	Boxes	7.1	7.6	7.7	7.7	8.0
Weight of 1000 seeds, g		6.1	6.3	6.4	6.4	6.5
Flax variety Kinelsky 2000						
Plant height, cm	General	59.0	61.4	63.1	63.7	64.0
	Technical	39.1	42.0	42.5	42.9	43.8
Quantity per 1 plant, pcs	Branches	2	3	3	3	3
	Boxes	6.5	6.7	6.8	6.7	6.9
Weight of 1000 seeds, g		5.10	5.2	5.3	5.3	5.4

1 - Inoculation of seeds with water before sowing (control);
2 - Inoculation of seeds "Baikal EM-1" before sowing;
3 - Inoculation of seeds "Baikal EM-1" before sowing + foliar treatment in the "herringbone" phase;
4 - Inoculation of seeds "Baikal EM-1" before sowing + foliar treatment in the budding phase;
5 - Inoculation of seeds "Baikal EM-1" before sowing + foliar treatment in the "herringbone" phase + foliar treatment in the budding phase.

The inoculation of flax seeds and the subsequent foliar treatment of the vegetative mass in the "herringbone" and budding phases of "Baikal EM-1" had a positive effect on the yield of seeds and straw (Table 4).

Table 4. Effect of microbiological fertilizer on the yield of seeds and straws of oil flax

Indicator		Option				
		1	2	3	4	5
Flax variety Lirina						
Seed yield, c/ha		13.3	15.0	17.2	17.5	19.3
increase	c/ha	-	1.7	3.9	4.2	6.0
	%	-	12.8	29.3	31.6	45.1
HCP_{05}		0.44				
Straw yield, c/ha		26.6	29.5	30.9	34.6	38.6
increase	c/ha	-	2.9	4.3	8.0	12.0
	%	-	10.9	16.2	30.1	45.1
$LSD_{0.05}$		0.34				
Flax variety Kinelsky 2000						
Seed yield, centner/ha		12.8	14.4	16.4	16.8	18.4
increase	c/ha	-	1.6	3.6	4.0	5.6
	%	-	12.5	28.1	31.3	43.8
HCP_{05}		0.40				
Straw yield, c/ha		25.6	28.3	29.5	33.5	36.8
increase	c/ha	-	2.7	3.9	7.9	11.2
	%	-	10.5	15.2	30.9	43.8
$LSD_{0.05}$		1.90				

1 - Inoculation of seeds with water before sowing (control);
2 - Inoculation of seeds "Baikal EM-1" before sowing;
3 - Inoculation of seeds "Baikal EM-1" before sowing + foliar treatment in the "herringbone" phase;
4 - Inoculation of seeds "Baikal EM-1" before sowing + foliar treatment in the budding phase;
5 - Inoculation of seeds "Baikal EM-1" before sowing + foliar treatment in the "herringbone" phase + foliar treatment in the budding phase.

The best result was obtained in the variant with the use of seed inoculation from the seeds of "Baikal EM-1" before sowing + foliar treatment in the "Christmas tree" phase + foliar treatment in the budding phase. The seed yield of the Lirina variety was 19.3 q/ha. Other options for the use of the drug also significantly exceeded the control option: in the option of seed inoculation "Baikal EM-1" before sowing, the seed yield was 15.0 c/ha; on the variant with the use of inoculation of seeds "Baikal EM-1" before sowing + foliar treatment in the "herringbone" phase - 17.2 c/ha; on the variant with the use of seed inoculation "Baikal EM-1" before sowing + foliar treatment in the budding phase - 17.5 c/ha. A similar effect of the microbiological fertilizer "Baikal EM-1" on the yield of seeds of oil flax plants is also observed in the variety Kinelsky 2000.

The straw yield of the Lirina variety in the variant of seed inoculation with water before sowing was 26.6 c/ha, and for the Kinelsky 2000 variety it was 25.6 c/ha. The highest straw yield in oil flax plants Lirina and Kinelsky 2000 was obtained in the variant with the use of Baikal EM-1 seeds inoculation before sowing + foliar treatment in the "Christmas tree" phase + foliar treatment in the budding phase - 45.1 and 43.8 c/ha, respectively.

CONCLUSIONS

In a field stationary experiment and laboratory conditions, an assessment was made of the varietal responsiveness of oil flax plants to the effect of the microbiological fertilizer "Baikal EM-1" in the soil and climatic conditions of the Penza region. It has been established that in the technology of growing varieties of oil flax plants, the microbiological fertilizer "Baikal EM-1" used for seed inoculation before sowing + foliar treatment of flax plants in the "Christmas tree" phase + foliar treatment of flax plants in the budding phase, contribute to an increase in germination energy, field germination, as well as increasing the length of the seedling and germinal root. This leads to an increase in plant height in the herringbone phase of 14.2 cm, in the control variant 11.4 cm, in the flowering phase 49.1 cm, which is 10 cm higher than the control variant. Leafiness in the "herringbone" phase was 75.8%, in the control variant 64.8%. The seed yield of the Lirina variety was 19.3 c/ha and straw was 38.63 c/ha, while in flax plants of the Kinelsky 2000 variety, the seed yield was 18.4 c/ha and the straw was 36.8 c/ha.

The use of microbiological fertilizer on the crops of oil flax varieties Lirina and Kinelsky 2000 easily fit into the cultivation technology, contribute to an increase in plant productivity and the production of environmentally friendly products.

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EFFECT OF FOLIAR FERTILIZATION ON THE QUALITY PARAMETERS OF WHEAT AND MAIZE CROPS

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Abstract

Wheat (Triticum aestivum L.) and maize (Zea mays L.) are widely consumed cereal crops throughout the world, representing a major staple food. Increased demand of food requires higher crop yields which are dependent of climatic conditions and soil fertility. Hence, for achieving this objective, it is necessary to adopt proper fertilization schemes. The excessive use of chemical fertilizers in agricultural systems poses negative environmental effects and accordingly, use of ecological inputs became a safer alternative. In this context, the aim of the present study was to assess the effect of ecological inputs' application on quality indicators for wheat and maize crops. In the experimental scheme was included foliar fertilization during vegetation period with CODAMIX and ECOAMINOALGA, as one treatment for wheat and two treatments for maize. The obtained results indicated that both applied fertilizers favoured accumulation of protein and starch in cereal seeds at levels higher than those identified for control variant. On the basis of the achieved data, it was found that application of ECOAMINOALGA was more efficient than CODAMIX and stimulated formation of seeds with better quality parameters for both crops subjected to this study.

***Key words**: foliar application, maize, proteins, starch, wheat.*

INTRODUCTION

Modern agriculture is mainly focused on using the resources with maximum efficiency to ensure a greater productivity for feeding the growing global population. Wheat (*Triticum aestivum* L.) and maize (*Zea mays* L.) are some of the most important cereal crops used in human food and animal feed throughout the world. Therefore, increasing cereals yield and crop quality has become an essential target.

To achieve this goal regardless of climatic conditions and soil properties, it is necessary to adopt proper fertilization schemes, avoiding an excessive use of chemical fertilizers which cause soil degradation and negative environmental effects.

Currently, researchers are more interested in using organic fertilizers and plant biostimulants which are considered a sustainable approach to improve the growth and productivity of field crops. By definition, biostimulants are substances that have ability to enhance plant growth, nutrient efficiency, abiotic stress tolerance in plants and crop quality traits (Van Oosten et al., 2017). Biostimulants are available in a variety of formulations with different ingredients in composition as humic substances, seaweed extracts (supplying active plant growth substances such as auxins and cytokinins) and amino acids (Kauffman et al., 2007).

Amino acids are the basic building blocks of proteins and perform numerous functions: growth stimulating, precursors of auxin and chlorophyll, stimulation of seeds germination (Paleckiene et al., 2007). Although plants are able to synthesize amino acids, this process consumes a lot of energy and consequently, the application of ready for uptake amino acids allows plants to save energy and to intensify their development, especially under critical conditions (Maini, 2006; Popko et al., 2014).

On the other hand, the cultivation of high quality cereal crops needs an adequate supply of micronutrients, which act as stimulants for macronutrients, in particular nitrogen (Potarzycki, 2004). Nevertheless, the availability of micronutrients is limited by the characteristics of the soil, as well as the agricultural practices, therefore an additional supply for plants is required.

The new stimulant products allow achieving significant increases in the quality and quantity of yield by improving the efficiency of fertilizer nutrients uptake. In fertilizers, amino acids form organic connections with minerals (amino acid chelates), which increase the availability of nutrients for plants (Popko et al., 2018; Niewiadomska et al., 2020).

Lately foliar application of micronutrients seems to be effective and it is becoming more popular (Johansson, 2008; Popko et al., 2018). Thus, recent studies reported that foliar application of liquid seaweed extract (Makawita et al., 2021) and organic fertilizers (Hussain et al., 2022) was efficient regarding nutrient availability for optimum development and growth resulting in improving quality of field crops cultivated under unfavourable environments.

Also, a positive impact of biostimulants (seaweed extracts and free amino acids complex) on the bean seeds antioxidant potential was noted, expressed by the increased synthesis of phenolics, flavonoid, anthocyanins and antioxidant activities (Kocira et al., 2020). Evaluation of the biostimulant potential for an aqueous extract obtained from duckweed (*Lemna minor* L.) on maize has evidenced improved maize germination, biomass, leaf area, pigment content (Del Buono et al., 2021).

Most studies revealed a positive impact of foliar fertilization not only on cereals crops but also on vegetable production. Application of organic products containing free amino acids, polysaccharides and oligoelements induced obtaining of pepper (Balan et al., 2014), tomatoes (Dobrin et al., 2018) and eggplant seedlings (Dobrin et al., 2016) with high quality and strong roots.

However, some authors reported no differences on yield when foliar treatments with comercial biostimulants were used on corn and soybean (Sharma et al., 2018; Lilley, 2020). Also, Feitosa de Vasconcelos (2019) noted small or no significant increase in the content of the nutrients in the maize and soybean.

In this context, the aim of the present study was to evaluate the influence of some ecological inputs' application on quality indicators for wheat and maize crops.

In the experimental scheme was included foliar fertilization during vegetation period with the organic fertilizers CODAMIX and ECOAMINOALGA as one treatment for wheat and two treatments for maize. These ecological products can supply cultivated plants with amino acids and elements in the case of their critical deficiencies. As amino acids are known to facilitate the transport of elements (metal translocation through xylem) (Jan et al., 2016), it is expected that an improvement of the quality of cereal grains to occur under this treatment.

MATERIALS AND METHODS

This study reports the results of the researches performed on wheat and maize seeds in order to evaluate the accumulation of protein and starch under foliar fertilization with two products destined to organic agriculture which act as biostimulant for plant growth and micronutrient fertilizer.

The field experiment was conducted in 2020 at the Agricultural Research and Development Station Pitești, Romania, and it was used as test crops wheat (Trivale variety) and maize (F376 hybrid).

The experimental scheme for each crop was composed of three variants: V1 - Control variant (no fertilization); V2 - Foliar fertilization with CODAMIX; V3 - Foliar fertilization with ECOAMINOALGA.

CODAMIX is a water-soluble fertilizer which contains microelements (Fe, Mn, Zn, Cu, B, Mo) chelated by citric acid, lignosulphonic acids and EDTA. It is used often as a supplement to NPK fertilising schedules (Sustainable Agro Solutions, Codamix producer, 2021).

ECOAMINOALGA is defined by its producer as a biostimulant obtained from soy and seaweed protein hydrolysis with over 40% organic matter and amino acids content. It is recommended for use in organic farming.

In Table 1 are centralized treatments for each experimental crop.

Table 1. Fertilization scheme

Experimental crop	Wheat	Maize
Preceding crop	Sunflower	Maize
Basal application	Bio Enne* 250 kg/ha	Bio Enne* 250 kg/ha
First treatment application (phenophase)#	25.05.2020 (grain filling)	25.05.2020 (7-8 leaves)
Second treatment application (phenophase) #	-	09.06.2020 (8 leaves)

*Bio Enne contains: 12% organic nitrogen, 23% water soluble sulphuric anhydride, 35% organic carbon

#Foliar application; 2.5 L solution 0.5%/ha/treatment; applied volume 150 L.

Cereal seeds obtained after harvest were analysed for protein and starch content using appropriate biochemical methods. The seeds samples were dried to room temperature and ground with the laboratory grinder into fine powder. The extractions of the biochemical compounds were conducted according to the protocol used for each determination.

Crude protein content was determined after digestion of the vegetal material by the Kjeldahl method described by Farid et al. (2017) with some modifications: 0.5 g of air-dried seeds was digested with 10 mL of concentrated sulphuric acid in Kjeldahl flask in the presence of solid catalyst. A volume of 30 mL of 33% sodium hydroxide solution was added after digestion. The released ammonia was received into 10 mL of 3% boric acid. The resulted ammonia was titrated with 0.1 N hydrochloric acid in the presence of Groack indicator (methyl red and methylene blue). The percentage of total nitrogen was estimated and converted into crude protein content. Data are presented as the mean of three replications with standard deviation.

Starch content was determined by a polarimetric method based on the optically activity of starch (Peris-Tortajada, 2004; Fărcaş et al., 2013). As starch is a biochemical compound insoluble in water, its extraction was carried out by boiling the samples in a hydrochloric acid solution. After dissolution, the samples were filtered and the optical rotation was measured using a polarimeter. The optical activity was measured at 20ºC, in a sample cell of 100 mm optical path length. Data are presented as the mean of three replications with standard deviation.

In addition to the above mentioned analyses, moisture was determined gravimetrically by mass difference before and after heating at 105ºC. Dry weight (DW) was used in calculation of crude protein content and starch content.

Statistical analyses were performed with the one-way Analysis of Variance (ANOVA). All measurements were carried out in triplicate and the results are presented as means value ± S.D. (standard deviation). The results were expressed in g% DW. Each experimental variant was compared with the control variant and the *P* values of <0.05 were considered significant.

RESULTS AND DISCUSSIONS

The performed researches aimed to reveal the qualitative improvement of the cereal seeds under foliar fertilization applied on the wheat and maize crops.

The effect of foliar fertilization on wheat seeds

The wheat seeds from both fertilized variants showed a higher content of crude protein (Figure 1) and starch (Figure 2) compared with the control variant.

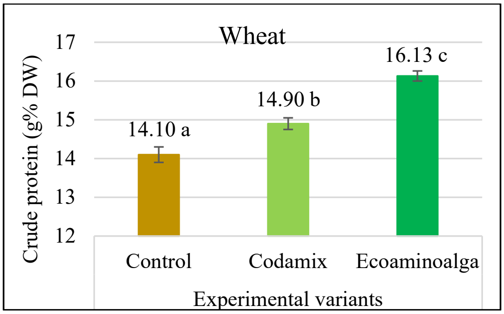

Figure 1. Accumulation of crude protein in wheat seeds
Note: all data were expressed as mean values ± S.D. (n = 3); significantly different means are indicated with different superscript letters (p<0.05)

Regarding the crude protein content, it worth to be mentioned the variant treated with ECOAMINOALGA which registered the highest value (16.13 ± 0.13 g%) as compared both to the control (14.10 g%) and the CODAMIX variant (14.90 g%) (Figure 1). In fact, statistical analysis showed significant differences between seeds protein content in all experimental variants. An increase of 5.67%, respectively 14.39% over control variant were found in case of CODAMIX and ECOAMINOALGA fertilization. Stepien and Wojtkowiak (2016) also reported that micronutrients foliar spraying contributed to a high proportion of proteins in wheat grain due to plant metabolism stimulation, but no significant difference was observed.

Popko et al. (2018) reported for wheat grains an increase of the protein content with 2.3-3.1% as against control variant under the application of amino acids based biostimulants products.

Moreover, Pichereaux et al. (2019) investigated the impact of a marine and a fungal biostimulants applied to durum wheat leaves and found an increase in protein quantity associated with a modification of the protein composition in the grains: after biostimulants treatments fifty proteins were found to be differentially represented, all of these being involved in metabolic pathways and processes.

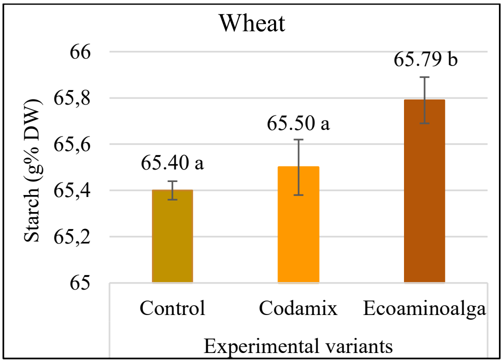

Figure 2. Accumulation of starch in wheat seeds
Note: all data were expressed as mean values ± S.D. (n = 3); significantly different means are indicated with different superscript letters ($p<0.05$)

Having in view that starch is the main source of energy in wheat grain, ranging from 60% to 70% of grain mass (Popko et al., 2018), we considered important to quantify the starch content.

The performed analyses evidenced higher values of starch content in wheat seeds for the variants treated with biostimulant products, as it follows: 65.50 ± 0.12 g% after the application of CODAMIX, respectively 65.79 ± 0.10 g% after the application of ECOAMINOALGA, in comparison with the control variants (65.40 ± 0.04 g%); the difference was significant only in the case of ECOAMINOALGA treatment (Figure 2).

The effect of foliar fertilization on maize seeds

Laboratory tests showed an increase of both biochemical characteristics of maize seeds: protein (Figure 3) and starch contents (Figure 4).

Significant differences were noted between all variants in terms of protein content. The achieved data regarding the crude protein content in maize seeds indicated an increase of 4.62% in the variant treated with CODAMIX and of 13.87% in the ECOAMINOALGA variant compared to the control variant (Figure 3).

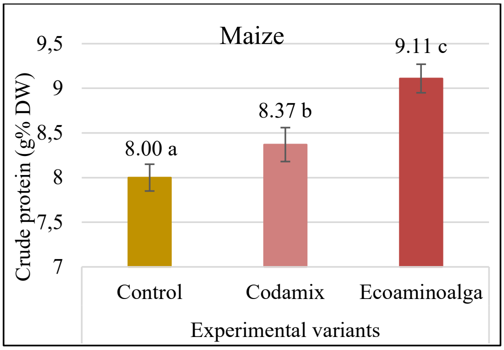

Figure 3. Accumulation of crude protein in maize seeds
Note: all data were expressed as mean values ± S.D. (n = 3); significantly different means are indicated with different superscript letters ($p<0.05$)

The starch content instead registered a slight increase in the fertilized variants (0.06% for CODAMIX and 0.35% for ECOAMINOALGA), significant differences in terms of recorded values being noted only for the ECOAMINOALGA variant both compared to the CODAMIX variant and to the control variant (Figure 4).

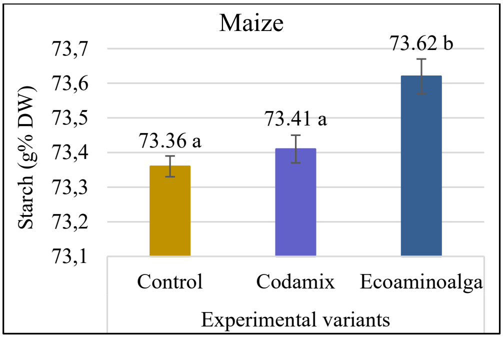

Figure 4. Accumulation of starch in maize seeds
Note: all data were expressed as mean values ± S.D. (n = 3); significantly different means are indicated with different superscript letters ($p<0.05$)

The effects of foliar fertilization on maize crop were studied also by other authors, but the conclusions are ambiguously. Some works reported no differences on yield when foliar micronutrients were used (Mueller & Diaz, 2011; Sharma et al., 2018). Instead, Macra and Sala (2021) found that the starch content ranged from 65.99 to 69.93 ± 0.21 g% when improved mineral fertilization with nitrogen by adding foliar biostimulator.

CONCLUSIONS

Results of the performed experiment showed beneficial effects of the foliar treatments with biostimulant products (CODAMIX and ECOAMINOALGA) on the quality parameters (protein and starch contents) for wheat and maize crops.

On the basis of the achieved data, it was found that application of ECOAMINOALGA was more efficient than CODAMIX and stimulated formation of seeds with better quality parameters for both crops subjected to this study. However, a more obvious increase in the accumulation of nutrients in the seeds after foliar treatment was noted for the wheat crop by comparison with the maize.

The biostimulant products tested in the present study are suitable to be recommended for an efficient agricultural production, mainly for organic agriculture, since they are safe for the environment and contribute to high quality crops.

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INFLUENCE OF SOME FOLIAR TREATMENT PRODUCTS ON PRODUCTIVITY IN CORIANDER VARIETIES (*Coriandrum sativum* L.)

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Abstract

The field experiment was carried out in 2020 and 2021 crop years on alluvial-meadow soils, on the land of the village of Voivodinovo - central-south Bulgaria. The experiment was set by the method of fraction parcels in four repetitions, with size of the crop parcel - 15 m^2, after a precrop - wheat. Three leaf treatment products were examined in the relevant doses: Grow Plant Gel Energy 20-8-60 + 2% MgO + amino acids and algae extract - 25 l/ha; Fulvin 40-22-80 l/ha; Isabion - 30 l/ha and were compared with an untreated control. The tested products were applied in the stage - budding of five coriander varieties: Jantar, Moroccan, Mesten drebnoploden, Thüringen and Marino. The present research work aims at examining the reaction of coriander varieties with relation to the applied leaf treatment products and their influence on the indicators productivity and seed yield. The obtained results showed that the examined leaf treatment products have a positive effect on seed yield, as well as on productivity elements of the following coriander varieties - Jantar, Moroccan, Mesten drebnoploden, Thüringen and Marino.Compared to the control, all varieties treated with Isabion preparation /30 l/ha/ registered the highest seed yield. Seed yield grew from 8.3 to 13.4 % during the crop years. The increase of seed yields after the application of Isabion - 30 l/ha was due to the higher values of the indicators number of seeds and weight of seeds per plant. The leaf treatment products applied on the coriander varieties increase the values of the indicator number of seeds from 11.3 to 18.6%, and weight of seeds from 5.1 to 21.4%, compared to the control.

Key words: *coriander, variety, foliar fertilizer, productivity, seed yield.*

INTRODUCTION

Coriander (*Coriandrum sativum* L.) is one of the most significant spices and aromatic crops in the world. It is an annual plant, belonging to the Umbelliferae family and mainly cultivated for its seeds.
In order to increase coriander seed yield and the content of etheric oil, as well as to overcome some abiotic stress factors, the incorporation of agro-technical and agro-chemical actions is crucially important, which include the use of leaf treatment products, such as growth regulators, bio-stimulators, retardants, bacterial preparations, vitamins and organic substances.
These products stimulate the biological potential of the coriander and have influence on growth rate with better absorption of nutrients. (Sahu et al., 2014). As a result, it has been registered higher values of the indicators productivity and seed yield compared with the control (Aishwath et al., 2012; Mishra et al., 2017; Haokip et al., 2016; Panda et al., 2007; Singh et al., 2012; Singh et al., 2017; Verma & Sen, 2008). According to Saxena et al. (2014), the efficacy of applying leaf treatment products is determined not only by the variety, but also by the climatic conditions during the vegetation stage. A study has been carried out in Russia and has established the influence of three bio-stimulants (Nagro, Agat - 25 K and Extrasol) on the productivity of two coriander varieties (Jantar and Alekseevski 190). It also has shown that both varieties react strongly toward the used products. The highest seed yield has been obtained with the application of Nagro preparation, which has exceeded the control variants of two varieties averagely with 19% (Vinogradov et al., 2018).
A study conducted in Bulgaria has been related to establishing some biologically active substances. It has been proven that these substances have positive influence on coriander and seed yield with increasing it averagely with 11.6% (Hristova and Nenkova, 2012). Other research studies have reported for the increase of seed yield from 7,4 to 16% (Kolev et al.,

2005; Petrova and Delibaltova, 2018). The study has been carried out in the region of South-eastern Bulgaria and its purpose has been to examine the influence of the biological substance Humustim on coriander. It has showed that the product, enriched in microorganisms, favours plant growth and increases stem height, the number of umbels and the weight of seeds compared to the control. As a result, the increase of seed yield has been established averagely for three years from 5 to 15% (Gramatikov and Koteva, 2006).
Results from these studies have registered that coriander reacts positively to the used leaf treatment products. It gives the opportunity for subsequent studies related to that culture. It is necessary to examine the new leaf treatment products launched on the market and to fix these preparations appropriate for coriander cultivation.
The present research work aims at examining the reaction of coriander varieties with relation to the applied leaf treatment products and their influence on the indicators productivity and seed yield.

MATERIALS AND METHODS

The field experiment was carried out in 2020 and 2021 crop years on alluvial-meadow soils, on the land of the village of Voivodinovo - central-south Bulgaria. The experiment was set by the method of fraction parcels in four repetitions, with size of the crop parcel - 15 m^2, after a precrop - wheat. Three leaf treatment products were examined in the relevant doses: Grow Plant Gel Energy 20-8-60 + 2% MgO + amino acids and algae extract - 25 l/ha; Fulvin 40-22 - 80 l/ha; Isabion - 30 l/ha and were compared with an untreated control. The tested products were applied in the stage - budding of five coriander varieties: Jantar, Moroccan, Mesten drebnoploden, Thüringen and Marino.
The experiment was performed by an adopted technology of cultivation. Soil treatment included ploughing-in of the stubble in June and tilling in depth 20-22 cm in September, two-time pre-planting cultivation with harrowing in depth 5-6 cm (Dallev and Ivanov, 2015). The phosphoric fertilizer was applied before tilling -80 kg/ha, and the nitrogen fertilizer - with the last pre-planting treatment - 10 kg/ha.
Sowing was performed annually in the period 10-20 February at a distance between rows - 12-15 cm and planting norm - 250 seeds per m^2 on depth of 3-4 cm.
The following indicators were reported: seed yield, plant height, number of umbels per plant, number of seeds per plant and seed weight per plant.
In order to establish the quantitative dependences between the examined indicators, the experimental data were processed mathematically by the method of the dispersion analysis/Anova/. The differences between variants were established by means of Dunkan`s multiple range test.
The meteorological factors during the vegetation period of coriander have influence on plant`s growth and productivity (Dyulgerov and Dyulgerova, 2016). Figure 1 and 2 show data for the amount of precipitations, as well as the monthly average air temperatures in the period February 2020 - July 2021. According to the results, the average daily air temperature in both crop years had slightly higher values than those for the multi-year period. It completely met the requirements of coriander with regard to heat from germination stage to ripening stage. Significant deviances from the crop requirements were not observed. Differences between both experimental years were related to the precipitation supply during the vegetation period. During the crop years 2020 and 2021 the precipitation amount was 347,7 and 351,0 mm, correspondingly, which exceeded with 55,7 and 59,0 mm the registered results for the period 1961-1990.

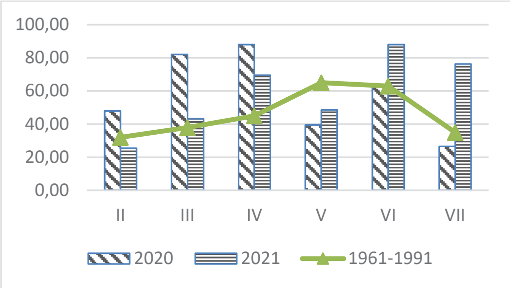

Figure1. Rainfall, mm

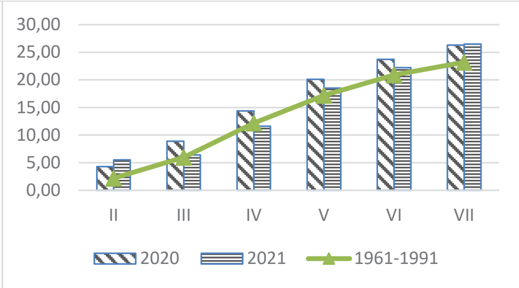

Figure 2. Average monthly air temperature, ^{0}C

In budding and flowering stages the precipitation sum was 39.5 mm in 2020, and 48.5 in 2021. It was about 25.5 and 16.5 mm less than the sum for a multi-year period, which accelerates the stages` course and influences the productivity. During the fruit-formation and ripening stages (June-July) there were fewer precipitations in 2020, while in 2021 they were about 52 mm more than the registered precipitation for the period 1961-1990. In this period plants are very sensitive toward moisture. Insufficient moisture leads to the formation of small seeds with low mass and lower yields (Dyulgerov and Dyulgerova, 2016). Taking into account both experimental years, 2021 was more favorable for the coriander because of more even distribution of precipitations and sufficient moisture supply in plants during the critical stages.

RESULTS AND DISCUSSIONS

More favourable climatic factors and particularly equable distribution of precipitations during coriander vegetation were observed in the crop year 2021 compared to 2020. It was a prerequisite for the obtainment of higher seed yields from the examined varieties.

The applied leaf treatment products influenced positively the values of this indicator for all tested varieties. Compared to the control, the highest yield was reported with the variant treated with Isabion - 30 l/ha (Table 1).

Table 1. Yield seeds kg/ha

Years of study	Treatment products	Cultivars				
		Jantar	Moroccan	Mesten drebnoploden	Thüringen	Marino
2020	Control	1446 ^{a}	2119 ^{a}	2034 ^{a}	1680 ^{a}	1623 ^{a}
	Grow Energy 20-8-60	1488 ^{b}	2235 ^{b}	2172 ^{b}	1779 ^{b}	1728 ^{b}
	Fulvin 40-22	1500 ^{b}	2240 ^{b}	2194 ^{c}	1770 ^{b}	1700 ^{b}
	Isabion	1578 ^{c}	2380 ^{c}	2251 ^{d}	1820 ^{c}	1782 ^{c}
2021	Control	1525 ^{a}	2209 ^{a}	2141 ^{a}	1768 ^{a}	1712 ^{a}
	Grow Energy 20-8-60	1589 ^{b}	2346 ^{b}	2268 ^{b}	1825 ^{b}	1810 ^{b}
	Fulvin 40-22	1617 ^{c}	2355 ^{b}	2286 ^{c}	1839 ^{c}	1835 ^{c}
	Isabion	1658 ^{d}	2505 ^{c}	2390 ^{d}	1951 ^{d}	1876 ^{d}

With relation to the untreated variants, yield rise was from 8.3 to 12.3% and from 8.7 to 13.4% for the examined varieties in 2020 and 2021, correspondingly. The received results were statistically proven. Moroccan variety reacted to most extent to the applied product Isabion - 30 l/ha. Yield grew from 261 kg/ha in the crop year 2020 to 296 kg/ha in 2021.

It was followed by Mesten drebnoploden variety, which grew from 217 and 249 kg/ha, and Thüringen variety with a yield 140-180 kg/ha higher than the control. Jantar variety reacted most weakly to the applied product Isabion.

Compared to the control, its yield increased during both years within the bounds from 8,7 to

9.1%. The applied preparations Grow Plant Gel Energy 20-8-60 + 2% MgO + amino acids and algae extract – 25 l/ha and Fulvin 40-22 - 80 l/ha contributed for the increase of seed yield from 3,0 to 7,0% in comparison with the control variants. The two-factor dispersion analysis statistically proved the strong influence of the varieties and the leaf treatment products on seed yield. Furthermore, the correlation between both factors was mathematically proven (Table 2).

Table 2. Two-way ANOVA analysis of the yield of seeds

Years of study	Source of Variation	Sum of Square (SS)	df	Mean Square (MS)	F	P-value	F crit
2020	Treatment products	315627.6	3	105209.2	145.8429	0.00*	2.758078
	Cultivars	6464557	4	1616139	2240.321	0.00*	2.525215
	Interactions	42920.67	12	3576.723	4,958116	0.00*	1.917396
2021	Treatment products	404204.1	3	134734.7	583.3093	0.00*	2.758078
	Cultivars	6663563	4	1665891	7212.169	0.00*	2.525215
	Interactions	42011.85	12	3500.988	15.15688	0.00*	1.917396

*F-test significant at P<0.05; ns non-significan

The received results related to the height of the examined varieties and the applied leaf treatment products showed that this indicator varied from 53,7 to 94,0 cm in the crop year 2020 and from 57,7 to 95,1 cm in 2021 (Table 3).

Table 3. Height of plants

Years of study	Treatment products	Cultivars				
		Jantar	Moroccan	Mesten drebnoploden	Thüringen	Marino
2020	Control	55.9 ^{a}	66.0 ^{a}	82.0 ^{a}	73.6 ^{b}	65,4 ^{a}
	Grow Energy 20-8-60	63.1 ^{b}	78.2 ^{b}	88.8 ^{b}	76.2 ^{c}	71.7 ^{c}
	Fulvin 40-22	53.7 ^{a}	76.2 ^{b}	94.0 ^{c}	62.7 ^{a}	75.6 ^{d}
	Isabion	63.3 ^{b}	81.8 ^{c}	90.6 ^{b}	64.5 ^{a}	69.6 ^{b}
2021	Control	60.1 ^{a}	70.4 ^{a}	84.1 ^{a}	74.2 ^{b}	70.3 ^{a}
	Grow Energy 20-8-60	64.8 ^{b}	80.8 ^{b}	89.6 ^{b}	77.2 ^{c}	79.8 ^{c}
	Fulvin 40-22	57.7 ^{a}	81.5 ^{b}	95.1 ^{c}	70.6 ^{a}	78.4 ^{c}
	Isabion	65.0 ^{b}	84.4 ^{b}	91.9 ^{b}	71.2 ^{a}	74.2 ^{b}

With relation to Moroccan, Mesten drebnoploden, and Marino varieties, all treated variants had higher values than the untreated ones. The use of Fulvin 40-22 - 80 l/ha and Isabion - 30 l/ha with Thüringen variety led to the decrease of plant height compared to the control. Using Fulvin 40-22 - 80 l/ha with Mesten drebnoploden and Marino varieties plant height in the end of vegetation stage was bigger with 13% - 15%, and with 19.8% - 23,9% for Moroccan variety treated with Isabion - 30 l/ha compared to the control.

Results from the dispersion analysis showed significant influence of the examined factors on plant height. The correlation between the leaf treatment products and the variety was also proven (Table 4).

Table 4. Two-way ANOVA analysis of the height of plants

Years of study	Source of Variation	Sum of Square (SS)	Df	Mean Square (MS)	F	P-value	F crit
2020	Treatment products	1145.034	3	381.6781	29.81967	0.00*	2.758078
	Cultivars	8875.974	4	2218.993	173.3651	0.00*	2.525215
	Interactions	2580.521	12	215.0434	16.80087	0.00*	1.917396
2021	Treatment products	1238.715	3	412.905	176.6753	0.00*	2.758078
	Cultivars	7832.884	4	1958.221	837.891	0.00*	2.525215
	Interactions	1238.524	12	103.2103	44.16202	0.00*	1.917396

*F-test significant at P<0.05; ns non-significan

The more favorable climatic factors in 2021 were a prerequisite for the formation of more umbels per plant with comparison to 2020 (Figures 3 and 4).

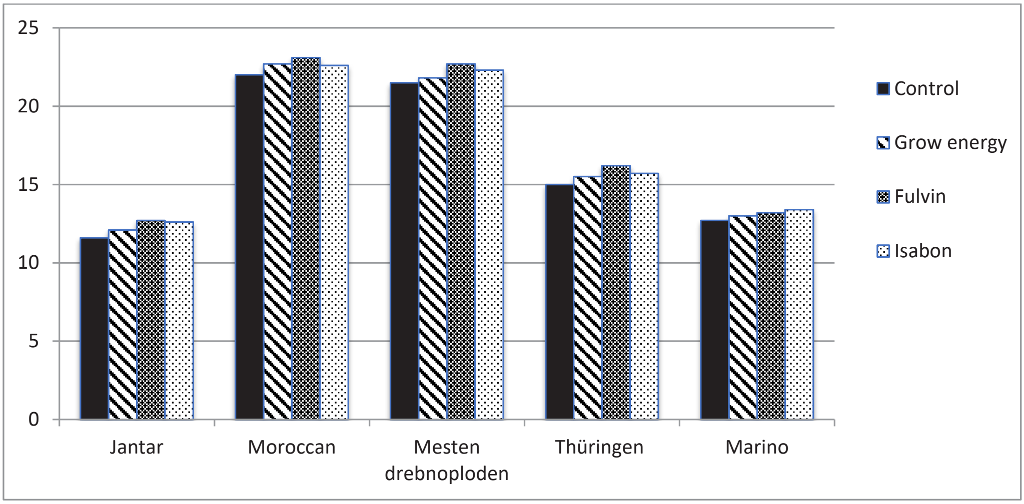

Figure 3. Number umbels per plant in 2020

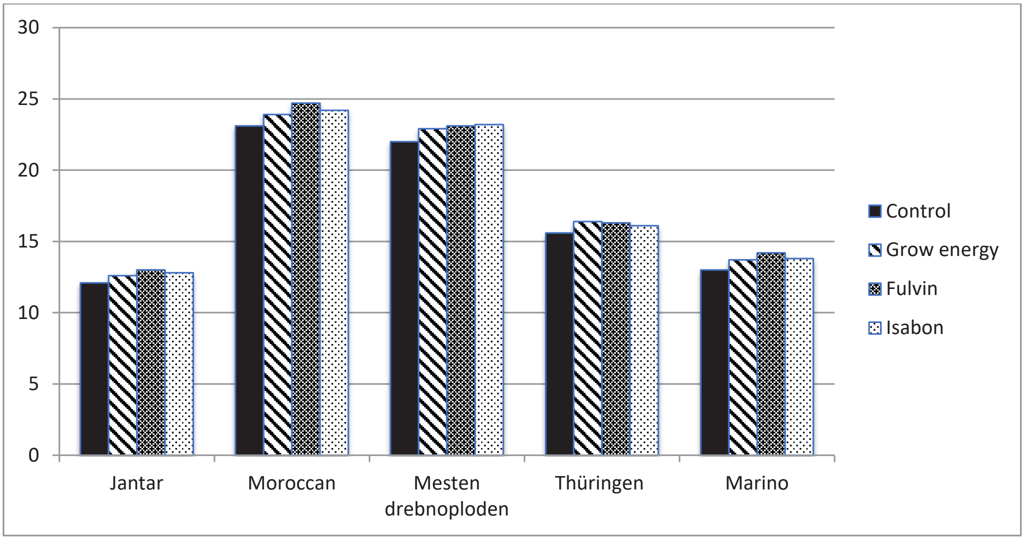

Figure 4. Number umbels per plant in 2021

The highest values of this indicator were registered for Moroccan variety treated with Fulvin 40-22 - 80 l/ha - 23.1 and 24.2 numbers. It exceeded the control with 5.0% and 6.9% for 2020 and 2021, correspondingly. Jantar variety had the fewest number of umbels - 11.6 and 12.1 numbers for the control to 12.7 and 13.0 numbers after the application of Fulvin 40-22 - 80 l/ha.

The use of this leaf product facilitated the increase of the number of umbels per plant for Mesten drebnoploden variety - to 5.6%, for Thüringen - to 8.0%, and for Marino - to 9.2%. The dispersion analysis registered statistically proven influence of the factors, and not proven influence of their interaction (Table 5).

Table 5. Two-way ANOVA analysis of the number of umbels per plant

Years of study	Source of Variation	Sum of Square (SS)	df	Mean Square (MS)	F	P-value	F crit
2020	Treatment products	9.965375	3	3.321792	10.00163	0.00*	2.758078
	Cultivars	1539.113	4	384.7783	1158.535	0.00*	2.525215
	Interactions	2.96275	12	0.246896	0.743382	0.70 ns	1.917396
2021	Treatment products	16.25937	3	5.419792	3.423837	0.02*	2.758078
	Cultivars	1852.974	4	463.2436	292.6442	0.00*	2.525215
	Interactions	16.67375	12	1.389479	0.877774	0.57 ns	1.917396

*F-test significant at P<0.05; ns non-significan

Data related to the number of seeds per plant showed that the applied leaf treatment products increased the values of this indicator during the crop years from 15.5% to 18.6% for Moroccan, and from 13.3% to 15.2% for Mesten drebnoploden compared to the control. Increase up to 14.1%, 12.7% and 11.3% was reported for Marino, Jantar and Thüringen varieties, correspondingly (Table 6).

Table 6. Number of seeds per plant

Years of study	Treatment products	Cultivars				
		Jantar	Moroccan	Mesten drebnoploden	Thüringen	Marino
2020	Control	109 a	273 a	250 a	220 a	156 a
	Grow Energy 20-8-60	118 b	288 b	270 b	232 b	160 b
	Fulvin 40-22	117 b	300 c	265 b	228 b	170 c
	Isabion	121c	324 d	288 c	248 c	178 d
2021	Control	120 a	289 a	271a	229 a	162 a
	Grow Energy 20-8-60	126 b	297 b	284 b	232 b	171 b
	Fulvin 40-22	129 b	311 b	294 b	237 b	178 b
	Isabion	135 c	334 c	307 c	256 c	182 c

For all varieties it was statistically proven that the applied leaf treatment products exceeded the control. The number of seeds was reported with highest values with all variants treated with Isabion - 30 l/ha, followed by those treated with Fulvin 40-22 - 80 l/ha and Grow Plant Gel Energy 20-8-60 + 2% MgO + amino acids and algae extract - 25 l/ha. The dispersion analysis showed statistically proven influence on the examined variants, as well as on the varieties along with their specific genetic features. The interaction between Variant and Variety was unproven (Table 7).

Table 7. Two-way ANOVA analysis of number of seeds per plant

Years of study	Source of Variation	Sum of Square (SS)	df	Mean Square (MS)	F	P-value	F crit
2020	Treatment products	9137.85	3	3045.95	12.57964	0.00*	2.758078
	Cultivars	359372.8	4	89843.21	371.0485	0.00*	2.525215
	Interactions	4325.275	12	360.4396	1.4886	0.15 ns	1.917396
2021	Treatment products	8518.25	3	2839.417	10.14681	0.00*	2.758078
	Cultivars	363546.8	4	90886.71	324.7887	0.00*	2.525215
	Interactions	3554.875	12	296.2396	1.058629	0.41 ns	1.917396

*F-test significant at P<0.05; ns non-significan

An important indicator affecting coriander yield is the mass of seeds per plant. The studied varieties treated with leaf products formed seeds with different weight (Table 8).

Table 8. Seed weight per plant

Years of study	Treatment products	Cultivars				
		Jantar	Moroccan	Mesten drebnoploden	Thüringen	Marino
2020	Control	0.61 a	1.18 a	1.07 a	0.97 a	0.70 a
	Grow Energy 20-8-60	0.66 b	1.24 b	1.10 b	1.11 b	0.74 b
	Fulvin 40-22	0.70 b	1.37 c	1.27 c	1.06 b	0.82 c
	Isabon	0.68 b	1.42 c	1.30 c	1.13 b	0.74 b
2021	Control	0.66 a	1.24 a	1.13 a	1.05 a	0.74 a
	Grow Energy 20-8-60	0.71 b	1.31 b	1.19 b	1.13 b	0.78 b
	Fulvin 40-22	0.73 b	1.39 c	1.29 c	1.11 b	0.81 b
	Isabon	0.79 c	1.45 d	1.34 c d	1.17 c	0.89 c

The lowest values of this indicator were registered with the control variants of the studied varieties. In 2020 the increase of seed mass varied from 8.1% to 14.7%; from 5.1% to 20.3%; from 2.8% to 21.4%; from 9.2% to 16.5% and from 5.7% to 17.0%, while in 2021 it was within the bounds of 7.6%-19.6%; 5.6%-16.9%; 5.3%-18.5%; 7.6%-11.4% and 5.4%-20.2% for Jantar, Moroccan, Mesten drebnoploden, Thüringen and Marino, correspondingly. This indicator had the highest values after the application of Isabion - 30 l/ha, and in the experimental years they were averagely up to 21,7% compared to the control.

Dispersion analysis results related to the influence of factors and their interaction on the indicator weight of seeds per plant showed clear reliability with relation to the alternation of the indicator (Table 9).

Table 9. Two-way ANOVA analysis of the yield of seeds

Years of study	Source of Variation	Sum of Square (SS)	df	Mean Square (MS)	F	P-value	F crit
2020	Treatment products	0.278845	3	0.092948	31.40146	0.00*	2.758078
	Cultivars	4.985013	4	1.246253	421.0315	0.00*	2.525215
	Interactions	0.128618	12	0.010718	3.620988	0.00*	1.917396
2021	Treatment products	0.31813	3	0.106043	22.93242	0.00*	2.758078
2021	Cultivars	5.055608	4	1.263902	273.3253	0.00*	2.525215
	Interactions	0.096733	12	0.008061	1.743242	0.08 ns	1.917396

*F-test significant at P<0.05; ns non-significan

The interaction between both factors was statistically proven for 2020, and it was not proven for 2021.

CONCLUSIONS

The examined leaf treatment products have a positive effect on seed yield, as well as on productivity elements of the following coriander varieties - Jantar, Moroccan, Mesten drebnoploden, Thüringen and Marino.
Compared to the control, all varieties treated with Isabion preparation /30 l/ha/ registered the highest seed yield. Seed yield grew from 8.3% to 13.4% during the crop years. The increase of seed yields after the application of Isabion - 30 l/ha was due to the higher values of the indicators number of seeds and weight of seeds per plant. The leaf treatment products applied on the coriander varieties increase the values of the indicator number of seeds from 11.3% to 18.6%, and weight of seeds from 5.1% to 21,4%, compared to the control. All treated variants of Moroccan, Mesten drebnoploden, and Marino varieties formed higher plants than the untreated variants. Taking into account Thüringen variety, the use of the products Fulvin 40-22 - 80 l/ha and Isabion - 30 l/ha led to decrease in the values of this indicator compared to the control.

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BROADLEAF WEEDS CONTROL IN WINTER WHEAT

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Abstract

During the period of 2018/2019-2019/2020, a field plot trial with the winter wheat variety Avenue was carried out. The experiment aimed to determine the efficacy of herbicide products for broadleaf weeds control. The studied products were Biathlon 4 D (tritosulfuron + florasulam) + Dash (adjuvant), Mustang (2.4 D ester + florasulam), and Sekator OD (iodosulfuron + amidisulfuron). The obtained results were compared with the untreated control. The efficacy of the herbicides against the weeds corn chamomile (Anthemis arvensis L.), common poppy (Papaver rhoeas L.), cleavers (Galium aparine L.), wild mustard (Sinapis arvensis L.), and forking larkspur (Consolida regalis Gray) was evaluated. High herbicide efficacy against all existing weeds was recorded. All evaluated parameters for the treated variants as plant height at the end of the vegetation, absolute and hectoliter seed mass, as well as winter wheat grain yields, had higher values compared to the untreated control.

Key words: *wheat, weeds, herbicides, efficacy.*

INTRODUCTION

Winter wheat (*Triticum aestivum* L.) is main grain crop in Bulgaria. The weeds are great competitors of wheat for nutrients, water, space, and light. The weeds can also cause indirect damages because many of them are hosts of harmful insects and diseases (Kalinova et al., 2012). The high weed infestation can decrease the yields by more than 70% (Atanasova and Zarkov, 2005). In the Modern agriculture the weed control in wither wheat is mainly accomplished by herbicide application. The choice of a proper herbicide, optimal time, and rate of application are one of the most important and responsible moments in wheat management (Abbas et al., 2009; Mitkov, 2014; Titiyanov et al., 2015; Mitkov et al, 2017a; Mitkov et al., 2017b; Petrova, 2017; Mitkov et al., 2018; Mitkov et al., 2020a; Mitkov et al., 2020b; Titiyanov et al., 2020; Yankova et al., 2020; Shaban et al., 2021; Yanev et al., 2021). Most of the herbicide products control only a specific group of weeds, and for assuring wide spectrum of weed control it is recommended to use herbicide combinations (Bostrom and Fogelfors, 2002; Chaudhry et al., 2008; Mitkov et al., 2017; Mitkov et al., 2018; Mitkov et al., 2020). Buctril Super 60 EC at a rate of 835 ml ha^{-1} and Starane-M at a rate of 875 ml ha^{-1} can be applied for broadleaf weed management (Ghulam et al., 2009). After combined application of carfentrazon + mcpp, tritosulfuron + dicamba, piraflufen + isoproturon, and amidosulfuron + iodosulfuron, Cirujeda et al. (2007) reported high efficacy against *G. aparine*.

The application of Atlantis WG - 0.50 kg ha^{-1} + 1.00 l ha^{-1} showed the highest control against *Anthemis arvensis*, *Papaver rhoeas,* and *Sinapis arvensis*. The highest efficacy against the weeds *Lamium purpureum* and *Avena fatua* after the application of Abak + Mero - 0.25 kg ha-1 + 1.00 l ha^{-1} was reported. The treatment with Osprey Extra + Biopower - 0.33 kg ha^{-1} + 1.00 l ha^{-1} showed the highest efficacy against *Lolium rigidum* and *Galium aparine*. The most difficult-to-control weeds were the volunteer of Clearfield® oilseed rape and *Veronica hederifolia* (Yanev et al., 2021).

The experiment aimed to study the herbicide efficacy and selectivity of some herbicides for broadleaf weeds control in winter wheat.

MATERIALS AND METHODS

The experiment was conducted during 2018/2019 - 2019/2020 on the agricultural land of Voyvodinovo village, district Plovdiv, Bulgaria. The trial was performed by the randomized block design in three replications. The size of the harvesting plot was 20 m². The following treatments were evaluated: 1. Untreated control; 2. Biathlon 4D - 50 g ha^{-1} (54 g/kg florasulam + 714 g/kg triasulfuron) + Dash (adjuvant) - 1.00 l ha^{-1}; 3. Mustang (300 g/l – 2.4 D + 6.25 g/l florasulam) – 800 ml ha^{-1}, and 4. Sekator OD (100 g/l + amidosulfuron + 25 g/l iodosulfuron + 250 g/l mefenpyr-diethyl - antidote) - 150 ml ha^{-1}. The herbicide application was performed in end of the tillering stage of the winter wheat (BBCH 29-30). For the purposes of the trial, the winter wheat variety Avenue was grown. The preceding crop of the winter wheat during the two experimental years was sunflower.

The potential weed infestation of the experimental field was presented by corn chamomile (*Anthemis arvensis* L.), common poppy (*Papaver rhoeas* L.), cleavers (*Galium aparine* L.), wild mustard (*Sinapis arvensis* L.), and field larkspur (*Consolida regalis* Gray).

The herbicidal efficacy was evaluated by the 10-score scale of EWRS (European Weed Research Society). The herbicidal selectivity was recorded by the 9-score scale of EWRS.

The following winter wheat indicators were evaluated:

- Plant height at the end of the growing season (cm). The measurement was performed on 10 plants of each variant in three replications;
- Winter wheat grain yield (t ha^{-1}) - by harvesting the entire experimental plot of all three replicates of each variant.
- Absolute and hectoliter seed mass of 1000 seeds. The evaluation was performed in three repetitions;

For statistical data evaluation of the Duncan's multiple range test by using the package of SPSS 19 software. The statistical differences were considered significant at $p<0.05$.

RESULTS AND DISCUSSIONS

Data regarding the efficacy of the evaluated herbicides on the 14th, 28th, and 56th day after treatment are presented in Tables from 1 to 6. On the 14^{th} day after herbicide application against the corn chamomile, an efficacy of 50 to 80% was reported (Table 1). An efficiency of 50% was recorded only in variant 2 (Biathlon 4D - 50 g ha^{-1} + Dash - 1.00 l ha^{-1}). At the next reporting date, the efficacy increased and reached 90-98% on average for the period.

On the last reporting date, the efficacy reached excellent values - 98-100%. The results obtained showed that the corn chamomile can be controlled by all herbicides evaluated in the study.

On the 14th day after the herbicide application against common poppy, low efficacy was reported after the application of Biathlon 4D - 50 g ha^{-1} + Dash - 1.00 l ha^{-1} (Table 2). Efficacy of 50-78% was established.

On the next reporting date, the efficiency increases and reaches 83-88% on average for the period.

At the last reporting date, the efficiency reached values of 93-100% on average for the period. The results show that common poppy can be controlled from all herbicidal products.

On the first reporting date after the herbicide treatment, low efficiency for the cleavers was reported - from 53 to 85% (Table 3). At the next reporting date, the efficiency increases and reaches 88-93%.

On the last reporting date, the efficiency reaches higher values - 93-100% in all variants on average for the period. The results show that the cleavers is more difficult-to-control than the corn chamomile and the common poppy.

Table 4 presents the efficacy of the tested herbicides against field larkspur. At the first reporting date, an efficacy of 45 to 93% was reported. As on the 14th day, the efficiency is the lowest for Biathlon 4D + Dash (45% average for the period). At the next reporting date, efficiency increased and reached higher values.

At the last reporting date, the efficiency reached 93-98% on average for the period.

At the first reporting date after herbicide treatment against wild mustard, an efficacy of 78 to 90% was reported (Table 5). On the next reporting date, the efficiency increased and reached 88-98%. At the last reporting date, the efficiency reaches values of 100%.

The results show that field mustard is 100% controlled by all studied herbicide products applied for the purposes of the experiment.

In both years of the trial, no visual signs of phytotoxicity to the crop were found for any of the evaluated herbicidal products.

Table 1. Herbicidal efficacy against *A. arvensis* on the 14th, 28th, and 56th day, %

Treatments	2019			2020			Average		
	14	28	56	14	28	56	14	28	56
1. Untreated control	-	-	-	-	-	-	-	-	-
2. Biathlon 4D - 50 g ha^{-1} + Dash - 1.00 l ha^{-1}	55	95	100	45	85	95	50	90	98
3. Mustang - 800 ml ha^{-1}	75	90	100	85	95	100	80	93	100
4. Sekator OD - 150 ml ha^{-1}	75	95	100	85	90	100	80	93	100

Table 2. Herbicidal efficacy against *P. rhoeas* on the 14th, 28th, and 56th day, %

Treatments	2019			2020			Average		
	14	28	56	14	28	56	14	28	56
1. Untreated control	-	-	-	-	-	-	-	-	-
2. Biathlon 4D - 50 g ha^{-1} + Dash - 1.00 l ha^{-1}	55	90	100	45	95	100	50	93	100
3. Mustang - 800 ml ha^{-1}	80	85	95	75	90	95	78	88	95
4. Sekator OD - 150 ml ha^{-1}	65	85	95	55	80	90	60	83	93

Table 3. Herbicidal efficacy against *G. aparine* on the 14th, 28th, and 56th day, %

Treatments	2019			2020			Average		
	14	28	56	14	28	56	14	28	56
1. Untreated control	-	-	-	-	-	-	-	-	-
2. Biathlon 4D - 50 g ha^{-1} + Dash - 1.00 l ha^{-1}	55	90	95	50	95	100	53	93	100
3. Mustang - 800 ml ha^{-1}	55	85	100	90	95	100	85	90	98
4. Sekator OD - 150 ml ha^{-1}	70	80	90	75	95	100	70	90	98

Table 4. Herbicidal efficacy against *C. regalis* on the 14th, 28th, and 56th day, %

Treatments	2019			2020			Average		
	14	28	56	14	28	56	14	28	56
1. Untreated control	-	-	-	-	-	-	-	-	-
2. Biathlon 4D - 50 g ha^{-1} + Dash - 1.00 l ha^{-1}	50	85	95	40	95	95	45	93	98
3. Mustang - 800 ml ha^{-1}	85	95	100	85	85	90	83	85	93
4. Sekator OD - 150 ml ha^{-1}	90	95	100	75	90	95	70	88	95

Table 5. Herbicidal efficacy against *S. arvensis* on the 14th, 28th, and 56th day, %

Treatments	2019			2020			Average		
	14	28	56	14	28	56	14	28	56
1. Untreated control	-	-	-	-	-	-	-	-	-
2. Biathlon 4D - 50 g ha^{-1} + Dash - 1.00 l ha^{-1}	80	90	100	75	85	100	78	88	100
3. Mustang - 800 ml ha^{-1}	95	100	100	85	95	100	90	98	100
4. Sekator OD - 150 ml ha^{-1}	90	95	100	80	90	100	85	93	100

In Table 6 are shown the results for the height of the winter wheat plants at the end of the growing season. The lowest were the plants from the untreated control - 73.43 cm on average for the study period. On average for the period, all variants in which herbicide treatment was carried out were higher - from 87.32 to 88.03 cm.

Table 6. Plant height at the end of the vegetation, cm

Treatments	2019	2020	Average
1. Untreated control	76.35 b	70.50 c	73.43
2. Biathlon 4D - 50 g ha^{-1} + Dash - 1.00 l ha^{-1}	88.71 a	86.36 b	87.54
3. Mustang - 800 ml ha^{-1}	88.90 a	87.15 a	88.03
4. Sekator OD - 150 ml ha^{-1}	88.58 a	86.98 ab	87.78

Values with different letters are with proved differences according to Duncan's multiple range test ($p < 0.05$).

The highest yield was reported in variants 2 (Biathlon 4D - 50 g ha^{-1} + Dash - 1.00 l ha^{-1}) and 4 (Mustang - 800 ml ha^{-1}) 8.53 and 8.35 t ha^{-1} respectively average for the trial period. After the treatment, Secator OD - 150 ml ha^{-1} the yields were also high - 8.12 on average for the period.

The yield from the control treatment was the lowest for the experimental conditions - 5.75 t ha^{-1} (Table 7).

Table 7. Winter wheat grain yield, t ha^{-1}

Treatments	2019	2020	Average
1. Untreated control	5.17 c	6.33 c	5.75
2. Biathlon 4D - 50 g ha^{-1} + Dash - 1.00 l ha^{-1}	8.15 a	8.91 a	8.53
3. Mustang - 800 ml ha^{-1}	8.24 a	8.45 a	8.35
4. Sekator OD - 150 ml ha^{-1}	7.70 b	8.09 b	7.89

Values with different letters are with proved differences according to Duncan's multiple range test ($p < 0.05$).

Absolute seed mass is a very important quality indicator (Mehmood et al., 2014). The results for this indicator are presented in Table 8. The lowest values for the absolute seed mass were found to be for the untreated control - 41.95 g on average for the period. All treated variants had higher results with a proven difference compared to the untreated control. The lowest absolute seed mass among the herbicide-treated variants was variant 4 (Secator OD - 150 ml ha^{-1}) - 46.09 g on average for the experimental period.

Table 8. Absolute seed mass, g

Treatments	2019	2020	Average
1. Untreated control	42.28 c	41.61 c	41.95
2. Biathlon 4D - 50 g ha^{-1} + Dash - 1.00 l ha^{-1}	46.36 a	47.18 a	46.77
3. Mustang - 800 ml ha-1	46.75 a	47.06 a	46.91
4. Sekator OD - 150 ml ha^{-1}	45.89 b	46.29 b	46.09

Values with different letters are with proved differences according to Duncan's multiple rage test ($p < 0.05$).

Table 9. Hectoliter seed mass, g

Treatments	2019	2020	Average
1. Untreated control	71.80 b	72.30 b	72.05
2. Biathlon 4D - 50 g ha^{-1} + Dash - 1.00 l ha^{-1}	77.50 a	77.20 a	77.35
3. Mustang - 800 ml ha-1	77.10 a	77.40 a	77.25
4. Sekator OD - 150 ml ha^{-1}	77.30 a	77.50 a	77.40

Values with different letters are with proved differences according to Duncan's multiple range test ($p < 0.05$).

The hectoliter mass of seeds is determined by the size of the grains, the presence of impurities, etc (Tonev et al., 2018). The lowest hectoliter seed mass for the untreated control was found - 72.05 kg (Table 9). The indicator for the other treatments varied from 77.25 - 77.40 on average for the period.

CONCLUSIONS

The experimental field was infested with 6 broadleaf weed species, typical for the winter wheat fields corn chamomile (*Anthemis arvensis* L.), common poppy (*Papaver rhoeas* L.), cleavers (*Galium aparine* L.), wild mustard (*Sinapis arvensis* L.), and field larkspur (*Consolida regalis* Gray).

In the treated variants, high herbicidal efficacy was found against *A. arvensis*, *P. rhoeas*, *G. aparine*, *S. arvensis,* and *C. regalis*.

No visual signs of phytotoxicity to the crop were found for any of the herbicides tested.

All studied parameters, such as plant height at the end of the growing season, absolute and hectoliter seed mass, as well as yields, were higher in all treated variants compared to untreated control.

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NEW GENOTYPES OF SWEET SORGHUM AND THEIR BIOMASS YIELDS IN THE SUSTAINABLE AGRICULTURE SYSTEM

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Abstract

The challenges of practicing a sustainable farming system include the use of renewable energy sources, fuels from residual crop biomass or biomass produced for this purpose. From the multitude of crops with high energy potential suitable for cultivation in climatic conditions in Romania, sweet sorghum (Sorghum bicolor (L.) Moench. var. Sacharratum). it proves to be one of the most important species, which is highlighted both by its high capacity to generate high yields, but also by the consistency and quality of fresh biomass production. Due to the stalks whose juice is rich in sugar (12-22% Brix), which can be easily converted into biofuel, either directly by fermentation or indirectly by obtaining alcohol, sweet sorghum is enlarged in culture, with obvious tendencies to increase surfaces on the European continent. The data presented in this paper were obtained from a study conducted on the chernozem soil in the Caracal Plain, in order to identify the ability of new hybrids of sweet sorghum to capitalize the climatic conditions specific to the area and to express their productive potential through high yields of fresh biomass with a high sugar content. The obtained data showed that the most valuable hybrid proved to be SASM 1, with a total biomass production of 88.1 t / ha and a ratio of stem participation to total biomass of 81.3%. The average soluble dry matter content (Brix) determined with the portable field refractometer, in the conditions of 2019 year, was 18.2% for the same hybrid.

Key words: *sweet sorghum, fresh biomass, yields, Brix content.*

INTRODUCTION

Characterized by a high sugar content of the stems and a chemical composition of the grain where starch predominates, sweet sorghum (*Sorghum bicolor* (L.) Moench. var. *Saccharatum*) is one of the most important agricultural sources used for the production of biomass that can be processed and converted. relatively easy in a type of fuel (bioethanol, synthesis gas), vegetable protein, feed or green manure (Reddy et al., 2005, Almodares, 2008, 2009; Matei, 2016; Antohe, 2007). In the current global energy context, green (renewable) energy is a critical source of energy that contributes to energy security, reducing dependence on fossil fuels and greenhouse gas emissions.

Many countries have developed alternative programs for fossil fuel energy in order to reduce dependence in the near future by providing at least 20-30% of them with bioethanol, biogas or biodiesel. Vinutha et al., 2014, shown that for India, more than 6.3 billion liters of ethanol were produced to reach target of replacing 20% of petroleum fuel with biofuel consumption, according to Ethanol Blending Program (EBP).

Sweet sorghum breeding programs have brought to market new genotypes with superior agronomic properties, adapted to various climatic conditions, capable of generating high biomass production and with a higher sugar content in stems than existing ones.

In a study based on multi-trait selection of sweet sorghum genotypes for bioenergy production, da Silva et al., 2020, tested 36 hybrids in two experimental areas of Embrapa Milho e Sorgo, in Sete Lagoas and Nova Porteirinha. The results demonstrated the existence of genetic variability among the genotypes of sweet sorghum, showing the possibility of selecting high-performance genotypes superior. The selection indexes tested were efficient in the selection of sweet sorghum hybrids with higher agroindustrial performance. Also, at least it was possible to

identify hybrids of sweet sorghum with high potential for bioenergy production.
Sweet, grain, and dual-purpose sorghums differ in a number of important traits, including biomass production, total solutes in the stem juice and sugar accumulation across the stem. In a study with five sorghum hybrids the obtained results showed that plant height, leaf number, leaf weight, cane yield, and juice yield were positively correlated with the sugar yield in fresh stalks (Kanbar, 2021).
The level of yields and quality of the productions were is influenced by genotypes, technology, environmental conditions, soil quality and harvest time (Soare et al., 2019; Partal et al., 2020; Matei et al., 2021; Velea et al., 2021).

MATERIALS AND METHODS

The research was carried out at Agricultural Research and Development Station Caracal (ARDS), during the 2019 year in the conditions of a chermozem soil, medium rich in nutrient and with a humus content which varied between 3% to 4%. The soil in the arable layer (0-20 cm) has a lutearic texture with a clay content (particles below 0.002 mm) of 36.2%, an apparent density of 1.42 g/cm^3, a total porosity of 47% and one medium penetration rate (penetration resistance of 42 kg/cm^2).
From the point of view of the hydric features of soil in the superficial layer, the wilting coefficient records the value of 12.3%, the field capacity 24.5% and the hydraulic conductivity is 9.2 mm/h.
The main aim of the study was research was to establish the most valuable sweet sorghum hybrid for the area of Caracal Plain, in the above soil conditions. Were experimented four hybrids: 2 typical sweet sorghum hybrids with provenience from the Republic of Moldavia (SASM 1 and SASM 2) and 2 hybrids from the Romanian market - BMR Gold and Supersile 20 - hybrids recommended for silage crops.
The culture was placed in rotation with whiter wheat as previous plant in randomized blocks of three repetitions. The sowing date was realized in the 2th of May with a complete emergence of sweet sorghum plants in 10th of May. The density used was 15 g.s/sq.m on the background of $N_{100}P_{80}K_{80}$ applied before sowing as granulated chemical compounds.
During the vegetation period were made biometrical determinations: height of plants, average leaves number and dimensions, stalks diameters. The total fresh biomass was register in milk maturity stage of plants development, on which occasion the percentage of participation of the main components of biomass was also determined: stems, leaves and panicles.
Also, we registered the sugar content as dry soluble substances (Brix content %) with portable refractometer.
Representative samples of each hybrid were extracted and using an electric roller press device were determinate the sweet juice percent and total amount of juice per hectare for each hybrid tested.
The collected data in the field were analyzed using statistical program of ANOVA.

RESULTS AND DISCUSSIONS

Climatic conditions (Figure 1 and Table 1) during the experiment had an important influence on the evolution of sweet sorghum crop. The recorded data certify that the 2019 year was an excessively hot year. Compared to the normal area, an average temperature of 12.7ºC was achieved, with 2.1ºC higher than the normal range for the area, which is 10.6ºC. Regarding the months of the warm period of the year (April - September) we find that in no month were temperatures lower than the multiannual average. The deviations were positive, ranging from 0.4ºC to 3.1ºC. It is noted as extremely hot in July, August and September, with a thermal surplus between 2.3ºC and respectively 3.1ºC. Also worth mentioning are the many days in July and August when the maximum temperature has exceeded the value of 38ºC and daily ETO had registered values of over 4.8 mm significantly reducing the water from soil. During the vegetation period of sorghum, from May to Octomber (when were made the final determinations), the total of 438.6 mm precipitations, numerically representing a sufficient value for a plant with relatively low requirements compared to the vegetation factor of water. The period of August-September was very poor in precipitation, with a deficit of -49.7 mm and respectively -37.6 mm led to a supplementary stress of sweet sorghum hybrids, having negatively repercussions to the total fresh biomass and sugar content registered in stalks.

Figure 1. Climatic conditions of 2019 year - period of March-November - precipitations and ETO (mm)

Table 1. Climatic conditions of 2019 year - period of January-September - precipitations and ETO (mm)

Year of 2019	Temperature [°C]			Solar radiation [W/m2]	Precipitations [mm]	Wind speed [m/s]		Daily ETO
Month	avg	max	min	avg	sum	avg	max	[mm]
January	-0.85	9.01	-13.47	41	38.6	1.6	8.5	0.2
February	3.42	17.41	-8.19	90	14.2	1.4	8.2	0.4
March	9.4	25.07	-3.96	156	25.2	1.7	9	2.8
April	12.11	27.16	-0.2	167	44.4	1.7	7.8	2.8
May	17.13	30.88	4.45	215	69	1.7	9.2	2.9
June	22.79	34.13	12.87	269	285.8	0.5	6	2.6
July	23.13	38.81	9.62	263	60	0.4	6.2	4.8
August	25.02	38.71	12.5	242	1	0.5	3.6	4.8
September	20.01	35.02	2.74	167	2	0.8	4.9	3.4
Octomber	13.64	54.05	2.15	107	20.8	0.8	7.6	3.4
November	11.4	23.81	2.55	46	74.4	1	5.9	0.5
May-Oct.	***20.26***				***438.6***			
Sum Jan-Nov					**635.4 mm**			

Morphological features of the sweet sorghum plants were influenced equally by the genetic heritage and the technological measures: plant's density, level of fertilization, water supply level and so on (Drăghici, 1999; Varvel, 2000; Matei, 2020, Paraschivu M. et al., 2021). In our study, the main morphological features determined in the tested assortment were presented in Table 2.

Table 2. Biometrical measurements of the assortment of sweet sorghum hybrids

Hybrid	Plant's height cm	Stalk diameter (cm)	Av. leaves/ plant	Av. length leaf (cm)	Av. width leaf (cm)
BMR Gold	282	2.03	15.4	70.8	8.4
SAȘM 1	324	2.16	15.2	68.7	7.3
SAȘM 2	305	2.11	15.7	71.4	7.6
Supersile 20	262	1.98	17.7	68.5	7.3
Average	**293**	**2.07**	**16**	**69.8**	**7.6**

Related the height of sorghum plants we can observe that the tallest plants, over 300 cm, were recorded at the Moldavian hybrids, SASM 1 and SASM 2, with 324 cm in case of first hybrid and 305 cm for the second hybrid mentioned. The smallest plants were observed at Supersile 20, of 262 cm, followed by BMR Gold hybrid with a value of 282 cm. In the climatic conditions' of 2019 year, the average/experiment was 293 cm.

Part of the biomass component, the dimensions of stalks have a powerful influence to the final yields of fresh biomass. The tested hybrids generate powerful plants with a diameter of stalk (measured on the middle section of plants) which range between 1.98 cm (Supersile 20) and 2.16 cm (SASM 1). With exception of Supersile 20 hybrid, all of hybrids had over 2 cm in diameter in the middle section of plant. In literature we found similar results of SASM 1 hybrid related the stalk's diameter, with values between 0.7 cm to 2.68 cm (Vladuț et al., 2019).

Guihua et al., 2011, found significative correlation between stalk (stem) diameter (SD) and fresh biomass yield, but no consistently significant correlations with sugar content (SC) in three trials.

Leaves dimensions also contribute on the total fresh biomass yield of sweet sorghum tested hybrids. Related the average numbers of leaves/plant we found a number of over 15 leaves/plant, with the highest number, of 17.7, at Supersile 20 hybrid. The differences between others hybrids were very small, of order of 0.2 to 0.5 leaves/plant.

In our designed experiment the average of length leaf was 69.8 cm. Longer leaves were recorded at SASM 2 hybrid, with a value of 71.4 cm, followed by BMR Gold hybrid with 70.8 cm and others 2 hybrids with almost equal size, of 68.7 cm and respectively 68.5 cm (SASM 1 and Supersile 20).

Regarding the width of the leaves, we record values on tested hybrids from 7.3 cm on SASM 1 to highest values of 8.4 cm at BMR Gold hybrid. For this indicator the average/experiment had a value of 7.6 cm.

The obtained fresh biomass yield of the assortment is presented in Table 3. The productions range between 68.3 t/ha (Supersile 20) to 88.1 t/ha (SASM 1 hybrid).

In comparison with the Control, the average yield/experiment, which realized 77.7 t/ha, with very significand increases in production is highlight only one hybrid, SASM 1, with a positive difference of 10.4 t/ha which exceeds the value of the control with 13.4%.

With positive differences, of 2.7 t/ha, the value of the SASM 2 hybrid is also noticeable, but from the statistically point of view that difference is considered as insignificant.

Table 3. Fresh biomass yield on the assortment of sweet sorghum hybrids

Hybrid	Fresh biomass yield			Signif.
	t/ha	%	Differences	
BRM Gold	74.1	95.4	-3.6	O
SASM 1	88.1	113.4	10.4	***
SASM 2	80.4	103.5	2.7	-
Supersile 20	68.3	87.9	-9.4	OOO
Average	**77.7**	**100.0**	**Control**	**Control**

LSD 5%=3.5 t/ha; LSD 1%=5.8 t/ha; LSD 0.1%=8.7 t/ha

Lower values than the Control were observed at the other two hybrids, with values of 74.1 t/ha in case of BMR Gold hybrid and respectively 68.3 t/ha for Supersile 20 hybrid. Both differences levels of yields were statistically point of view ensured view ensured: significative for BMR Gold and very significant for Supersile 20.

Main components of the fresh biomass on sweet sorghum are: stalks, leaves and panicles. Stalk weight, stalk volume, stalk diameter, and plant height had significantly strong associations with juice yield, which were consistent across different sorghum ideotypes (Carvalho et al., 2017). In order to establish which hybrid is more valuable in our experiment from this point of view we extract samples and separate and registered the main components. The recorded results are presented in Figures 2 and 3.
Stalks percentage rage in our assortment from 72.3% at Supersile 20 hybrid to 81.3% at SASM 1 hybrid. Looking at the figure 2 we can say that the values are closer to the highest, with 79.2 % on SASM 2 hybrid and 78.5% at BMR Gold genotype.

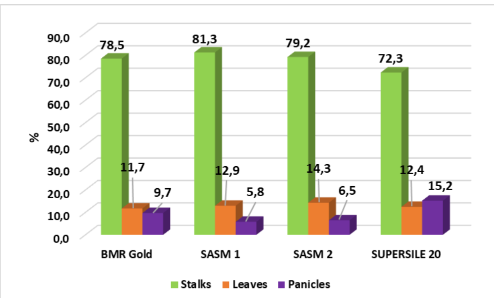

Figure 2. The percentage of biomass components for tested hybrids (%)

The participation percent of leaves to the total fresh biomass realized in the experimented conditions had values between 11.7% at BMR Gold hybrid and 14.3% at SASM 2 hybrid. The other hybrids from the assortment record closer values, of 12.9 in case of SASM 1 hybrid and 12.4% on the Supersile 20 hybrid.
The highest differences of recorded values were observed in case of percentage of leaves, which range between 5.8% at SASM 1 hybrid to 15.2% at Supersile 20 genotype. We must note the lower values recorded by the two hybrids from the Republic of Moldova, a value justified by the fact that they are sterile forms, and in the tested conditions they did not form seeds or accidentally formed small quantities.
If we compare those results with the data from various studies made on this subject, we can say that the results fall within the margin reported by other researchers.

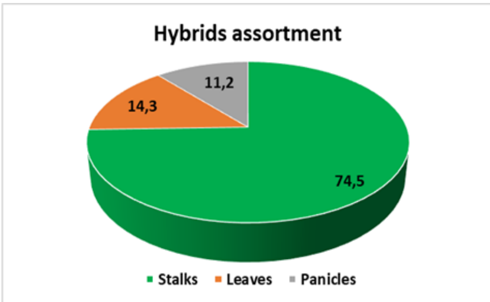

Figure 3. The percentage of biomass components in average/experiment (%)

In average/experiment (Figure 3) the main components are: 74.5% stalks, 14.3% leaves and 11.2% panicles.
Other criteria in order to evaluate the suitability a sweet sorghum hybrid to capitalize the climate and soil conditions in an area is the accumulation of carbohydrates in the stem, but also the quality of the sweet juice (the ratio between reducing and non-reducing sugar, the amount of juice/kg of stalks, the amount of alcohol/ethanol obtained (Băbeanu et al., 2017).
In these conditions we start to determinate the total dry soluble substances (*BRIX content %*) using a portable refractometer (Figure 4) and the results obtained at the assortment of sweet sorghum hybrids are presented in Figure 5.
Determinations of the BRIX content (%) in stalks, carried out in the milk maturity phase of

the grains of sweet sorghum plants, show values which range between 14.3% at Supersile 20 hybrid and 20.1% at BMR Gold hybrid. The Moldavian hybrids, SASM 1 and SASM 2 realized closer values of 18.2% and respectively 17.2%. The average of BRIX content on sweet juice/experiment was 17.5%.

Figure 4. Field aspects from Brix (%) determinations with portable refractometer

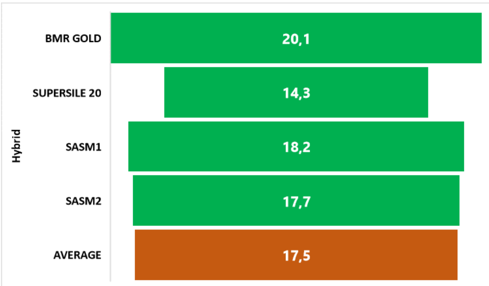

Figure 5. Brix content (%) at sweet sorghum hybrids from assortment

Based on the data collected we go froward and we determined the total yield of juice/ha in relative to the weight of the squeezed stalks for each hybrid from assortment. In order to obtain sweet juice, we used an electric roller press (with 3 tamburs) for squeezing sorghum stalks (Figure 6). Before squeezing the stalks, we remove the leaves from the sorghum plants and also and the final internode of the stalk (near the panicle) due his chemical compositions rich in minerals, which can negatively affect the process of obtaining ethanol.

At worldwide production of cellulosic ethanol fuel and diversify the supply of raw materials include new crops such cassava and sweet sorghum (Sanyuan Tang et al., 2018). In China, in 2020, the total yield of ethanol had reach 4.0 million tons, up 90% related at 2015 year when the production was 2.1 million tons.

The same strategy was observed in USA such an increase of the area of sweet sorghum has already occurred due to the rapid development of ethanol refineries based of grain and sweet juice. This is already demonstrated by a 19% increase in sorghum crop areas in 2007 compared to 2006. This review focuses on the benefits of sorghum as a source of ethanol and its future for mass planting.

Figure 6. Electric roller press for extracting sweet juice

Looking at the data presented in Figure 7, we can observe that the highest quantity of sweet juice was generated by SASM 1 hybrid with almost 30 thousand liters/ha in the mentioned experimental conditions.

Valuable from this point of view proves to be also SASM 2 hybrid, with a total yield of sweet juice of 24.5 thousand liters/ha.

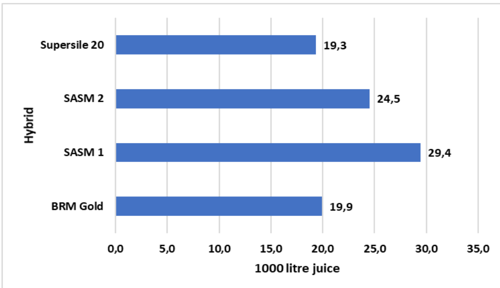

Figure 7. Theoretical estimations of the juice (thousand liters/ha) at sweet sorghum assortment

The others two hybrids had values near the limit of 20 thousand liters/ha (19.9 thousand liters/ha for BMR Gold hybrid and respectively 19.3 thousand liters/ha in case of Supersile 20 hybrid.

CONCLUSIONS

As most important aspects related the goals and results of our experiment, we can synthetize and highlights the most important conclusions, as follow:

- due to its genetic variability, in terms of the sugar and juice content of the stalks, such as total soluble sugars, green stalks yield, amount of juice and grain yield, various research institutes in the country and abroad have created sweet sorghum hybrids capable of achieving good yields in different cultivation conditions;
- in the climatic conditions from ARDS Caracal, in 2019 year, the sweet sorghum plants had good conditions for plant's development, this aspect being found in the measured biometric values;
- the sweet sorghum hybrids tested realized very valuable yields of fresh biomass, almost 90 t/ha, with high percentage of stalks from those, over the values of 80%;
- typical hybrids of sweet sorghum proved to have the most valuable features to produce high biomass yields, but also high efficiency of sweet juice, with very good quality of it due the Brix content of 18-20%.

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CROP RELATIONSHIP "YIELD - EVAPOTRANSPIRATION" FOR COMMON BEAN

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Abstract

The aim of the study is the crop relation "Yield-Evapotranspiration" (ET) for common beans, based on data obtained by full irrigation and irrigation with reduced irrigation rates. The experiment conducted in the experimental field of Agricultural University of Plovdiv with "Dobrudzhanski 7" variety in the period 2014-2016. The relationship has been studied in two directions - with regard to the summary ET and in terms of ET by phases. Thus the vegetation period of the beans is divided according to the following phases: I - growth, II - flowering, III - productive (pod development and grain filling) and IV - maturing. In both cases, existing formulas (linear, power and multi-power) were used, where the experimental data was processed by the smallest squares method. The relationship "Yield-Seasonal ET" is best represented by two-power formula: $\Delta Y = [1-(1-\Delta ET)^N]^M$*. The graph is expressed graphically by the S-curve and R = 0.986 (N = 2.3 and M = 9.1). The crop relationship "Yield-ET by phases" is best expressed by the two-power formula at R = 0.921. The power of the whole vegetation period is N=1.3 and in phases is:* $m_1 = 0.05$, $m_2 = 0.79$, $m_3 = 0.49$ *and* $m_4 = 0.28$*. This means that the second sub-period is the most sensitive. The first period has very little sensitivity and the third and fourth periods are intermediate.*

***Key words**: irrigation, water deficit, water stress, yield, common bean.*

INTRODUCTION

The relationship between the yield and evapotranspiration is a special case of the "Yield-Water". It can be considered as a relation between total yield and seasonal ET as well as a relationship between total yield and ET established by phases, in which case parameters are obtained that characterize the sensitivity of the culture through a specific phenophases to a different degree of reduction of evapotranspiration during this same phase. To establish the relationship between yield and seasonal ET, the FAO linear formula is used worldwide (Doorenbos and Kassam, 1979). This type is also the dependence of Kraftty and Kotov (1970), representing a family of curves. Davidov (1994) creates a power and two-power equations for calculating the parameters of the same dependence, whose graphical solution is most often the corresponding convex parabola and S-curve (Kalaydjieva, 2014).

There are also several formulas for the determination of phase dependency parameters, such as Jensen (1968), Steward and Hagan (1969), Dawney (1972), FAO linear and multi-power by Davidov (1994).

By attitude to beans, the publications related to the "Yield - ET" dependence are too few and concern only the "Yield - seasonal ET" heading. Barros and Hanks (1993) and Topak et al. (2009) consider this relationship to be linear, recommending a global FAO's formula. Other authors present the relationship by a second degree equation (Hegde and Srinivas, 1990), and in order to obtain a maximum yield ET should be in the range of 268 to 299 mm. According to the results of a field experiment conducted in Suceava (Romania) there is no correlation between yield and ET (Saicu, 1987, 1988). Kalaydjieva (2014) gives detailed information about this dependence, but for French Beans. According to the author, the relation "Yield-seasonal ET" is best represented by Davidov's two-power formula at n = 1.5 and m = 2.5. The author finds that bean is most sensitive to ET during the period of beans formation and growth.

The aim of the paper is to establish the parameters of the Yield-Evapotranspiration relationship for common bean.

MATERIALS AND METHODS

The experiment was carried out during the period 2014-2016 in the experimental field of the Agricultural University of Plovdiv on soil type alluvial meadow with common bean (*Phaseolus vulgaris*) variety "Dobrudzhanski - 7". The experiment is based on the blocking method in four replicates with the size of the harvested parcels - 10 m^2. For the study of relationship "Yield - ET" are used data for relative yield and relative ET from different variants as follow: 1) without irrigation; 2) irrigation with 25% of the irrigation rate determined by full irrigated bean (25% m); 3) irrigation with 50% of the irrigation rate, determined by full irrigated bean (50% m); 4) irrigation with 75% of the irrigation rate determined by full irrigated bean (75% m); 5) full irrigation (100% m).

The irrigations of the optimal variant (variant 5) are given at 80% of FC (field capacity) pre-irrigation soil moisture in the 0-40 cm layer and the irrigation rate is calculated to wet up-to FC the entire active soil layer (0-60 cm). For this purpose, the dynamics of soil moisture was monitored during 5-7 days by weight method (Atanasov et al., 1972). Irrigation of the experimental plots is gravitationally performed on short closed furrows. Evapotranspiration is determined by the balance method according to the formula (Kirkova, 2003; Zhivkov, 2013):

$$ET = W_b - W_e + M_n + M_m \text{ (mm)} \quad (1)$$

where: ET is evapotranspiration for reporting period (mm);

W_b and W_e - water supply at beginning and end of period (mm);

M_n - sum of used precipitation (mm);

M_m - the used part of the irrigation rate (mm)

The parameters of the relationship between yield and evapotranspiration are defined in two directions - "Yield - seasonal ET" and "Yield - ET by Phase", using different formulas as follows:

Relationship "Yield - seasonal ET"

The parameters of this type of dependence are established by the data on the relative yield and the relative aggregate evapotranspiration by variants and years. For this purpose, the following formulas are used:

Linear equation /FAO/ (Doorenbos and Kassam, 1979)

$$\frac{Y}{Y_o} = 1 - K_c\left(1 - \frac{ET}{ET_o}\right) \quad (2)$$

where: Y is the yield under reduced irrigation regime;

Y_o - optimum irrigation yield;

ET - evapotranspiration in yield Y;

ET_o - evapotranspiration in Y_o yield;

Two-power equation (Davidov, 1994)

$$\frac{Y}{Y_0} = \left[1 - \left(1 - \frac{ET}{ET_0}\right)^N\right]^M \quad (3)$$

where: N - is the the power for the entire vegetation period;

M - the power for the crop

Power formula (Kalaydjieva, 2014; Kalaydzhieva et al., 2015; Petrova and Matev, 2020)

$$\frac{Y}{Y_0} = 1 - a\left(1 - \frac{ET}{ET_0}\right)^n \quad (4)$$

where: a is the coefficient of the yield.

Relationship "Yield - ET by phases"

In connection with establishing the parameters of this dependence, the bean vegetation period is conventionally divided into the following four sub-periods (phases):

- Phase one - growth, including phenophases from germination to the beginning of budding phase or on average from the second decade in May to the second of June inclusive.
- The second phase - flowering, involving the phenophases from the beginning of the budding until the end of the flowering or the average whole third decade of June and the heat of July.
- Third phase - productive, including the period of formation and growth of beans, or on average from the first to the second ten days of July inclusive.
- Fourth phase - seed pouring and ripening.

For each variant and year, the phase duration is determined according to specific phonological observations.
Experimental data was processed using the smallest squares method using the YIELD program through the following equations:

Power relationship (Davidov, 1994)

$$\frac{Y}{Y_0} = \prod_{1}^{S} \left[1 - A_i \left(1 - \frac{ET_i}{ET_{0i}} \right)^{Ni} \right] \tag{5}$$

where: s is the number of phases;
A_i - the coefficient determining the sensitivity of the phase;
N_i - phase's power;
ET_i - the evapotranspiration for phase (i) – available.

Two-power formula (Davidov, 1994)

$$\frac{Y}{Y_0} = \prod_{1}^{S} \left[1 - \left(1 - \frac{ET_i}{ET_{0i}} \right)^{N} \right]^{Mi} \tag{6}$$

where: M_i is power indicator by phase;
N - the power for the vegetation period.

Linear relationship /FAO/ (Doorenbos and Kassam, 1979)

$$\frac{Y}{Y_0} = \prod_{1}^{S} \left[1 - A_i \left(1 - \frac{ET_i}{ET_{0i}} \right) \right] \tag{7}$$

Based on the final results calculated from the above formulas, graphs reflecting the test points and corresponding relationships are plotted to illustrate the degree of approximati

RESULTS AND DISCUSSIONS

Meteorological conditions

The influence of the irrigation regime on the yield and the evapotranspiration and the relation between them is determined to a great extent by the meteorological conditions of the vegetation period.
Regarding precipitation, the first experimental year is middle-wet (19.8% probability) with a drought in the third ten days of June and the first of July, coincidentally with the end of the growth period and the period of buttoning - the beginning of flowering. During the period of harvesting and pouring of the grain, the amount of rainfall ranges from 30 to 40 mm for ten days, providing for a large extent the ET of the plants. In terms of the amount of temperature, the year is average with a 46.5% probability, and with respect to the air water pressure deficit - with 96.3%.
The second experimental year (2015) is humid with a 13.2% probability with drought from the third ten days of June to the second of August (inclusive), i.e. During the reproduction period of bean the year is dry. The amount of precipitation is significant at the end of August, but they are of no practical significance for the yield. With regard to the temperature sum, the year is warm with a probability of 19.2%, and in terms of the air water pressure deficit – medium with probability of 80%. For the period May-August, the third year of the experiment (2016) is the average rainfall probability (41.5%) and the warmest of the temperature (14.1%). This year saw a comparatively uniform precipitation distribution over ten days, although they are extremely low in quantity. The sum of the air water pressure deficit is 1352.5HPa, which characterizes it as average dry with a probability of 21.3%.

Relationship "Yield - seasonal ET" by FAO's linear formula

All the initial data needed to establish the parameters of this dependence are presented in Table 1.
Figure 1 shows experimental data by year, average and total for the entire experiment period, averaged using the FAO's linear formula. The yield coefficient for the first two experimental years has very low relative values (respectively Kc = 1.07 and 1.13). This means that a minimum water output of 10-13% is sufficient to obtain a minimum yield, for which the productivity is maximal for the particular conditions the optimal variant. This is virtually impossible for this culture, so the relationship to the FAO's formula cannot be considered correct, despite the high correlation coefficient (Table 2). A little more realistic are the results of this formula, valid for 2016. The yield coefficient is Kc = 1.58, which means that under these conditions for yielding a yield other than zero, water should be consumed equal to 38-40% of ET with optimal irrigation. Here the correlation coefficient is highest (R = 0.939).

Relationship "Yield - seasonal ET"

Table 1. Output data for "Yield – seasonal ET" relationship

Variant	Yield		ET		Yield		ET	
	kg/da	Y/Y_0	mm	ET/ET_0	kg/da	Y/Y_0	mm	ET/ET_0
	2014				2016			
100 % m	239	1.00	398.9	1.000	267	1.00	339.7	1.000
75 % m	232	0.97	372.4	0.934	255	0.95	307.2	0.904
50 % m	212	0.89	322.4	0.833	228	0.85	292.4	0.861
25 % m	199	0.83	322.0	0.807	173	0.65	260.2	0.766
dry	153	0.64	299.1	0.750	126	0.47	244.7	0.720
variant	2015				average			
100 % m	252	1.00	415.8	1.000	253	1.00	384.8	1.000
75 % m	241	0.96	395.9	0.952	243	0.96	358.5	0.932
50 % m	231	0.92	351.7	0.846	224	0.87	322.2	0.837
25 % m	193	0.77	319.2	0.768	188	0.75	300.5	0.781
dry	147	0.58	289.4	0.696	142	0.56	277.7	0.722
m - irrigation rate								

The dependence on aggregated and averaged experimental data is influenced by the parameters characterizing the first two experimental years.

As a result, relatively low values of the yield coefficient (Kc = 1.27 and 1.21) are obtained, which means that at ET to 20-25% of that at optimal irrigation, a minimum yield should be expected.

Still, within the limits of the real crop yield, this linear dependence is representative.

The approximation of the mean experimental data is R = 0.933 and at all experimental points R = 0.9.

Figure 2 shows the experimental and calculated FAO linear formula yields and the relationship between them at R = 0.904.

Despite the high correlation coefficient, the graphs show very clearly the discrepancies between the experimental and calculated relative yields.

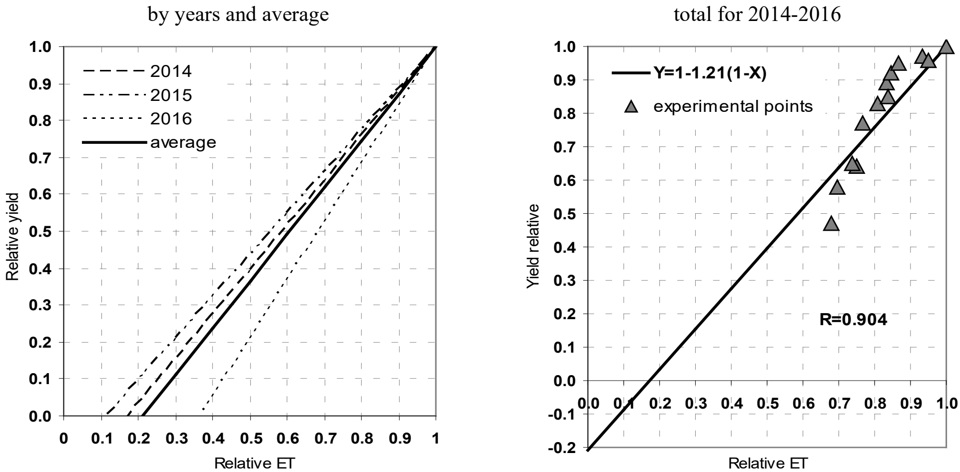

Figure 1. "Yield – seasonal ET" relationship by the FAO's formula

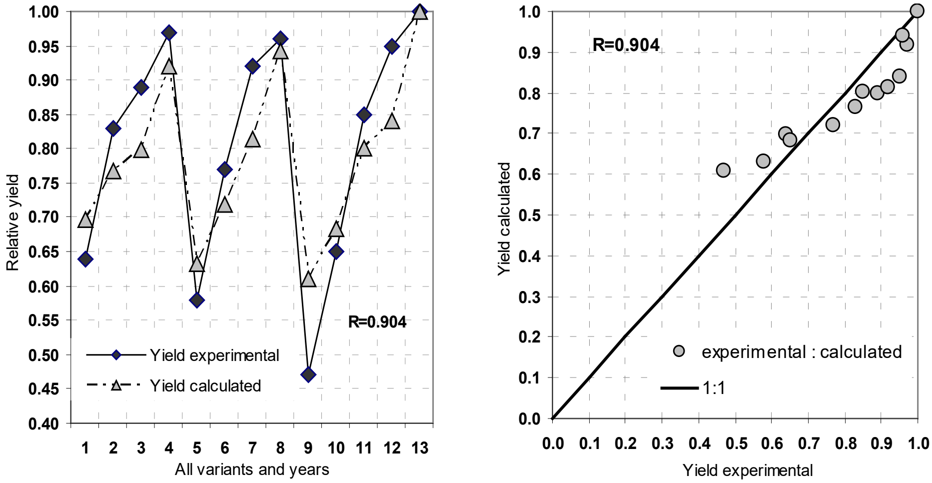

Figure 2. Relationship between experimental and calculated yield by the FAO's formula

"Yield - seasonal ET" relationship by the two-power formula

On the Figure 3, the same experimental data were applied, approximated by the two-power formula.

The results graphically represent S-curves, which very smoothly present the change of the relative yield with the change of the relative ET. As a result, the accuracy of the approximation is clearly visible on the graph. In this sense, the graphs presented in Figure 4 are also indicative.

Apart from the fact that the deviations of the calculated points from the experimental points are considerably smaller than those using linear dependence, a higher correlation coefficient (R = 0.986) is also achieved here.

All this gives reason to believe that the two-power formula surpasses FAO's linear formula in a way of interpretation and accuracy.

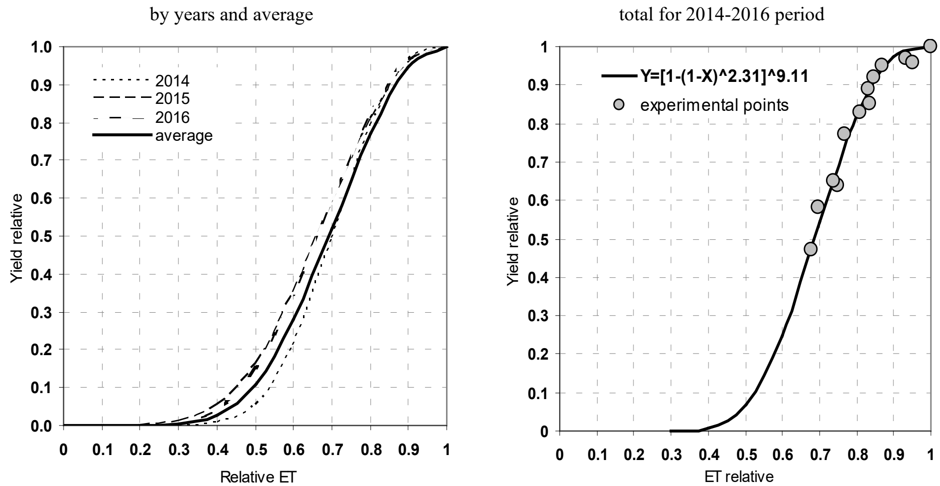

Figure 3. "Yield - total ET" relationship by the two-power formula

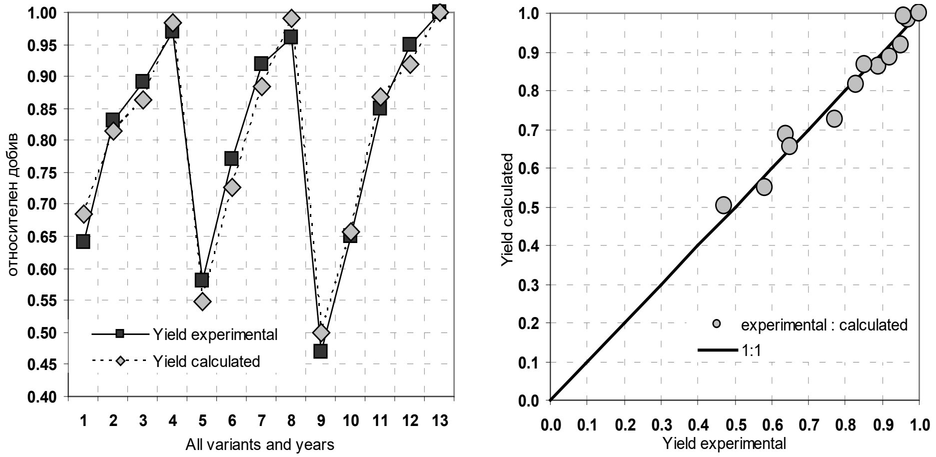

Figure 4. Relationship between experimental and calculated yield by the two-power formula

"Yield - seasonal ET" relationship by the one-power equation

This equation has a yield coefficient similar to that of the FAO linear formula, but has a variable power. This allows for an abscissa to be measured at a specific ET value at which yield can be expected while at the same time the dependency is graphically expressed by the parabola. This increases the accuracy of the approximation and at the same time follows the real trends in the change of the two indicators. In general, the FAO formula can be considered to be a special case of Davidovs's one-power formula.

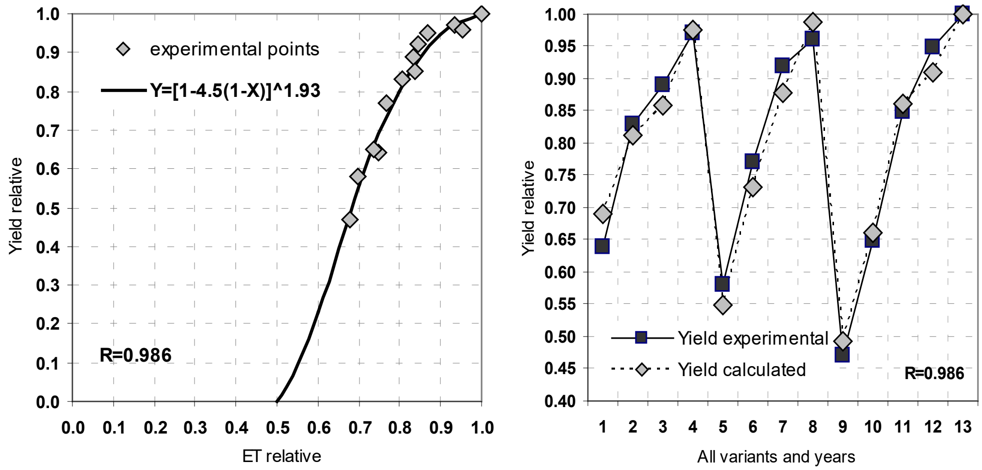

Figure 5. "Yield - total ET" relationship by the one-power formula

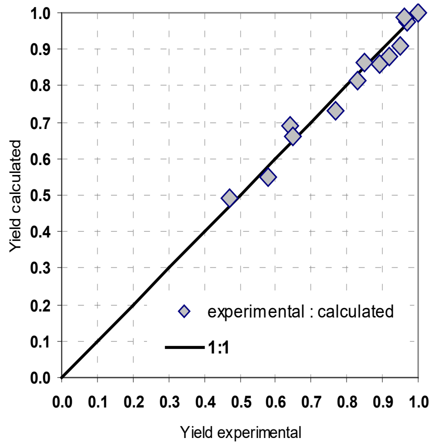

Figure 6. Relationship between experimental and calculated yields by the one-power formula

All experimental points are plotted in Figure 5. The same is done by the one-power Davidov's formula, as a result of which the parabola was drawn. The same corresponds to the following parameters: a = 4.5, n = 1.19 and R = 0.986. Depending on the dependence thus determined, a minimum yield can be expected for ET having values above 50% of those obtained with optimal irrigation. From the graph, it is clear that the experimental points are located on or adjacent to the curve, and the correlation coefficient matches that of the two-power formula. This is due to the fact that in the real yield range the two curves almost completely coincide, i.e. there is approximation of the experimental data with the same precision.

Table 2. "Yield - seasonal ET" relationship parameters

Year	Linear relationship		Two-power relationship		
	K_c	R	n	m	R
2014	1.07	0.894	2.96	17.43	0.999
2015	1.13	0.930	2.25	7.69	0.990
2016	1.58	0.939	2.39	8.94	0.999
average	1.27	0.933	2.22	9.14	0.994
total	1.21	0.904	2.31	9.11	0.986

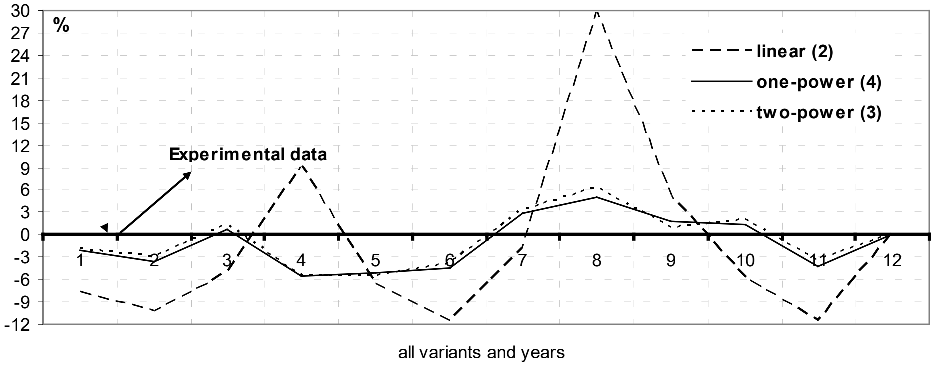

Figure 7. Relative deviation of the calculated yield in comparison to the experimental yields using the three formulas

The relationship between the experimental yields and the calculated one-power formula of Davidov is illustrated in Figure 6 at R = 0.986 and in Figure 7 the percentage deviation of the calculated yields in the three formulas used is plotted. Since the FAO's formula is globally recognized, large deviations cannot be grounds for rejection, but a much better combination of high precision and true interpretation of the biological features of culture demonstrates the formulas of Davidov (the one-power and the two-power). This is clearly visible on the graph, which categorically fills the comments made above.

Relationship "Yield-evapotranspiration" by phases (periods)

The all baseline data for ET in absolute and relative values, as well as for the yield, needed to establish the parameters of this dependence are presented in Table 3.

Table 3. Yield and evapotranspiration by phases in absolute and relative values

year	relative rate	yield		ET for different periods							
				I germination-budding		II budding-end of flowering		III formation and growth of beans		IV seed pouring and ripening	
		kg/da	relative	mm	relative	mm	relative	mm	relative	mm	relative
1	2	3	4	5	6	7	8	9	10	11	12
2014	0.00	153	0.64	75.6	1.000	83.8	0.838	76.2	0.627	63.5	0.624
	0.25	199	0.83	75.6	1.000	88.0	0.880	91.6	0.754	66.8	0.656
	0.50	212	0.89	75.6	1.000	87.5	0.875	96.2	0.792	73.0	0.717
	0.75	232	0.97	75.6	1.000	94.0	0.940	112.5	0.926	90.3	0.887
	1.00	239	1.00	75.6	1.000	100.0	1.000	121.5	1.000	101.8	1.000
2015	0.00	147	0.58	97.4	0.957	63.6	0.759	75.3	0.607	53.1	0.473
	0.25	193	0.77	99.0	0.972	73.3	0.875	89.7	0.723	57.2	0.510
	0.50	231	0.92	99.6	0.978	74.4	0.888	99.4	0.802	78.4	0.699
	0.75	241	0.96	99.8	0.980	77.8	0.928	120.4	0.971	91.8	0.818
	1.00	252	1.00	101.8	1.000	83.8	1.000	124.0	1.000	112.2	1.000
2016	0.00	126	0.47	110.6	0.927	61.9	0.630	51.0	0.569	28.4	0.696
	0.25	173	0.65	110.9	0.930	67.9	0.691	56.3	0.628	30.6	0.750
	0.50	228	0.85	113.3	0.950	70.4	0.716	56.9	0.635	36.7	0.900
	0.75	255	0.95	114.9	0.963	84.8	0.863	78.9	0.881	39.4	0.966
	1.00	267	1.00	119.3	1.000	98.3	1.000	89.6	1.000	40.8	1.000
average	0.00	142	0.56	94.5	0.961	69.8	0.742	67.5	0.601	48.3	0.598
	0.25	188	0.75	95.2	0.967	76.4	0.815	79.2	0.702	51.5	0.639
	0.50	224	0.87	96.2	0.976	77.4	0.826	84.2	0.743	62.7	0.772
	0.75	243	0.96	96.8	0.981	85.5	0.910	103.9	0.926	73.8	0.890
	1.00	253	1.00	98.9	1.000	94.0	1.000	111.7	1.000	84.9	1.000

The following results were obtained:

1) One-power formula (5) with $N = 1.1$ and a correlation coefficient $R = 0.892$.

The values of the Ai coefficient are as follows: I period - $A_1 = 0.05$, II period - $A_2 = 0.89$, III period - $A_3 = 0.16$, IV period - $A_4 = 0.32$. Figure 8 shows the experimental and calculated values of the yield, and in Figure 9 the dependence between yield and ET separately for each phase. It can be seen from the graph that both the clearer phases are described by slightly curved curves. According to the location of these curves in the coordinate system, the period of buttoning and flowering can be considered as the most sensitive. It is critical in watering in all bean cultures, including common bean. Despite the brevity of the phase (amid the high demands of plants on the water) and the still low strain of meteorological factors, beans require irrigation in almost every growing season. This makes it possible to take into account the increased sensitivity of the second period compared to the rest, as seen in Fig. Less but still sensitive are the third and fourth periods, and the first is almost not affected.

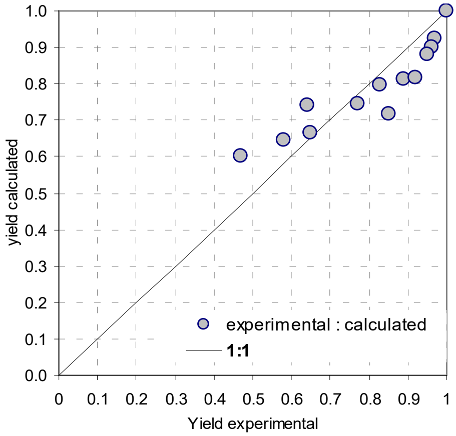

Figure 8. Relationship between experimental and calculated coefficients by formula (5)

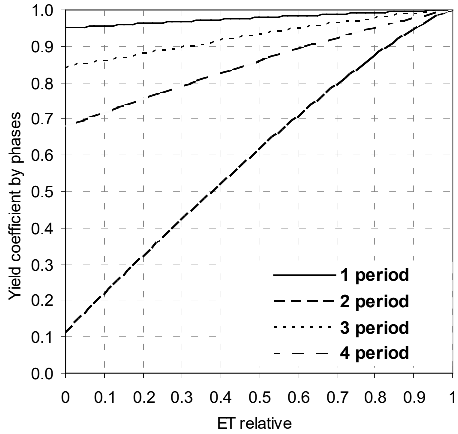

Figure 9. "Yield-evapotranspiration" by phases using formula (5)

The lack of sensitivity with regard to the first period is due to the fact that in the variants used for the study of the dependence, irrigation during this period is rarely imposed and this is most often done at the end of the period. Therefore, no significant influence of the irrigation regime on the real ET can be taken into account. In practice during this part of the vegetation the soil humidity is almost always in optimal limits and there is no way to detect the real sensitivity of the phase. The sensitivity of the third and fourth periods is mainly due to the following:

- ✓ During this part of the vegetation the yield is formed and the requirements of the plants to the water are very large;
- ✓ The temperature and the air humidity deficiency are very high, the leaf mass is very well developed, as a result of which the ET reaches maximum values.

The length of the period is relatively high, which, in the absence of precipitation, is a prerequisite for the realization of a larger number of irrigation. This leads to a greater difference in the relative ET of the individual variants within the phase.

2) Davidov's formula (6) at N = 1.3 and a correlation coefficient R = 0.921.

The power values by phases are as follows: I period - $m_1 = 0.05$, II period - $m_2 = 0.79$, III period - $m_3 = 0.49$, IV period - $m_4 = 0.28$. In addition to demonstrating high precision in the approximation of experimental data, thanks to its two powers, this formula describes a more gradual change in the yield factor when changing the ET values. Figure 10 shows the relationship between the experimental and calculated relative yield values. Here we can clearly see the greater accuracy of interpretation and the smaller deviations of the calculated from the experimental yields at R = 0.921. According to the graph of Figure 11, the sensitivity of the first period is again the smallest, followed by the period including the time between the end of grain filling and ripening. The results valid for this period are mainly due to the residual impact of the irrigations submitted during the previous period. The second and third periods show the highest sensitivity, with the advantage being once again on the side of the buttoning - blooming period.

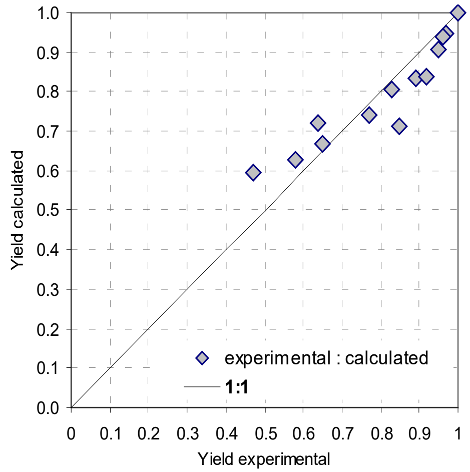

Figure 10. Relationship between experimental and calculated coefficients by formula (6)

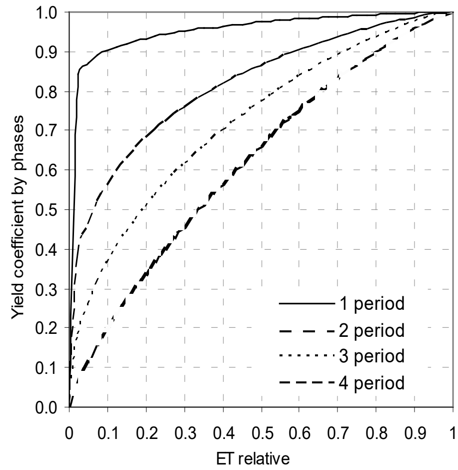

Figure 11. "Yield-evapotranspiration" by phases using formula (6)

3) FAO's formula (7) linear with correlation coefficient R = 0.878.

The values of the A_i coefficient are as follows: I period - $A_1 = 0.05$, II period - $A_2 = 0.74$, III period - $A_3 = 0.23$, IV period - $A_3 = 0.22$.

The Figure 12 shows the experimental and calculated relative yields of the formula, and in Figure13 – the relationship between the yield and the evapotranspiration is presented separately for each phase. Here again, the magnitude of the parameters A_i expresses the degree of influence of the evapotranspiration on the yield or the sensitivity of the phase. Therefore, as in the previous two cases, the second period is the most sensitive, and the first is the least sensitive. The third and fourth periods again occupy an intermediate position and practice as parameters coincide.

The data for the deviations between the experimental and calculated yields for the four formulas used are shown in Table 4. The smallest relative deviations of the calculations from the experimental yield are obtained using the two-power formula (6), with very similar results as the differences in formula (5). The linear formula (7) demonstrates less accuracy, and in some cases the discrepancy between the experimentally determined and calculated yields varies between -17 and + 30%.

They notice the more significant variations in the non-irrigated variant and the one irrigated by 50%, this being true for all years in the three formulas used without any logical explanation. For all other variations, variations vary considerably narrower.

Based on the results obtained for the dependence between the yield and phase evapotranspiration found in formulas (5), (6) and (7), the following more important findings can be made:

The relationships established by the three formulas have a high and almost equal correlation coefficient, which proves the usability of each of them;

For each of the dependencies obtained, the influence of the individual phases is determined, the same being the largest in the second phase and insignificantly in the first phase, the third and the fourth ones occupying the intermediate position;

Taking into account the results obtained in the different formulas, preference should be given to formula (6), since the smoother and highest accuracy reflects the change in the ratio between the relative yield and the relative evapotranspiration through the phases.

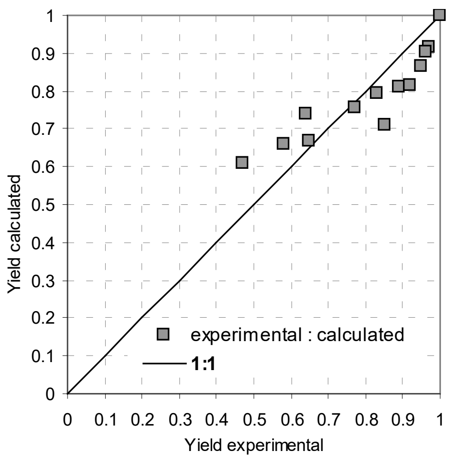

Figure 12. Relationship between experimental and calculated coefficients by formula (7)

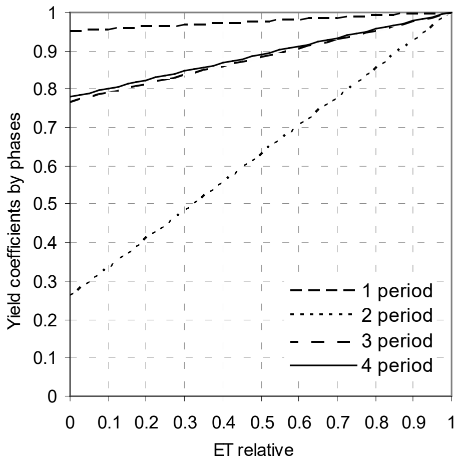

Figure13. "Yield-evapotranspiration" by phases using formula (7)

Table 4. Difference between experimental and calculated yield using different formulas

year	variant	Experimental yield		calculated yield								
				Formula (5)			Formula (6)			Formula (7)		
		kg/da	%	kg/da	%	±%	kg/da	%	±%	kg/da	%	±%
2014	dry	153	0.64	177	0.74	15.8	172	0.72	12.3	176	0.74	15.3
	25%m	199	0.83	190	0.79	-4.5	192	0.80	-3.4	190	0.80	-4.5
	50%m	212	0.89	194	0.81	-8.3	199	0.83	-6.2	194	0.81	-8.7
	75%m	232	0.97	221	0.92	-4.9	226	0.95	-2.4	219	0.92	-5.6
	100%m	239	1.00	239	1.00	0.0	239	1.00	0.0	239	1.00	0.0
2015	dry	147	0.58	163	0.65	10.7	158	0.63	7.5	167	0.66	13.3
	25%m	193	0.77	188	0.75	-2.6	187	0.74	-3.1	191	0.76	-1.0
	50%m	231	0.92	206	0.82	-10.8	211	0.84	-8.6	206	0.82	-10.9
	75%m	241	0.96	227	0.90	-5.8	237	0.94	-1.8	228	0.90	-5.6
	100%m	252	1.00	252	1.00	0.0	252	1.00	0.0	252	1.00	0.0
2016	dry	126	0.47	160	0.60	27.1	159	0.59	25.9	163	0.61	29.3
	25%m	173	0.65	178	0.66	2.6	179	0.67	3.3	178	0.67	2.8
	50%m	228	0.85	191	0.72	-16.0	190	0.71	-16.6	189	0.71	-17.1
	75%m	255	0.95	235	0.88	-8.0	242	0.91	-5.0	231	0.87	-9.2
	100%m	267	1.00	267	1.00	0.0	267	1.00	0.0	267	1.00	0.0
m - full irrigation rate												

CONCLUSIONS

The relationship "Yield - total ET" is best represented by Davidov's two-power formula. The same is expressed graphically through the S-curve, with a high correlation coefficient (R = 0.986) and value of powers n = 2.3 and m = 9.1.

The relationship Yield-evapotranspiration" by phases is the best presented by two-power formula with R = 0.921. The power's value for entire vegetation period is N = 1.3. The power values by phases are as follows: I period - m_1 = 0.05, II period - m_2 = 0.79, III period - m_3 = 0.49, IV period - m_4 = 0.28. this means that the sensitivity of the first period is the smallest, followed by the period including the time between the end of grain filling and ripening. The second and third periods show the highest sensitivity, with the advantage being on the side of the budding - flowering period.

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EVALUATION OF SOME SOIL HERBICIDES AND THEIR COMBINATIONS IN MAIZE

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Abstract

In the growing seasons of 2020 and 2021, a field plot trial with the maize hybrid P 9241 (FAO 370) was conducted. The trial was performed on the experimental field of the department of "Agriculture and herbology" at the Agricultural University - Plovdiv, Bulgaria. The evaluated herbicidal products were Aspect® T (200 g/l flufenacet + 333 g/l terbuthylazine), Adengo® 465 SC (225 g/l isoxaflutol + 90 g/l thiencarbazone-methyl + 150 g/l cyprosulfamide (antidote)), and Merlin® Flexx SC 480 (240 g/l isoxaflutole + 240 g/l cyprosulfamide (antidote)). The herbicidal products were applied alone and in combinations after sowing before germination of the crop. The natural weed infestation of the experimental field was presented by the following late spring weed species: Setaria viridis L., Digitaria sanguinalis (L.) Scop., Chenopodium album L., Amaranthus retroflexus L., Xantium strumarium L., Abutilon theophrasti Medic, Datura stramonium L., Solanum nigrum L., and Portulaca oleracea L. The highest herbicidal efficacy, as well as the highest seed yields after the alone application of Adengo® 465 SC, was recorded.

Key words: *maize, weeds, herbicides, efficacy.*

INTRODUCTION

One of the factors limiting the development of cultivated plants is the annual ubiquity and development of weeds and nutrient availability in soil (Yanev, 2015; Yanev et al., 2014a).
There is a large number of literature sources that prove both the harmful effects of weeds and the great possibilities for chemical control over them. Weeds are a very limiting factor for realizing the potential of crops (Tonev, 2000; Kostadinova et al., 2016; Tonev et al., 2019; Dimitrova et al., 2020). Studies by several authors show that depending on the type and degree of weeding, corn yield can be reduced from 24.0 to 96.7% (Mukherjee and Debnath 2013; Dimitrova et al., 2013; Najafi and Tollenar, 2005; Oerke and Dehne, 2004; Khan et al., 2003). A wide range of weed species may be infesting the maize fields. Some of them are *Amaranthus* spp., *Chenopodium album* L., *Abutilon theophrasti* Medik., etc. (Tonev et al., 2011; Tonev, 2008; Nikolov et al., 2005; Mousavi, 2001).
Chemical weed control is the most common weed control (Yanev 2021; Yanev 2020). The method is highly efficient, fast, and easy. Proper use of herbicides reduces weed control costs by up to 60%, reduces fuel and energy costs, and soil erosion (Valcheva, 2011). The proper herbicide must meet the following requirements - to be selective for the crop; to be highly effective against the existing weeds; its application rates should not lead to the accumulation of residues in plant production and soil; should not deteriorate the quality of production ad should be harmless to soil microorganisms and the environment (Yanev and Kalinova, 2020; Goranovska and Yanev, 2016; Hristeva et al., 2015; Yanev and Kalinova, 2015; Semerdjieva et al., 2015; Hristeva et al., 2014; Yanev et al., 2014b; Rao, 2000).
According to Kalinova et al. (2000) for control of late-spring weeds in maize, the application Stomp 33 EC + Mistral 4 SC may be accomplished. It is important to note that the use of pendimethalin has a lower risk of groundwater contamination compared to other herbicides such as alachlor (Brahushi et al., 2011). In areas infested with light-preferable weeds, tall and fast-growing hybrids should be grown (Tonev, 2013). For control of grass weeds mainly, after sowing before germination of the crop, the herbicides S-metolachlor, Isoxaflutol, Pendimethalin, Dimethenamid-P may be applied. Also, for broadleaf weeds, soil-applicable herbicides such as

Terbuthylazine; Mesotrione; Flumioxazine, etc. may be sprayed (Tonev et al., 2019).
The aim of the study is to evaluate the efficacy of soil herbicides and combinations in maize.

MATERIALS AND METHODS

In 2020 and 2021 a field experiment with the maize hybrid P 9241 was conducted. The trial was situated in the Training and Experimental Field of the Department of Agriculture and Herbology at the Agricultural University – Plovdiv, Bulgaria.
The experiment is based on the block method in 4 repetitions with a total size of the working plot of the four repetitions 112 m².
A preliminary inspection of the experimental field was performed. In the reporting field nine types of weeds, typical for the crop were identified. The average weed density in the two experimental years, per 1 m^2 was as follows: *Setaria viridis* L. - 12.5 specimens; *Digitaria sanguinalis* (L.) Scop. - 5.5 specimens; *Chenopodium album* L - 18 specimens; *Amaranthus retroflexus* L. - 8 specimens; *Xantium strumarium* L. - 6 specimens; *Abutilon theophrasti* Medic. - 5 specimens; Datura stramonium L. - 5.5 specimens; *Solanum nigrum* L. - 59.5 specimens; *Portulaca oleracea* L. - 11 specimens.
The study included the following treatments: 1. Untreated control; 2. Aspect T (200 g/l flufenacet + 333 g/l terbuthylazine) - 1.5 l ha^{-1}; 3. Aspect T - 1.0 l ha^{-1}; 4. Aspect T - 0.75 l ha^{-1}; 5. Aspect T - 0.4 l ha^{-1}; 6. Aspect T + Adengo 465 SC - 1.0 l ha^{-1} + 0.22 l ha^{-1} (in tank mixture); 7. Aspect T + Adengo 465 SC (225 g/l isoxaflutole + 90 g/l thiencarbazone-methyl + 150 g/l ciprosulfamide - antidote) - 0.75 l ha^{-1} + 0.22 l ha^{-1} (in tank mixture); 8. Aspect T + Merlin Flexx 465 SC (240 g/l isoxaflutole + 240 g/l ciprosulfamide - antidote) - 1.0 l ha^{-1} + 0.21 l ha^{-1} (in tank mixture); 9. Aspect T + Мерлин Флекс 465 СК - 0.75 l ha^{-1} + 0.21 l ha^{-1} (in tank mixture); 10. Adengo 465 SC - 0.44 l ha^{-1}.
All treatments were performed after sowing before germination of maize (BBCH 00).
The herbicide spraying was accomplished via electrical backpack sprayer SOLO model 417 (Solo, Germany) with a volume of the working solution of 300 l ha^{-1}.
Maize was grown as a mono-cropping system under drop irrigation conditions.
The soil preparation before sowing of the crop included deep autumn ploughing in 30-35 cm of depth. Also, two disking operations were performed. Pre-sowing fertilization with NPK 15:15:15 at the rate of 300 kg ha^{-1} was accomplished. Sowing was carried out in the optimal time for the crop at a spacing of 25 x 70 cm. Spring dressing with NH_4NO_3 at the rate of 300 kg ha^{-1} was also done.
The herbicide efficacy evaluations were performed 14, 28, and 56 days after herbicidal application. The 10-score scale of EWRS (European Weed Research Society) for visual rating was used.
For herbicidal selectivity, the 9-score scale of EWRS was used.
The results of the conducted research with the software package of SPSS 17 program of one- and two-factorial analysis of variance were processed.

RESULTS AND DISCUSSIONS

On Table 1 is shown the obtained efficacy against the weed *S. viridis* L average for both experimental years. At treatments 2, 6, 8, and 10 the herbicidal efficacy on the 14th day after application varies from 90 to 100%.
On the 56th day, the efficacy decreased. The highest and long-lasting efficacy to the 56th day after treatments after the application of Aspect T + Merlin Flexx - 1.00 + 0.21 l $ha^{-1}$and Adengo - 0.44 l ha^{-1} was recorded - 90%.

Table 1. Efficacy of the studied herbicides against *S. viridis* average fort the period (%)

Treatments	Days after treatments		
	14	28	56
1. Untreated control	-	-	-
2. Aspect T - 1.50 l ha^{-1}	95	90	80
3. Aspect T - 1.00 l ha^{-1}	70	65	55
4. Aspect T - 0.75 l ha^{-1}	50	40	20
5. Aspect T - 0.40 l ha^{-1}	20	10	0
6. Aspect T + Adengo - 1.00 + 0.22 l ha^{-1}	90	85	75
7. Aspect T + Adengo - 0.75 + 0.22 l ha^{-1}	70	60	40
8. Aspect T + Merlin Flexx - 1.00 + 0.21 l ha^{-1}	100	100	90
9. Aspect T + Merlin Flexx - 0.75 + 0.21 l ha^{-1}	85	80	65
10. Adengo - 0.44 l ha^{-1}	100	100	90

The efficacy results regarding the weed *D. sanguinalis* are presented on Table 2. Despite the high efficacy (85-95%) of treatments 2, 6, 8 and 10 against this weed, excellent efficacy was not recorded from any treatment. After the last reporting date (56 days after treatments) severe decrease of the herbicidal efficacy was found (55-80%).

Table 2. Efficacy of the studied herbicides against *D. sanguinalis*, average fort the period (%)

Treatments	Days after treatments		
	14	28	56
1. Untreated control	-	-	-
2. Aspect T - 1.50 l ha^{-1}	90	80	70
3. Aspect T - 1.00 l ha^{-1}	65	55	45
4. Aspect T - 0.75 l ha^{-1}	40	30	5
5. Aspect T - 0.40 l ha^{-1}	15	0	0
6. Aspect T + Adengo - 1.00 + 0.22 l ha^{-1}	85	75	55
7. Aspect T + Adengo - 0.75 + 0.22 l ha^{-1}	65	55	30
8. Aspect T + Merlin Flexx - 1.00 + 0.21 l ha^{-1}	95	90	80
9. Aspect T + Merlin Flexx - 0.75 + 0.21 l ha^{-1}	80	75	55
10. Adengo - 0.44 l ha^{-1}	95	90	80

The efficacy of the studied herbicides against the broadleaf weed Срещу *Ch. album* is presented on Table 3. On the 14th day, the efficacy of treatments 2, 6, and 8 was 100% but decreased in time. The highest results for treatment 10 (Adengo - 0.44 l ha^{-1}) were recorded. The efficacy of this treatment was 100% from the 14th till the 56th day after the treatments. It is noteworthy that in variants 6 and 8 the efficacy is also high - in the range of 90-95% reported on the 56th day after treatment. The herbicidal effect of the product Aspect T applied at a dose of 1.50 l ha^{-1} (85%) was also satisfactory.

Table 3. Efficacy of the studied herbicides against *Ch. album*, average fort the period (%)

Treatments	Days after treatments		
	14	28	56
1. Untreated control	-	-	-
2. Aspect T - 1.50 l ha^{-1}	100	95	85
3. Aspect T - 1.00 l ha^{-1}	80	70	50
4. Aspect T - 0.75 l ha^{-1}	50	40	20
5. Aspect T - 0.40 l ha^{-1}	20	5	0
6. Aspect T + Adengo - 1.00 + 0.22 l ha^{-1}	100	100	95
7. Aspect T + Adengo - 0.75 + 0.22 l ha^{-1}	75	70	60
8. Aspect T + Merlin Flexx - 1.00 + 0.21 l ha^{-1}	100	95	90
9. Aspect T + Merlin Flexx - 0.75 + 0.21 l ha^{-1}	80	70	55
10. Adengo - 0.44 l ha^{-1}	100	100	100

The highest average efficacy results against the weed *A. retroflexus* for the treatments with Aspect T - 1.50 l ha^{-1} (variant 2) and Adengo - 0.44 l ha^{-1} (variant 10) were recorded. Also, the use of Aspect T (1.0 l ha^{-1}) in a tank mix with the products Adengo and Merlin Flexx showed high herbicidal efficacy on the three reporting dates. A satisfactory effect against weed *A. retroflexus* was also obtained from the lower tested dose of 1.0 l ha^{-1} of Aspect T.

Against the weed species *Xa. strumarium,* 100% efficacy after the application of the tank mixture of Aspect T + Merlin Flexx - 1.00 + 0.21 l ha^{-1}, as well as for the alone application of Adengo - 0.44 l ha^{-1} was recorded on the 14th day after application (Table 4). On the 14th day after applying the product Aspect T - 1.50 l ha^{-1} led to 90%, and the tank mixture of Aspect T + Adengo - 1.00 + 0.22 l ha^{-1} to 95% efficacy. At the last reporting date, 90% control over the weed from the product Adengo applied alone was found. In all other variants of the experiment on the 56th day after treatments satisfactory control of weed was not reported.

Table 4. Efficacy of the studied herbicides against *Xa. strumarium,* average fort the period (%)

Treatments	Days after treatments		
	14	28	56
1. Untreated control	-	-	-
2. Aspect T - 1.50 l ha^{-1}	90	80	60
3. Aspect T - 1.00 l ha^{-1}	65	50	30
4. Aspect T - 0.75 l ha^{-1}	40	20	0
5. Aspect T - 0.40 l ha^{-1}	10	0	0
6. Aspect T + Adengo - 1.00 + 0.22 l ha^{-1}	95	85	70
7. Aspect T + Adengo - 0.75 + 0.22 l ha^{-1}	75	60	30
8. Aspect T + Merlin Flexx - 1.00 + 0.21 l ha^{-1}	100	90	75
9. Aspect T + Merlin Flexx - 0.75 + 0.21 l ha^{-1}	75	60	35
10. Adengo - 0.44 l ha^{-1}	100	95	90

From the data presented on Table 5 it is seen that the herbicidal efficacy of the products Aspect T - 1.50 l ha^{-1} T, Adengo - 0.44 l ha^{-1}, as well the tank mixture of Aspect T + Merlin Flexx - 1.00 + 0.21 l ha^{-1} against the broadleaf weed *A. theophrasti* was high on the three reporting dates. The efficacy of the tank mixture of Aspect T + Adengo - 1.00 + 0.22 l ha^{-1} against the weed was also high. The efficacy of the other treatments against the weed *A. theophrasti* was unsatisfactory.

Table 5. Efficacy of the studied herbicides against *A. theophrasti,* average fort the period (%)

Treatments	Days after treatments		
	14	28	56
1. Untreated control	-	-	-
2. Aspect T - 1.50 l ha^{-1}	100	95	90
3. Aspect T - 1.00 l ha^{-1}	80	70	60
4. Aspect T - 0.75 l ha^{-1}	50	35	20
5. Aspect T - 0.40 l ha^{-1}	10	5	0
6. Aspect T + Adengo - 1.00 + 0.22 l ha^{-1}	95	90	85
7. Aspect T + Adengo - 0.75 + 0.22 l ha^{-1}	80	70	60
8. Aspect T + Merlin Flexx - 1.00 + 0.21 l ha^{-1}	100	95	90
9. Aspect T + Merlin Flexx - 0.75 + 0.21 l ha^{-1}	90	80	65
10. Adengo - 0.44 l ha^{-1}	100	100	100

The herbicidal efficacy against the weed *D. stramonium* was very good to excellent at treatments 2, 6, 8, and 10 (Table 6) on the three reporting days. In the other variants of the experiment, an unsatisfactory herbicidal effect against weeds was observed. The efficacy of the lowest evaluated rate of Aspect T (0.40 l ha^{-1}) at the last reporting date (56th day after application of the products) reached 10% only.

Table 6. Efficacy of the studied herbicides against *D. stramonium,* average fort the period (%)

Treatments	Days after treatments		
	14	28	56
1. Untreated control	-	-	-
2. Aspect T - 1.50 l ha^{-1}	100	100	95
3. Aspect T - 1.00 l ha^{-1}	90	80	70
4. Aspect T - 0.75 l ha^{-1}	70	50	30
5. Aspect T - 0.40 l ha^{-1}	50	30	10
6. Aspect T + Adengo - 1.00 + 0.22 l ha^{-1}	100	100	95
7. Aspect T + Adengo - 0.75 + 0.22 l ha^{-1}	90	80	70
8. Aspect T + Merlin Flexx - 1.00 + 0.21 l ha^{-1}	100	95	90
9. Aspect T + Merlin Flexx - 0.75 + 0.21 l ha^{-1}	95	85	75
10. Adengo - 0.44 l ha^{-1}	100	100	100

The only excellent efficacy (100%) from the 14th till the 56th day after treatments against the weed *S. nigrum* after the application of Adengo - 0.44 l ha^{-1} was recorded (Table 7). The alone application of the product Aspect T at the rate of 1.50 l ha^{-1} showed 100% efficacy on the 14th day after treatments. The efficacy of the treatment decreased to 80% in time.

The combined application of Aspect T at the rate of 1.0 l ha^{-1} in tank mixture with Merlin Flexx and Adengo showed 95% on the first reporting date. For the other variants in the experiment on the 56th day after treatment, the efficacy was extremely low and ranged from 0 to 50%. It is correct to note that the density of the weed *S. nigrum* was the highest compared to other weeds species in the experiment (over 70 specimens per m² was reported).

Table 7. Efficacy of the studied herbicides against *S. nigrum,* average fort the period (%)

Treatments	Days after treatments		
	14	28	56
1. Untreated control	-	-	-
2. Aspect T - 1.50 l ha^{-1}	100	90	80
3. Aspect T - 1.00 l ha^{-1}	70	55	40
4. Aspect T - 0.75 l ha^{-1}	40	20	5
5. Aspect T - 0.40 l ha^{-1}	10	0	0
6. Aspect T + Adengo - 1.00 + 0.22 l ha^{-1}	95	85	70
7. Aspect T + Adengo - 0.75 + 0.22 l ha^{-1}	75	60	45
8. Aspect T + Merlin Flexx - 1.00 + 0.21 l ha^{-1}	95	85	75
9. Aspect T + Merlin Flexx - 0.75 + 0.21 l ha^{-1}	70	60	50
10. Adengo - 0.44 l ha^{-1}	100	100	100

The recorded efficacy against the weed *P. oleracea* is shown on Table 8. High efficacy is observed when using the herbicidal product Aspect T 1.50 l ha^{-1} alone - 100% on the first reporting date. The application of Adengo - 0.44 l ha^{-1} showed the highest results - 100% on the three evaluation dates.

Table 8. Efficacy of the studied herbicides against *P. oleracea,* average fort the period (%)

Treatments	Days after treatments		
	14	28	56
1. Untreated control	-	-	-
2. Aspect T - 1.50 l ha^{-1}	100	95	85
3. Aspect T - 1.00 l ha^{-1}	70	55	35
4. Aspect T - 0.75 l ha^{-1}	40	20	0
5. Aspect T - 0.40 l ha^{-1}	10	0	0
6. Aspect T + Adengo - 1.00 + 0.22 l ha^{-1}	100	90	80
7. Aspect T + Adengo - 0.75 + 0.22 l ha^{-1}	80	60	40
8. Aspect T + Merlin Flexx - 1.00 + 0.21 l ha^{-1}	100	95	85
9. Aspect T + Merlin Flexx - 0.75 + 0.21 l ha^{-1}	85	65	45
10. Adengo - 0.44 l ha^{-1}	100	100	100

Visible signs of phytotoxicity were not observed in any of the variants.

The disperse analyses of the obtained data for the maize grain seed yields showed proved differences among the treatments (Table 9). The average yields obtained for the period are shown. The maize productivity is determined by the differences in the herbicidal efficacy differences. The lowest results for the untreated control were obtained (6.56 t ha^{-1}). According to the degree of mathematical proof, seven separate groups are distinguished (a, b, c, d, e, f, g). It was found that treatment 10 (Adengo - 0.44 l ha^{-1}) is from the group (g) - the most distanced group from the untreated control (a) and respectively treatment 10 showed the highest grain yield - 13.45 t ha^{-1}. After the decrease of the Aspect T rates, the productivity also decreased. At the lowest Aspect T rate of 0.40 l ha^{-1}, the yields of 6.72 t ha^{-1} were comparable to those of the untreated control.

Table 9. Maize grain seed yield, t ha^{-1}

Treatments	Yields
1. Untreated control	6.56 a
2. Aspect T - 1.50 l ha^{-1}	10.00* e
3. Aspect T - 1.00 l ha^{-1}	8.72* c
4. Aspect T - 0.75 l ha^{-1}	8.16* b
5. Aspect T - 0.40 l ha^{-1}	6.72 a
6. Aspect T + Adengo - 1.00 + 0.22 l ha^{-1}	9.52* d
7. Aspect T + Adengo - 0.75 + 0.22 l ha^{-1}	8.88* c
8. Aspect T + Merlin Flexx - 1.00 + 0.21 l ha^{-1}	12.24* f
9. Aspect T + Merlin Flexx - 0.75 + 0.21 l ha^{-1}	8.89* c
10. Adengo - 0.44 l ha^{-1}	13.45* g

All results with a * have significant differences with the untreated control. The values with different letters have significant differences at $p < 0.05$.

CONCLUSIONS

The herbicidal product Adengo 468 SC applied at a rate of 0.44 l ha^{-1} alone and the tank mixture of Aspect T (1.00 l ha^{-1}) + Merlin Flexx (0.21 l ha^{-1}) showed the highest efficacy results against the weeds *S. viridis* and *D. sanguinalis.*

Excellent (100%) herbicidal efficacy against *Ch. album, A. retroflexus, A. theophrasti, D. stramonium,* and *S. nigrum* after the application of Adengo 468 SC - 0.44 l ha^{-1} was recorded.

The lowest herbicidal efficacy against all weeds in the experiment from the product Aspect T applied alone at a rate of 0.40 l ha^{-1} was reported.

No visible signs of phytotoxicity were observed in either variant throughout the maize vegetation.

The highest maize grain seed yield after the application of Adengo 468 SC - 0.44 l ha^{-1} was found (13.44 t ha^{-1}).

Of all the herbicide-treated variants, the lowest yields after the treatment with Aspect T at a rate of 0.40 l ha^{-1} were obtained.

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SEED COTTON YIELD AND YIELD COMPONENTS AFFECTED BY THE MINERAL FERTILIZATION AND THE WEATHER CONDITIONS

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Abstract

The aim of the study was to determine the reaction of cotton to different fertilizer rates and combinations under the influence of different weather conditions. In 1966 a long-term stationary fertilizer experience was established at the Field Crop Institute in Chirpan, Bulgaria. The results represent 2019 and 2020 crop years. The experiment was based on two-field crop rotation. Cotton variety Philipopolis was grown with durum wheat, without irrigation. The following doses of nitrogen and phosphorus were applied: 40, 80, 120 and 160 kg ha^{-1}. Potassium fertilizer was used at a rate of 80 kg ha. $N_0P_0K_0$ was adopted as a control. $N_{160}P_{40}$ had the greatest effect on seed cotton yield and boll weight; $N_{160}P_{80}$ - lint yield and ginning; $N_{160}P_{120}$ - plant height; $N_{120}P_{120}$ - number of boll per plant and $N_{40}P_{80}$ - fiber length. The strongest correlation was observed between lint yield and ginning ($P = 0.902^{***}$), and fiber length was negatively related to all traits. Yield and yield components can be strongly influenced by different weather conditions.

Key words*: phosphorus, potassium, nitrogen fertilization, weather conditions.*

INTRODUCTION

The foundations for working with cotton in Bulgaria were laid in 1901 in Sadovo. In 1925 the research institute was founded in Chirpan, where the main activity with cotton began. Bulgaria is located on the northernmost border for growing crops. However, there are good conditions for its cultivation.

More than 100 countries of the world produce cotton over an area of 33.2 million hectare with an average annual cotton production of 18.9 million tons (Hussain et al., 2020). In the EU, only three countries grow this crop on an area of 320 000 ha. Greece is the main producer with 80% of the total area, followed by Spain with 20%. EC Regulation 73/2009 changed the quota and reduced the area for cotton in Bulgaria to 3 342 ha. This area is extremely insufficient, given that in the recent past (1950s) the area was 200 000 ha.

The problem of productivity remains acute worldwide. According to estimates by the International Cotton Committee, world average yields have not increased since 1992/1993, with an average yield of 80 kg ha or 2% per year over the last 50 years (Stoylova et al., 2016). In recent years, with the emergence of global environmental issues, rising awareness of global warming and the increased coast of nitrogen have spurred an interest in the investigation of nitrogen fertilization (Chen et al., 2019). This is because application levels in a given year are based on their application rates from the previous year (Dhakal et al., 2019). This fact has led to an increase in studies of agricultural practices that reduce the amount of N lost (Allanov et al., 2019). Cotton yield can be restricted by the amount of available nutrients in the soil, especially if the supply does not meet the requirements of the plant (Echer et al., 2019). Therefore during its production process, a great amount of chemical fertilizers are used (Cevheri and Yilmaz, 2018). High rates of nitrogen fertilization frequently lead to a decrease in boll production as a result of excessive development and maturation of yield later in the growing season (Chen et al., 2019). Thus, it is necessary to optimize N fertilizer input boot to meet crop requirement and to reduce environmental pollution (Geng et al., 2016). Chen et al. (2018) reported that in Xinjiang (China) the nitrogen rate for the highest yield is 300 kg ha^{-1}, while the norm in the Yangtze River Valley is 240 kg ha^{-1}. Gomaa et al. (2019) report that in Egypt the highest agronomic efficiency was reported at 140 kg N ha^{-1}. In Turkey, Calakoglu (1980) recommended an optimal dose of 80-120 kg N ha^{-1}, 60-90 kg P ha^{-1} and 100-200 kg K ha^{-1}. In

Uzbekistan, the official recommended application rate of N for cotton is 160-180 kg ha^{-1} (Devkota et al., 2013).

The aim of the study was to determine the reaction of cotton to different fertilizer rates and combinations under the influence of different weather conditions.

MATERIALS AND METHODS

In 1966 a long-term stationary fertilizer experience was established at the Field Crop Institute in Chirpan, Bulgaria. The results from 2019 and 2020 were used to assess the impact of N, P and K fertilization on yield and its components. The soil type is Pelic Vertisol. The humus stock in the 0-20 cm layer is 1386 kg ha^{-1} and decreases in depth. The total N content was 0.20% and decreased to 0.13% to 40 cm. $CaCO_3$ is 0.00% for 0-20 cm and 0.25% for 40 cm.

The experiment was set in 4 replications with a plot size of 10 m^2, in two-field crop rotation, cotton Philippopolis variety was grown with durum wheat, without irrigation. The degrees of the tested factor were a randomized complete block design. Enter row-space was 95 cm. Ammonium nitrate was chosen as nitrogen (NH_4NO_3). The commercial product has a nitrogen content of 34.4%. The following doses were applied: 40, 80, 120 and 160 kg N ha^{-1}. Phosphorus was incorporated in the form of triple superphosphate with a content of 46% and the following norms: 40, 80, 120 and 160 kg P ha^{-1}. Potassium sulphate (K_20) with a content of 50%, in the norm of 80 kg K ha was used as potassium fertilizer. NPK fertilizers were incorporated before sowing cotton with the last cultivation. $N_0P_0K_0$ was adopted as a control. The cotton was harvested by hand.

The following traits were examined: seed cotton yield (kg ha^{-1}); lint yield (kg ha^{-1}); ginning (%); plant height (cm); harvested bolls per plant (number); boll weight (g); fibre length (mm).

The effective effect of fertilization on yield, yield components and plant height were statistically analyzed by analysis of dispersion (ANOVA). The main effects were compared using Fisher's LSD with the least significant difference P = 0.1%. The correlation analysis was performed using the software statistics 13.0 (TIBCO, Software, 2018), with the least significant difference P = 0.01%.

RESULTS AND DISCUSSIONS

From the meteorological data presented in Table 1 it can be seen that the vegetation period in the two studied years had similar sums of temperatures. However, compared to the multi-year period, both years were warmer.

Regarding the amount of precipitation, 2019 was close to the amount of the multiannual period. The difference was 35 mm. The amount of precipitation for 2020 was much lower than the previous year and the multiannual period. The least precipitation was reported in the critical phases for cotton.

Table 2 presents the mean squares of the studied traits. In order to facilitate comparison, the absolute values of square sums of the different sources were presented with their share in the total variance (100 x SQI / SQT).

The studied parameters were significantly influenced by fertilization. An exception is boll weight, where there was no significant difference. Most of the total dispersion was taken from harvested bolls per plant (84.04%).

Table 1. Meteorological data during the vegetative period of cotton, 2019, 2020 and 1928-2020

year	months						Σ IV-IX	Σ VI-VIII	Σ V-IX
	IV	V	VI	VII	VIII	IX			
Temperature sum, Σ t °C									
1928-2020	351	502	624	724	719	566	3186	2067	2835
2019	335	533	681	727	771	623	3670	2179	3335
2020	314	515	614	764	788	661	3656	2166	3342
Rainfall, Σ mm									
1928-2020	44	60	65	53	39	37	298	157	254
2019	51	21	123	77	53	15	340	253	289
2020	62	50	62	12	2	3	191	76	129

Also a large share was observed in seed cotton yield (58.17%) and plant height (46.03%).
The coefficient of variation showed that fiber length (2.07%) and ginning (3.56%) were the most stable indices studied. Harvested bolls per plant (8.77%), plant height (7.07%) and lint yield (6.58%) were the most variable. Seed cotton yield remained relatively stable (4.71%).

Table 2. Effect of the fertilization on cotton yield and yield components (mean squares - % of total)

Source of variance	df	Seed cotton yield, kg ha	Lint yield, kg ha	Ginning, %	Plant height, cm	Harvested bolls per plant, number	Boll weight, g	Fibre length, mm
Replicate	2	33.41***	74.39***	90.56***	45.77***	1.84-02***	2.71	75.81***
Fertilization	17	58.17***	20.68**	5.11	46.03***	84.04***	47.14	16.94***
Error	34	8.42	4.93	4.33	8.20	15.95	50.15	7.26
VC, %		4.71	6.58	3.56	7.07	8.77	5.03	2.07

NS - no significant; *, **, *** significant at P=5%, P=1% and P=0.1%

Seed cotton yield varied significantly between years, ranging from 1352 kg ha^{-1} in 2020 to 2415 kg ha^{-1} in 2019 (Table 3). These large differences between the years can be explained by the differences in meteorology (Table 1). In 2020 in the critical phases of flowering-budding the precipitation was a total of 14 mm, while for 2019 it was 68 mm. When growing cotton without irrigation, the environmental was a decisive influence on both the yield of cotton seeds and the lint yield. In both years studied, fertilization with $N_{160}P_{40}$ was the most productive for seed cotton yield. This led to the highest average seed cotton yield - 2336 kg ha^{-1}, exceeding the control by 53.0%. On average for the observed period, the analysis of variance showed a proven effect for all studied combinations of fertilization. McConnell et al. (1993) reported that fertilization with nitrogen above 112 kg ha^{-1} did not significantly increase seed cotton yield, which is inconsistent with our results.
In the first year of the study, the greatest effect on lint yield was observed under the action of fertilization with $N_{160}P_{80}$ (1169 kg ha^{-1}). In the second year, the yield of cotton lint also differs significantly. Record low yields were reported, the lowest being from the unfertilized variant - 432 kg ha^{-1}. With 83.6% more lint was the variant fertilized with $N_{80}P_{120}$ (793 kg ha^{-1}). On average from two years the trend continues and the analysis of variance confirms the effect of fertilization. The highest average lint yield was the variant $N_{160}P_{80}$ - 944 kg ha^{-1}, which is 61.6% higher than the variant without fertilization. The results obtained from our study contradict the report of Al-Assaf (2020). The author reports that the lint yield increases from 0 to 45 kg N ha^{-1}, then decreases at 60 kg N ha^{-1}, while in our study the highest lint yield was obtained from the highest rate of N. Luo et al. (2018) confirm the results obtained by us.
The ginning in both years moved within narrow limits, which showed that fertilization had no effect, which confirms the results of the total dispersion (Table 3). The highest ginning in 2019 showed fertilization with $N_{160}P_{80}$ (48.9%). In 2020, the ginning of fertilized variants was even narrower. An increase in the values to one degree of the fertilizer rate was reported. With an increase after this degree, the values decreased. The highest values were reported by $N_{80}P_{120}$ (36.6%). Clawson et al. (2006) also observed that nitrogen fertilization did not affect the values of the trait. Devkota et al. (2013) observed an inverse relationship between ginning and N rates. The authors report that as the norm increases, the values decrease, which coincides with our results. On average from the two years, the analysis of variance showed low reliability, although all variants exceeded the control. Only $N_{40}P_{120}$ (41.7%) and $N_{160}P_{80}$ (42.4%) remained with a confirmed impact.
Mineral fertilization had a positive effect on the components of the yield (Table 4). It is clear that the low rates did not have or had a weaker effect on plant height. Increasing the values with increasing dose was maintained up to fertilizer rates of 160:120 NP. From this variant, the highest plants were measured, exceeding the control by 57.9%. At the higher rate of 160:160 NP the plants height decreases. McConnell et al. (2000) confirm the results obtained by us. Panhwar et al. (2018) and Allanov et al. (2019), however, observed an

increase in plant height with increasing fertilizer rate.

The analysis of dispersion showed a proven effect of the fertilizer factor on harvested bolls per plant. Ahmad et al. (2021) confirm the positive effect of mineral fertilization on harvested bolls per plant. The results showed that fertilization with $N_{120}P_{120}$ was the most efficient, as this variant exceeded the non-fertilization by 95.2%.

Table 3. Seed cotton yield (kg ha^{-1}), lint yield (kg ha^{-1}) and ginning (%) for 2019, 2020 and average

Fertilization rates		2019			2020			average		
		Seed cotton yield, kg ha^{-1}	Lint yield, kg ha^{-1}	Ginning, %	Seed cotton yield, kg ha^{-1}	Lint yield, kg ha^{-1}	Ginning, %	Seed cotton yield, kg ha^{-1}	Lint yield, kg ha^{-1}	Ginning, %
$N_0P_0K_0$		1703	737	43.3	1352	432	32.0	1527	584	37.7
$N_{40}P_{40}$		2073	931	44.9	1724	572	35.8	1898**	751**	40.4^{NS}
$N_{40}P_{80}$		2043	823	45.2	1820	655	36.0	1913***	789**	40.6^{NS}
$N_{40}P_{120}$		2163	1017	47.0	1753	636	36.3	1958***	826***	41.7*
$N_{40}P_{160}$		2024	891	44.0	1880	669	35.6	1952***	720*	39.8^{NS}
$N_{80}P_{40}$		2345	1051	44.8	2003	713	35.5	2177***	882***	40.2^{NS}
$N_{80}P_{80}$		2194	957	43.6	2060	726	35.2	2127***	841***	39.4^{NS}
$N_{80}P_{120}$		2295	948	41.3	2167	793	36.6	2231***	870***	39.0^{NS}
$N_{80}P_{160}$		2293	1009	44.0	1903	678	35.6	2098***	843***	39.8^{NS}
$N_{120}P_{40}$		2310	993	43.0	2221	781	35.1	2265***	887***	39.1^{NS}
$N_{120}P_{80}$		2134	967	45.3	1993	699	35.1	2063***	833***	40.2^{NS}
$N_{120}P_{120}$		2325	1053	45.3	2020	707	35.0	2172***	880***	40.2^{NS}
$N_{120}P_{160}$		2048	889	43.4	2023	717	35.4	2035***	803***	39.4^{NS}
$N_{160}P_{40}$		2415	1077	44.6	2258	777	34.4	2336***	927***	39.5^{NS}
$N_{160}P_{80}$		2391	1169	48.9	2008	720	35.9	2199***	944***	42.4**
$N_{160}P_{120}$		2214	939	42.4	1915	691	36.1	2064***	815***	39.3^{NS}
$N_{160}P_{160}$		2377	987	41.5	1978	707	35.7	2147***	847***	38.6^{NS}
$N_{120}P_{120}K_{80}$		2259	983	43.5	1785	616	34.7	2022***	799**	39.1^{NS}
LSD	5%							205	114	3.0
	1%							282	157	4.1
	0.1%							386	216	5.6

NS - no significant; *, **, *** significant at P=5%, P=1% and P=0.1%

Although with small differences, a decrease in harvested bolls per plant was observed with increasing rate. Chen et al. (2019) come to the conclusion that high rates of nitrogen fertilization frequently lead to a decrease in boll production as a result of excessive vegetation development and maturation of yield later in the growing season.

The analysis of variance by variants confirms the results of the total variance in Table 2 on the effect of fertilization on boll weight. $N_{160}P_{40}$ had the greatest impact. This treatment exceeded the control by 13.14%. When fertilizing with 80:40 NP a close increase was reported - 12.47%. The results of this study correspond to the results obtained by Niu et al. (2021). The authors report that fertilization has a positive effect on boll weight up to a certain threshold, after this threshold the values do not increase. That the two variants with the heaviest bolls were from the low P rate confirms the statement of o et al. (2020) that phosphorus fertilization has no effect.

Fiber length values moved in different directions and no specific trend was observed. This is confirmed by Hernández-Cruz et al. (2015), which conclude that that the different N rates applied did not affected the fibre-quality components of cotton. Fertilization with higher rates showed results that were close to or lower than the variants with low fertilizer rates. The longest lint and almost identical values were reported

when applying $N_{40}P_{80}$ and $N_{40}P_{40}$, 9.0% and 8.6% more than the control, respectively.
The correlation analysis presented in Table 5 shows strong and proven relationships between most of the studied traits. The strongest relationship was between lint yield and ginning (P = 0.902 ***). This result clearly shows that with increasing ginning lint yield also increases. A number of authors, such as Shao et al. (2016) and Zeng and Meredith (2009) confirm a similar strong relationship between the two traits.

Table 4. Plant height (cm) and yield components average for the test period

Fertilization rates		Plant height, cm	% of control	Harvested bolls per plant, number	% of control	Boll weight, g	% of control	Fibre length, mm	% of control
$N_0P_0K_0$		53.0	100.0	6.3	100.0	4.49	100.00	26.8	100.0
$N_{40}P_{40}$		60.1^{NS}	113.4	7.8^{*}	123.8	4.73^{NS}	105.35	29.1^{***}	108.6
$N_{40}P_{80}$		64.3^{*}	121.3	8.9^{***}	141.3	4.86^{NS}	108.24	29.2^{***}	109.0
$N_{40}P_{120}$		68.6^{**}	129.4	9.9^{***}	157.1	4.62^{NS}	102.90	27.4^{NS}	102.2
$N_{40}P_{160}$		61.6^{NS}	116.2	9.1^{***}	144.5	4.89^{*}	108.91	27.4^{NS}	102.2
$N_{80}P_{40}$		68.4^{*}	129.1	11.4^{***}	181.0	5.05^{**}	112.47	28.5^{***}	106.3
$N_{80}P_{80}$		70.7^{**}	133.4	11.2^{***}	177.8	4.99^{*}	111.14	27.4^{NS}	102.2
$N_{80}P_{120}$		67.8^{**}	127.9	11.7^{***}	185.7	4.63^{NS}	103.12	28.0^{*}	104.5
$N_{80}P_{160}$		69.7^{**}	131.5	10.8^{***}	171.4	5.01^{*}	111.58	27.6^{NS}	103.0
$N_{120}P_{40}$		80.7^{***}	152.3	11.8^{***}	187.3	4.54^{NS}	101.11	28.1^{**}	104.9
$N_{120}P_{80}$		76.4^{***}	144.2	11.0^{***}	174.6	4.95^{*}	110.25	28.1^{**}	104.9
$N_{120}P_{120}$		78.2^{***}	147.6	12.3^{***}	195.2	4.88^{NS}	108.69	28.1^{**}	104.9
$N_{120}P_{160}$		79.2^{**}*	149.4	9.8^{***}	155.6	4.86^{NS}	108.24	27.3^{NS}	101.9
$N_{160}P_{40}$		76.5^{***}	144.3	11.8^{***}	187.3	5.08^{**}	113.14	26.8^{NS}	100.0
$N_{160}P_{80}$		80.7^{***}	152.3	12.2^{***}	193.7	4.77^{NS}	106.24	28.8^{***}	107.5
$N_{160}P_{120}$		83.7^{***}	157.9	9.6^{***}	152.4	4.47^{NS}	99.56	28.5^{***}	106.3
$N_{160}P_{160}$		81.4^{***}	153.6	10.9^{***}	173.0	4.89^{*}	108.91	27.7^{NS}	103.4
$N_{120}P_{120}K_{80}$		74.7^{***}	140.9	8.5^{*}	134.9	4.76^{NS}	106.01	28.5^{***}	106.3
LSD	5%	10.7	20.2	1.5	23.8	0.40	8.91	1.0	3.7
	1%	14.7	27.7	2.0	31.8	0.54	12.03	1.3	4.9
	0.1%	20.2	38.1	2.6	41.3	0.71	15.81	1.7	6.3

NS - no significant; *, **, *** significant at P=5%, P=1% and P=0.1%

It is impressive that boll weihgt did not correlate with any of the traits, and fiber length is in a negative relationship with all. The same negative correlation between fiber length and all studied traits was reported by Nawaz et al. (2019).

Table 5. Correlation coefficients between the studied traits

	seed cotton yield	*lint yield*	*ginning*	*plant height*	*harvested bolls per plant*	*boll weihgt*	*fibre length*
seed cotton yield	1						
lint yield	0.881^{***}	1					
ginning	0.601^{***}	0.902^{***}	1				
plant height	0.772^{***}	0.738^{***}	0.544^{***}	1			
harvested bolls/plant	0.705^{***}	0.437^{***}	0.099^{NS}	0.516^{***}	1		
boll weihgt	0.278^{NS}	0.245^{NS}	0.162^{NS}	0.145^{NS}	0.227^{NS}	1	
fibre length	-0.521^{***}	- 0.772^{***}	- 0.841^{***}	-0.480^{***}	-0.071^{NS}	-0.148^{NS}	1

n=34; *** 0.01%; **0.05%; *0.1%

CONCLUSIONS

Mineral fertilization has a strong effect on yield and some of its components. Boll weight and ginning were not affected. Fertilization with $N_{160}P_{40}$ had the greatest effect on seed cotton yield and boll weihgt; $N_{160}P_{80}$ - lint yield and ginning; $N_{160}P_{120}$ - plant height; $N_{120}P_{120}$ - boll weight and $N_{40}P_{80}$ - fibre length. The strongest correlation was observed between lint yield and ginning (P = 0.902 ***), and fiber length was negatively related to all traits. Yield and yield components can be strongly influenced by weather conditions. These results can be helpful to breeders for production practices.

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WILD ALFALFA IN THE SEMI-NATURAL GRASSLANDS OF CENTRAL NORTHERN BULGARIA

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Abstract

The study was conducted in the Central Northern Bulgaria in order to establish some biological, morphological and qualitative characteristics of wild species of genus Medicago. Medicago arabica (annual species) and Medicago falcata (perennial species) have the highest share in grassland, with significant seasonal productivity and feed quality. Medicago arabica dominates in spring and Medicago falcata in summer. Medicago falcata fodder is the richest in protein (25.32%) and has the most favourable ratio of crude protein and crude fiber. Compared to other short-lived species, Medicago falcata has lower levels of minerals and calcium. The presence of the fast-growing, drought-resistant species Medicago minima and Medicago polymorpha may be associated with the observed spring and late droughts in the study areas. The concentration of crude fiber (38.39%), crude fat (4.94%), acid-detergent lignin (10.98%), calcium (2.97%) and phosphorus (0.33%) is predominant in the biomass of Medicago polymorpha. The dry matter of the species has the lowest in vitro digestibility (80.71%) and hemicellulose concentration (4.61%). Medicago arabica has the lowest content of crude fiber (25.09%) and the highest of crude ash (13.45%), and acid-detergent fiber (27.90%). Compared to Medicago polymorpha (38.39%), the fiber fraction in the composition of the species is 53.0% lower. Medicago minima and Medicago lupulina registered an insignificant difference in the values of the indicators characterizing the fiber components of the cell walls and in vitro digestibility of the dry matter. The species have a low content of ADL (6.24-6.26%) and the highest digestibility of dry matter (84.39-84.41%). Medicago minima has the lowest value for the amount of crude protein (19.86%) and the highest for the content of hemicellulose (11.82%).

Key words*: Medicago spp., morphological characteristics, chemical composition.*

INTRODUCTION

Bulgaria is extremely rich in local plant material of legume forage grasses, including alfalfa. This implies excellent adaptability and potential for the use of these species as forage crops to improve soil fertility. Wild forage grasses provide a fuller realization of the ecological resources in the semi-natural grasslands, and the monitoring of their share is an important indicator for the change of the habitats and the functioning of the meadow ecosystems.

Alfalfa fields are highly productive and important contributors to the biodiversity of agricultural systems (Putnam et al., 2001; Georgieva, N., & Nikolova, 2015; Marinova et al., 2019; Vasileva et al., 2020). The best known member of the genus *Medicago* is *Medicago sativa* (an important forage crop) with superior traits such as cold resistance, salt tolerance, wide adaptability, high yield, good herbage quality, resistance to frequent cutting, good persistence, soil amelioration, and economic benefit (Veronesi et al., 2010; Shi et al., 2017). *Medicago sativa* achieves a high rooting rate in deep and hard soil layers, forms soil macropores that improve soil aeration and structure (Peoples et al., 2009), and *Medicago polimorpha* and *Medicago intertexta* species are drought tolerant, making them suitable for growing in dry and semi-dry areas (Bhandaria et al., 2020). *Medicago falcata* is one of the stress-tolerant candidate leguminous species and is able to fix atmospheric nitrogen. This ability allows leguminous plants to grow in nitrogen deficient soils. *Medicago species* synthesize a variety of bioactive natural products that are used to engage into symbiotic interactions but also serve to deter pathogens and herbivores (Gholami et al., 2014). The genus *Medicago* is an important socio-economic resource that offer novel genetic diversity required to maintain future food security and the changing climate conditions (Kell et al., 2008; Desheva et al., 2016;

Marinova, 2020a, b). The significance of wild alfalfa as a model plant for genomic research and, accordingly, for the identification of genes associated with stress resistance in the most important grass-forage crops (Iantcheva & Revalska, 2018) is of great importance.

The objective of the present study was to determine the share, main biological and morphological characteristics, as well as the quality of forage biomass of genus *Medicago*, found in mesophytic grassland, typical for the plains and hilly regions of Central Northern Bulgaria.

MATERIALS AND METHODS

The studied mesophytic grass cover is predominantly used for unregulated grazing. It is located in a hilly region (43°15′04″N; 25°18′37″E), with an average altitude of 112–134 m, near the Rositsa river valley. The climate is continental, the average annual rainfall is 544 mm, and the average rainfall during vegetation is 367 mm, with high annual fluctuations. For the study period (2018-2020) the share for the vegetation season in the region are shown in Figure 1. Spring droughts, as well as late summer and autumn droughts, were observed in all three experimental years.

The soil reaction is neutral (pH 7.05), the humus content is 3-4%, the level of mobile phosphorus (5.3 mg/100 g), and nitrogen (23.0 mg/100 g) is medium and with potassium is good (48.4 mg/100 g).

During 2018-2020 on months April - July on the territory of study area the relative share of *Medicago* in grassland was assessed by 10 strip transects (10/0.5 m) on the Uranov occurrence scale (Stoyanov, 2013). Scores are determined by the number of transects in which the species occurs (Table 1).

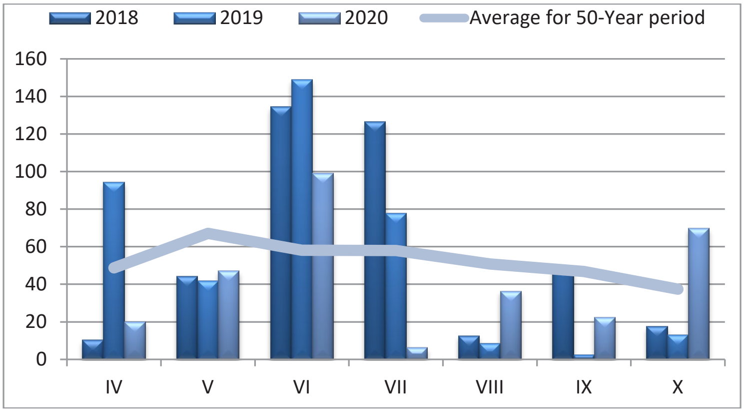

Figure 1. Monthly precipitation (mm) for the vegetation period (April-October) during the experimental years (mm)

Table 1. Scores are determined by the number of transects in which the species occurs

Species share in the grassland	Score
species present with some individuals	+
5% (present in 2 of 10 transects)	1
5-25% (present in 2-4 of 10 transects)	2
25-50% (present in 4-8 of 10 transects)	3
50-75% (present in 6-8 of 10 transects)	4
75-100% (present in 8-10 of 10 transects)	5

To monitor the indicators, such as data and synchronization of blossoming, height/ length of generative stems (cm), dry matter content, as well as to assess the forage quality of biomass from the identified species the samples were taken in the phenophase of bud formation and flowering of the first regrowth in the third experimental year (2020). The chemical composition of the dry forage matter was analyzed, which includes: Crude protein (CP, %) according to Kjeldahl, as a percentage of dry matter (%, DM); Crude fiber (CF, %)

according to AOAC (2016); Crude ash (CA, %) according to AOAC (1990); Crude fat (Cft, %) by extraction in a *Soxhlet* type extractor and drying in a laboratory oven at 95°C to constant weight (according to BDS/ISO-6492); Ca (%) and P (%) contents were carried out by the procedures of AOAC (2016). The fibrous structural elements in the plant cell are analyzed in laboratory: Neutral Detergent Fibers (NDF, %); Acid detergent fiber (ADF, %) and Acid detergent lignin (ADL, %) by the Van Soest & Robertson (1979) detergent assay and *in vitro* dry matter digestibility (IVDMD) according to a two-way pepsin-cellulase method of Aufrere (1982). The polyosides are empirically calculated: Hemicellulose (%) = NDF - ADF and Cellulose (%) = ADF - ADL. The lignification degree is expressed as the percentage of ADL and NDF.

RESULTS AND DISCUSSIONS

The following 4 short-lived alfalfa species were identified in the grassland: *M. arabica, M. minima, M. polymorpha* and *M. lupulina*. Two medium-long-term species were observed: *M. falcata* and *M. sativa*.

For the study period, the relative share in grassland of *M. arabica* and *M. falcata* was the highest (Table 2). Both species had equal average scores, with *M. arabica* being the dominant legume species in spring and *M. falcata* in summer, with a corresponding relative share in the grassland of about 25%. Regarding the share of both species, the highest seasonal and annual fluctuations were observed (SD = 0.98 and SD = 0.97). The annual species *M. polymorpha* is characterized by the most stable share in grassland over the years.

Table 2. Monthly and average scores for the share of Species of Genus *Medicago* in grassland studies

Species	2018 yr				2019 yr				2020 yr				Mean	SD
	IV	V	VI	VII	IV	V	VI	VII	IV	V	VI	VII		
M. arabica	3	3	-	-	3	2	-	-	1	1	-	-	2.17	0.98
M. minima	2	2	-	-	1	1	-	-	-	1	2	-	1.50	0.55
M. polymorpha	2	2	-	-	1	2	-	-	2	2	-	-	1.83	0.41
M. lupulina	1	2	1	-	1	2	1	-	1	2	2	-	1.44	0.53
M. falcata	-	1	3	2	-	1	3	3	-	1	3	3	2.22	0.97
M. sativa	-	1	1	1	-	1	2	2	-	1	1	1	1.22	0.44
	2.0	1.8	1.7	1.5	1.5	1.5	2.0	2.5	1.3	1.3	2.0	2.0		

The most early-ripening species among all established is *M. minima* (small seeds) - Table 3. The annual species enters the bud-formation-blossoming period in the last ten days of April, and in mid-May in the phenophase of pod formation.

M. minima has a spreading habitus and short generative stems, due to which its forage potential is insignificant, despite the distinct share of the species in the grassland and the established very high dry matter content during spring growth. The species is of interest as an early and fast-growing legume component of grassland, with a seasonal role in trophic relationships of the ecosystem (Zhang et al., 2013; Song et al., 2017).

The other two annual species, such as *M. arabica* and *M. polymorpha* are equal both in phenological development and in dry matter content in their fresh biomass.

M. lupulina is a biennial species and has the slowest development among the established short-lived alfalfa.

It is characterized by a spreading habitus and high values in terms of dry matter content in the studied grassland. The perennial species *M. falcata* is characterized by the latest and slowest development, as it entered the bud-formation period-beginning of blossoming in the period 5-15 July. It formed medium-tall, semi-spreading plants. It is characterized by uneven growth of generative stems and consequently with prolonged blossoming (until the end of July).

Table 3. Biological and morphological characteristics of the identified species of Genus *Medicago*

Species	Beginning of blossoming	Height/length of generative stems, cm	Growing habitus	Dry matter content, %
M. arabica	1-10 V	55.4	semi-spreading	19.75
M. minima	22-30 IV	25.7	spreading	28.57
M. polymorpha	1-10 V	32.5	semi-upright	19.45
M. lupulina	20-30 V	45.6	spreading	26.07
M. falcata	5-15 VI	58.6	semi-spreading	24.25
M. sativa	5-15 V	75.4	upright	23.40

The dry matter content in the beginning of blossoming was high (24.25%). These biological features determine the pasture suitability of the species and the interest in it for the improvement of cultivated alfalfa through interspecific hybridization (Riday & Brummer, 2006).

The presented results for the share of the species can be related to the specific way of using the grassland for the present study. In Bulgaria, mesophytic meadows located near settlements are used for unregulated grazing, and are often overgrazed. This establishes species with high grazing sustainability, such as *M. arabica* and *M. falcata*, as well as the fast-growing species of *M. minima*, which maintains its populations by self-sowing (early summer). According to Li et al. (2013) pasture use favors low-growing or semi-spreading species, which is confirmed by our results. The effect of the way the grassland is used can be related to the low share of the cultivated species of alfalfa, which is characterized by low grazing sustainability and upright growing habitus.

Medicago minima resides in various climatic environments, namely semi-arid and Mediterranean climates, and they are the most abundant annual *Medicago* plants (Kabtni et al., 2020). *Medicago polymorpha* also shows drought tolerance (Kirilov et al., 2016). Drought resistance may be associated with higher scores of these species for grassland share in the first and third experimental years, when severe spring droughts were observed.

Among the short-lived alfalfa species, *M. polymorpha* is characterized by the highest content of crude protein, crude fiber, cude fat, calcium and phosphorus (Table 4). The excess in the values of the indicated indicators in percentage units was respectively from 0.7 to 2.9 (for CP), from 7.1 to 13.3 (for CFr), from 0.91 to 1.52 (for CF), from 0.05 to 0.71 (for Ca) and from 0.12 to 0.19 (for P). Kamali et al. (2020) also define *M. polymorpha* as good enough for grazing specially at vegetative and blossoming stages. NDF and ADF content of plants increased with the growth but their CP, Ash, P, K, Cu, DMD, OMD, DOMD content and Ca decreased. The quantitative ratio of crude protein/crude fiber, assessed as the main indicator of quality and nutritional value of grass biomass in the studied short-lived wild species varied from 1/1.21 to 1/1.62. The most favorable ratio was observed for *M. arabica* (1/1.21). These results support the finding by Genç Lermi and Palta (2016) that the species have high agronomic potential than other annual legumes. *M. arabica* can fix nitrogen about 12 kg da^{-1} per year, improve soil properties, to assist feed requirements and to be used land as alternative legumes.

Table 4. Basic chemical composition (%) of Species in Genus *Medicago*

Species Indicator	*M. arabica*	*M. minima*	*M. polymorpha*	*M. lupulina*	*M. falcata*
Crude protein (CP)	20.78	19.86	23.66	22.94	25.32
Crude fiber (CF)	25.09	30.76	38.39	31.34	29.53
CP / CF	1 / 1.21	1 / 1.55	1 / 1.62	1 / 1.37	1 / 1.17
Calcium (Ca)	2.75	2.92	2.97	2.26	2.24
Phosphorus (P)	0.14	0.16	0.33	0.21	0.21
Ca / P	19.6 / 1	18.3 / 1	9.0 / 1	10.8 / 1	10.7 / 1
Crude ash (CA)	13.45	9.53	11.89	10.45	9.08
Crude fat (Cft)	3.42	3.89	4.94	4.03	3.97

For the perennial species *M. falcata*, an optimal value of the commented indicator (1/1.17) was also observed, which defines the species as a very valuable grazing component of the grassland in the summer months.

The dry matter of the perennial species *M. falcata* has the highest concentration of crude protein, as well as the most favorable ratio for the content of crude protein and crude fiber. Compared to short-lived species, *M. falcata* has a lower content of minerals and calcium.

For all analyzed species, a high content of Ca was observed, which leads to significantly higher values than the optimal ones for the ratio of the two macroelements (Ca/P). They ranged from 9.0/1 (*M. polymorpha*) to 19.6/1 (*M. arabica*). *M. arabica* can be mentioned as the species with the largest mineral imbalance and respectively with potential adverse effect on metabolic processes in ruminants (Hovi et al., 2003), given its higher share in grassland in spring and its higher forage productivity.

Cell wall fiber components and *in vitro* dry matter digestibility of species in genus *Medicago*

The content of neutral-detergent fibers (an indicator that makes up the total content of the fiber components of the cell walls) and acid-detergent fibers (ligno-cellulose complex, which determines the digestibility of animal fodder) varies from 32.10% (*M. polymorpha*) to 37.58% (*M. minima*) at an average value of 35.27% and from 25.02% (*M. falcata*) to 27.90% (*M. arabica*) at an average value of 26.42% (Table 5). The results obtained by us regarding the content of acid detergent fiber (27.90%) and neutral detergent fiber (36.84%) in the dry matter of *Medicago arabica* correspond to those established by Aydın et al. (2010), namely - 15.47-29.0% (CP), 22.60-32.93% (ADF) and 30.54-46.39% (NDF).

The high concentration of the lignin fraction (10.98%) in the dry matter of *M. polymorpha* is associated with lower digestibility (80.71%) of the biomass of the species compared to that of other alfalfa species.

The species *M. minima* and *M. lupulina* are with the lowest degree of lignification (coefficient = 16.66-17.30) (Figure 2) and with the lowest content of acid-detergent lignin (6.24-6.26%). Thus, they registered 2.0% higher *in vitro* digestibility of dry matter compared to the average value of the indicator (82.75%) in the studied species.

The biological value of the fodder mass largely depends on the content of fully digestible polyoside hemicellulose and incompletely digestible cellulose. In the studied wild alfalfa species, the concentration of hemicellulose in the dry matter ranged from 4.61% (*M. polymorpha*) to 11.82% (*M. minima*).

Empirically calculated values of the cellulose fraction ranged from 16.08% (*M. falcata*) to 19.68% (*M. lupulina*). The highest degree of lignification (coefficient = 34.21) was the grass mass of *M. polymorpha*, followed by that of *M. falcata* (coefficient = 26.52) and *M. arabica* (coefficient = 25.22).

Table 5. Basic structural fiber components of cell walls and *in vitro* digestibility of dry matter (%) of species of genus *Medicago*

Species Indicator	*M. arabica*	*M. minima*	*M. polymorpha*	*M. lupulina*	*M. falcata*	*Mean±Sx*	*SD*
NDF	36.84	37.58	32.10	36.08	33.73	***35.27±1.02***	***2.3***
ADF	27.90	25.76	27.49	25.92	25.02	***26.42±0.55***	***1.2***
ADL	9.29	6.26	10.98	6.24	8.95	***8.34±0.92***	***2.1***
Hemicell.	8.95	11.82	4.61	10.16	8.71	***8.85±1.19***	***2.7***
Cellulose	18.61	19.50	16.51	19.68	16.08	***18.85±0.75***	***1.7***
IVDMD	82.03	84.39	80.71	84.41	82.20	***82.75±0.72***	***1.6***
Mean±Sx	***30.60±11.19***	***30.89±11.60***	***28.73±11.20***	***30.42±11.60***	***29.12±11.33***		
SD	***27.4***	***28.4***	***27.4***	***28.6***	***27.7***		

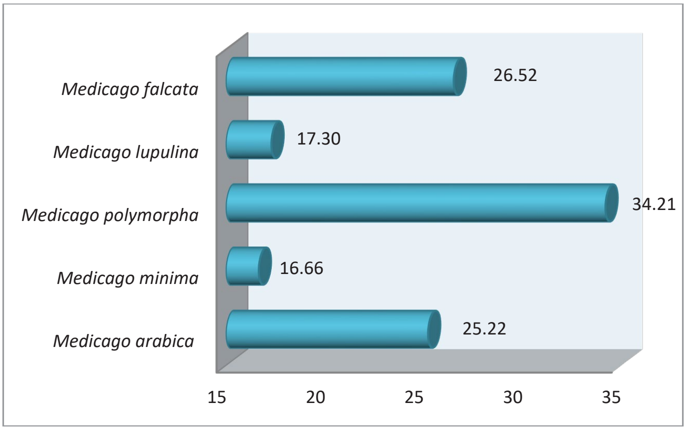

Figure 2. Lignification degree of forage biomass of species in genus *Medicago* (coefficient)

CONCLUSIONS

Among the six wild alfalfa species identified, the annual species *M. arabica* and the perennial *M. falcata* had the highest share, respectively significance for seasonal productivity and forage quality of the studied mesophytic grassland. *M. arabica* was the dominant legume species in spring and *M. falcata* in summer. The share of fast-growing, drought-resistant species, such as *M. minima* and *M. polymorpha,* may be associated with the observed spring and late droughts in the study area.

The dry matter of *M. falcata* had the highest concentration of crude protein (25.32%), as well as the most favourable ratio for the content of crude protein and crude fiber (1/ 1.17). Compared to other short-lived species, *M. falcata* had a lower content of minerals (9.08%) and calcium (2.24%).

The dry fodder mass of *M. polymorpha* was the richest in crude fiber (38.39%), crude fat (4.94%), acid-detergent lignin (10.98%), calcium (2.97%) and phosphorus (0.33%), and demonstrated the most favourable ratio between the amount of the two macroelements (9.0/1). The dry matter of that short-lived species had the lowest *in vitro* digestibility (80.71%) and hemicellulose concentration (4.61%).

M. arabica had the lowest content of crude fiber (25.09%) and the highest concentration of minerals (13.45%), and acid-detergent fiber (27.90%) - a factor that determines the relatively lower digestibility of 0.9% compared to the average and by 2.9% compared to the highest value of the indicator) of the dry matter. Compared to *M. polymorpha*, the fiber fraction in the composition of *M. arabica* was 53.0% lower.

The difference in the results of the analyzed and empirically determined biochemical parameters (fiber components of the cell walls and *in vitro* digestibility of dry matter) in *M. minima* and *M. lupulina* was insignificant. The studied species registered low content of ADL (6.24-6.26%) and highest digestibility of dry matter (84.39-84.41%). *M. minima* was the species with the lowest value in terms of crude protein (19.86%) and the highest in terms of hemicellulose (11.82%).

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COMPARISON OF CROP ROTATION VS. MONOCULTURE: A SUNFLOWER CASE

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Abstract

The influence of the crop rotation on sunflower (Helianthus annuus L.) yield and yield components is limited. Therefore a study in three consecutive growing seasons of sunflower (2018, 2019, and 2020) was conducted. The trial was performed on the experimental field of the department of "Agriculture and herbology" at the Agricultural University of Plovdiv, Bulgaria. The experiment was performed by the long plots method. Two crop rotations were evaluated: 1. Winter wheat - sunflower and 2. Sunflower - sunflower (monoculture). All evaluated parameters of sunflower as plant height at the end of the vegetation, head diameter, seed yield, seed oil content, as well as the absolute mass of 1000 seeds and hectoliter seed mass were influenced by the preceding crop. The highest results for the rotation of winter wheat - sunflower were reported, while statistically lower results for the sunflower monoculture were found.

***Key words**: sunflower, preceding crop, yield.*

INTRODUCTION

It is considered that the sunflower is the fourth oilseed crop in the world (Nisar et al., 2011). It is also found that the percentage of oil and protein in seeds is 40-55% and 23% respectively (Jadaan et al., 1999). The seeds also contain linoleic acid, oleic acid, and linoleic acid (Nasralla et al., 2014).
In Bulgaria, sunflower is the main oilseed crop. In 2021 the total harvested area was 703 985 ha with a total production of 1 682 491 tones and an average seed yield of 2.39 t ha^{-1} (www.mzh.government.bg).
Sunflower brings diversity to dryland crop rotations as warm-season and intermediate water-use crops (Anderson et al., 1999; Johnston et al., 2002). According to Lecomte and Nolot (2011) sunflower have rotational benefits for winter crops. Crop rotation plays a major role in crop yielding (Hilton et al., 2018). The preceding crops must be carefully chosen for obtaining higher yields and seed quality. Several authors are working for identifying optimal rotations and the influence of the preceding crop (Christen and Sleling, 1995; Sieling and Christen, 1997; Ma et al., 2003; Rathke and Diepenbrock, 2006; Sieling and Kage, 2010; Stobart, 2012; Stobart and Bingham, 2013; Sieling and Christen, 2015; Basa et al, 2016; Fordoński et al., 2016; Cherkasova and Rzaeva; 2021; Neshev, 2022). According to Johnston et al. (2002) and Lecomte and Nolot (2011), sunflower is usually grown in 3-4 year rotations with cereals, oilseed rape and legumes.
The yield and the yield components are specific to each sunflower hybrid, but they are influenced by the growing factors - environmental and technological (Ion et al., 2015). The causes of yield decrease are complex and many factors have been implicated such as alteration of soil physicochemical properties by land management practices and changes in the composition of soil microorganisms (Bennett et al., 2012). Some authors suggest shorter rotations when disease-resistant hybrids are used. Many sunflower producers apply 3- or 2-year rotation and some are considering monoculture. Monoculture is the crop rotation antithesis - growing the same crop for several years in the same area (Robinson et al., 1979).
Having in mind the above-mentioned facts, the present study was conducted to enrich the knowledge of the sunflower grown as monocrop and in rotation with winter wheat.

MATERIALS AND METHODS

The trial was conducted in three consecutive vegetation seasons of sunflower (2018, 2019, and 2020). The research was performed on the experimental field of the department of "Agriculture and herbology" at the Agricultural University of Plovdiv, Bulgaria.

The following crop rotations were under evaluation: 1. Winter wheat - sunflower and 2. Sunflower - sunflower (monoculture).

The experiment was conducted by the long plots method.

The following parameters were evaluated:

- Plant height before harvest (m). Measurements were done on 4 samples of 25 plans per rotation = 100 plants total;
- Head diameter (cm). Measurements were done on 4 samples of 25 plans per rotation = 100 plants total;
- Sunflower seed yield (t ha^{-1}) by harvesting the whole plots with plot harvester of Wintersteiger Company;
- Absolute mass of 1000 seeds (g) (in four replications) (Tonev et al., 2018);
- Hectoliter seed mass (kg) (in four replications) (Tonev et al., 2018);
- Seed oil content (%) was determined by the Soxhlet method as described by Ivanov and Popov (1994). The analyses were performed in three replications per rotation.

The soil on the experimental field is classified as Mollic Fluvisols, with average sandy-clay mechanical composition, not high humus content, and weak-alkaline reaction. The nitrogen content is low, the content of phosphorus varies from low to average and the potassium content is high (Popova et al., 2012).

The sunflower (*Helianthus annuus* L.) hybrid grown in the study was SY Bacardi CLP - Clearfield Plus® (Syngenta Company). The hybrid is selected to be grown by Clearfield® Plus Technology of sunflower.

On the experimental field deep ploughing, two times disc harrowing, and two times cultivation before sowing were accomplished.

On the whole experimental area, basic combine fertilization with 250 kg ha^{-1} NPK (15:15:15) and spring dressing with 200 kg ha^{-1} NH_4NO_3 was done. The sunflower plants were sown at a planting distance of 20 x 70 cm.

The agrometeorological data is provided by the department of "Botany and Agrometeorology" at the Agricultural University of Plovdiv, Bulgaria.

The presented data is for the average monthly minimum and maximum air temperatures (°C) as well as precipitation (mm) for the vegetation periods of sunflower (from April till August) during the three study years (2018, 2019, and 2020).

For statistical analysis of the collected research data the independent samples t-test was applied by using IBM SPSS statistics 26 software.

RESULTS AND DISCUSSIONS

In Tables 1 and 2, the data for the average daily precipitation and temperatures during the sunflower's vegetation in the three experimental years (2018, 2019, and 2020) is presented.

According to the meteorological data for the individual years, it can be assessed how climatic conditions affected the herbicide efficacy, as well as the growth and development of the plants.

The precipitation was not equally distributed during the sunflower's vegetation in the three years of research but was enough for the plant's growth and development.

Table 1. Average monthly precipitation for the vegetation periods of sunflower, mm

Years/ Month	2018	2019	2020
April	24.0	68.9	92.9
May	98.4	22.8	60.1
June	116.4	89.7	81.9
July	89.6	79.4	45.3
August	31.2	33.8	25.5

The average minimum and maximum air temperatures differed during the growing seasons of sunflower.

The air temperatures were suitable for sunflower's growth.

Throughout the three study years, no extreme values affecting the crop were recorded.

Table 2. Average monthly precipitation for the vegetation periods of sunflower, mm

Years/ month	2018		2019		2020	
	max t°	min t°	max t°	min t°	max t°	min t°
April	23.9	8.9	20.1	8.6	18.6	4.1
May	27.1	12.6	24.8	11.5	17.9	5.7
June	28.0	16.4	28.0	18.5	31.2	10.8
July	29.1	18.8	31.2	19.3	32.1	16.2
August	30.2	17.5	31.4	21.0	31.9	20.7

In the next six tables the results concerning plant biometry, productivity and seed quality are presented.
According to a several authors, plant growth and development is influenced by the previous crop in the rotation (Arihara and Karasawa, 2000; Haase et al., 2007; Rieger et al., 2008; Friberg et al., 2019). These findings correspond with the obtained data related to the current study. The average height of the plants from Rotation 1 was 1.72 m and did not differ in wide ranges in the different years of the study. When growing sunflower as monocrop the height of the plants decreased from 1.67 m in 2018 to 1.31 m in 2020 (Table 3).

Table 3. Sunflower plant height, m

Rotations	2018	2019	2020	Average
1. Winter wheat - sunflower	1.73	1.67	1.76	1.72
2. Sunflower - sunflower	1.67	1.42	1.31	1.47
Rotation 1 / Rotation 2	ns	*	*	*

Asterisks (*) indicate significant differences between the averages of both tested cultivars by independent samples t-test at $P \leq 0.05$, ns-non significant difference.

The sunflower head diameter followed the tendency of the plant height (Table 4). The differences in the sunflower heads from the plants of rotation 1 did not differ to a great extent. Average for the period of the study the sunflower heads of this rotation were 18.62 cm in diameter. The sunflower heads decreased their diameter in the mono-cropping system (Rotation 2) from 18.25 cm in 2018 to 16.12 cm in 2020.

Table 4. Sunflower head diameter, cm

Rotations	2018	2019	2020	Average
1. Winter wheat – sunflower	18.45	19.04	18.38	18.62
2. Sunflower – sunflower	18.25	17.46	16.12	17.28
Rotation 1 / Rotation 2	ns	*	*	*

Asterisks (*) indicate significant differences between the averages of both tested cultivars by independent samples t-test at $P \leq 0.05$, ns-non significant difference.

In Table 5 is presented the sunflower seed yield. As well as the growth parameters, the productivity of the plants was also influenced by the preceding crop. Anderson et al. (1999) found that the highest sunflower seed yield was obtained in the wheat-corn-sunflower-fallow rotation. In the present experiment higher and stable yields were found when the sunflower was sown after winter wheat (Rotation 1) - 2.54 t ha^{-1}. Severe yield decrease was observed when the sunflower was grown as monoculture (Rotation 2). In the first year of the study (2018) the seed yields were 2.53 t ha^{-1} and diminished to 1.64 t ha^{-1} in the third experimental year (2020).

Table 5. Sunflower seed yield, t ha^{-1}

Rotations	2018	2019	2020	Average
1. Winter wheat - sunflower	2.57	2.64	2.41	2.54
2. Sunflower - sunflower	2.53	2.18	1.64	2.12
Rotation 1 / Rotation 2	ns	*	*	*

Asterisks (*) indicate significant differences between the averages of both tested cultivars by independent samples t-test at $P \leq 0.05$, ns-non significant difference.

The indicator absolute seed mass is crucial for the yield's formation (Georgiev et al., 2014). There were negligible differences observed in the different years of the trial when the sunflower was grown after preceding crop winter wheat (Rotation 1). The absolute mass of the sunflower seeds from this rotation was 62.14 g on average for the period. The mono-cropping system of sunflower (Rotation 2) led to a severe decrease of the evaluated parameter also. In the first trial year, the absolute seed mass was 61.85 g and 51.78 g in the last experimental year (Table 6).

Table 6. Absolute seed mass, g

Rotations	2018	2019	2020	Average
1. Winter wheat – sunflower	62.41	60.57	63.43	62.14
2. Sunflower – sunflower	61.85	57.42	51.78	57.02
Rotation 1 / Rotation 2	ns	*	*	*

Asterisks (*) indicate significant differences between the averages of both tested cultivars by independent samples t-test at $P \leq 0.05$, ns-non significant difference.

The seed hectoliter mass and yield depend on the production year (Vujaković et al., 2014). In the current research, the indicator hectoliter seed mass was influenced by the crop rotation. In Rotation 1, as the other studied parameters, the highest results were obtained. Average for the research years the hectolitre seed mass was 41.17 kg.

For Rotation 2 the average result of 38.44 kg was a function of the decrease of the indicator's values in the second and third year of growing sunflower as monocrop (Table 7).

Table 7. Hectoliter seed mass, kg

Rotations	2018	2019	2020	Average
1. Winter wheat - sunflower	41.33	40.67	41.50	41.17
2. Sunflower - sunflower	41.67	38.33	35.33	38.44
Rotation 1 / Rotation 2	ns	*	*	*

Asterisks (*) indicate significant differences between the averages of both tested cultivars by independent samples t-test at P ≤ 0.05, ns-non significant difference.

Seed oil percentage amounted to an average of 42.8% and was affected by the year, rather than sowing date or preceding crop (Hemeid and Zeid, 2020). Reverse results were obtained in the present research. The preceding crop affected the seed oil content of sunflower. Robinson et al. (1967) reported that the seed oil content of sunflowers in rotation with soybeans was higher than the seed oil content of sunflowers grown as a monoculture. These findings correspond to the results obtained in the current research.

Table 8. Sunflower seed oil content, %

Rotations	2018	2019	2020	Average
1. Winter wheat - sunflower	45.14	46.41	45.87	45.81
2. Sunflower –- sunflower	44.89	41.31	38.70	41.63
Rotation 1 / Rotation 2	ns	*	*	*

Asterisks (*) indicate significant differences between the averages of both tested cultivars by independent samples t-test at P ≤ 0.05, ns-non significant difference.

The seed oil content of the plants from Rotation 1 (winter wheat - sunflower) was lower than those of the plants grown as a mono-cropping system (Table 8). The seed oil content of sunflower of Rotation 1 was 45.81% on average for the two research years. In contrast, the seed oil content of the plants from Rotation 2 decreased from 44.89% in 2018 to 38.70% in the third research year.

CONCLUSIONS

The obtained results confirmed that the preceding crop influences the growth and development of the sunflower. If sown after winter wheat the highest results for all studied parameters were obtained.

The growing sunflower as a mono-cropping system is not a good farmer practice. In the second and third years of the study, the results of the studied indicators (vegetative, productive, and qualitative) for the monoculture of sunflower were diminished.

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STUDY OF SOME GROWTH AND REPRODUCTIVE ELEMENTS IN THE *Cassia angustifolia* SPECIES

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Abstract

Cassia angustifolia (family Fabaceae), popularly known as Senna, is a valuable plant drug in Ayurveda and modern system of medicine for the treatment of constipation. Cassia prefers sandy, light, well-drained soils. In its areas of origin, it grows in bushes and semi-desert pastures, especially in valleys, floodplains and on the banks of rivers. It is found from sea level to altitudes of 1,300 meters. A field experiment was conducted to the National Institute of Research and Development for Potato and Sugar Beet Brasov to highlighting aspects of biology and technology regarding the introduction of the species into culture in Romania. A two-factor experiment was designed, located according to the method of subdivided plots, in three repetitions of the 3 x 3 x 3 type, the length of a variant being 2 m, and the paths with a width of 1 m and 9 rows of plants per plot.

Key words*: biology, Cassia angustifolia, medicinal plant, senna, technology.*

INTRODUCTION

Cassia angustifolia Vahl. is a native plant from Asia, Egypt, Sudan, Saudi Arabia, Yemen, and Pakistan. According to some authors, it has about 580 species. Many of these species are used for medicinal purposes, others are considered ornamental (Trease & Evans, 1983; Evans, 1992) or as a source of tanning material of economical value.

Cassia angustifolia, synonymous with *Senna alexandrina* Mill., belongs to the *Fabaceae* family, *Caesalpinioideae* subfamily, includes shrubs and herbaceous plants distributed throughout the tropics and subtropical regions. Some species are also found in temperate regions (Randell et al., 1998; Savulescu et al., 2018). *Cassia angustifolia* has a variety of uses in Unani medicine, as well as in other traditional medicine systems. The plant is appreciated mainly for its properties, being generally used in ordinary constipation. The laxative principles sennoside A and sennoside B, isolated from senna leaves and pods, are important ingredients in purgative drugs (Tripathi, 1999)

Cassia angustifolia is a perennial plant, 60-80 cm tall, glabrous to subglabrous (Figure 1). The leaves are alternate, paripinnate, having 6-10.5 cm long, with 5-9 pairs of lanceolate leaflets, with the whole edge, with acute tip, long about 1.2-4.5 cm and 3.5-10 mm wide, glabrous hairy on both sides, of pale green colour.

Figure. 1 *Cassia angustifolia* Vahl.
Source: https://www.soin-et-nature.com

The flowers are on type 5, with free, slightly zygomorphic elements, pedicles are 3-4 cm long, grouped in terminal or axillary raceme, up to 15 cm long. The sepals are slightly uneven, yellow-green coloured, 10-13 mm long and 6-9 mm wide. The petals are yellow and slightly uneven, 14-17 mm long and 7-10 mm wide. The 10 stamens are free. The ovary is hairy and stipitate. The plant blooms in April-June. The fruit is a dehiscent sparsely hairy pod, 5-6 cm long and 1.7-2.3 cm wide, slightly curved, with approx. 10 seeds. The fruits are turning black at maturity. The anatomy of the stem and leaf are similar to the *Fabaceae* family, being reconfirmed in specialized papers (Metcalfe 1979; Toma & Rugina, 1998; Dickison et al., 2005; Lo et al., 2011; Santhan, 2014, Savulescu et al., 2018).

Senna leaves and pods have been used in herbal medicine since ancient times (Bojor & Raducanu, 2001).

Pods contain sennosides, anthraquinones, aloe-emodin, cathartic acid, cathartin, kaempferol, catharkaempferol, chrysophanic acid, rhein, isorhamnetin, emodin, kaempferin, mucilage, phaeoretin, sennacrol, and sennapicrin. Senna leaves contain free anthraquinones and their O- and C-glycosides and free sugars. Newly sprouted leaves after the rain are high in sennosides which decline as the leaves mature. Laxative potency of senna was found to be reasonably uniform in mice with a variation of 25% of the mean, and repeated administration of the doses over many weeks did not cause any tolerance. Sennatin, a preparation containing 20 mg of purified sennosides, reduced colonic transit time by more than half and abolished loperamide-prolonged colonic transit in healthy volunteers (Akbar, 2020).

Cassia angustifolia Vahl (*Fabaceae*), commonly known as “senna” is employed in various indigenous systems of medicine against several diseases and almost every part of the plant has diverse medicinal properties. The seeds are used as an anthelmintic, digestive, and to treat skin diseases and abdominal troubles (Srivastava et al., 2006).

It is contraindicated in intestinal stenosis, intestinal obstruction, Chron's disease, ulcerative colitis, appendicitis, to children under 12 years, the first trimester of pregnancy, lactation, diarrhoea, and dehydration. It is not administered for more than a week. Excessive doses lead to watery diarrhoea, accompanied by intense colic pain and even nausea and vomiting. Although it is used on a fairly large scale, it should be administered only on the recommendation of a doctor (Nadasan, 2003).

Being a resistant species, it can be grown in saline and rainy conditions. The cultivation of senna does not require high costs for irrigation, manure, pesticides, protection, and other pre- and post-harvest care. This makes the plant an ideal crop for arid regions where water supply, desertification control, sand dune stabilization are major challenges (Pareek & Gupta, 1984).

MATERIALS AND METHODS

The work proposed to highlight some aspects of biology and technology regarding the introduction into culture of the species *Cassia angustifolia* Vahl.

The aim was: acclimatization of the material in the field, by selecting representative plants such as vigour, uniformity and health, the study of plant biology on the growth and development of foliar and reproductive apparatus, adaptability to specific environmental conditions. Determinations were made on the elements of productivity: plant height, number of flowering stems, mass of flowers, number of inflorescences, mass of the underground part, average number of leaves and their mass, mass of plants, production of fresh and dried herba (g/plant).

Pedoclimatic conditions of the experimental area

The experiments were located in the experimental field of the National Research and Development Institute for Potato and Sugar Beet Brasov, the Laboratory of Technology and good agricultural practices, the Department of Medicinal and Aromatic Plants.

The experimental field is located in the Brasov Depression (Barsa Country), at 25°45'E longitude and 45°42'N latitude. The altitude at which the experimental field is located is 520 m (Mihai, 1975).

The climate of the Brasov Depression is temperate continental, characterized by the transition between temperate oceanic and temperate continental climate: wetter and cooler in mountainous areas, with relatively low rainfall and slightly lower temperatures in lower areas.

The chernozomoid soil on which the experiment was based, has a pH between 5.3 and 6.5, being a moderate acid to weak acid soil, with a humus content between 3.5 and 5%, which indicates an average to good supply of organic matter (Vidican et al., 2013).

Climatic characterization of the years 2016-2018 at NIRDPSB Brasov.

The average monthly air temperatures in Brasov, between October 1, 2016 - September 30, 2017, were lower at the beginning of the analysed interval compared to the multiannual average. Thus, in October an average value of 6.9°C was registered. January has a lower value of 8.4° and March has positive values of 6.6°C. The amount of precipitation (688.2 mm) exceeded the multiannual average value by 53.8 mm (8.5%). This year's monthly precipitation level was close to the multiannual average. The agricultural year 2017-2018 was warmer. During the autumn-winter period, the average air temperature was 1.5°C higher than the MAA value (0.7°C). The average monthly temperatures were higher, compared to the multiannual values, in the whole interval October - March, with deviations between 0.5 and 3.3°C. During the vegetation period (April - August) the air temperature was higher by an average of 2.7°C, compared to MAA. The agricultural year 2017-2018 was richer in precipitation compared to the values characteristic of the area, their amount exceeding by 141.3 mm the multiannual value of 177.0 mm. Between April and September, the rainfall was generally below the multiannual values, except in June and July, when they exceeded the multiannual values, especially in June, by more than 100.0 mm (Ghimbav meteorological station, Brasov).

The experimental model. In order to establish the optimal nutrition space, different planting distances were tested, which would allow the mechanization of maintenance works, correlated with the planting period, and adapted to the specific climatic conditions.

The research started by setting up a two-factor experiment, based on the randomized block model, each variant having three rows in three repetitions.

The length of a variant was 200 cm, and the paths were 100 cm wide.

Factor: A - distance between rows, with graduations: 25 cm, 50 cm, 70 cm.

Factor: B - distance between plants per row: continuous row, 15 cm, 25 cm.

The variant with continuous row density/25 cm is considered the control of the experience.

Determinations at plants harvest for herba. Each experimental factor was followed by the dynamics of emergence and growth of the leaf apparatus until flowering, when three plants were harvested from each variant/experimental repetition.

The following biometric determinations were made for each harvested plant: plant height; root mass; the number of leaves and their mass; the number of flowering stems and their mass; average fresh herba production.

Statistical analysis. Experimental data processing and paper writing were done using Windows Vista, Windows XP, Excel and Word. The analysis of variance was calculated for all elements studied, using the PoliFact statistical program - for fully randomized multifactorial experiments, theoretical t values and DL limit differences for 5%, 1% and 0.1%. The interpretation of the experimental data was done after "Analysis of biological variants" (Bonnier., 1957) and "Principles of the methodology of agronomic and veterinary medical research" (Ardelean, 2010).

RESULTS AND DISCUSSIONS

The analysis on the average mass of *Cassia angustifolia* plants on each factor studied in 2016, stand out positive influences of factor A at each graduation, with distinctly significant values in the variant planted at 50 cm between rows, with an average increase of 170.56 g, and the variant with 70 cm between rows with very significant average values of 221.00 g compared to the control (Table 1).

Table 1. The influence of factor A (row spacing) on the mass of *Cassia angustifolia* plants in 2016

Sym	Dist. between rows	Average (g)	%	Differece (g)	Sign.
A1	25	128,11	100,0	0,00	Mt.
A2	50	170,56	133,1	42,44	**
A3	70	221,00	172,5	92,89	***
DL (p 5%)				17,88	
DL (p 1%)				29,59	
DL (p 0.1%)				55,39	

The influence of factor B (distance between plants in a row) on the average mass of plants is very significant in both planting variants: B2 with an average increase of 182.44 g, and B3 with an increase of 216.33 g compared to control B1 (Table 2).

Table 2. The influence of factor B (distance between plants in a row) on the mass of plants of *Cassia angustifolia* in 2016

Sym	Dist. between plants on a row (cm)	Average (g)	%	Difference (g)	Sign.
B1	10	120,89	100,0	0,00	Mt.
B2	25	182,44	150,9	61,56	***
B3	50	216,33	179,0	95,44	***

DL (p 5%)	17,5
DL (p 1%)	24,65
DL (p 0.1%)	34,83

From the data in Table 3, which shows the influence of the interaction between factor A on the average mass of senna plants in the second experimental year, it is observed that planting at 50 cm brought a significant increase in production, with a difference of 28, 11 g compared to the control.

Table 3. The influence of factor A (distance between rows) on the mass of *Cassia angustifolia* plants in 2017

Sym	Dist. between rows (cm)	Average (g)	%	Difference (g)	Sign.
A1	25	132,22	100,0	0,00	Mt.
A2	50	160,33	121,3	28,11	*
A3	70	244,00	184,5	111,78	***

DL (p 5%)	25,21
DL (p 1%)	41,71
DL (p 0.1%)	78,08

The variants planted at 70 cm had very significant increases, reaching differences of 111.78 g, compared to the control variant planted at 25 cm between rows.

Table 4. The influence of factor B (distance between plants in a row) on the mass of plants of *Cassia angustifolia* in 2017

Sym	Dist. between plants on a row (cm)	Average (g)	%	Difference (g)	Sign.
B1	10	110,11	100,0	0,00	Mt.
B2	25	185,78	168,7	75,67	***
B3	50	240,67	218,6	130,56	***

DL (p 5%)	13,67
DL (p 1%)	19,19
DL (p 0.1%)	27,09

From the data on the influence of factor B interaction (distance between plants in a row) on the average mass of *Cassia angustifolia* plants in 2017 (Table 4), it is shown that the results were very significant in all variants compared to the control.

In 2018, the influence of factor A is positively noticed, which reacted favourably to both variants of distance between rows compared to the control variant. The studied variants registered very positive meanings this year (Table 5).

Table 5. The influence of factor A (distance between rows) on the mass of *Cassia angustifolia* plants in 2018

Sym	Dist. between rows (cm)	Average (g)	%	Difference (g)	Sign.
A1	25	134,33	100,0	0,00	Mt.
A2	50	181,78	135,3	47,44	***
A3	70	212,67	158,3	78,33	***

DL (p 5%)	14,77
DL (p 1%)	24,44
DL (p 0.1%)	45,75

The influence of factor B (distance between plants in the same row) on the average mass of *Cassia angustifolia* plants ensures very significant differences compared to the control variant (Table 6), with an average difference of 53.89 g in variant B2 and 85.56 in variant B3.

Table 6. The influence of factor B (distance between plants in a row) on the mass of plants of *Cassia angustifolia* in 2018

Sym	Dist. between plants on a row (cm)	Average (g)	%	Difference (g)	Sign.
B1	10	129,78	100,0	0,00	Mt.
B2	25	183,67	145,5	53,89	***
B3	50	215,33	165,9	85,56	***

DL (p 5%)	8,29
DL (p 1%)	11,64
DL (p 0.1%)	16,44

CONCLUSIONS

Analyzing the results obtained on the influence of the distance between rows and between plants one the same row on some elements of growth and development of the foliar and reproductive apparatus in the species *Cassia angustifolia* with direct results on the average mass of plants, the following assessments can be made:

- in the climate and soil conditions from NIRDPSB Brasov, *Cassia angustifolia* species finds good conditions for growth and development;

- in the three experimental years there are significant and very significant increases in both factors studied compared to the control;
- these results recommend as favourable planting distances 50/70 cm between rows and 25 cm between plants per row.

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MANAGEMENT OF PESTS AND PATHOGENS IN RYE CROP IN DRY MARGINAL ENVIRONMENT IN SOUTHERN ROMANIA

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Abstract

*Climate change is expected to cause the spread of pathogens and pests in areas where they have not been relevant before, bringing new challenges for cropping systems based on crops diversification by minor cereals. Rye is a minor cereal that contributes to crop species diversity in Central and Eastern Europe, especially in marginal environments unfavourable for wheat production. During 2019-2020, a plant–pest-pathogen interaction profile was observed on Suceveana rye genotype in a randomized complete block design in dry area from Research and Development Station for Plant Culture on Sands Dabuleni in South of Romania. The best protection against leaf rust was provided by Dithane M 45+Bioinsekt (the 1st assessment = 2.98%; the 2nd assessment = 4.86%), while the best control against pests was provided by Mimox+Bioinsekt (the 1st assessment = 0.83%) and Mimox+ Decis Expert 100 EC (the 2nd assessment = 1.03%). For pests and leaf rust control was noticed the synergistic effect of insecticides and fungicides used in the experiment. Negative and significant correlations of attack degrees with grain yield (r =-0.7886**, respectively r = -0.8332**) were noticed.*

Key words: *leaf rust, Puccinia recondita f.sp. secalis, pests, pesticides formulation, attack degree.*

INTRODUCTION

The impact of climate change on spontaneous and cultivated plants has led to changes in floristic composition, invasive plants proliferation and variability of reproduction, adaptability and development (Răduțoiu et al., 2012; Sărățeanu et al., 2013; Sărățeanu et al., 2016; Sărățeanu et al., 2019; Cosmulescu et al., 2020; Răduţoiu, 2020; Răduţoiu and Cosmulescu, 2020; Sărățeanu et al., 2020; Răduţoiu and Băloniu, 2021).

The predictions show that global temperature will increase by 2.5 to 4.5°C by the end of 21st century as a result of the rising concentrations of greenhouses gases in the atmosphere (Bernstein et al., 2008).

In the context of climate change crop production and food security are ones of the major global challenges in the 21st century, cereal food supply being expected to increase over 70% by 2050 when global population is predicted to 9.8 billion people (Howden et al., 2007; Godfray et al., 2010; Ray et al., 2013; Tripathi et al., 2016; Bonciu, 2019c; Lal, 2021; Malhi et al., 2021). During the last decades, despite the negative impact of climate change and other global constrainers (e.g. Covid-19 pandemic) on the food supply, crop production increased significantly due to many changes in agricultural systems as a consequence of interaction among multiple factors such as globalization in food production, genetic progress, biotechnologies, improved cropping technologies, better pests, diseases and weeds management, agricultural digitalization and farmers faster access to the information (Butnariu et al., 2006; Matei, 2011; Matei, 2016; Partal et al., 2013; Partal et al., 2014; Bonciu, 2018, Diaconu et al., 2019; Dima et al., 2019; Bonciu, 2019a, Bonciu, 2019b; Bonciu, 2020a; Bonciu, 2020b; Matei et al., 2020a;

Matei et al., 2020b; Partal and Paraschivu, 2020; Bonciu et al., 2021; Dima et al., 2021a; Dima et al., 2021b; Drăghici et al., 2021; Paraschivu and Cotuna, 2021). However, this progress comes to face additional factors as climate variability and climate changes.

Agricultural systems are also affected by changes in temperatures (global warming) impacting directly crops yield and indirectly the biotic constrainers and might result in invasion of weeds, pests and pathogens in areas where they have not been relevant before (Coakley et al., 1999; Chakraborty and Pangga, 2004; Cotuna et al., 2013; Bălașu et al. 2015a, Bălașu et al., 2015b, Manole et al., 2015; Paraschivu et al., 2015; Paraschivu et al., 2017; EEA Report, 2017; Cotuna et al., 2018; Paraschivu et al., 2019; Juroszek et al., 2020; Zală, 2021).

Thus, some pathogens and pests tend to become more aggressive even in cropping systems based on crops diversification by minor cereals.

Rye (*Secale cereale*) is a minor cereal, closely related to barley and wheat, having a major role in crop species diversity in temperate regions of Central and Eastern Europe, especially in marginal environments where soil and climate are unfavourable for wheat production. In 2020 European Union (EU) produced 9.175.000 tonnes of rye grains from which 71.82% was produced in Germany and Poland (USDA, 2020).

Despite the fact that rye is an important source of resistance gene for wheat in combating leaf rust, stem rust, stripe rust, powdery mildew, Barley yellow dwarf virus (BYDV) and insect resistance to Hessian fly, Russian wheat aphids, and green bug, it is affected by various pathogens and pests (Zhang et al., 2001; Saulescu et al., 2011).

One of the most important diseases of rye in Central and Eastern Europe is Brown rust (BR), known also as Leaf rust (LR), caused by the obligate biotrophic basidiomycete *P. recondita* f. sp. *secalis* (Prs) (Roberge ex. Desmaz) (Roux and Wehling, 2010; Meidaner et al., 2012).

In natural conditions, yield losses can be up to 40%, but they can be as high as 80% in case of early infection (Solodukhina, 2002; Wehling et al., 2003).

Although, resistance is currently considered as the most economical and effective control measure of this disease, cereal rusts exhibit considerable capacity for generating, recombining and selecting for resistance under the impact of climate variability and they can adapt to new environment. Therefore, additional fungicides used is still remaining an important part of integrated disease management. The application of fungicides led to 29% higher yields comparatively with untreated plots (Hartleb et al., 1995). In experimental trials epoxiconazole, pyraclostrobin and fluxapyroxad showed high efficiency in controlling leaf rust in rye (Kupferund and Schröder, 2014). Little research is reported in controlling pathogens and pests in rye system in dry marginal areas.

In this context the present paper emphasises the management of rye-pest-pathogen interaction in dry marginal environment from Southern Oltenia, Romania, using different formulations of conventional and biological pesticides.

MATERIALS AND METHODS

During 2019-2020 growing season, a plant–pest-pathogen interaction profile was observed on Suceveana rye genotype using different pesticide formulations in a randomized complete block design with three replications in dry area from Research and Development Station for Plant Culture on Sands Dăbuleni, located in Southern Oltenia, Romania (43°48′04″N 24°05′31″E), on sandy soil, poorly supplied with nitrogen (between 0,04-0,06%), well supplied with phosphorus (between 54 ppm and 77 ppm), reduced to a medium supplied with potassium (between 64 ppm to 83 ppm), low in organic carbon (between 0.12-0.48%) and weakly acidic pH to neutral (between 5.6 and 6.93).

Technological measures applied included broadcasting the fertilizers at sowing time with $N_{80}P_{80}K_{80}$, one side nitrogen fertilization during vegetation with N_{70}, starter irrigation with 250 m^3 water/ha and supplemental irrigation with 300 m^3 water/ha at heading stage. Also, weeds control was done using Dicopur Top 464 SL (1 l/ha) applied in postemergence to control annual and perennial dicotyledons accordingly with the recommendations (cereals to the formation of the first internode and the weed species in the small phase of about 2-4 leaves and a maximum of 10-15 cm high for perennial weeds).

Plant–pathogen interaction was assessed in natural infection with *P. recondita* f. sp. *secalis* (Prs) (Roberge ex. Desmaz) in a randomized complete block design (RCBD) with three replications. Each plot had 5 m^2, a space of 1 m between blocks and 0.5 m between plots. Treatments were applied in two different moments (14.04.2020 and 05.05.2020).

Disease observations were recorded since the first appearance (booting stage) of leaf rust infection on Suceveana rye genotype and at early dough stage (Zadoks scale) (Zadoks et al., 1974).

For all assessed trail variants were determined Frequency (F%) and Intensity (I%) of leaf rust and insect's attack.

Leaf rust Intensity (%) was recorded for each trial variant assessing 10 plants randomly selected and pre-tagged plants of the central four rows of each plot and the mean of the ten plants was considered as the value for a plot. Rust severity was determined by visual observation and expressed as percentage coverage of leaves with rust pustules (from 1% to up 75%) using the sale developed by Oladiran and Oso (1983) (Table 1).

Table 1. Leaf rust intensity expressed as percentage coverage of leaves with rust pustules (Oladiran and Oso, 1983)

Category	Percentage leaf rust infection relative to susceptible check
0	0 - no attack
1	1-10% of leaf area covered with rust pustules
2	11-25% of leaf area covered with rust pustules
3	26-50% of leaf area covered with rust pustules
4	51-75% of leaf area covered with rust pustules
5	> 76% of leaf area covered with rust pustules

For assessing the intensity of insect's attack was used the following scale (Table 2).

Table 2. Intensity of insect's attack expressed as percentage of damaged leaves

Category	Percentage of damaged leaves
0	0 - no attack
1	1-3% leaves damage
2	3-10% leaves damage
3	10-25% leaves damage
4	25-50% leaves damage
5	50-75% leaves damage
6	75-100% leaves damage

The attack frequency has been set with a metric frame (50 cm x 50 cm), taking in account the relative value of the attacked plants' number in report with the total number of the analysed plants or organs.

These parameters were used to calculate Attack Degree (AD%) using the formula: AD% = (F% x I%)/100 (Cociu and Oprea, 1989).

The treatment combinations are presented in Table 3.

Table 3. Treatments used in the experimental trial

Factor A fungicides	Factor B insecticides
a1-no treatment	b1-no treatment
a2-Dithane M 45 – 2 kg/ha	b2-Decis Expert 100 EC-75 ml/ha
a3-Mimox - 3 L/ha	b3-Bioinsekt – 0.5-1 L/ha
	b4-Neemex - 1-1.25 L/ha

In order to characterize the evolution of climatic parameters (air temperature, rainfall, humidity, wind speed) into the experimental field it was used an automatic weather station (AWS).

Means were compared with the no treated genotype Suceveana (control).

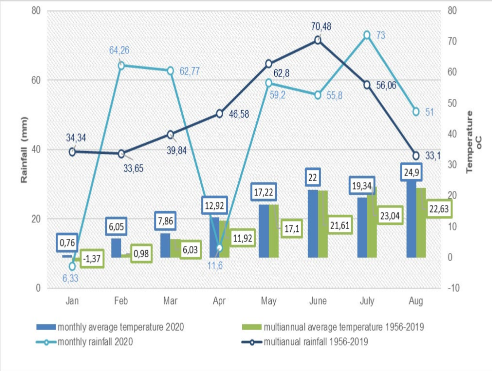
The experimental data were calculated and analysed, using MS Office 2019 facilities, while statistical analysis involved analysis of variance procedure (ANOVA) and significant differences were determined by the SD test at P<0.05 (Saulescu, 1967).

RESULTS AND DISCUSSIONS

In dry marginal areas the effects of climate change and climate variability on crops health have been associated with changes in pathogens and insects' life cycles, including many generations, increased incidence, pathogenicity, aggressiveness traits (Chakraborty and Newton, 2011; Newton et al, 2011; West et al., 2012; Elad and Pertot, 2014; Fones at al., 2020).

During 2019-2020 cropping season favourable climatic conditions led to the infection with *P. recondita* f. sp. *secalis* (Prs) (Roberge ex. Desmaz) and insects attack (*Schizaphis graminum*, *Eurygaster integriceps*, *Mayetiola destructor, Chlorops pumilionis*).

For scouting optimization and to predict the treatment moments rainfalls and temperatures were taken into account. Humidity was determined by the amount of rain of 383.96 mm, comparatively with multiannual average rainfall of 376.85 mm, while the monthly average temperature was 13.9°C comparatively with multiannual average temperature of 12.7°C (Figure 1).



* automatic weather station DRSPCS Dabuleni, Romania

Figure 1. Climatic conditions during the study period (2020 year)

During January to August 2020 the monthly average temperature increased up to +1.2°C comparatively with multiannual average temperature for January to August between 1956-2019 for the same geographic area. This temperature increase follows the global trend in planet warming. Thus, accordingly with a report of National Oceanic and Atmospheric Administration (NOAA, September 2020) monthly average temperature for January to August 2020 increased up to +1.03°C (+15.03°C) at the global level comparatively with average temperature recorded on Earth in the 20th century (+14°C).

Rainfall amount for evaluated period was slightly higher with 7.11 mm than multiannual amount for dry areas in Southern Romania. The humidity at leaf level cumulated with increased temperature favoured the development of Leaf rust disease, which exhibited the first symptoms at the end of April 2020.

Optimal environmental conditions for disease development are temperatures ranging from 15°C to 20°C, but the fungus can develop at the temperature of 2-35°C.

The fungus needs approximately six hours of moisture on leaves to start developing. With much moisture and suitable temperatures, lesions are formed within 7-10 days and spore production reduplicate another uredospore generation (Kolmer, 2013).

Identification of the fungus *P. recondita* f. sp. *secalis* (Prs) (Roberge ex. Desmaz) and its characteristics were done in the Phytopatology Laboratory of Agriculture Faculty in University of Craiova, using MOTIC BIM-151B LED (40-1000x) microscope. The diameter of uredinia can reach even 1.5 mm, their colour is orange to brown and their shape is round to ovoid. The average size of uredospores release from uredinia is 20 mm in diameter and colour orange-brown (Figure 2). Uredospores have up to eight germ pores scattered in dense walls.

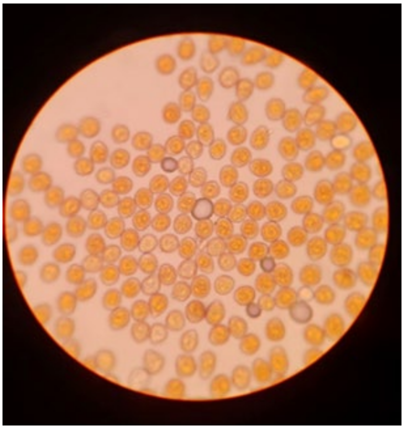


Figure 2. Uredospores of *Puccinia recondita* f. sp. *secalis* (Prs) (Roberge ex. Desmaz) (original photo Paraschivu Mirela, 2020)

Săvulescu (1953) showed that uredospores of leaf rust were visible on rye leaves at the end of May or the beginning of June, but the currently results show that in the context of climate change, with higher monthly average temperature and ununiform rainfalls, these fruiting bodies of the pathogen (uredinia with uredospores) appear earlier. These findings suggest a modification of life cycle of the pathogen *P. recondita* f. sp. *secalis* by many generation numbers and higher resistance of uredospores to increased temperature. Also, Harvell et al. (2002) suggested that rising temperatures will (i) increase pathogen development transmission, and generation number; (ii) increase overwinter survival and reduce growth restrictions during this period and (iii) alter host susceptibility.

P. recondita f. sp. *secalis* spores are spread by splashing water and wind leading to many successive infections. Meidaner (2012) showed that minimum wind speed for uredospores splashing is 2 m/s.

Leaf rust pustules are small, with thousands of spores within, circular to oval shape, with orange to light brown dusty spores (uredospores) on upper surface of leaves surrounded by a light-coloured halo (Figure 3).

Figure 3. Pustules with uredospores of *Puccinia recondita* f. sp. *secalis* (Prs) (Roberge ex. Desmaz) (original photo Paraschivu Mirela, 2020)

In case of severe attack leaf rust pustules may extend also on the leaf sheaths, stalks and husks.

Insects' determination has been done using Stereo Microscop STM-45B (7-45x). Specific attack symptoms have been assessed on rye leaves.

Previous findings emphasized that Suceveana variety is very susceptible to *P. recondita* f. sp. *secalis* and it is necessary fungicide treatment as a part of integrated crop management (Paraschivu et al., 2021).

During the cropping season 2019-2020 the most affected variant by the attack of pests and pathogens was a1b1 (control - no treatment).

The results emphasized that at the 1st determination (27.04.2020 - the beginning of booting stage) after the 1st praying was applied the incidence of leaf rust severity was low for all fungicides applied [Dithane M 45 (AD = 5.53%) and Mimox (AD = 6.89%)] comparatively with the control variant (no treatment) (AD =8.64%).

There were not find significant differences between the two fungicides applied no matter with insecticide combination. It was observed that Neemex insecticide has a slightly fungicide effect when it was applied alone (AD = 7.27%) or mixed with fungicides (Dithane M 45 + Neemex – AD= 4.88% and Mimox + Neemex - GA = 5.42%) (Table 3).

Table 3. The influence of the 1st treatment applied for controlling pathogens and insect's attack on rye during 2019-2020 cropping season

Fungi-cide	Insecti-cide	Attack degree the 1st det.- after the first treatment 27.04.2020					
		Leaf rust			Insects		
		AD%	Dif. %	Signif	AD%	Dif. %	Signif
Netratat	Netratat	8,64	Mt		2,89	Mt	
	Decis Expert 100 EC	8,03	0,61		1,10	1,79	ooo
	Bioinsekt	5,12	3,52	ooo	1,64	1,25	oo
	Neemex	7,27	1,37	o	1,32	1,57	oo
Dithane M 45 2 kg/ha	Netratat	5,53	Mt		3,16	Mt	
	Decis Expert 100 EC	5,10	0,43		1,46	1,7	ooo
	Bioinsekt	2,98	2,55	ooo	0,97	2,19	ooo
	Neemex	4,88	0,65		1,28	1,88	ooo
Mimox 3 l/ha	Netratat	6,89	Mt		2,12	Mt	
	Decis Expert 100 EC	6,23	0,66		1,28	0,84	oo
	Bioinsekt	3,76	3,13	ooo	0,83	1,29	oo
	Neemex	5,42	1,47	o	1,07	1,05	oo
	LSD 5%		1,26			0,43	
	LSD 1%		2,08			0,82	
	LSD 0,1%		2,45			1,68	

*dif. < 5% significance level
no treatment variant = control

After the 2nd treatment applied when it was done the 2nd determination it was observed that the evolution of leaf rust wasn't significant despite successive infections with uredospores suggesting that treatments applied were effective. Even for the 2nd treatment the lowest attack degrees for leaf rust were noticed for variants treated with fungicides (Table 4).

Table 4. The influence of the 2nd treatment applied for controlling pathogens and insect's attack on rye during 2019-2020 cropping season

Fungi-cide	Insecti-cide	Attack degree the 2nd det.- after the second treatment 30.05.2020					
		Leaf rust			Insects		
		AD%	Dif. %	Signif	AD%	Dif. %	Signif
Netratat	Netratat	10,89	Mt		3,67	Mt	
	Decis Expert 100 EC	9,90	0,99		1,35	2,32	ooo
	Bioinsekt	7,25	3,64	ooo	2,13	1,54	oo
	Neemex	8,72	2,17	oo	1,89	1,78	oo
Dithane M 45 2 kg/ha	Netratat	6,85	Mt		3,83	Mt	
	Decis Expert 100 EC	5,98	0,87		1,78	2,05	ooo
	Bioinsekt	4,86	1,99	oo	1,22	2,61	ooo
	Neemex	5,63	1,22	o	2.16	1,67	oo
Mimox 3 l/ha	Netratat	8,52	Mt		2,79	Mt	
	Decis Expert 100 EC	7,84	0,68		1,03	1,76	oo
	Bioinsekt	5,75	2,77	ooo	1,30	1,49	oo
	Neemex	6,83	1,69	o	1,12	1,67	oo
	LSD 5%		1,09			0,85	
	LSD 1%		1,87			1,07	
	LSD 0,1%		2,28			1,87	

*dif. < 5% significance level
no treatment variant = control

When insecticides were applied together with fungicides it was observed that insects attack

degree was lower comparatively with the control (no treatment), than when they were applied alone. Decis Expert 100 EC offered the best protection against insects attack when it was applied alone for both treatments (AD = 1.10% - the 1st determination and AD = 1.35% for the 2nd determination). When insecticides were mixed with fungicides the best control of the insects was offered by Bioinsekt for both treatments (Mimox+Bioinsekt - AD= 0.83% and Decis Expert 100 EC - AD = 1.03%).
The highest yields were obtained for the variants with fungicides mixed with Bioinsekt (Dithan M 45 + Bioinsekt = 3106.719 kg/ha and Mimox + Bioinsekt = 3041.502 kg/ha).
Negative high correlations were observed between grain yield and pathogens and insects attack in 2019-2020 cropping season. These findings indicate that yield increased due to the impact of biotic constrainers on plants which led to less healthy plant tissue available for photosynthesis.
The response of rye to treatments applied along with grain yield (t/ha) suggested the presence of inverse relation between the disease and pests' severity and grain yield. The highest significant loss percentages were found in no treated variant. The value of determination coefficient (R^2 = 0.6943) indicated that up to 69% of variation in rye yield could be explained by leaf rust attack. It was noticed a highly significant correlation between leaf rust severity and grain yield (r = -0.8332***) (Figure 4).

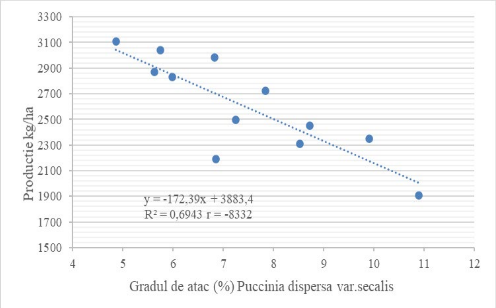


Figure 4. Relationship between Leaf rust severity and rye grain yield in 2019-2020 cropping season

Yield loses due to Leaf rust in rye in Europe were also reported previously by different authors (Solodukhina, 2002; Roux and Wehling, 2010; Meidaner et al., 2012).

The value of determination coefficient (R^2 = 0.6219) indicated that up to 62% of variation in rye yield could be explained by insects' attack. It was noticed a highly significant correlation between insects attack and grain yield (r = -0.7886**) (Figure 5).

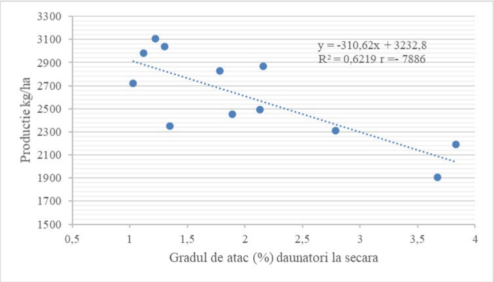


Figure 5. Relationship between insects attack and rye grain yield in 2019-2020 cropping season

Also, Matei et al. (2021) showed that thermohydric stress along biotic constrainers (pests and pathoges) have a significant negative impact on yield of Suceveana variety, especially in dry marginal areas from Romania (Matei et al., 2021).

CONCLUSIONS

The present study was carried out to assess impact of different formulations of fungicides and insecticides on the attack of *P. recondita* f. sp. *secalis* (Prs) (Roberge ex. Desmaz) and insects (*Schizaphis graminum, Eurygaster integriceps, Mayetiola destructor, Chlorops pumilionis*) in natural conditions in dry area from Southern Romania during 2019-2020 cropping season. The study emphasized that the increase of monthly temperature with +1°C may lead to earlier incidence of the disease and insects attack starting even with the end of April. The best protection against leaf rust was provided by Dithane M 45+Bioinsekt (the 1st assessment - attack degree = 2.98%; the 2nd assessment - attack degree = 4.86%), while the best control against pests was provided by Mimox+Bioinsekt (the 1st assessment - attack dregree = 0.83%) and Mimox+ Decis Expert 100 EC (the 2nd assessment - attack degree = 1.03%). For both pests and leaf rust control it was noticed the synergistic effect of insecticides and fungicides used in the experiment. Negative and significant correlations of pests and leaf rust attack degrees with grain yield (r = -0.7886**, respectively r = -0.8332**) were found during 2019-2020 cropping season.

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YIELDS AND QUALITY OF WHEAT AND MAIZE CULTURES UNDER THE INFLUENCE OF MANAGEMENT PRACTICES IN SOUTH AREA OF ROMANIA

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Abstract

For wheat and maize the yields and quality are affected by management practices, soil and climate conditions and genetic characteristics. The research was conducted between 2019 and 2021, in the experimental field of NARDI Fundulea and the purpose of this study was to evaluate the effect of agrotechnical measures and climatic conditions on the yield and quality of wheat and corn. The experiment involved four different soil works, using three maize hybrids (Iezer, Mostistea and F423) and three wheat varieties (Glosa, Izvor and Pitar) and three fertilized options. The hight productions and good quality of wheat and maize were maximized by applying the factors in associated variants. The results showed that the crops were very significantly affected by the conditions of the year as well as most of the interactions between the factors. The conservative tillages of the soil associated with the fertilization with manure have potentiated the genetic characteristics of the crop plant, raising the final quality of the production by 5-10%, depending on the variant.

Key words: *maize, wheat, yield and quality, management practices.*

INTRODUCTION

The variation of production and quality between hybrids is determined by the genetic characteristics of the hybrid, climatic conditions and applied crop technology (Partal & Paraschivu, 2020; Paraschivu et al., 2019; Bene et al., 2014). The impact of climate change, especially drought, on agricultural yields can have varying consequences depending on the species, the crop area and the technological methods used (Donatelli et al., 2012).

High and stable production while maintaining the environment is a challenge for farmers, especially in the face of climate change. Drought followed by the rainy season can favor the conditions of manifestation of fungal diseases (Ajetomobi, 2016; Raza et al., 2019).

Technological practices in agriculture, such as genetic improvement of varieties and hybrids, fertilizer and pesticide technology, agricultural machinery and tools, and farm management have been developed through research to understand their implications for the growth and stability of agricultural yields (Kumaraswamy and Shetty, 2016; Rehman et al., 2017).

This research will review the factors that affect the yield and quality of wheat and maize crops and will provide recommendations to reduce production losses while preserving the environment.

The evolution of climatic elements has a varied influence on agricultural yields, depending on the type of soil and the technological measures applied in agricultural crops (Moss et al., 2010).

MATERIALS AND METHODS

The research on the influence of technological links on its production and quality in wheat and maize crops was performed between 2019-2021 carried out on the cambic chernozem from Fundulea, in the non-irrigated area, in a stationary experiment. Regarding the physical properties of the soil, the humus content is higher in the first 15 cm due to the former bedding and gradually decreases to depth. The soil consists of several horizons:

- Ap + Aph - 0-30 cm, clay-clay-dust with 36.5% clay and permeability 492, pH 5.9.
- Am - 30-45 cm, clay-clay with 37.3% clay, compacted, DA 1.41g / cm³, pH 5.9.

- A/B (45-62 cm), Bv1 (62-80 cm), Bv2 (82-112 cm), Cnk1 (149-170 cm), Cnk2 (170-200 cm).

Depending on the agricultural year, the water supply of the soil is favorable for field crops, groundwater at 10-12 meters.

The experimental factors studied have the following gradations: factor A - soil work: a1 – no-tillage, a2 - disk, 3 - plow in autumn, a4 - chisel; factor B - fertilization system: b1 - unfertilized (N0P0); b2- fertilized with nitrogen and phosphorus at a dose of 90 N kg/ha + 75 kg P2O5/ha (N90P75) and b3 - fertilization with manure administered at 4 years (autumn) at a dose of 20 t/ha and factor C - variety/hybrid: wheat: c1 - Glosa, c2 - Izvor, c3 - Pitar, and maize: c1 - Iezer, c2 - Mostistea, c3 - F423.

The experiments have five repetitions in a randomized block system; The plot size for maize experiment was 56.0 m^2 (4 rows x 20 m long x 70 cm distance between rows) and for wheat the main plots are 240 m^2 (30 m x 8 m) and the sub-plots 48 m2 (6 m x 8 m). During the experiment, all the technological links were observed, so that the precursor plant for both crops was the pea, from a rotation of 4 years. The determinations regarding the quality of the seeds were performed as follows: for the hectolitre weight - HW - with the help of the hectoliter balance for cereals Model ML-HECTO 100, and for the weight of one thousand grains - WTG - with the help of the Kern EMB 500 precision balance.

Processed and interpreted statistically according to the method of analysis of variance.

Meteorological data were recorded at the NARDI Fundulea weather station and varied widely during the experimentation period especially depending on the distribution of precipitation during the vegetation period.

RESULTS AND DISCUSSIONS

Climatic aspects

The experimentation period recorded notable differences from one year to another due to the amount and periodic distribution of precipitation.

In 2019, the months with the lowest rainfall were 6.2 mm in September, compared to the 48.5 mm multiannual average and August with 12.6 mm compared to the 49.7 mm multiannual average. The greatest amount of precipitation occurred in July, with 87.4 mm, about 16.3 mm above the multiannual average. Regarding the thermal regime, between June and September, the recorded values show that the average monthly temperatures were higher than the multiannual average, in June by 2.8ºC above the multiannual average (Table 1).

The year 2020 was dry, with accentuated water deficit and high temperatures, compared to the multiannual average. Precipitation from sowing to maturity was insufficient to cover the water needs of the crops. The months with the lowest rainfall were 5.4 mm compared to 49.7 mm and July with 34.2 mm compared to 71.1 mm. Higher than average annual temperatures have exacerbated the drought. The average temperatures recorded in the agricultural year 2020 were 2.6ºC higher than the multiannual average.

In 2021, a normal year in terms of water quantities recorded, but with an uneven distribution, especially in July, August and September. The temperatures registered a difference of 1.2ºC compared to the multiannual average. The climatic data obtained were corroborated with the elements followed during the vegetation period of the crops.

Table 1. The meteorological parameters in the experimental period (Fundulea, 2019-2021)

Years/Months		Jan	Febr	Mar	Apr	May	Jun	July	Aug	Sept	Oct	Nov	Dec	Total/ Average
Precipitations (mm)	2019	53.8	21.4	22.4	51.4	124	74.6	87.4	12.6	6.2	38.2	33.2	16.2	541.4
	2020	2.0	16.6	29.8	14.0	57.8	68.4	34.2	5.4	68.6	24.0	20.0	77.6	423.2
	2021	77.0	16.2	59.0	31.0	57.6	135	21.2	24.2	4.0	56.4	33.8	37.6	553.2
50 years average		**35.1**	**32.0**	**37.4**	**45.1**	**62.5**	**74.9**	**71.1**	**49.7**	**48.5**	**42.3**	**42.0**	**43.7**	**584.3**
Temperatures (°C)	2019	-1.1	3.8	9.3	11.2	17.2	23.6	22.9	24.7	19.3	12.0	11.0	4.0	13.2
	2020	0.9	5.2	8.3	12.4	16.8	21.8	25.1	25.5	20.8	12.8	6.2	4.0	13.5
	2021	1.6	3.2	5.1	9.7	17.2	21.1	25.3	24.2	17.3	10.2	7.7	2.6	12.1
50 years average		**-2.4**	**-0.4**	**4.9**	**11.3**	**17.0**	**20.8**	**22.7**	**22.3**	**17.3**	**11.3**	**5.4**	**0.1**	**10.9**

Yield and quality of wheat

Wheat cultivation has changed at the production level under the direct influence of the applied technological variants. Thus, in 2020, 2871 kg/ha were obtained for the no-tillage control variant, thus becoming the lowest production in the factor graduation series. The basic tillage of the land by discussion recorded a production of 3579 kg/ha, with 708 kg more compared to the no-tillage control variant. The basic tillage variant for plowing recorded a production of 4590 kg/ha with 1719 kg over the control variant, thus becoming the best variant. The work of the soil with the chisel registered a production of 3968 kg/ha with 1097 kg/ha over the uncultivated control variant (Table 2).

The fertilization system showed a significant variation, so that the non-fertilized control variant registered a production of 3185 kg, thus becoming the lowest production in the series of factor graduations. Fertilization of the crop with $N_{90}P_{75}$ resulted in a production of 4615 kg/ha with 1430 kg (or 34.1%) over the control. The application of manure at a dose of 20 t/ha determined a production of 4490 kg/ha with 40.9% above the value recorded by the control.

The variety with the highest production was Pitar, with 3350 kg/ha, followed by Glosa with 3280 kg/ha, in the conditions of 2020. The Izvor variety obtained an average production of 3220 kg/ha, with 60 kg under the control variant -Glosa variety.

Table 2. Production results obtained for wheat crop in 2020

Variant	Production/Diference			HW		WTS	
	(kg/ha)	(%)	Semnific.	kg/hl	%	g	%
A. Soil tillages							
A1 - Mt	2871	100.0	0	77.0	100.0	45.0	100.0
A2	3579	124.6	708*	78.0	101.3	45.2	100.4
A3	3968	138.2	1097**	78.1	101.4	45.2	100.4
A4	4590	159.8	1719**	78.6	102.1	45.3	100.7
DL (kg/ha / kg/hl / g)	DL= (P 5%= 698 /P 1% = 1103 / P 0.1% = 1922)			DL = (0.69 /1.09 /2.07)		DL= (1.20 / 1.99/3.41)	
B. Fertilization type							
B1 - Mt	3185	100.0	0	77.0	100.0	45.0	100.0
B2	4615	134.1	1430**	78.4	101.8	45.3	100.7
B3	4490	140.9	1305**	78.5	101.9	45.2	100.4
DL (kg/ha / kg/hl / g)	DL= (P 5%= 674.2 /P 1% = 1000.2 /P 0,1% = 1866)			DL= (0.71 /1.15 /2.24)		DL= (1.23/ 2.03 /3.50)	
C. Varieties / Hybrids							
C1 - Mt	3280	100.0	0	77.0	100.0	45.0	100.0
C2	3220	98.0	-60	78.4	101.8	45.3	100.7
C3	3350	102.1	70	78.4	101.8	45.0	100.0
DL (kg/ha / kg/hl / g)	P 5% = (583.5 /P 1% = 992.1 /P 0.1% = 1688.0)			DL= (0.77 / 1.23 / 2,18)		DL= (1.18 / 2.01 / 3.22)	

The hectolitre weight registered different values depending on the grading of the factors. The highest values were recorded for the version with soil tillage by autumn plowing, 78.6 kg/hl.

Fertilization of the crop led to obtaining a maximum value of 78.5 kg/hl for the variant with the application of manure 20 t/ha (Figure 1).

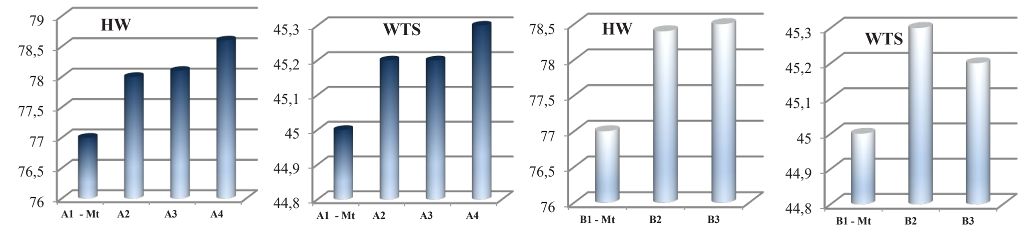

Figure 1. The influence of the factors on the HW and WTS in 2020

In the conditions of 2021, the no-tillage control variant obtained 2510 kg/ha, thus becoming the lowest production in the series of factor graduations. The basic tillage of the disk was 3497 kg/ha, 987 kg more than the no-tillage control. The basic tillage variant for plowing recorded a production of 4306 kg/ha with 1796 kg over the control variant, thus becoming the best variant. The tillage with a chisel registered a production of 4128 kg/ha with 1618 kg/ha over the no-tillage control variant (Table 3).

The fertilization system showed an important variation, so that the unfertilized control variant registered a production of 2822 kg, thus becoming the lowest production in the series of factor graduations. Fertilization of the crop with $N_{90}P_{75}$ led to a production of 3850 kg/ha with 1028 kg (or 34.1%) over the control. The application of manure at a dose of 20 t/ha resulted in a production of 4071 kg/ha with 44.3% recorded by the witness.

Wheat crop production data according to factor C graduations - the variety shows that the Glosa control variant recorded a production of 2550 kg, thus becoming the lowest production in the factor graduation series. The Izvor variety led to a production of 3520 kg/ha with 970 kg (or 38%) over the control, and the Pitar variety at 3480 kg/ha with 930 kg over the control (36.4%).

Tabel 3. Production results obtained for wheat crop in 2021

Variant	Production /Diference			HW		WTS	
	(kg/ha)	(%)	Semnif.	kg/hl	%	g	%
A. Soil tillages							
A1 - Mt	2510	100.0	0	76.0	100.0	44.0	100.0
A2	3497	139.3	987*	77.0	101.3	44.2	100.4
A3	4128	164.5	1618**	77.1	101.4	44.2	100.4
A4	4306	171.6	1796**	77.6	102.1	44.3	100.7
DL (kg/ha / kg/hl / g)	DL= (P 5%= 788 /P 1% = 1204 / P 0.1% = 2100)			DL = (0.60 /1.01 /2.00)		DL= (1.10 / 1.89/3.21)	
B. Fertilization type							
B1 - Mt	2822	100.0	0	76.0	100.0	44.0	100.0
B2	3850	136.4	1028*	77.4	101.8	44.3	100.7
B3	4071	144.3	1249**	77.5	101.9	44.2	100.4
DL (kg/ha / kg/hl / g)	DL= (P 5%= 624.2 /P 1% = 1122 /P 0.1% = 1906)			DL= (0.69 /1.05 /2.13)		DL= (1.13/ 2.11 /3.30)	
C. Varieties / Hybrids							
C1 - Mt	2550	100.0	0	76.0	100.0	44.0	100.0
C2	3520	138.0	970*	77.4	101.8	44.3	100.7
C3	3480	136.4	930*	77.3	101.5	44.3	100.7
DL (kg/ha / kg/hl / g)	P 5%= (620 /P 1% = 1102 /P 0.1% = 1855)			DL= (0.70 / 1.20 / 2.27)		DL= (1.18 / 2.24 / 3.20)	

The hectolitre weight registered different values depending on the grading of the factors. The highest values were recorded for the version with soil tillage by autumn plowing, 77.6 kg/hl.

Fertilization of the crop led to obtaining a maximum value of 77.5 kg/hl for the variant with the application of manure 20 t/ha - application to previous culture (Figure 2).

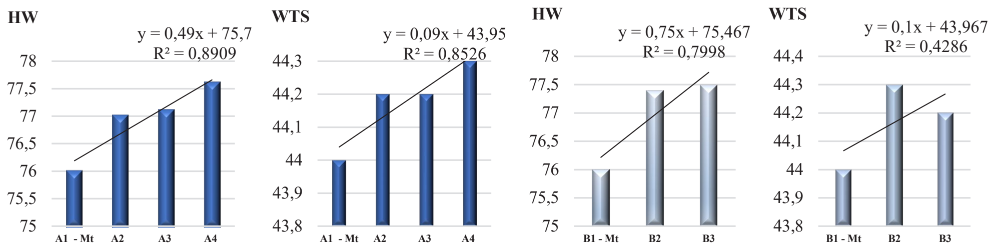

Figure 2. The influence of the factors on the HW and WTS in 2021

Yield and quality of maize

The maize crop registered variations in production level under the direct influence of the applied technological variants. In the conditions of 2020, for the no-tillage control variant, 4130 kg/ha were obtained, thus becoming the lowest production in the factor graduation series. The basic tillage of the disking recorded a production of 6000 kg/ha, with 1870 kg more compared to the unworked control. The basic tillage variant for plowing recorded a production of 6200 kg/ha with 2070 kg over the control variant, thus becoming the best variant. The work of the soil with the chisel registered a production of 5950 kg/ha with 1820 kg/ha over the no-tillage control variant, being equal to the value of 6000 kg/ha registered by the disk option (Table 4).

Regarding the fertilization system: the non-fertilized control variant registered a production of 4050 kg, thus becoming the lowest production in the series of factor graduations. Fertilization of the crop with $N_{90}P_{75}$ resulted in a production of 6344 kg/ha with 2294 kg (or 56.6%) over the control. The application of manure in a dose of 20 t/ha determined a production of 5625 kg ha by 38.8% over the value registered by the non-fertilized control variant.

The yield data for maize crop according to factor C graduations show that the Iezer hybrid recorded a production of 5400 kg/ha, the Mostistea hybrid achieved an increase of 8.3%, ie 450 kg/ha compared to the control, and the hybrid F423 registered 6000 kg/ha, with 11.1% over the control.

Tabel 4. Production results obtained for maize crop in 2020

Variant	Production /Diference			HW		WTS	
	(kg/ha)	(%)	Semnific.	kg/hl	%	g	%
A. Soil tillages							
A1 - Mt	4130	100.0	0	70.7	100.0	265.5	100.0
A2	6000	145.9	1870 **	71.2	100.7	285.1	107.5
A3	5950	143.9	1820 **	71.3	100.8	281.3	105.9
A4	6200	149.9	2070 ***	71.3	100.8	285.2	107.4
DL (kg/ha / kg/hl / g)	DL= (P 5%= 671.9 /P 1% = 1112.0 / P 0.1% = 2081)			DL = (2.24 /3.99 /6.92)		DL= (11.48 / 18.99/35.54)	
B. Fertilization type							
B1 - Mt	4050	100	0	70.4	100.0	249.5	100.0
B2	6344	156.6	2294***	71.1	100.9	291.2	116.7**
B3	5625	138.8	1575 ***	71.8	101.9	303.0	121.4**
DL (kg/ha / kg/hl / g)	DL= (P 5%= 374.2 /P 1% = 619.2 /P 0.1% = 1159)			DL= (3.88 /6.43 /12.03)		DL= (68.61/ 113.5 /212.5)	
C. Varieties / Hybrids							
C1 - Mt	5400	100.0	0	69.9	100.0	233.3	100.0
C2	5850	108.3	450	72.6	103.8**	270.0	115.7
C3	6000	111.1	600*	72.8	104.1**	270.0	115.7
DL (kg/ha / kg/hl / g)	P 5% = (483.5 /P 1% = 732.1 /P 0.1% = 1176.0)			DL= (1.77 / 2.93 / 5.48)		DL= (35.6 / 58.91 / 110.3)	

The hectolitre weight registered the highest values were recorded for the version with the hybrid F423, with 72.8 kg/hl.

Fertilization of the crop led to obtaining a maximum value of 71.8 kg/hl for the variant with application of manure 20 t/ha (Figure 3).

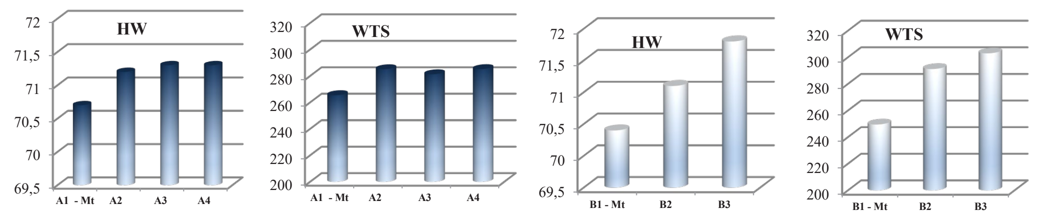

Figure 3. The influence of the factors on the HW and WTS in 2021

In the conditions of 2021, the no-tillage control variant registered 3100 kg/ha, thus becoming the lowest production in the factor graduation series. The basic tillage of the tillage recorded a production of 4560 kg/ha, with 1460 kg more compared to the unworked control. control, thus becoming the best variant (Table 5).

The production data for maize crop according to the B factor graduations - crop fertilization, show us that the unfertilized control variant registered a production of 3020 kg, thus becoming the lowest production in the factor graduation series. Fertilization of the crop with $N_{90}P_{75}$ resulted in a yield of 5522 kg/ha with 2502 kg (or 82.8%) above the control. The application of manure at a dose of 20 t/ha determined a production of 5620 kg/ha with 86.1% above the value recorded by the control option.

Regarding the hybrid, the data show that the Iezer control variant registered a production of 4800 kg/ha, the variant with the Mostistea hybrid achieved an increase of 26.7%, ie 1280 kg/ha compared to the control, and the F423 hybrid reached 6000 kg/ha, 25% above the value recorded by the witness variant.

Tabel 5. Production results obtained for maize crop in 2021

Variant	Production /Diference			HW		WTS	
	(kg/ha)	(%)	Semnif.	kg/hl	%	g	%
A. Soil tillages							
A1 - Mt	3100	100.0	0	69.6	100.0	254.4	100.0
A2	4560	147.0	1460 **	70.0	100.6	274.0	107.7
A3	5000	161.3	1900 **	70.1	100.7	270.2	106.2
A4	5188	167.4	2088 ***	70.1	100.7	274.1	107.7
DL (kg/ha / kg/hl / g)	DL= (P 5%= 675 /P 1% = 1122 / P 0.1% = 2059)			DL = (2.31 /3.56 /7.05)		DL= (13.56 / 21.55/36,88)	
B. Fertilization type							
B1 - Mt	3020	100	0	70.4	100.0	248.5	100.0
B2	5522	182.8	2502***	71.1	100.9	290.2	116.7**
B3	5620	186.1	2600 ***	71.8	101.9	302.0	121.5**
DL (kg/ha / kg/hl / g)	DL= (P 5%= 362/P 1% = 752 /P 0.1% = 1277)			DL= (3.88 /6.43 /12.03)		DL= (68.20/ 114.6 /221.6)	
C. Varieties / Hybrids							
C1 - Mt	4800	100.0	0	68.9	100.0	223.3	100.0
C2	6080	126.7	1280 ***	71.6	103.9**	260.0	116.4
C3	6000	125.0	1200**	71.3	103.4**	258.3	115.6
DL (kg/ha / kg/hl / g)	P 5%= (499.2 /P 1% = 787.2 /P 0,1% = 1210.0)			DL= (1.77 / 2.90 / 5.44)		DL= (36.3 / 59.25 / 112.3)	

The hectolitre weight registered different values depending on the grading of the factors. Fertilization of the crop led to obtaining a maximum value of 71.8 kg/hl for the variant with the application of manure 20 t/ha and 71.1 kg/hl for the $N_{90}P_{75}$ variant (Figure 4).

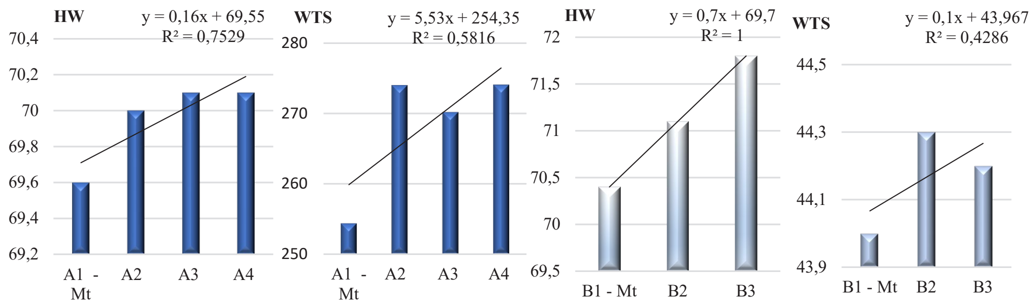

Figure 4. The influence of the factors on the HW and WTS in 2021

CONCLUSIONS

Management practices have sustainably increased yields and quality, while facilitating the maintenance of crop adaptability. The promotion of varieties and hybrids with unfavorable climate resistance and high and stable yields in a limited humidity environment requires the combination of conventional and unconventional technological methods.

In the conditions of the chernozem in the Southern Plain, in the successful application of the minimum works, the technology with the loosening works without turning the furrow made with the chisel or the work of the soil with the disk achieves high and stable productions close to the plowing variant and much more efficient compared to the no-tillage variant.

It is recommended that the basic work of soil with the chisel be carried out alternately (at 3-4 years) with autumn plowing, considering a series of advantages that it brings to the soil, and last but not least to the productivity of crops in the two systems working, conventional and conservative.

In both crops, fertilization with manure at a dose of 20 t/ha which justifies its importance by improving the properties of the soil over time, and fertilizing crops with NP contributes to increasing final production.

The variety / hybrid manifests its genetic potential depending on the technology applied and the climatic conditions. For the wheat crop, Izvor and Pitar varieties stood out with high yields, and for maize crop, the Mostistea hybrid.

In order to ensure food security and maintain the production and quality of agricultural crops, interdisciplinary research is needed to find viable solutions to all environmental and technological challenges.

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PARAMETERS ANALYSIS OF THE *Ostrinia nubilalis* Hbn. ATTACK AT MAIZE CROPS IN THE CONDITIONS OF CENTRAL MOLDOVA

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Abstract

Maize is cultivated on 2,678.5 thousand ha in Romania, and its cultivation on large areas attracts a number of pests that attack various parts of the plant in different developmental phases. One of these dangerous pests is Ostrinia nubilalis Hbn., a species that occurs during the growing season of maize and causes production losses by the attack on the stem and cob. The larvae produce various attacks, influenced by climatic conditions, the frequency of attacked plants being between 15.7 and 67.9% in the south-west of the country, in the south-east of the country varies between 43.3-79.4%, in the Transylvanian Plain has values between 60.00% and 81.88%, in the west of the country the attack is around 41%, and in the east of the country by 30.20%. The importance of attacks by Ostrinia nubilalis Hbn. at maize led to the initiation of studies in 2019 at the A.R.D.S. Secuieni to determine the influence of technological factors on the parameters of attack (frequency of attack, average number of holes, galleries and larvae and average length of gallery) produced by larvae. For the maize sown in epochs, the optimal epoch, the IIIrd, recorded the lowest values of the parameters: the frequency of the attack was 18.65%, were identified 0.60 holes/plant, 0.39 galleries/plant and 0.38 larvae/plant, and the average length of the galleries was 8.39 cm. The behavior of genotypes at the attack produced by larvae varied within very wide limits, the frequency of the attack was between 36.56% at the early genotype Vibrion and reached 48.50% at the late genotype Olt.

Key words: *technological factors, frequency of attack, galleries, larvae, correlation.*

INTRODUCTION

Maize occupies important areas both in Romania and in Europe. At the level of 2020, in our country, the cultivated area with maize was 2.68 million ha, obtaining, on average, 4083 kg/ha (FAO STAT DATA, 2022). The temperate climate of the European continent offers favorable conditions for the cultivation of maize on large areas. Thus, the crop occupies 28,250 million ha in the north of the continent, the cultivated area increases significantly in the southern region (2.75 million ha) and western (2.41 million ha), while in Eastern Europe, maize is found on 14 million ha. Average yields range widely between 5449-6829 kg/ha in the eastern and northern regions of Europe and between 8556-9296 kg/ha in the south and west of the continent (FAO STAT DATA, 2022). Due to the wide distribution of maize cultivation, one of the most common pests is *Ostrinia nubilalis* Hbn. Among the stages of the insect, the most damaging is the larva, which creates holes on the stem, on the leaves, on the panicle or eats the grains on the cobs. Most often it bites and penetrates the stem where it creates galleries of different sizes. They weaken the plant's integrity, break the stem and reduce the plant's nutrient supply. The attack produced by the species *Ostrinia nubilalis* Hbn. is favorabile for the installation of fusariosis in a percentage of 23.9-41.9% and contributes to the contamination of grain production with mycotoxins (Jurca et al., 2009).

The literature recommends compliance with prevention measures to reduce the population and reduce the attack of larvae of *Ostrinia nubilalis* Hbn. by chopping maize crop residues, which reduce the chances of survival of mature larvae during the winter, by performing soil work (plowing and phoughed stubble field) which helps to reduce the population of insect larvae, by crop rotation, which reduces the attack of larvae on cultivated areas with maize, by sowing at the optimum time, by using at sowing genotypes that showed a certain tolerance to larval attack, and in the years when the insect exceeds the Economic Damage Threshold (18% of plants have eggs or 1-2 larvae have been identified/plant), it is recommended to apply measures to control the larvae (Trotuș et al., 2021).

In Romania, one of the objectives regarding the improvement of maize remains the resistance/ tolerance to *Ostrinia nubilalis* Hbn., although for over 40 years, we have been working on the selection of genotypes resistant / tolerant to this pest, the frequency of larval attack is oscillating in hybrids. Analyzing the evolution of the attack, it is noted that between 2002-2004, the frequency of the attack was very low, only 2-17%, due to lower temperatures, below the multiannual average, and between 2018-2020 (23-33%) the frequency decreased damage due to heavy rains, from the period of vegetative growth of maize (Haș et al., 2021a; Haș et al., 2021b).

Internationally, extensive studies and research have been conducted on the tolerance of genotypes to larval attack as the species remains one of the major pests of maize on the European continent.

Bohn et al. (1999) analyzed the tolerance of dentate and flint maize genotypes, establishing that grain production decreased by 0.28% for every 1% of the attacked plant, and each larva identified inside the stem reduced the production potential by 6.05%.

Demirel and Konuskan (2017) found that plant damage caused by larvae was different at sweet maize. The damage of the larvae on the stem and cobs was different for each sweet maize hybrid, at the stem, the attack was between 32.45% (2015) and 59.34% (2016). Regarding the attack of larvae on cobs, it varied between 14.31% (2016) and 25.73% (2015).

Lopez-Malvar et al. (2021) found that there is a link between the high size of the plants and the length of the galleries, these genotypes having a longer vegetation period and a higher degree of susceptibility to larval attack.

Considering the importance of the attacks produced by the species *Ostrinia nubilalis* Hbn., in the maize crops from Central Moldova and not only, at A.R.D.S. Secuieni from 2019, researches have been initiated regarding the influence of the sowing epochs and the maize genotype on the attack produced by larvae.

MATERIALS AND METHODS

In order to achieve our proposed objectives, in the period 2019-2021, a series of experiences were placed in the experimental field of the Secuieni - Neamț Agricultural Research and Development Station.

The unit is located at geographical coordinates of 26°5' east longitude and 46°5' north latitude. The experiments were placed in the field according to the randomized block method, in three repetitions and included the following experimental factors:

- five epochs sown from the first decade of April to the second decade of May;
- 11 maize genotypes: Deliciul Verii, Vibrion (FAO 290), Inventive (FAO 300) Turda 248 (FAO 300), Turda Star (FAO 370), Turda 344 (FAO 370), Method (FAO 380), Turda 332 (FAO 390); Kerala (FAO 400), Olt (FAO 430) and Messir (FAO 500).

One variant consisted of four rows of maize with a total area of 28 m^2 (10 x 2.8 m).

The experiments were located on a typical cambic chernozem type soil, with a pH of 6.29 in water, a humus content of 2.3, a nitrogen index of 2.1, a P_2O_5 content of 39 ppm, a K_2O content of 161 ppm.

The cultivation technology of this species was specific to the conditions in Central Moldova, in compliance with the experimental protocol (Trotuș et al., 2020).

In order to establish the attack caused by the pest, at the end of the vegetation period, plant samples were collected from each variant/ repetition and were established the parameters of the attack: frequency of attacked plants, average number of holes/plant, average number of galleries/plant, number of larvae/plant and length of galleries (cm).

The results obtained were interpreted using the analysis of variance and the correlation coefficient (r).

RESULTS AND DISCUSSIONS

The attack produced by the larvae of the species *Ostrinia nubilalis* Hbn. was influenced by the experienced sowing epoch.

From the analysis of the obtained results, it was found that the five epochs registered variations of the attack, between 22.5% (Ist epoch - the difference which was ensured statistically as distinctly significant) and 28.07% (IVth epoch - the difference which was ensured as very significant) compared to 18.65% as recorded at the optimal epoch (IIIrd epoch, control), where the attack was much lower (Figure 1).

The average number of holes/plant created by the larvae to enter the stem was between 0.60 holes/plant (IInd epoch) and 1.12 holes/plant (IVth epoch), a value almost double that was recorded in the IIIrd epoch - 0.60 holes/plant (Figure 1).

The average number of galleries/plant created by larvae at the attacked plants showed the lowest values for maize sown in the IIIrd epoch, was of 0.39 galleries/plant compared to maize sown in IVth and Vth epochs which recorded the most galleries (0.75 galleries/plant and 0.96 galleries/plant) (Figure 1).

Regarding the average number of larvae/plant, it is found that the maize sown in the Vth period had the highest number of larvae (1.15 larvae/plant) together with the one sown in the IVth epoch (0,83 larvae/plant) while maize sown in the optimal period (IIIrd epoch) showed the lowest number of larvae (0.38 larvae/plant), indicating that a large number of larvae find favorable conditions for feeding, perforating and consuming plant tissues (Figure 1).

The average length of the gallery/plant recorded values of 15.62 cm (Vth epoch) and 19.20 cm (IVth epoch), higher than the optimal epoch - 9.36 cm, and the differences were statistically assured as distinctly significant and very significant (Figure 1).

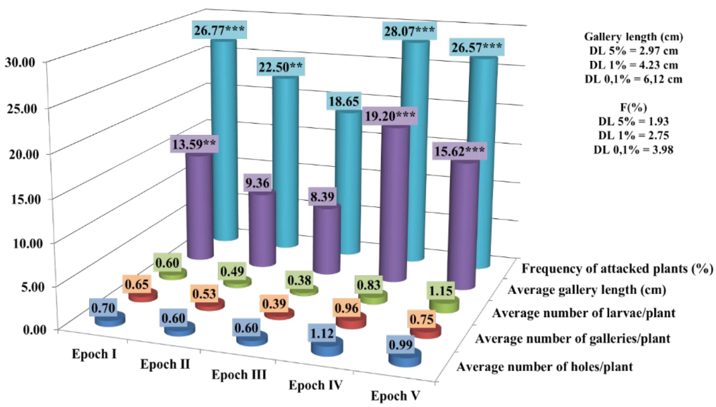

Figure 1. The evolution of the attack produced by the larvae of the species *Ostrinia nubilalis* Hbn. to the maize sown in different epochs, average 2019-2021

In the conditions of the Center of Moldova, it was found that the late sown maize provides favorable feeding conditions for the larvae, the attack being as intense as that recorded in the early sown maize.

The results obtained are in accordance with those published in the scientific literature. Mason *et al*. (1996) observed that the larvae create galleries in the stem and cobs depending on the phenological stage of the maize, in this case it will find the late sown maize more attractive and will produce more aggressive attacks through longer galleries, and the percentage of surviving larvae will increase. Pilcher and Rice (2001) and Anderson et al. (2003) argue that late sowing increases the level of attack by *Ostrinia nubilalis* Hbn. larvae compared to an earlier sowing epoch. The development of the crop is staggered and overlaps with the appearance of larvae that cause more damage to the stem and cob, which leads to a decrease in production of late-sown maize.

Štěpanek et al. (2008) studied the influence of several technological factors, including the sowing epoch, on the level of damage of the species *Ostrinia nubilalis* Hbn. Researchers find that late sowing significantly affects the percentage of plants attacked, reaching 53.9%.

Other important factors that favors the attack of larvae are the varied climatic conditions in June and July when adults appear, lay eggs and hatch larvae, but also the oscillating population density of *Ostrinia nubilalis* Hbn.

The influence of the sowing epochs on the parameters led to the following correlations:

- a direct and very close correlation was established between the parameters the average number of holes/plant and the average number of galleries/plant, the correlation coefficient (r = 0.9354) was interpreted as distinctly significant, because one or more holes correspond to a single gallery (Figure 2);

- between the average number of galleries/plant and the average length of the gallery, the correlation coefficient was very significant (r = 0.9834), because several galleries were identified and their dimensions increased;

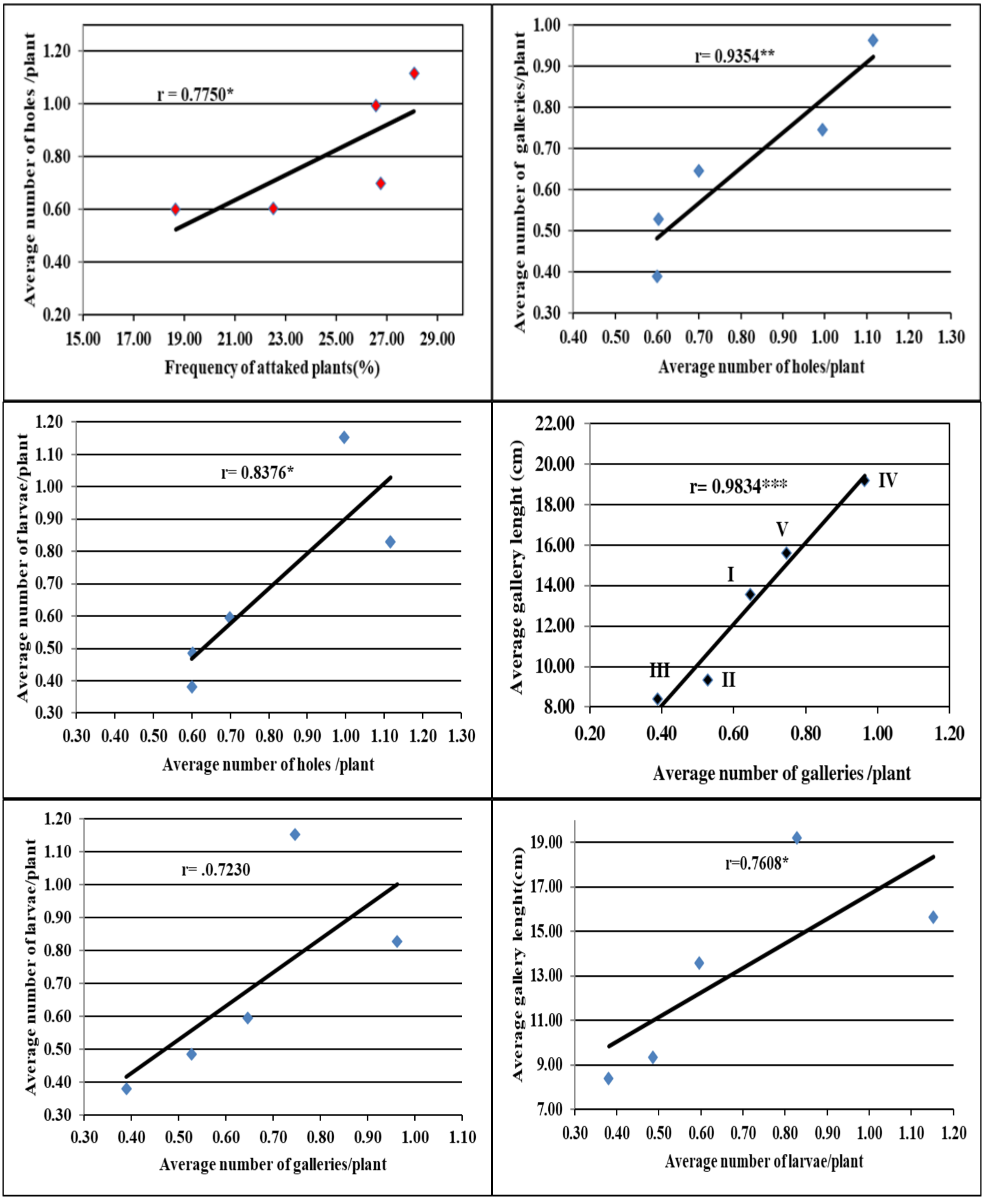

Figure 2. The influence of the sowing epoch on the attack parameters produced by the species *Ostrinia nubilalis* Hbn., average 2019-2021

- the correlation coefficient between the number of holes/plant and the number of larvae/plant was interpreted as significant (r = 0.8376), because the larvae that attack the maize plants create one or more holes on the same plant (Figure 2);
- between the frequency of attacked plants and the number of holes/plant, the correlation was direct, the correlation coefficient was interpreted significantly (r = 0.7750) and is due to the fact that more holes/plant were identified per plant than the percentage of attacked plants;
- regarding the correlation between the number of larvae/plant and the average length of the galleries, this relationship is direct and the correlation coefficient was interpreted as significant (r = 0.7608) due to the fact that parameters are determined at the end of the vegetation period and we cannot say for sure if this is the real number of larvae that have fed in the galleries;
- there was no correlation between the number of galleries/plants and the number of larvae/plants (r = 0.7230) because some of the larvae that enter the plants and create galleries, do not survive until the maturity of the maize, when plant samples were collected and sectioned (Figure 2).

The attack of larvae at maize genotypes varied according to their tolerance to the numerical pressure of the pest population and the climatic conditions during laying and hatching of the larvae.

From the 11 experienced maize genotypes, the highest frequency values had the Deliciul Verii (59.72%) and Turda 344 (64.56%) genotypes, the differences register were ensured as distinctly significant and very significant compared to the average experience (46.43%). The Vibrion, Turda Star and Messir genotypes had obtained lower attack values, the differences were assured and interpreted as significantly negative compared to the average experience (Figure 3).

Analyzing the number of holes created by the larvae per plant, it is observed that the favorite of the larvae was the maize with sweet grains, Deliciul verii (2.79 holes/plant) followed by the Kerala (1.72 holes/plant) and Turda 344 (1.75 holes/plant), which recorded the most holes compared to the average experience (1.29 holes/plant) and showed statistically assured differences and interpreted as very significant and significant (Figure 3).

Regarding the number of galleries/plant created by the larvae, it is found that most galleries were registered in the genotypes Deliciul Verii (2.20 galleries/plant) and Kerala (1.50 galleries/plant), which had statistically assured differences and interpreted as very significant and distinctly significant compared to the average experience (1.10 galleries/plant) (Figure 3).

The genotypes that had the lowest number of galleries/plant were Turda Star (0.57 galleries/plant), Vibrion (0.71 galleries/plant) and Messir (0.77 galleries/plant), the differences being statistically assured and interpreted as significant negative and distinctly significant negative compared to the average experience (1.10 galleries / plant) (Figure 3).

The number of identified larvae/plant varied, being between 0.55 larvae/plant (Messir) and 1.27 larvae/plant (Kerala), the average experience being 0.82 larvae/plant (Figure 3.). It is noted that five of the 11 hybrids had higher values of the average number of larvae/plant compared to the average experience, of 0.83 larvae/plant: Kerala - 1.27 larvae/plant; Method - 1.0 larvae/plant; Deliciul Verii - 1.07 larvae/plant, Inventive - 0.92 larvae/plant; Olt - 0.88 larvae/plant (Figure 3).

Regarding the average length of the gallery, it was found that the genotypes Deliciul Verii (30.94 cm) and Turda 344 (20.16 cm) were the longest galleries, compared to the average experience, the differences being statistically assured and interpreted as very significant and distinctly significant.

The smallest galleries were identified at the Messir (9.16 cm) and Turda Star (11.49 cm) genotypes compared to the average experience (16.87 cm). Also, longest galleries were recorded at Inventive (19.03 cm) and Turda 322 (17.58 cm), the rest of the genotypes having values below the average of the experience (16.87 cm) (Figure 3).

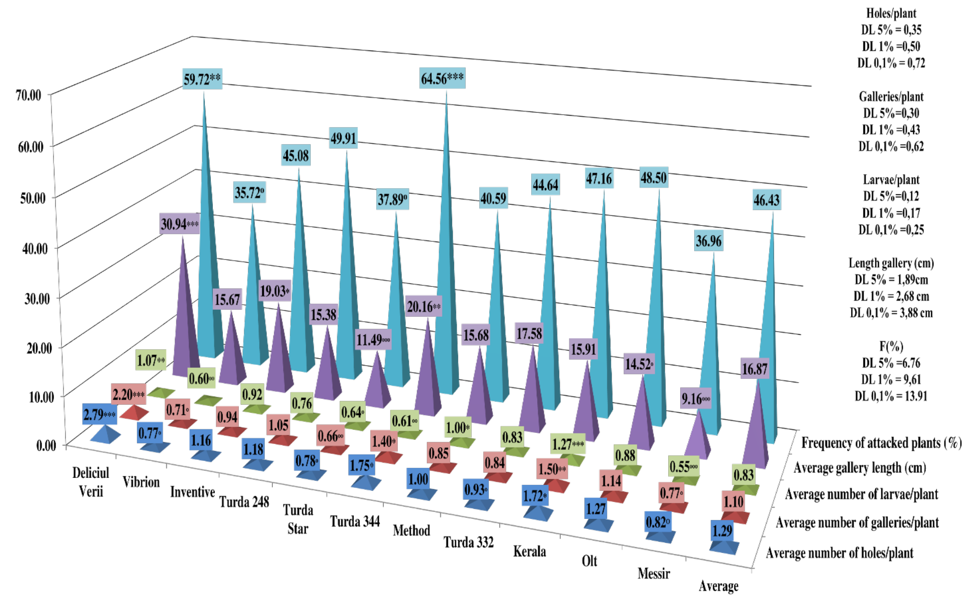

Figure 3. The evolution of the attack produced by the larvae of the species *Ostrinia nubilalis* Hbn. at different hybrids cultivated in the conditions of Central Moldova, average 2019-2021

Analyzing the frequency of attack at the maize genotypes according to the characteristics of the grains, it is observed that the sweet maize was deeply affected by the larval attack. From the point of view of the maturity group, there is an increase in the attack from early hybrids to late hybrids compared to the average experience:

- Kerala genotype has an attack rate (47.16%) close to average (46.43%), but the number of holes/plant (1.72) and galleries/plant (1.50) was much higher than the average experience and also most larvae/plant were recorded (1.27);
- at the Turda 332 genotype, the larvae created galleries of close size (15.91 cm) of average experiance (16.87 cm), and the number of holes/plant (0.93) and galleries/plant (0.84) recorded was below average;
- the attack parameters recorded for the Olt hybrid had values close to average (1.27 holes/plant, 1.14 galleries/plant, 0.88 larvae/plant, average gallery length of 14.50 cm, and attack frequency of 48.50%);
- Method genotype recorded a lower attack (40.59%) than average, several holes/plant (1.00) and galleries/plant (0.85) were identified, but the number of larvae/plant identified (1.00) was higher than the average experience (0.83);
- the Vibrion and Turda Star genotypes had low values of the parameters followed well below the experience average;
- Messir genotype had a lower attack (36.96%) than the average experience number of holes/plant (0.82), galleries/plant (0.77), larvae/plant (0.55) and length the average of the galleries was also much lower (9.16 cm);
- in the conditions of Central Moldova, the genotypes Deliciul Verii and Turda 344 recorded the highest values of the parameters followed compared to the average experience, being the most affected by the attack of larvae:
- the genotypes Inventive and Turda 248, had close values of attack (45.08% and 49.91%) of the average number of holes/plant (1.16 and 1.18), of the average number of galleries/plant (0.94 and 1.05), of the average number of larvae/plant (0.92 and 0.76), of the average length of the galleries (19.03 cm and 15.38 cm) of the average experience (46.43% attack, 1.29 holes/plant, 1.10 galleries/plant, 0.83 larvae/plant, 16.87 cm gallery length).

Analyzing the correlations recorded at the tested maize genotypes established between the parameters, the following were found (Figure 4):

- between the average number of holes/plant and the number of galleries/plant, a correlation coefficient was recorded which was interpreted

as very significant (r = 0.9947), for each hole a gallery was determined (Figure 4);
- a correlation coefficient was recorded between the average number of galleries/plant and the average length of the galleries, which was interpreted as significant (r = 0.8319) (Figure 4);

- the correlation coefficient between the two parameters, the frequency of the attacked plants and the average number of holes/plant was interpreted as significant (r = 0.8160), the attacked plants registering one or more holes;

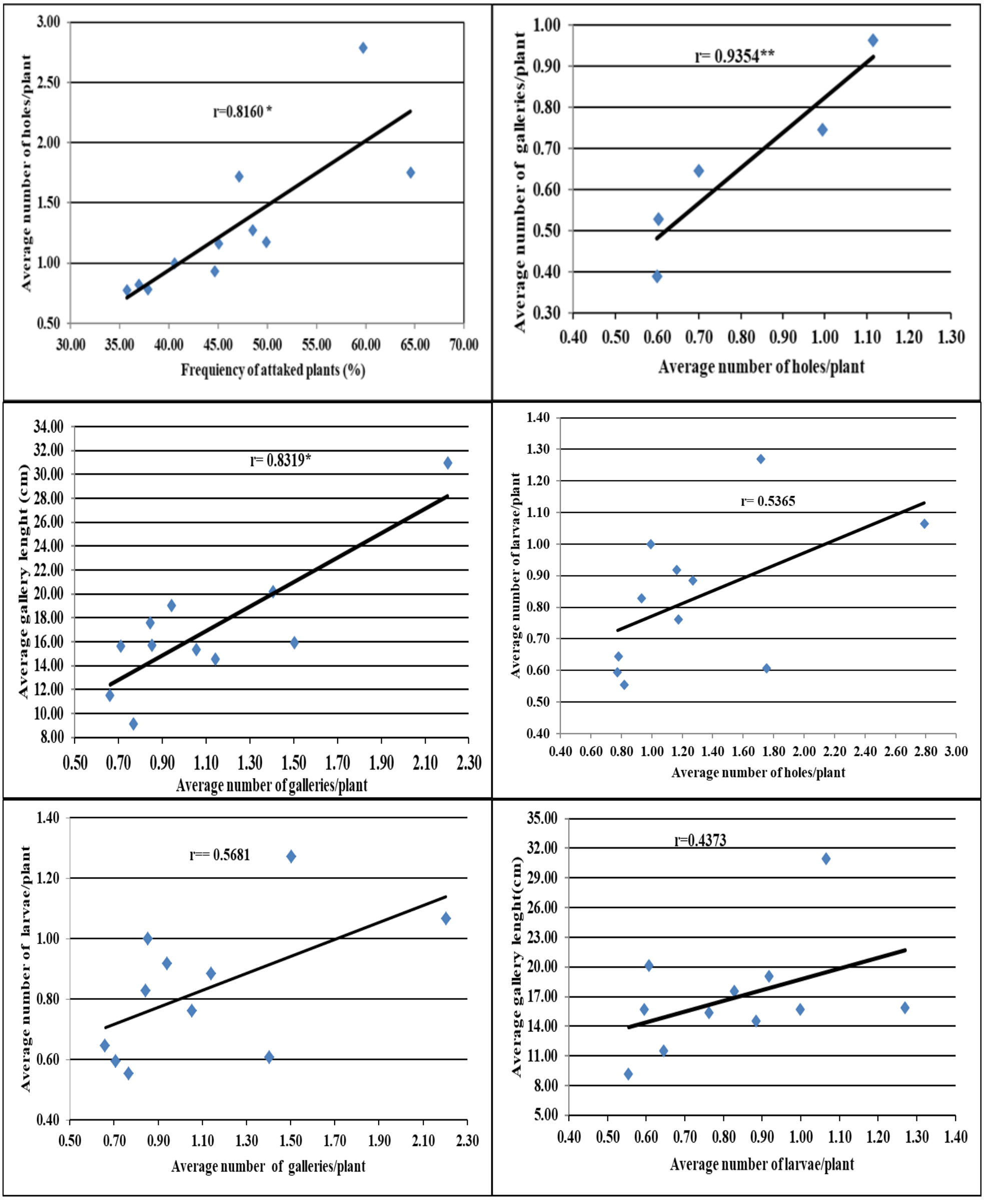

Figure 4. The influence of the Romanian and foreign maize genotypes on the attack parameters produced by the species *Ostrinia nubilalis* Hbn., average 2019-2021

- although the larvae managed to create holes, galleries of different sizes inside the plants, their lack of galleries was noticed, which suggests that they either perished or migrated to other plants that offered more favorable feeding conditions. Thus, between these parameters, the average number of holes/plant and the average number of larvae/plant (r = 0.5365), the average number of galleries and the average number of larvae (r = 0.5681), the average number of larvae/plant and the average length of the galleries (r = 0.4373) established a positive correlation coefficient, but without statistical assurance (Figure 4).

The results obtained were similar to those published by other researchers in the literature. Lopez-Malvar et al. (2021) argues that the faster rate of development of early genotypes coincides with the appearance of the maximum flight peak, with the laying and hatching of larvae, which shows that the precocity of the hybrid will attract females to lay eggs. Also, as the plant evolves, it increases the hardness of the tissues that begin to lignify and strengthen the cell wall, which interrupts the progress of the larvae.

Sculz et al (1997) and Melchinger et al. (1998) reported significant variations in the genotypes analyzed in terms of production, frequency of attack and average length of galleries. They concluded that the results could help to improve the number of sources for obtaining genotype tolerance for *Ostrinia* attack by identifying genotypes that showed, reduced stem attack and small galleries.

Raspudic et al. (2009) monitored several FAO 450-700 late maturing maize genotypes over two years, finding that the average length of the galleries ranged from 13.70 to 29.20 cm (2007) and 40.84 to 64.42 cm (2008). The average number of larvae/plant ranged from 0,96 to 2.16 in 2007 and from 1.28 to 2.03 larvae in 2008, respectively. Regarding the two parameters, the length of the galleries and the number of larvae it was established that there is a significant positive correlation at all hybrids in both years.

In Croatia, the research conducted by Sarajlić et al. (2017) is highlighted the importance of temperatures and precipitation during the appearance and evolution of the insect. In unfavorable conditions, the appearance of adults is delayed by up to 10 days. The monitored genotypes recorded higher attacks in 2012, which was characterized by being dry and hot, while in 2014, the attack decreased due to the increase in rainfall and the decrease in average temperature. The researchers found that genotypes affected by larvae had 50% increases in the average length of the gallery (2012 - 24.97 cm; 2014 - 22.50 cm) compared to 2013 when the larvae created smaller average galleries of 10.87 cm.

Although Szulc et al. (2021) recorded reduced attacks of stay green genotypes, in our case the attack on genotypes with this trait, Inventive and Method had attack values close to average.

CONCLUSIONS

The largest number of holes, larval galleries and the longest galleries were recorded for maize sown in the IVth and Vth epochs.

From the point of view of the hybrid maturity group, there is a lower tolerance to larval attack on the studied genotypes and an increase in attack from early (Vibrion - 35.72%) to late hybrids (Olt - 48.50%) is observed.

In terms of grain variety, the sugar genotype Deliciul verii had the highest values of the frequency of attacked plants (59.72%) the number of holes/plant (2.79 holes/plant), the average number of galleries/plant (2.20 galleries/plant) and the average length of the gallery (30.94 cm).

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RESEARCH ON BARLEY DISEASES IN THE CONVENTIONAL CULTURE AND IN THE CONVERSION PERIOD, MURIGHIOL LOCATION, TULCEA COUNTY

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Abstract

The aim of our research was to establish the incidence of micromycete attack on barley grown in classical technology and in culture during the conversion period to move to organic farming, in the Murighiol area, Tulcea county, in 2020/2021. The most common micromycetes in barley crops were P. teres which causes net blotch of barley, P. graminea responsible for barley leaf stripe disease and Puccinia hordei agent pathogen of leaf rust on barley. In the case of barley cultivated in a conventional system, the control variant determined a degree of attack of 29.5% for P. teres, 6% for P. graminea and 11% for P. hordei. In the barley variant during the conversion period, the values recorded were 28.5% for P. teres, 4.5% for P. graminea and 12% for P. hordei. The application of treatments to conventionally grown barley was over 50% effective in controlling pathogens and in the barley variant during the conversion period to which the Amer Micro product was applied, there were lower values of the attack of the monitored pathogens, compared to the control variant.

Key words: *barley, pathogens, diseases, degree of attack.*

INTRODUCTION

Barley is one of the oldest cultivated plants with uses in human nutrition, animals and as a raw material in industry (Muntean et al., 2003). The protection of barley crops ensures productions that satisfy the requirements of cultivating this plant in obtaining superior quantitative and qualitative productions. Barley is attacked by cereal and barley-specific pathogens, such as *Blumeria graminis* f. sp. *hordei* that causes powdery mildew, net blotch of barley caused by *Pyrenophora teres*, micromycete barley leaf stripe disease caused by *Pyrenophora graminea*, the leaf rust whose pathogen is *Puccinia hordei*. Barley diseases affect the health of plants causing severe symptoms but also cause significant economic losses (Neate and McMullen, 2005). Cultivation of resistant genotypes and interventions in crop technology and the application of strategies to control them can reduce the losses caused by barley disease. *Pyrenophora teres* the causative agent of barley net blotch one of the most important economic diseases in barley producing losses between 10% and 40% and even with the possibility of compromising crops (Galano et al., 2011; Jayasena et al., 2007) being present wherever barley is grown (Shipton et al., 1973; Sato and Takeda, 1997; Tekauz, 1990; Moya et al., 2018). *Pyrenophora graminea* causes the leaf stripe disease and the plants with characteristic symptoms on the leaves produce sterile ears (Zad et al., 2002), causing production losses of both quantitative and qualitative nature (Arabi et al., 2004; Porta-Puglia et al., 1986; Damaci and Aktuna, 1983; Aktas, 1984). The attack of the pathogen was present in barley in two rows (Cristea and Gheorghies, 1997). The attack of leaf rust caused by the micromycete *Puccinia hordei* occurs in all areas of barley cultivation with variable values of the incident producing more severe yield losses in sensitive varieties and in areas where barley crops mature later. The leaf rust attack reduces crop levels by reducing the number of fertile ears and grain weight (Arnst et al., 1979). In epidemic conditions, production losses of up to 62% have been reported for susceptible varieties (Park et al., 2015). The calculation of the effectiveness of treatments in combating diseases of cultivated plants is required to ascertain their impact on health and crop yield

(Alexandru et al., 2019; Buzatu et al., 2018; Jaloba al., 2019; Toth and Cristea, 2020).

MATERIALS AND METHODS

The aim of the research was to identify and establish the attack of the main diseases of barley grown in conventional cultivation system and barley in the conversion period for the transition to organic cultivation. Diseases were identified and the frequency, intensity and degree of attack were calculated. To calculate the incidence of the attack or its frequency, the formula was used: Frequency (F%) = n x 100/ N, where N = number of plants observed (%), n = number of plants specific symptoms (%). The intensity was noted in percentages and calculated according to the formula: Intensity (I%) = Σ (ixf)/n (%) where, i = percentage given, f = number of plants/organs with the respective percentage, n = total number of attacked plants/organs. Based on the data obtained by calculating the frequency and intensity, the degree of attack was calculated: GA= F x I/100 (%), where: GA = attack degree (%), F = frequency (%), I = intensity (%). The effectiveness of the treatment was calculated according to the formula: E (%) = [(GA var c – GA var t)/GA var c], where: GA var c = degree of attack in the control variant (untreated) and Ga var t= degree of attack in the treated variant. The biological material was the Cardinal variety. The treatment of the barley seed in conventional cultivation was done with the product Admiral 0.5 l/t and the fungicide Zamir was applied at a dose of 0.75 l/ha. The witness was untreated. For the barley crop in the conversion period for the transition to an ecological system, the seed used for sowing was untreated, but passed through the selector and administered the AmerMicro product, certified from an ecological point of view. The barley control variant during the conversion period was free of treatment.

RESULTS AND DISCUSSIONS

In the conditions of the agricultural year 2020-2021 (Figure 1) in the area of experimentation for barley cultivation both in conventional cultivation system (Figure 2) and for barley cultivation in the conversion period (Figure 3), in order to the transition to organic cultivation showed important and common diseases of barley, caused by micromycetes: the barley net blotch caused by *Pyrenophora teres*, barley leaf stripe disease caused by *Pyrenophora graminea*, the leaf rust agent pathogen *Puccinia hordei*. In the case of the attack of *Pyrenophora teres* on the leaves, characteristic brown spots with velvety appearance were found as a result of the formation of specific asexuate fructifications (Figure 4).

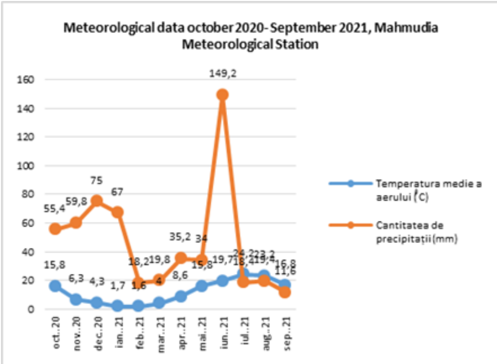

Figure 1. Meteorological data October 2020 - September 2021, Mahmudia Meteorological Station, Tulcea County

In the case of the attack of barley leaf stripe disease *Pyrenophora graminea*, the presence of elongated brown-gray spots with a larger darker border with a velvety gray center was noted due to the formation of specific fructifications (Figure 5). The presence of pustules with uredospores and teleutospores specific to the genus *Puccinia* (Figure 6) identified the rust attack on barley grown in the two cropping systems. In the conditions of the agricultural year 2020-2021, barley net blotch recorded a frequency of 100% and an intensity of 29.5% which led to an attack value of 29.5%. At the same variant, barley leaf stripe disease registered a frequency of 6% and in terms of the attack of leaf rust it had an incidence of attack of 100% and an intensity of 11%, resulting in a value of the degree of attack of 11%. In barley culture in conventional culture, the treated values of the monitored pathogens were reduced so that the intensity in the case of *Pyrenophora teres* attack decreased to 12.5%, the frequency remained maximum which led to a value of the degree of attack equal to the value intensity, GA = 12.5%.

Regarding the attack of barley leaf stripe disease, it can be said that the treatment of the seed reduced the incidence of the pathogen to 1.5%, compared to the control variant in which a value of 6% was noted. Observations on the rust attack on the leaves showed a decrease in the intensity of the attack which reached 5% (Table 1). Observations on the pathogen attack evaluated for barley in the conversion period, data from the same table (Table 1) show that the attack of *Pyrenophora teres* had a frequency of 100%, in both variants as well as in conventional culture but with a value of intensity I = 28.5%, resulting in a degree of attack of GA = 28.5%. Regarding the attack of *Pyrenophora graminea*, the data showed that the frequency of the attack was F = 4.5%. The net blotch and barley leaf stripe disease were present with different incidents in barley varieties grown in Romania (Pana et al., 2015). Research on the influence of technological links on *P. graminea* attack has established correlations on the level of fungal attack (Cristea et al., 1998). We consider that subjecting the seed to the selection operation has removed the seeds carrying a potential attack. The micromycete *Puccinia hordei* recorded a significantly higher attack value of 12% than in the control variant in the conventional culture system. In the barley version in the conversion period to which the Amer Micro product was applied, the attack values of the monitored pathogens were lower (Table 1).

Figure 2. Barley crop aspect - conventional culture (original)

Figure 3. Aspect of the barley crop in the conversion period (original)

Figure 4. *Pyrenophora teres* (FA *Drechslera teres*-conidia) (original)

Figure 5. *Pyrenophora graminea* (FA *D. graminea*-conidia) (original)

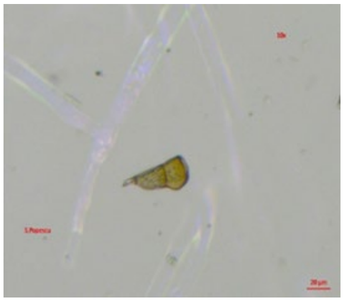

Figure 6. *Puccinia hordei* (teleutospore) (original)

Table 1. Observations regarding the attack of barley leaf diseases in conventional culture and in the conversion period (2020-2021) Sarinasuf - Murighiol location, Tulcea county

Variety/culture system	Variant Treat/ control	The pathogen/disease *Pyrenophora teres*/ Barley net bloch			*Pyrenophora graminea*/ Leaf barley stripe	*Puccinia hordei*/ Leaf rust		
		F (%)	I (%)	GA (%)	F (%)	F (%)	I (%)	GA (%)
Cardinal/ conventional system	Treat	100	12.5	12.5	1.5	100	5.0	5.0
	Control	100	29.5	29.5	6.0	100	11	11
Cardinal/ conversion period	Treat	100	21.5	21.5	3.0	100	8.5	8.5
	Control	100	28.5	28.5	4.5	100	12	12

The application of the treatment with the Zamir product in a dose of 0.75 l/ ha to the barley cultivated in conventional system registered values of efficacy of 57.6% in the case of the net blotch attack and of 75% in the case of the *P. graminea* attack and of 54.5% for leaf rust attack (Table 2). Research on the application of treatments has shown that they have significantly reduced the attack of barley pathogens.

Table 2. Effectiveness of treatment on barley leaf diseases in conventional culture (2020-2021) Sarinasuf - Murighiol location. Tulcea county

Variety/culture system	Variant Trait/ control	The pathogen/disease *Pyrenophora teres*/ Barley net bloch		*Pyrenophora graminea*/ Leaf barley stripe		*Puccinia hordei*/ Leaf rust	
		GA (%)	E (%)	GA (%)	E (%)	GA (%)	E (%)
Cardinal/ conventional system	Trait	12.5	57.6	1.5	75	5	54.5
	Control	29.5	-	6.0	-	11	-
Cardinal/ conversion period	Trait	21.5	24.5	2.5	44.4	8.5	29.2
	Control	28.5	-	4.5	-	12	-

CONCLUSIONS

Incidence diseases of barley in the experimental area in the conditions of the year 2020-2021 cultivated in conventional systems and during the conversion period were caused by the micromycetes of *Pyrenophora teres*, *Pyrenophora graminea*, and *Puccinia hordei*. The frequency of the attack was maximum in *P. teres* and *P. hordei* micromycetes in all experimental variants. The attack values of *P. teres and P. hordei* were significantly higher in the barley crop during the conversion period. The attack of *P. graminea* micromycete was lower in the barley in the conversion period compared to the untreated variant in the conventional system. which we attribute to the seed selection operation.

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BRASSICAS AS A ROTATION CROP. POTENTIAL AND PERSPECTIVES

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Abstract

Crop rotation has been one of the approaches that has most improved the efficiency of farming systems around the world as it has the potential to improve soil conditions and increase the productivity of the system. Brassica spp. and related plants have received attention in recent years for its potential use as a rotation crop due to their ability to control soilborne pathogens. The production of sulphur compounds called glucosinolates is the main, although not the only, mechanism behind the reduction of soil pathogens by Brassica spp. These compounds break down to produce isothiocyanates that are toxic to many organisms in the soil, in a process known as biofumigation. In this review, the typical characteristics of Brassica spp. which makes them a valuable option as a rotational crop are discussed, as well as examples and the perspective of its use for this purpose.

***Key words**: biofumigation, Brassicas, crop rotation, glucosinolates.*

INTRODUCTION

One of the main challenges of agriculture nowadays is meeting the ever-increasing food demand and coping with the immense pressure on crop production due to the ever-rising population and changes in the climate (Abegunde, Sibanda, & Obi, 2019; Fahad et al., 2017; Gliessman, 2020; Qi et al., 2018). Maintaining soil health is a critical step to increase agricultural efficiency (Lehmann, Bossio, Kögel-Knabner, & Rillig, 2020), and in recent years there has been a growing concern over certain practices that accelerate soil erosion and nutrients depletion (Kopittke, Menzies, Wang, McKenna, & Lombi, 2019). Some calculations state that 60% of soil depletion since the 1950s is due to farming practices and other anthropogenic causes (Novotny, 1999; Uğuz et al., 2020). The role of agricultural researchers in this setting is to transform scientific knowledge into techniques that tackle the previously mentioned issues and at the same time increase farmer's understanding of the viability of their farming activities (He, Zhang, Wang, Zeng, & Zhang, 2018).

Crop rotation is one of such techniques, and it makes up one of the main approaches for sustainable farm managing that also helps to keep the soil's health. The effect of crop rotation is to disrupt the soil pathogen's life cycle and to restore the nutrients when certain plant species are introduced in the rotation scheme, which also causes agricultural systems to be less dependent on fertilizers and biocides (Costa et al., 2020). Another advantage of crop rotation is that this technique is compatible with organic agriculture and has become a cornerstone of it (Uğuz et al., 2020).

However, since worldwide agriculture has many production variables, market swings and a wide variety of levels of awareness amongst farmers, the mechanisms for diffusing, adapting, and making crop rotation adoption profitable are many, and this have been a barrier for agricultural practices (Shah et al., 2021).

In the other hand, Brassicas, whose two of their main exponents are Broccoli and Cauliflower, are traditional European crops that have become widespread in Asia in recent decades while their presence in Europe has been quite stable (Branca, 2007) The interest in these two crops has grown in recent years partly due to all the genetic improvement programs and the new opportunities offered by the food industry. The many healthy metabolites found on several

Brassicas allow them to be defined as functional foods and are also a factor towards the increase of its consumption (Dominguez-Perles et al., 2011; Favela-González, Hernández-Almanza, & De la Fuente-Salcido, 2020; Reda et al., 2021). This abundance of metabolites is strongly related also with some of the properties that make brassica crops, alongside their economic value, an interesting possibility when considering crop rotation. In this work we review the current knowledge of the characteristics that make *Brassicas* suitable crops for rotation, as well as several recent research endeavours aimed at the understanding of its potential in this sense and examples of its use.

BRASSICAS MAIN PHYTOCHEMICALS

Brassicaceae represents a very diverse and important family of plants which contains more than 300 genera and over 3000 species (Branca, 2007). This plant provides not only nutrients but also many heterogeneous chemical compounds (Table 1) that are adapted to a variety of functions and that are also considered as beneficial to human well-being and health (Favela-González et al., 2020)

Of all this compounds, glucosinolates are probably the most interesting ones for the purpose of crop rotation since it has been described that when released to the rhizosphere, they have biocidal effects on other organisms including plants, nematodes, insects, and fungi.

Glucosinolates

Previously called thioglucosides, this are water-soluble anions present in at least sixteen families of dicotyledonous angiosperms including many edible species. They are N-hydroxy sulfates with a sulfur-bound b-d-glucopyranose/b-thioglucose moiety and a sulfonated oxime, differing from a side chain derived from one of the amino acids, whichconstitutes the basis for their classification (Sikorska-Zimny & Beneduce, 2021), that is conformed by three main groups:

- Aliphatic group, from Met, Ala, Leu, Ile and Val
- Indolic group, from Trp
- Aromatic group, from Phe and Tyr

This is not the only classification for this compound, being an alternative system the one proposed by Romeo, Iori, Rollin, Bramanti & Mazzon (2018).

Table 1. Main bioactive compounds present in Brassica plants. From Favela-González et al. (2020)

Phytochemical class	Major constituent	Constituent types
Glucosinolates (β-thioglucoside-N-hydroxysulfates)	(β-thioglucoside-N-hydroxysulfates) Water soluble organic anions share a basic structure	**Aliphatic** Dehydroerucin, Epiprogoitrin Glucoalyssin, Glucoerucin, Glucobrassicanapin, Glucoiberin, Glucocapparin, Glucoerysolin, Glucohirsutin, Glucoibervirin, Glucolepidin, Gluconapin, Gluconapoleiferin, Glucoraphanin, Glucoputranjivin Glucoraphenin, Glucorerysolin Glucosiberin, Progoitrin, Sinigrin **Indolic** 4-Hydroxyglucobrassicin, Neoglucobrassicin 4-Methoxyglucobrassicin, Glucobrassicin, **Aromatic** Glucobarberin, Gluconasturtiin, Glucosibarin, Glucosinalbin, Glucotropaeolin
Phenoles	Hydroxycinnamic acids, Flavonoids, Anthocyanins	Caffeic, ferulic, sinapic and p-coumaric acids, Flavonols with quercetin, kaempferol and isorhamnetin Cyanidin-3-sophoroside-5-glucoside
Tocopherol (vitamin E) and carotenoids	α- δ- and γ-tocopherols α- carotenoids with lutein, β- carotene	Precursors of vitamin A (2S)-2,5,7,8-tetramethyl-2-[(4S,8S)-4,8,12-trimethyltridecyl]-3,4-dihydro-2H-chromen-6-ol

In *Brassica* species glucosinolates are accumulated in intact plants but are released when the plant is injured. At this point, the enzyme myrosinase (β-thioglucosidase glucohydrolase, E.C.3.2.3.1) hydrolyses the glucosinolates and this reaction yields breakdown produces like isothiocyanates, nitriles, thiocyanates, epithionitriles, and oxazolidinethiones (Cartea & Velasco, 2008; Favela-González et al., 2020).

The ability of both glucosinolates and glucosinolates hydrolysis products (GHPs) for having a positive effect in reducing soil pathogens is well documented (Agrawal & Kurashige, 2003; J.w, A.t, & P, 2001; Rahmanpour, Backhouse, & Nonhebel, 2009; Sotelo, Lema, Soengas, Cartea, & Velasco, 2015) and different authors have tested this hypothesis in both soil and *in vitro* assays. Bending & Lincoln (2000) was one of the first attempts to properly investigate the toxic effect of GHPs in soilborne pathogens, resulting in a limitation of the growth of bacteria, fungus, and nematodes. Other research like Lazzeri & Manici (2001) and Motisi, Montfort, Doré, Romillac, & Lucas (2009) have corroborated this and also have shown differences in the effect strength and duration depending in the specific compound. In Aires et al. (2009) and Sotelo et al. (2015) the in vitro effect of glucosinolates and GHPs on six plant pathogenic bacteria and two pathogenic bacteria and two fungi respectively was evaluated, showing that both glucosinolates and its hydrolysis produces coming from *Brassica* extracts can have the potential to be used in biofumigation for the control of multiple diseases.

In addition glucosinolates and their by-products are also widely recognized as defensive compounds against herbivores and are likely to be involved in the defence against insects and other plagues (Rask et al., 2000) but at the same time evidence also suggest that in some cases this compounds might act also as feeding cues for some insects, which are differently stimulated to fed by various glucosinolates (Renwick, Radke, Sachdev-Gupta, & Städler, 1992).

It is interesting also to mention that the biocidal activity of glucosinolates is not only specific for plant pathogens, and activity against numerous human pathogens has been described (J.w et al., 2001), as well as an effect in reducing as much as a 50% in the relative risk for cancer in certain sites (Kune, Kune, & Watson, 1987), being this probably some of the reasons why many Brassicas like cabbage and mustard have been used as poultices and antitumoral agents for centuries.

Another interesting property of glucosinolates and GPHs is their activity as allelochemicals (Rehman et al., 2019), which implies their potential use of glucosinate-rich plants extracts in biological weed control, something that several studies like Awan, Rasheed, Ashraf, & Khurshid (2012) and Turk & Tawaha (2003) have confirmed.

Phenoles

Phenolic extracts from several species of Brassicas have proven to have also allelopathic effects in other plant species (Haddadchi & Gerivani, 2009). The main components of phenolic substances in Brassicas are caffeic and sinapic acids. The other phenolic acids and their esters, such as salicylic, o-coumaric, ferulic, syringic and cinnamic acid, are minor substitutes in *Brassica* species (Zukalova & Vasak, 1998). Interference with plant-water balance appears to be one mechanism of action of phenolic acids causing a reduction in plant growth although phenolics compounds might also decrease decreased seed germination, ion uptake, leaf expansion, chlorophyll content, photosynthesis and electron transport (Colpas, Ono, Rodrigues, & Passos, 2003).

BRASSICAS IN CROP ROTATION SYSTEMS

Although an direct relationship between the presence of phytochemicals and the benefits of Brassicas has generally being observed, when used as a rotation crop, Brassicas have been shown to supress diseases also through effects on soil microbial communities and development of suppressive conditions, that are separate from the biofumigation response (Larkin & Lynch, 2018). In Larkin & Honeycutt (2006) it was observed that in rotations with canola and rapeseed (*Brassica napus* L.) distinct microbial community characteristics from non-Brassica rotations were exhibited, and these rotations resulted in reduced incidence and severity of *Rhizoctonia* disease in potatoes, even when the rotations were not incorporated as green manures.

Disease suppression in some cases has not been consistently associated with high glucosinolate-producing crops, and it has been observed that in some cases this suppression is completely independent of the glucosinolate content (Cohen, Yamasaki, & Mazzola, 2005; Larkin &

Griffin, 2007). It is very important to notice that disease benefits are not the only ones considered when having Brassicas as rotation crops, in McGuire (2003) it is shown that many other characteristics such as increased porosity and organic matter content, which may lead to lower disease levels as well as increased crop yields, are present when Brassicas crops are used.

Even if the potential of Brassicas to reduce disease and improve overall soil condition has been proven, it is not yet clear which crops are best for which diseases and how to manage these crops for an effective disease reduction, and how to best implement these crops into a rotation and production system. In this case, it is necessary to perform a detailed study of each case. In Larkin & Lynch (2018) they evaluated six different *Brassica* crops and standard rotation crops (ryegrass and buckwheat) as green manure and rotation crops alongside with potato, showing a similar performance for all *Brassica* crops compared to that of ryegrass and buckwheat.

Another crop in which Brassicas' potential as a rotation crop have been investigated is pepper. In Ros et al. (2016), several cultivars from *Raphanus sativus*, *Brassica juncea* and *Sinapis alba* were evaluated for its suitability as a rotation crop and as a green amendment during the process of biosolarization. They have shown that the joint action of the non-multiplier effects of the brassicas and biosolarization reduced the damage to the roots of the following pepper crop during the first months, which translated into an improvement in production compared to the control. These results are relevant for soil management and pepper production systems, but more trials under different conditions and sowing dates of brassicas will be necessary in order to recommend the use of Brassicas as a crop for biosolarization of pepper greenhouses, both in organic farming and in conventional production.

The study by Tiwari et al., (2021) is another example of research where *Brassica* crops, in this case *Brassica carinata*, was used for diversifying crop rotation and its potential to improve integrated weed management evaluated. Their research objective was to evaluate the influence of *B. carinata* on weed population dynamics of several cropping systems. As a result, they found an interesting synergistic effect of both a reduction in the weed emergence and an increase in *B. carinata* biomass when rotating this crop with peanut (*Arachis hypoge*a L.) indicate that *B. carinata* can enhance integrated weed management strategies at the rotational level for summer crops by reducing seed banks of summer weed species, in addition to its potential as a winter biofuel crop.

This previous example shows another advantage of the use of Brassicas as rotation crops, which is the added value that most *Brassica* species have, either as food, or biofuel and many other applications. This is very important since one factor of particular importance to growers is whether a full-season rotation crop is needed to achieve disease control. The disadvantage of rotation crops is that it takes the field out of any kind of production for that season. The use of a Brassica cover crop, such as condiment mustard or cauliflower, with an high value produce that can also be effective in reducing disease, and also if the *Brassica* crop can be effective as a fall cover crop implemented after a regular seasonal rotation crop, would give growers more flexibility in how to effectively implement Brassicas for disease control into their production system (Larkin & Lynch, 2018).

Just as important as figuring out the specific benefits of using Brassicas as rotation crops, it is important to define any probable negative interaction with other crops. Some *Brassica* species, when included in crop rotation, caused inhibiting of germination and seedling growth of succeeding small-grain crops (Bialy, Oleszek, Lewis, & Fenwick, 1990). Most of the studied cases are related to the harmful effect on small-grained crops (Oleszek, 1987; Vera, McGregor, & Downey, 1987) so, the evaluation of this negative effect is very important when studying the inclusion of *Brassica* in rotation systems with cereals.

CONCLUSIONS

While the use of chemical herbicides, pesticides, and synthetic growth regulators is generally unavoidable in crop production, ecological alternatives such as crop rotation may aid in the long-term sustainability of global food security. Exploring the potential of *Brassica* as a rotation crop as a means of increasing productivity without jeopardizing environmental safety could be fruitful in this sense. However, this field of study is still in its early stages, and its full potential has yet to be realized. So far, research has shown that *Brassica* species have a lot of potential, which may be exploited in a variety of ways to enhance crop output in the face of climate change.

To improve the allelopathic potential of major Brassica crops, plant breeders and molecular biologists should collaborate with agronomists. Phytochemical genes should be identified in more allelopathic cultivars and then introduced into non-allelopathic or less allelopathic crops and cultivars. It's also possible to find growth-regulating secondary metabolites to boost crop yields in both normal and stressful situations. This will not only reduce the cost of production but will also reduce the environmental hazards caused by chemical pollution, helping towards achieving the goal of sustainable crop production without compromising the environmental safety.

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COMPARATIVE ANALYSIS OF HERBS PRODUCTION IN SOME PERENNIAL SPECIES OF THE GENUS *Artemisia*

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Abstract

Very few species of the genus Artemisia have been studied from an agro-phytotechnical point of view, although most of them are perennial, aromatic plants, with possible uses in medicine, human nutrition, animal feed, biofuel production, pharmaceutical or food industry, well adapted to environmental conditions, resistant to drought. The authors studied nine species of the genus: Artemisia absinthium, Artemisia abrotanum, Artemisia argyi, Artemisia austriaca, Artemisia dracunculus, Artemisia lavandulaefolia, Artemisia pontica and Artemisia vulgaris. Based on research and measurements, it has been established that there is a directly proportional relationship between plant height and grass production, with high-altitude species having the best yields. The species Artemisia lancea and Artemisia lavandulaefolia, of Asian origin, adapted well to the pedo-climatic conditions in Iasi county and had a significantly higher production than the control Artemisia absinthium.

Key words*: Artemisia, biomass, herba, plant height.*

INTRODUCTION

Genus *Artemisia* spp. from the family *Asteraceae* Bercht. & J. Presl., comprises about 500 distinct species, widespread especially in the temperate zone of the northern hemisphere and less in Africa or South America. These are usually perennial species, less annual or biennial, aromatic, growing in the form of shrubs or semi-shrubs with a height of 10-350 cm, glabrous or pubescent stems and leaves of very different shapes and colors. Some species are important for the pharmaceutical industry, the plants being used as raw material for the preparation of some medicines, and others for the food industry, animal feed or for the production of biofuels. The use of medicinal and aromatic plants, including wormwood (*Artemisia* spp.) In the prevention and treatment of certain diseases, along with allopathic medicine, is a common practice in Romania. Spontaneous species of the genus *Artemisia* (wormwood) have been used for hundreds of years in our country in food (spice, wine), animal feed (sheep, goats), folk medicine (feverfew, burns, healing, tonic, digestive, hepatoprotective, anthelmintic, diuretic, analgesic, anti-inflammatory, etc.) and veterinary medicine (insect repellent). The plants from *Artemisia* spp. Have a high ecological plasticity, meeting from the lowland area to the mountainous area, occupying both the arid and the humid area. The most used species of the genus today are *Artemisia annua*, *Artemisia absinthium* and *Artemisia vulgaris*. The main aim of the current research is to identify new spontaneous species of the genus *Artemisia* that are valuable from a phytotechnical point of view in terms of biomass (herba) production, which should be improved and then taken to culture. To date, spontaneous species of the genus *Artemisia* have been studied only from a botanical and ecological point of view and there is a possibility that some species have very valuable agrophytic properties for production.

MATERIALS AND METHODS

The researches were carried out in the field of experience of the disciplines of Phytotechnics and Medicinal Plants, it is part of the patrimony of the "Vasile Adamachi" farm, Iași Didactic Resort. The analyzes were performed in the Phytotechnics and Physiology laboratories of the Agricultural and Environmental Research

Institute Iasi, within the Iasi University of Life Science. The location is between 47^0 10 'and 47^0 15' north latitude and 27^0 30 '-27^0 35' east longitude. In the experimental area the climate has a pronounced continental character. It is largely influenced by the presence of Atlantic and Continental anticyclones. During the summer, dry weather predominates, with high temperatures, the maximum value of which can reach over 40^0C. The current trend of global warming must also warn producers of medicinal and aromatic plants. The total annual amount of precipitation ranges between 460 and 600 mm. Sometimes, in summer, torrential rains fall, and in autumn long-lasting drizzles (Table 1).

Table 1. Temperatures and precipitation recorded during the experiment period (2015-2016)

Specification/Month	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII	Average
Year 2015													
Average temperatures	-3.2	-0.6	5.3	10.5	16.9	21.1	23.8	23.0	19.2	9.4	6.4	2.0	9.3
Multiannual average	-3.5	-1.8	3.1	10.2	16.0	19.5	21.2	20.5	15.9	10.0	4.1	-0.8	9.5
Deviation	-0.3	1.2	2.2	0.3	0.9	1.6	2.6	2.5	3.3	-0.6	2.3	1.2	-0.2
Recorded rainfall, mm	18.8	8.8	56.1	32.4	7.7	51.1	22.8	40.8	19.8	66.4	104.2	10.2	439.1
Multiannual environments	29.7	26.9	28.4	43.9	55.9	82.6	69.3	56.0	45.3	32.5	37.0	29.7	537.2
Deviation + -	-10.9	-18.1	27.7	-1.5	-48.2	-31.5	-46.5	-15.2	-25.5	33.9	67.2	-19.5	-98.1
Year 2016													
Average temperatures	-2.5	5,.	6.5	13.3	15.3	20.9	22.6	21.4	18.3	8.2	4.0	0.4	11.1
Multiannual average	-3.5	-1.8	3.1	10.2	16.0	19.5	21.2	20.5	15.9	10.0	4.1	-0.8	9.5
Deviation	-1.5	3.5	3.4	3.0	-0.7	1.4	1.4	0.9	2.4	-1.8	-0.1	-0.4	1.6
Recorded rainfall, mm	80.0	28.8	33.8	76.2	70.4	142.4	24.0	53.4	10.2	212.0	69.8	20.6	821.6
Multiannual environments	29.7	26.9	28.4	43.9	55.9	82.6	69.3	56.0	45.3	34.5	37.0	29.7	537.2
Deviation + -	50.3	1.9	5.4	32.3	14.5	59.8	-45.3	2.6	-35.0	179.5	32.8	9.1	284.4

The experiment was placed on a cambic chernozem soil, also known as leached chernozem, with the subtype of mesocalcaric cambic chernozem. In order to achieve the established objectives. The experiment was placed on a cambic chernozem soil, also known as leached chernozem, with the subtype of mesocalcaric cambic chernozem. In order to achieve the objectives, the experiment focused on the comparative cultures of the nine species of *Artemisia*: *Artemisia absinthium, Artemisia abrotanum, Artemisia vulgaris, Artemisia dracunculus, Artemisia austriaca, Artemisia pontica, Artemisia lancea, Artemisia lavandulaefolia, Artemisia argyi*. The experience was one-factor. The sowing was carried out in plots of 9 sqm/variant, in randomized blocks, with two repetitions for each *Artemisia* species. The distances between rows and between plants in a row were different depending on the requirements of each species. The experiment was stationary, the plants being perennial, and the determinations were made every year, on plants taken at random from the area delimited for each species and marked. The experimental groups were established in 2014 through the vegetative organs of each species, and in the following years observations were made and samples were taken. To determine the dynamics of plant growth, the plant material was used on the entire surface of each plot. on which the phenological observations were made, the stage of vegetation, the general appearance, the state of vegetation, the presence of weeds, attacks of diseases and pests. for all measurements during the growing season, from the beginning of late March to early April, at intervals of seven days, and 10 days, respectively, until the time of flowering of the latest species. The determinations consisted of measuring the height of the plants, counting the branches and leaves. Biometric measurements on plant growth and development were performed in 2015 and 2016, when the plants of the nine species were two and three years old, respectively. At the end of these measurements, the green biomass production was calculated and a comparative analysis of the grass production for the nine *Artemisia* species was performed, taking as a control the *Artemisia absinthium* species.

RESULTS AND DISCUSSIONS

In March 2015, observations were made regarding the on set of vegetation in each species, an aspect genetically determined by the territorial origin of the analyzed species, given that the temperature and humidity were the same for all species (Table 2).

Table 2. Planting time for *Artemisia* spp.

Species name	Origin	Start date in vegetation
Artemisia absinthium L.	Eurasia and North Africa and widely naturalized in Canada and the northern United States	12-16.03.2015
Artemisia abrotanum L.	Central and south-eastern Europe, the Mediterranean region	04-06.03.2015
Artemisia argyi H. Lev. & Vaniot	East Asia (China, Korea, Mongolia), East Russia	15-16.03.2015
Artemisia austriaca L.	Kazakhstan, Kyrgyzstan, Russia, Tajikistan; SW Asia (Iran), C, E and SW Europe	05-07.03.2015
Artemisia dracunculus L.	Southeast Russia, Central and Northern Asia	25.03-05.04.2015
Artemisia lavandulaefolia DC.	China, Japan, Russia, Mongolia	16-18.03.2015
Artemisia lancea Vaniot	East Asia (Korea, China, Taiwan, East Russia, Japan and India)	29.03-03.04.2015
Artemisia pontica L.	Southeast Europe	18-22.03.2015
Artemisia vulgaris L.	Native to Europe, Asia, North Africa and Alaska, it is native to North America	10-20.03.2015

The fastest start in vegetation was highlighted in the species *Artemisia abrotanum* and *Artemisia austriaca*, and the slowest start in vegetation was in the species *Artemisia dracunculus* and *Artemisia lancea*. This aspect is extremely important in practice, in establishing the time of sowing/planting in order to make the most of the water supply in the soil in early spring, especially in dry regions. In the two years of research, the nine species of the genus *Artemisia* studied had an average stem height of 169.08 cm. However, there are large differences between species compared to this average value of the species, as can be seen in Table 3.

Table 3. The maximum stems height of *Artemisia* spp.

Species of the	Stem height (cm)			Difference from species average		The difference from the control	
Artemisia spp.	2015	2016	Average	cm	%	cm	%
Artemisia absinthium	196.00	206.70	201.30	32.22	19.56	-	100,00
Artemisia dracunculus	144.70	145.30	145.00	-18.08	-10.75	-56.30	-27.96
Artemisia abrotanum	151.70	150.30	151.00	-18.08	-10.69	-50.30	-24.99
Artemisia austriaca	73.00	72.70	72.70	-96.38	-57.00	-128.60	-63.88
Artemisia lancea	238.70	237.70	238.20	69.12	40.88	36.90	18.33
Artemisia argyi	100.70	189.00	189.90	20.82	12.31	-11.50	-5.71
Artemisia lavandulaefolia	242.00	239.30	240.60	71.52	42.30	39.30	19.52
Artemisia pontica	102.30	93.00	97.60	-71.48	-42.28	-103.70	-51.50
Artemisia vulgaris	188.00	183.00	185.50	16.42	9.71	-15.80	-7.85
Average			169.08				

Some species have been placed above the average height, such as *Artemisia absinthium*, *Artemisia lancea, Artemisia argyi, Artemisia lavandulaefolia* and *Artemisia vulgaris*. The most significant positive difference from the species average was recorded in *Artemisia lavandulaefolia* (71.52 cm, respectively 42.30%), and in *Artemisia lancea*, which exceeded the average by 69.12 cm (40.88). These are followed by *Artemisia absinthium*

(32.22 cm and 19.56%), *Artemisia argyi* (20.82 cm and 12.31%) and *Artemisia vulgaris* (16.42 cm and 9.71%). The other four species had a smaller size than the average species, with *Artemisia austriaca* (-96.38 cm and -57% respectively), *Artemisia pontica*, with -71.48 cm (-42.28%) and *Artemisia abrotanum* with -18.08 (-10.69%) less than the average height of all species. Taking as a witness the species *Artemisia absinthium*, considered the most important and at the same time cultivated, we can see that only 3 species exceed it in height of the respective stem, *Artemisia lancea* (by 18.33%), and *Artemisia lavandulaefolia* (by 19.52%), the other species being smaller. These include *Artemisia austriaca* (-63.83%), *Artemisia pontica* (-51.5%,) and to a lesser extent *Artemisia abrotanum* (-24.99%). grass at the optimum time of harvest for each species. 10 plants from each variant were chosen at random, on which the biometric measurements were made, and these were harvested in their entirety, weighed and the average plant production was determined. After counting the plants in each variant, depending on the size of the area, the density of the plants at harvest and the production per unit area and per hectare were calculated (Table 4).

Table 4. Plant density and herba production at harvest (average 2015-2016)

Artemisia spp.	Plant density, thou pl.	Biomass, g/pl	Herba yield, t/ha	Biomass, kg/m^2
Artemisia absinthium	37.0	516.0	19.10	1.91
Artemisia abrotanum	28.0	643.0	18.00	1.80
Artemisia argyi	31.0	600.0	18.60	1.86
Artemisia austriaca	64.0	170.0	10.90	1.09
Artemisia dracunculus	37.0	392.0	14.50	1.45
Artemisia lavandulaefolia	34.0	748.0	25.40	2.54
Artemisia lancea	28.0	936.0	26.20	2.62
Artemisia pontica	34.0	328.0	11.10	1.11
Artemisia vulgaris	36.0	517.0	18.60	1.93
Average value	36.3	538.8	19.6	1.96

Being perennial crops, the density is the same in the two years of experience, and the differences in the average weight of the plants in the two climatic years were insignificant, so that the production situation will be presented as the average value of the two years. Analyzing the plant density, we find an average of 36 thousand pl/ha for all nine species, well correlated with the size of the plants (height). Only three species had above average density; *Artemisia austriaca* (64 thousand pl./ha, almost double the average value), with the lowest production per plant (170 g) and *Artemisia absinthium* with 37 thousand pl./ha, slightly above average, and *Artemisia dracunculus* - equal to the species *Artemisia absinthium*. Most species recorded values of density below the average of nine (between 31-34 thousand pl./ha), but with the lowest values are *Artemisia abrotanum* and *Artemisia lancea* (28 thousand pl./ha). They also recorded the highest yields per plant (936 g for *Artemisia lancea* and 643 g for *Artemisia abrotanum*). Only *Artemisia lavandulaefolia* had a high density (34 thousand pl./ha) and a high weight per plant (748 g), second after Artemisia lancea. *Artemisia absinthium* and *Artemisia dracunculus* species, at the same density (37 thousand pl./ha) they recorded different weights on the plant (516 g and 392 g/pl., respectively), because in *Artemisia dracunculus* the height is lower. We can also notice the species *Artemisia argyi* which gave a good production per plant (600 g) at a density of 31 thousand pl/ha.

The average weight of a plant in the nine species reached 534.7 g, and the average biomass was 1.96 g/sqm, depending on both density and average value per plant, as well as biomass production (herba) per hectare (19.60 t). The species *Artemisia vulgaris* had a density close to *Artemisia absithium* and having similar dimensions, both the grass production and the other parameters were close. Comparative analysis of the production of species per hec-tare is presented in Table 5, both in relation to the average of the species and to the control - *Artemisia absinthium* and expressed in absolute and relative values, as averages over the two years.

Tabel 5. Comparative analysis of herba production in *Artemisia* spp. (average 2015-2016)

Artemisia spp.	*Herba production, t/ha*	Differences from the average		Differences from the *A. absinthium*	
		t/ha	%	t/ha	%
Artemisia absinthium	37.0	516.0	19.10	1.91	0.00
Artemisia abrotanum	28.0	643.0	18.00	1.80	-5.76
Artemisia argyi	31.0	600.0	18.60	1.86	-2.62
Artemisia austriaca	64.0	170.0	10.90	1.09	-42.93
Artemisia dracunculus	37.0	392.0	14.50	1.45	-24.10
Artemisia lavandulaefolia	34.0	748.0	25.40	2.54	32.98
Artemisia lancea	28.0	936.0	26.20	2.62	37.17
Artemisia pontica	34.0	328.0	11.10	1.11	-41.36
Artemisia vulgaris	36.0	517.0	18.60	1.93	-2.61
Average value	36.3	538.8	19.60	1.96	

At a first analysis we can see the big difference between the *Artemisia* species in terms of grass production, from 10.9 t/ha for *Artemisia austriaca*, to 26.2 t/ha for *Artemisia lancea*. Productions above the average of the species gave their majority, but the species *Artemisia lancea* can be noticed, with 8 t/ha more, (by 47.3% higher than the average), *Artemisia lavandulaefolia* with 7.62 t/ha more (with 42.8% higher than average). The species *Artemisia absinthum*, the most cultivated in our country, achieved 19.1 t/ha, with 1.32 t/ha more than the average of the species (7.42%). The species *Artemisia argyi* and *Artemisia abrotanum* exceeded the average of the species by 0.50 t/ha and 0.10 t/ha, respectively - that is -2.76 and -0.55%, respectively. The species *Artemisia austriaca* and *Artemisia pontica* were well below the average of the species, with 7.20 and 6.90 t/ha respectively minus, i.e. 39.8 and 38.12%. The comparison with the control *Artemisia absinthium* showed, on the one hand, the good production of this species, compared to six other species classified under it, which gave yields with 0.5-8.2 t/ha lower (-2.62% to -42.9%), the smallest difference, with an almost equal production, recording *Artemisia argyi*, and the largest, *Artemisia austriaca* with more than 8 t/ha minus (-42.9%), followed by *Artemisia pontica* (-41.6%). However, there are two species that are much more productive than *Artemisia absinthium*, namely *Artemisia lancea* and *Artemisia lavandulaefolia*, which exceeded it by 7.1 t/ha and 6.3 t/ha, respectively (37.2% and 33%). The higher biomass production can also be explained by the higher size of the plants of the species *Artemisia lancea* and *Artemisia lavandulaefolia* in compared to the control *Artemisia absinthium*. They quickly adjusted to the much more favorable conditions in Iasi and reacted positively, especially to the fertility of the soil. From this it can be deduced that they may be of interest to be cultivated, even more than *Artemisia vulgaris* or *Artemisia absinthium* which are cultivated in Romania.

CONCLUSIONS

Research has shown that *Artemisia lancea* and *Artemisia lavandulaefolia* have a significantly higher production than the control *Artemisia absinthium*. This is mainly due to the direct correlation between plant height and grass production, high-altitude species (*Artemisia lancea* and *Artemisia lavandulaefolia*), with the best production. The current results require new research on the content of active substances useful for the pharmaceutical or food industry and then the development of cultivation technology of the two species *Artemisia lancea* and *Artemisia lavandulaefolia* under the local climate and soil conditions in Romania.

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INFLUENCE OF SOWING DATE ON THE MORPHOLOGICAL CHARACTERS AND YIELD COMPONENTS ON SUNFLOWER HYHBRIDS

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Abstract

Three sunflower hybrids: F708 (H1), HF 7104 (H2) and FD18E41 (H3) were sown at three different sowing dates (SD): 10 March (SD1), 25 March (SD2) and 10 April (SD3) in order to determine the influence of sowing date on the morphological characters and yield components. Research was performed in the field experiments in Tulcea county in 2020 under rainfed conditions. The highest values for head diameter, plant population, 1000-seed weight, seed yield and hectolitre mass were obtained at SD2. Between the hybrids H3 had the highest yield - 2029.67 kg ha^{-1}. At the interaction between sowing date and hybrid the highest no. of leaves/plant was for SD1H2 (17.8) while the great head diameter was for SD2H1 (16.61 cm). H1 and H2 had their high yield at SD2 (2288 kg ha^{-1} and 1799.3 kg ha^{-1}) while H3 at SD3 (2566.3 ha^{-1}).

***Key words**: sowing date, sunflower, hybrids, yield components.*

INTRODUCTION

Sunflower (*Helianthus annuus* L.) is the main oil crop in Romania being cultivated on 1.17 million ha in 2020 (retrieved from: https://www.madr.ro/culturi-de-camp/plante-tehnice/floarea-soarelui.html). Sunflower is a temperate zone crop, which can behave well under different climatic and soil conditions (Canavar et al., 2010). In Dobrogea (Tulcea and Constanta counties) which is an arid region, sunflower is cultivated on about 1/5 of the total agriculture area of Romania (Manole et al., 2019).

Although sunflower is a better adapted crop to water stress than other crops, the main factors affecting sunflower production in rainfed conditions are irregular and inadequate amount of precipitation during the growing season (Agele, 2003; Olowe, 2013). The different growing factors (environmental and technological factors) influence strongly the yield and the yield components of the head for each sunflower hybrid (Ion et al., 2015).

One of the most important factors for a high and stabile yield is sowing date. An early sowing can avoid the dry atmosphere and water deficiency during flowering and seed filling stages but on the other hand the emergence can be extended and different weeds (*Poygonum convolvulus* L., *Sinapis arvenis* L., *Chenopodium album*) can cause problems (Vranceanu, 1974). When planting is delayed soil moisture gained during winter season can be inefficient valued due to evapotranspiration, the crop did not have enough time to fill achenes (Killi & Altunbay, 2005) and the yield decreased owing to high temperature during flowering (Ahmed et al., 2020).

Across the climatic regions it turns out that the optimum sowing time for sunflower vary really much, from February (El-Saied et al., 1989) – August (Lawal et al., 2011) to November (Ahmed et al., 2015). The results from one climatic region are not available to be implemented to a different one due to natural conditions. Thus studies like these have to carry out from time to time in all climatic regions and provide the needed information for farmers.

Studies proved that beyond the influence over yield, sowing time influence also the emergence, flowering time, plant high, number of leaves, stem diameter, oil content (Petcu et al., 2010), dry matter (Sofield, 1977; Ahmed, 2015), fertile/infertile seeds (Baghdadi et al., 2014), or head diameter (Allam et al., 2003).

The aim of this research was to examine how different sowing dates influence morphological characters and yield components of different sunflower hybrids in the climatic conditions specific for Dobrogea area in 2020.

MATERIALS AND METHODS

Plant material and field trials. The experiment was carried out in the field experiments in the South of Tulcea county (Beidaud - 44°42' N latitude and 28°34' E longitude) during 2020 on a chernozem argiloiluvial soil under rainfed conditions. The sunflower hybrids used were: F708 (H1), HF 7104 (H2) and FD18e41 (H3), bred at the National Agricultural Research and Development Institute Fundulea. They were sown at three different sowing dates (SD): 10 March (SD1), 25 March (SD2) and 10 April (SD3). Sowing density was 55,000 plants ha^{-1}. The space between rows was 70 cm. The plot size was 560 m^2 (5.6 m x 100 m). The previous crop was winter wheat. A hoeing was used to reduce weeds infestation before inflorescence being visible.

Morphological characters and yield components. At maturity from each plot a number of five representative sunflower heads (taken from average plants) in three replications were analysed for determining head diameter, number of seeds per head and 1000 - seeds weight (g). Number of green leaves was determined for 10 plants in three replications at the flowering stage. Plant density was determined by counting the plants within 28 m^2 (10 linear meters for 4 rows) in three replications. It was also determined hectolitre mass (kg hL^{-1}). The yield (kg ha^{-1}) was calculated using formula = no. of heads per ha*no. of seeds per head*1000 seeds weight (g)/1000*1000. The results were adjusted at 9% moisture content. The grain (achene) moisture was determined using a moisture analyser (Pfeuffer Helite).

Weather conditions. At Beidaud area for the sunflower growing period (March-August), the mean temperature has increased continuous from 7.7°C (March) to 23.9°C (August). The sum of rainfall for the same period was 115.2 mm insufficient for covering the sunflower water requirements for a good development which is over 400 mm (Pejic et al., 2009). Rainfall was irregular during the months of sunflower vegetative period (Figure 1).

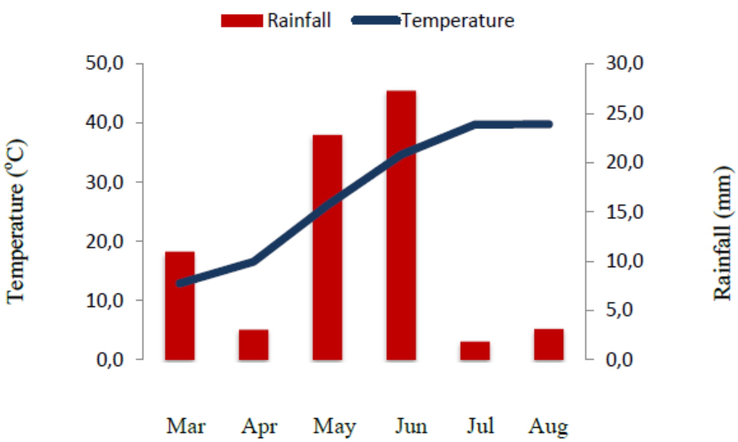

Figure 1. Average temperature (°C) and monthly distribution of rainfall (mm) during the sunflower growing season

Statistical analysis. Collected data were statistically analysed by ARM-9 software using Tukey's HSD (Honestly Significant Difference) test (P< 0.05).

RESULTS AND DISCUSSIONS

Tukey's HSD test (P< 0.05) was performed in order to determine if there are significant differences between the sowing dates and sunflower hybrids (Table 1). Taking into account one by one the factors: sowing date and hybrid, there were not statistical differences for all traits assessed with one exception (no. of leaves/plant between hybrids).

The plants sowed at SD1 had the highest no. of leaves/plant. A possible explication for this is that an early sowing leads to a longer growing season. Similar results were obtained by Ahmed et al. (2015). Among hybrids, the average no. of leaves/plant varied from 15.47 (HF 7104) to 11.53 (FD18E41). This morphological character is influenced by the genetic potential same as head diameter.

Head diameter had higher values at SD2 (15.02 cm) followed by SD3 (14.76 cm). In most researches head diameter had the great values in SD1 (Miller, 1984; Allam, 2003; Lawal et al., 2011; Ozturk et al., 2017; Demir, 2019).

As in this experiment and other researches show that this character is directly proportional with the no. of seeds/head (Birck et al., 2016), yield (Lawal et al., 2011) and hectolitre mass.

Plant population can suffer in late sowing due to a less amount of rainfall available. In SD3 plant population was less with 6389 plants ha^{-1} than in SD2 and less with 4841 plants ha^{-1} than in SD1. Among hybrids it varied from 44642 plants ha^{-1} (FD18e41) to 35992 plants ha^{-1} (F708).

Between sowing dates no. of seeds/head increased constant alongside with the delay of sowing and between hybrids FD18E41 had the great no. of seeds/head (1207.33). This trait is influenced by the level of temperature and radiation conditions around anthesis, during and immediately after floral differentiation (Cantagallo & Hall, 2000; Chimenti et al., 2001).

Sowing on 25 March produced heavier seeds while sowing on 10 April produced lighter seed weight from 38.94 g (1000-seed weight) to 34.68 g (1000-seed weight).

Due to a lack of precipitations during the winter season the yield for SD1 had the lowest value - 1446.3 kg ha^{-1}. After 10 March the rainfall helped the plants to develop better thus for SD2 the yield was 2107.3 kg ha^{-1}. For SD3 the high temperature occurred during flowering stage lead to a decrease of the yield - 1816.7 kg ha^{-1}. In other studies the yield decreased when the sowing was delayed due to a shortened growing season (Allam et al., 2003; Lawal et al., 2011; Ahmed et al., 2020). Over the sowing dates FD18E41 seems to be the most suitable for this area with a yield of 2029.67 kg ha^{-1} (Table 1).

The interaction between sowing date and hybrid showed that there were no statistic differences on plant population and hectolitre mass. The highest no. of leaves/plant was for SD1H2 (17.8) while the great head diameter was for SD2H1 (16.61 cm). According to Balalic et al. (2016) head diameter is influenced by the abiotic factors on the year of production (temperature, amount and distribution of rainfall) but it is mostly influenced by the hybrid.

The highest no. of seeds/head (1660.33) and yield (2566.3 kg ha^{-1}) was for SD3H3. H1 and H2 had their high yield at SD2 while H3 at SD3 (Table 2). In Romania for 2020 the average yield for sunflower was 1,880 kg ha^{-1} (retrieved from: https://www.madr.ro/culturi-de-camp/plante-tehnice/floarea-soarelui.html).

CONCLUSIONS

Plant population decreased once with the sowing delay from 41745.7 (plants ha^{-1}) to 36904.7 (plants ha^{-1}). Between sowing dates, sowing at 25 March has given the highest seed yield. FD18E41 hybrid behaved the best in Beidaud area due its genetic characteristics. The higher yield was obtained with FD18E41 hybrid sowed at 10 April. Similar researches have to be repeated at specific periods due climate change in all climatic regions.

Table 1. Effect of sowing date and hybrid on morphological characters and yield components during 2020 sunflower growing season

	No. of leaves/plant	Head diameter (cm)	Plant population (plants ha^{-1})	No. of seeds/head	1000-seed weight (g)	Seed yield (kg ha^{-1})	Hectolitre mass (kg hL^{-1})
SD1(10 March)	15.93-	14.28-	41745.7-	800.57-	36.48-	1446.3-	40.96-
SD2 (25 March)	11.57-	15.02-	43293.7-	1172.88-	38.94-	2107.3-	43.36-
SD3 (10 April)	11.40-	14.76-	36904.7-	1246.66-	34.68-	1816.7-	42.40-
Tukey's HSD P< 0.05	4.90	4.55	10241.18	694.16	9.82	1239.84	8.90
Standard Deviation	1.68	1.56	3524.28	238.88	3.38	426.67	3.06
H1 (F708)	12.91b	15.54-	35992.00-	1062.44-	39.68-	1753.00-	39.68-
H2 (HF 7104)	15.47a	14.72-	41309.34-	950.36-	34.10-	1587.67-	42.30-
H3 (FD18e41)	11.53b	13.82-	44642.67-	1207.33-	35.71-	2029.67-	44.76-
Tukey's HSD P< 0.05	2.49	4.55	10241.18	694.16	10.04	1239.84	8.90
Standard Deviation	0.85	1.56	3524.27	238.88	3.45	426.66	3.06

Different letters in columns differ at significant difference according to Tukey's HSD test; P< 0.05
"-": no significant difference

Table 2. Effect of interaction between sowing date and hybrid on morphological characters and yield components during 2020 sunflower growing season

	No. of leaves/plant	Head diameter (cm)	Plant population (plants ha^{-1})	No. of seeds/head	1000-seed weight (g)	Seed yield (kg ha^{-1})	Hectolitre mass (kg hL^{-1})
SD1H1	15.87ab	15.94ab	33214.3-	821.00c	43.30a	1557.0ab	41.93-
SD1H2	17.80a	14.95abc	46190.3-	749.73c	34.40bc	1493.3ab	37.57-
SD1H3	14.13bc	11.95d	45833.3-	831.00c	31.77c	1288.0b	43.40-
SD2H1	12.73cd	16.61a	39404.7-	1368.67ab	40.10ab	2288.0ab	39.50-
SD2H2	14.00bc	14.68abc	42023.7-	1019.33bc	37.80abc	1799.3ab	44.67-
SD2H3	11.00de	13.78cd	48452.7-	1130.67bc	38.93abc	2234.7ab	45.93-
SD3H1	10.13de	14.06bc	35357.3-	997.67bc	35.63abc	1413.3b	37.60-
SD3H2	14.60bc	14.51bc	35714.3-	1082.00bc	32.00c	1470.7b	44.67-
SD3H3	9.47e	15.71abc	39643.0-	1660.33a	36.43abc	2566.3a	44.93-
Tukey's HSD P< 0.05	2.72	1.96	18243.72	417.63	7.83	1073.54	14.66
Standard Deviation	0.93	0.67	6280.61	143.77	2.69	369.58	5.047

Different letters in columns differ at significant difference according to Tukey's HSD test; P< 0.05
"-": no significant difference

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BIODIVERSITY AND ADAPTABILITY OF SOME AGRICULTURAL PLANTS USED AS TECHNOLOGICAL ELEMENTS IN THE PRACTICE OF THE DRY-FARMING WORK SYSTEM IN SOUTHEAST AREA OF ROMANIA

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Abstract

Global warming has become a problem in many areas. The orientation of farmers towards an agriculture adapted to drought conditions, which uses dry-farming systems, allows the responsible and sustainable management of agricultural lands, without fragmenting habitats and contributing to the extinction of some species of flora and fauna. The survival of some species with a role in biodiversity for agricultural crops, the adaptability of some of them in dry areas and the improvement to create different hybrids with resistance to increasingly aggressive environmental factors, is due to this type of agriculture and to the new directions in specialized research. The study was conducted as an open-field experience, in the southeastern part of Romania, at the Agricultural Research and Development Station, Braila. The research started with the agricultural year 2019 but its climatic conditions were registered as excessive, which is why the capitalization of the results was made only for the agricultural year 2020-2021. Of the 7 cultivated plant species that do not normally fit into the crop plan in the study area, only three species (flax, sorghum, mustard) coped with climate stress and could be analyzed qualitatively and quantitatively.

Key words*: biodiversity, adaptability, dry-farming, climate stress, alternative species.*

INTRODUCTION

Classical agriculture has produced over time, through the application of cultivation schemes and intensive work, the degradation of the soil and the environment (Derpsch, 2001). Heavy machinery, inadequate soils (overmuch humidity) and over-exploitation of agricultural land, caused the erosion of the soil surface layer generating its loss of fertility, compaction, destruction of porosity (Lipiec et al., 2005) and reduction of degrading organisms that by their nature produce organic matter (Somasundaram et al., 2020) in the soil, necessary for plant nutrition. Agriculture, the main and secondary products of field crops, biodiversity and pedo-climatic conditions form an indispensable mutual link for humans and animals. For this reason, the main concern is to protect nature by all possible means, using environmentally friendly technological sequences. Protecting and restoring ecosystems has a positive impact on the environment, agricultural production and farmers' profits. These are the reasons why the dry-farming system, together with conservative agriculture, is gaining momentum in plant cultivation. Through minimally invasive tillage and the "recycling" of plant debris remaining after crop harvesting (Kassam et al., 2018), the quality of the soil (De Almeida et al., 2018) and the environment (Palm et al., 2014) improves over the years, resulting in higher yields (Dumanski et al., 2006) and reduced negative impact.

The crop of *Cannabis sativa* L. can be used in food industry (seeds), building materials (woody part of the stem) industry, textiles and pharmaceuticals industries. Due to its morphological characteristics, this plant has no natural parasites, suppresses weed growth (which is why it´s unnecessary to apply herbicides), creating a favourable microclimate for pollinating insects at the inflorescences level and attracting them by the odours emitted (Sorrentino, 2021) therefore favouring the distribution of pollen to the neighbouring flora. Hemp is a large plant that consumes CO_2, releasing less gas into the atmosphere, which is why it grows rapidly and develops a biomass three times higher than flax plants. To obtain an amount of 8-12 t/ha hemp biomass, it consumes 10-15 t CO_2 (Sorrentino, 2021). It has also been shown to produce more biomass when fertilized with urea, as it is eliminated more slowly than ammonium nitrate fertilizers, which are harmful to the environment due to the nitrogen oxide which has stronger greenhouse effect than carbon dioxide.

The crops of *Linum usitatissimum* L. and *Ricinus communis* L. are especially used in the production of edible oil. Castor is a plant that can withstand strong radiation, drought and heat conditions very well (Diaz-Lopez et al., 2020). *Sinapis alba* L. is a quality plant for animal feed but can also be used as a biofuel, with zero CO_2 emissions (Mikic et al., 2009). *Sorghum bicolor* M. is suitable for those cultivation areas with rainfall deficit. It is 95% cultivated for animal feed and only 5% for the production of ethanol, a less polluting oil substitute, which results from the fermentation of starch (Zhan et al., 2003). *Sorghum sudanense* L. is considered a weed in agricultural crops but cultivated as such, it is used in animal feed and bioenergy production due to its qualities, especially the large amount of biomass (Venuto & Kindiger, 2008), being also a plant that withstands the stress caused by environmental factors. *Panicum milliaceum* L. is also grown for animal feed. Corn, sunflower and mustard crops are grown in areas characterized by drought conditions but also in areas with normal conditions in terms of temperature and humidity.

MATERIALS AND METHODS

The agricultural crops studied in the Dry-Farming system are those of hemp (*Cannabis sativa* L.) - Succesiv variety, sorghum (*Sorghum bicolor* M.) - ES Alize hybrid, millet (*Panicum miliaceum* L.) - Marius variety, Sudan grass (*Sorghum sudanense* L.), castor (*Ricinus communis* L.) - Dragon variety, flax (*Linum usitatissimum* L.) - Lirina variety, mustard (*Sinapis alba* L.) - Alex variety, corn (*Zea mays* L.) - DKC 5141 hybrid and sunflower (*Helianthus annuus* L.) - Rustica hybrid, most of which are considered alternative crops for crop rotations in areas with prolonged drought.

The experience was placed within the S.C.D.A. Braila - plot 89 - Chiscani experimental field, during the agricultural years 2019 - 2021. The studies were carried out on the growth, development and production of some plants rarely found in the crop plans of agricultural farms in eastern Romania and on commonly used plants in zonal crops, grown on field processed using minimal work systems.

Straw crops (*Triticum aestivum* L., *Hordeum vulgare* L., *Secale cereale* L., *Triticale* M.), *Zea mays* L., *Helianthus annuus* L., *Sorghum bicolor* M. and *Panicum miliaceum* L. were sown in areas of 100 m^2 (30 m^2/plot - repetition), where five types of works of dry-farming system were applied (plowing, paraplowing, scarification, heavy-disk, no-tillage). In comparison, crops of flax, hemp, mustard, Sudanese grass and castor, together with maize, sunflower and sorghum, were sown on areas of 30 m^2 (10 m^2/plot - repetition), on a land cultivated by classic plowing system. Observations and measurements were made on the biometrics of the plants, on the quantity and quality of the seeds obtained, depending on the soil works and the phytotechnical characteristics of the plants, according to the specialized literature.

RESULTS AND DISCUSSIONS

The agricultural year 2019 - 2020 was one of heat and drought. The average annual temperature of 13.3ºC exceeded the multiannual temperature of 10.9ºC, by 2.3ºC. Precipitation was 221 mm lower the multiannual average of 442 mm (Table 1). This was reflected in the crops of straw, hemp, Sudanese grass and castor, which produced insignificant yields.

The agricultural year 2020-2021 was also hot but it accumulated precipitation about 40% above the multiannual average of 442 mm

(Table 2). Compared to the previous year, the deviation of the average annual temperature (12.4ºC), compared to the multiannual one (10.9ºC), was 1.5ºC. The accumulated annual rainfall was 618 mm, with a deviation of +176 mm from the annual multimedia (442 mm).

Table 1. The thermal and pluviometric regime of the agricultural year 2019-2020, at S.C.D.A. Braila

Climate conditions 2019 - 2020						
Month	**Average air temperatures (°C)**	**Multiannual monthly average**	**Deviation from multiannual T (°C)**	**Precipitations (mm)**	**Multiannual monthly average**	**Deviation from the multiannual precipitation average (mm)**
IX	18,5	11,5	7,0	1	32	-31,0
X	13,2	5,6	7,6	23,9	30	-6,1
XI	10,2	0,6	9,6	8,7	33	-24,3
XII	3,9	-2,1	6,0	14,3	36	-21,7
I	0,9	-0,2	1,1	4	28	-24,0
II	4,6	4,7	-0,1	28	27	1,0
III	8,7	11,2	-2,5	2,6	26	-23,4
IV	11,9	16,7	-4,8	4,6	35	-30,4
V	16,4	20,9	-4,5	45,8	48	-2,2
VI	22,0	22,9	-0,9	30,1	62	-31,9
VII	24,4	22,1	2,3	54,8	46	8,8
VIII	24,6	17,3	7,3	3,1	39	-35,9
Average	**13,3**	**10,9**	**2,3**	**221**	**442**	**-221**

Table 2. The thermal and pluviometric regime of the agricultural year 2020-2021, at S.C.D.A. Braila

Climate conditions 2020 - 2021						
Month	**Average air temperatures (°C)**	**Multiannual monthly average**	**Deviation from multiannual T (°C)**	**Precipitations (mm)**	**Multiannual monthly average**	**Deviation from the multiannual precipitation average (mm)**
IX	20,3	11,5	8,8	39,5	32	9,5
X	15,1	5,6	9,5	26,5	30	-6,5
XI	5,7	0,6	5,1	24,5	33	-11,5
XII	4,7	-2,1	6,8	67,7	36	39,7
I	2,2	-0,2	2,4	41,2	28	14,2
II	2,4	4,7	-2,3	7,4	27	-18,6
III	4,7	11,2	-6,5	31,4	26	-3,6
IV	9,4	16,7	-7,3	53,3	35	5,3
V	16,7	20,9	-4,2	75,8	48	13,8
VI	20,2	22,9	-2,7	173,8	62	127,8
VII	23,9	22,1	2,7	40,4	46	1,4
VIII	23,4	17,3	6,1	36,7	39	4,7
Average	**12,4**	**10,9**	**1,5**	**618**	**442**	**176**

The height of *Zea mays* L. plants was between the range of 150-300 cm in all types of soil works (Table 3). The crop sown on the plot prepared by heavy-disk work, had the smallest average size, while on the plot prepared using the scarifier, it had the largest average size. These differences show that the root system of *Zea mays* L. plants prefers loose soils both at the surface where germination takes place and at greater depths.

The plants of *Helianthus annuus* L. have exceeded the upper limit of the size specified in the literature, on those plots prepared with the plow, the paraplow and the scarifier, which indicates that the worked soil at greater depths than 25 cm, allows the deep penetration of the root system, thus accessing the depleted water sources in the surface layer of the soil (Table 3). On the plot prepared with the heavy-disc and on the no tillage plot, sunflower presented average heights between 130 and 175 cm, reacting well to them as well. *Sorghum bicolor* M. on the other hand, did not reach the minimum plant height, described in the literature (Table 3).

The insertion height of the *Zea mays* L. cobs did not fall within the range according to the literature, but this depends on the characteristic of the hybrid, environmental factors and other parameters (Table 4). It should be noted, however, that the insertion heights were different depending on the soil work. On the scarified plot, due to the hight, the insertion point of the cob was also higher. Although in the paraplowed plot the plants were taller than those on the heavy-disk plot, the insertion point of the cob was lower. Compared to the plowing work, the insertion point of the cob was also lower although the plants had similar heights.

The calatidium of *Helianthus annuus* L. plants was larger in diameter than of the plants grown on scarified and heavy-disk prepared soils. These observations show that sunflower grows best on loose soils at greater depths (Table 4).

Table 3. Biometric measures of crops, depending on soil tillage and literature

Crop	Average height (cm)					Phytotechnical features in the literature
	Plow	Paraplow	Scarification	Heavy Disc	No Tillage	
Zea mays L.	212,17	212,00	228,67	190,33	208,67	150 - 300
Helianthus annuus L.	190,67	198,00	182,67	168,00	165,33	130 - 175
Sorghum bicolor M.	120,00	116,67	116,33	97,67	120,33	150 - 300

Table 4. Biometric measures of propagating organs, depending on soil tillage and literature

Indicator	Plow	Paraplow	Scarification	Heavy Disc	No Tillage	Phytotechnical features in the literature
Insert height of the *Zea mays* L. cob (cm)	77,09	55,00	84,50	63,33	70,00	100 - 130
Diameter of *Helianthus annuus* L. calatidium (cm)	19,33	18,67	23,00	22,33	19,33	10 - 40

Cannabis sativa L. showed a much smaller size than the lower limit of the range in the literature (Table 5). This may be due to pedo-climatic factors and applied technology sequences. *Sorghum sudanense* L. and *Ricinus communis* L. have developed much higher sizes than those described in the literature, so that the soil prepared by the classical-plow system, together with the pedo-climatic conditions specific to the study area, are favorable for these crops, stimulating the intense growth of biomass. The *Sinapis alba* L. crop behaved the same way, with an average plant hight above the maximum limit of the specific range, proving that it can be suitable for cultivation in the study area.

Table 5. Biometric measurements of poorly cultivated agricultural plants in the eastern part of Romania

Crop	Plant height (cm) / repetitions			Average height (cm)	Phytotechnical features in the literature
Cannabis sativa L.	128	123	164	138,33	180 - 320
Sorghum sudanense L.	285	300	310	298,33	150 - 200
Ricinus communis L.	230	215	245	230,00	100 - 150
Linum usitatissimum L.	55	60	53	56,00	55 - 75
Sinapis alba L.	112	93	117	107,33	60 - 100

In favourable conditions of plant growth and development, *Linum usitatissimum* L. plants can produce a yield between 1000 and 1100 kg/ha. As can be seen in Table 6, the average production exceeded by 46.5 kg/ha the upper limit described in the literature, confirming the adaptability of the crop to the conditions of the eastern part of Romania. However, the quality of the seeds was not optimal, the TGW being slightly below the limit of 7-8.5 and the specific weight with 9.7 kg/hl below the lower limit of 75 kg/hl.

The average crop yield of *Sinapis alba* L. was 767 kg/ha (Table 7). In optimal cultivation conditions, *Sinapis alba* L. can produce yields between 1000 - 1500 kg/ha. The quality indices were also below the optimal limits of 6.3 g in terms of TGW and 68 kg/hl regarding the specific weight.

Straw grain production was on average 2800 kg/ha in the agricultural years 2019 - 2021 (Figure 1), being affected by the excessive drought of 2019-2020, when they recorded productions with 1586.4-2284.2 kg/ha lower than those obtained in the agricultural year 2020-2021 (Figure 2). *Zea mays* L., *Helianthus annuus* L. and *Sorghum bicolor* M. have been shown to be particularly resistant to the lack of rainfall due to their morphological characteristics, in particular of the pivoting root system, which allowed them to access soil water at greater depths.

Table 6. Flaxseed crop yields and quality indices in the agricultural year 2020-2021

Flaxseed (*Linum usitatissimum* L.)					
Repetition	Yield (kg/10 m.p.)	Production (kg/ha)	U %	MH (kg/hl)	MMB (g)
1	0.92	936.18	7.4	62.8	6.86
2	1.16	1179.12	7.5	64.9	7
3	1.3	1324.29	7.3	65.2	6.94
Average	1.13	1146.53	7.40	64.30	6.93

Table 7. Mustard crop yields and quality indices, in the agricultural year 2020-2021

Mustard (*Sinapis alba* L.)					
Repetition	Yield (kg/10 m.p.)	Production (kg/ha)	U%	MH (kg/hl)	MMB (g)
1	0.78	769.71	10.2	61.8	5.72
2	0.64	635.08	9.7	65.8	6.33
3	0.9	897.03	9.3	65.6	5.48
Average	0.77	767.27	9.73	64.40	5.84

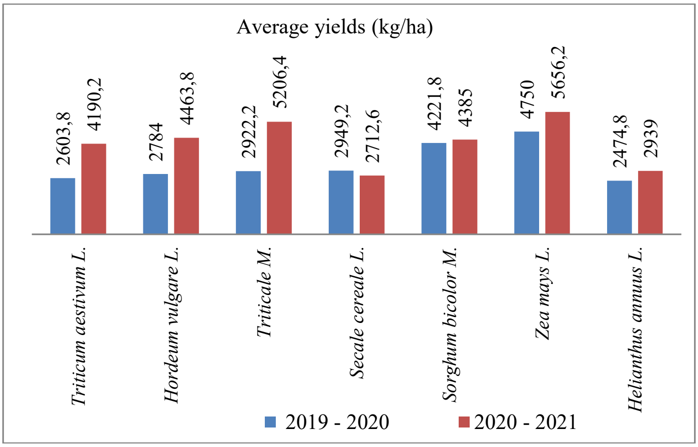

Figure 1. Average yields of crops, in the agricultural years 2019-2021

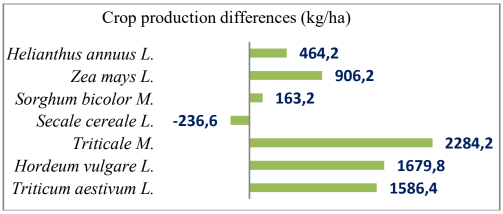

Figure 2. The differences in crop production, between the agricultural years 2020-2021 and 2019-2020

CONCLUSIONS

The drought of the agricultural year 2019-2020 had a negative impact on most crops, especially on straw crops that produced insignificant yields. The adaptability of the less common crop plants to the agricultural cultivation schemes of the Eastern area of Romania, regarding the yield, was achieved by *Linum usitatissimum* L. and *Sinapis alba* L. crops, in the agricultural year 2020-2021. *Sorghum bicolor* M has produced almost equal yields in both years, which proves that it is a crop plant resistant to climate change. *Sorghum sudanense* L., *Ricinus communis* L. and *Sinapis alba* L. responded positively in terms of biomass development to the amounts of rainfall accumulated in the second year of the study. *Helianthus annuus* L. has developed well in the deep loosened soil, on plots where plowing, scarifying and paraplow works were applied. *Zea mays* L. plants had a lower insertion height of the cob compared to the interval described in the literature, but this may be due to several factors related to both the genetic characteristics of the hybrid and pedo-climatic factors. In both years, both *Zea mays* L. and *Helianthus annuus* L. crops recorded stable yields despite the variability of climatic factors.

In terms of seed quality, *Linum usitatissimum* L. and *Sinapis alba* L. did not show significant differences compared to the specific optimum values. The insertion of *Cannabis sativa* L., *Sorghum sudanense* L., *Ricinus communis* L., *Linum usitatissimum* L. and *Sinapis alba* L. in the agricultural crop plan may be a beneficial alternative to soil, biodiversity of agricultural species and agricultural land use, where ordinary crops are no longer suitable in the new climatic context. The system of dry-farming works is not suitable for all agricultural crops, which is why it is important to continue the study, in order to alternate at certain periods of time, the minimum system of soil works with the classic one, especially for crop plants which have a penetrating and pivoting root system. At the same time, observations must be made over several years to cover a wide range of climatic conditions.

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EFFECTIVENESS OF BIOSTIMULANTS APPLIED TO WHEAT, SUNFLOWER AND SOYBEAN CROPS

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Abstract

It is known that the application of organic substances has effects to stimulate the development of plants. The paper presents the effect of two plant biostimulants (FERT - H and FERT - A) with organic matter of vegetable origin (protein hydrolyzate, respectively seaweed extract) on quality and production indicators for wheat, sunflower and soybean crops. The plant biostimulants were tested for three years by foliar application both in the experimental field in a wide range of crops, obtaining statistically significant and very significant yields compared to the unfertilized control. The obtained yields ranged between 50-60% for wheat, 8-9% for sunflower and 24-38% for soybean. Although there were differences in production between the two biostimulators, these were not significant. The plant biostimulants with natural organic matter (algae and soy hydrolysate) that were used can influence crop nutrition leading to increased product quality.

***Key words**: plant biostimulants, protein hydrolysate, seaweed extract, foliar application.*

INTRODUCTION

In the context of the Community's agricultural policy and the principles of the circular economy, we consider it is necessary to identify alternative sources (waste or by-products) which, with minimal processing, could be sources of nutrients (especially nitrogen, phosphorus potassium and trace elements) that can be used as a fertilizer in both organic and conventional agriculture.

The use of organic substances with crop stimulating effects in agriculture is necessary and encouraging in the context of European sustainable development policies. The application of biostimulants by spraying on plants, leads to the accumulation of a higher content of nutrients in their tissue and to positive metabolic changes. For these reasons, the development of new biostimulants has become a point of scientific interest (Nardi et al., 2016; He et al., 2018; Bulgari et al., 2019).

Algae extracts, humic and fulvic acids, protein hydrolysates and microorganisms have many positive effects on plants, namely: increasing production, intensifying photosynthesis, increasing the rate of absorption and utilization of nutrients, increasing resistance to biotic and abiotic stress (Van Oosten et al., 2017; Colla et al., 2015). These biostimulants can be officially used as fertilizers, which are regulated in the EU by Regulation (EU) 1009 of 2019.

Numerous studies have shown the beneficial effects of algae, useful as plant biostimulators (Hong et al., 2007; Zodape et al., 2008) and soil improvers (Jayaraj et al., 2008) on plant nutrition. Algae-based products improve seed germination, increase plant tolerance to environmental factors, and increase plant yield and quality (Zhang et al., 2008; Zodape et al., 2008).

A number of studies have shown that algae extracts have supported the development of the root system and lead to increased production in many plant species: corn (Jeannin et al., 1991), tomatoes (Crouch et al., 1992; Dobromilska et al., 2008; Kumar and Sahoo, 2011; Goñi et al., 2018; Di Stasio et al., 2018), vines (Mancuso et al., 2006), strawberries (Alam et al., 2013), and wheat (Kumar and Sahoo, 2011).

The result of the process of hydrolysis of products of plant or animal origin is divided into two categories: protein hydrolysates (a mixture of polypeptides and amino acids of plant or animal origin) and free amino acids (proline, valine, leucine) (Van Oosten et al., 2017). Such compounds are, in fact, a mixture of soluble amino acids and peptides, resulting from enzymatic, thermal and chemical processes, obtained from proteins of animal or vegetable origin (Carillo et al., 2019; Colla et al., 2015; Shahrajabian et al., 2021).

There is considerable evidence that protein hydrolysates and certain amino acids (proline, betaine but also their precursors and derivatives) increase plant tolerance to abiotic stress (drought, high or low temperatures, salinity, oxidative conditions) (Ertani et al., 2009; Colla et al., 2014; Colla et al., 2017; Shahrajabian et al., 2021).

In the last two decades, interest in this type of product has grown steadily, as short-chain peptides in protein hydrolysates have been shown to have a higher nutritional value and can be used more efficiently than an equivalent mixture of free amino acids (McCarthy et al., 2013).

Amino acids and peptides play an important role in increasing plant tolerance to heavy metals through the sequestration process that allows them to survive in areas contaminated with metals without suffering toxic effects (Singh et al., 2016).

Phytochelatins are organic polymers related to metals and plant products and are a class of phytochemicals that can reduce the toxic effects of metals on human health (eg cadmium) (Seregin and Kozhevnikova, 2020).

The paper presents the development of new fertilizers starting from natural substances and products accepted by European regulations for use in organic farming. The selected natural substances were from the class of biomaterials with biostimulatory properties, namely: protein hydrolysates from biomass and /or extracts from algae (*Ascophyllum nodosum*).

It has been suggested that organic substances in the composition of biostimulators may help plants to overcome the abiotic and biotic stresses (Battacharyya et al., 2015; Balabanova, 2021; Neshev, 2020).The new biostimulant products are characterized by a complex structure due to natural organic substances with biostimulatory effect, enriched with trace elements in chelated structures (Mg, Mn, Fe, Cu, Zn, B and S), and are intended to stimulate plant nutrition and growth, root activity and prevention and control of nutritional deficiencies.

MATERIALS AND METHODS

Two biostimulators were selected to evaluate the effects of their application on 3 test crops: wheat, sunflower and soybeans. The compositional characteristics of the biostimulators were: FERT-H product including a hydrolysed soy protein, matrix containing secondary elements and microelements and FERT-A including an algae extract (*Ascophyllum nodosum*), matrix containing secondary elements and microelements.

For each crop, 3 foliar treatments were applied during the vegetation period with a concentration of 0.5% and a dose of 2.5 l/ha. The application times for the three crops are shown in Table 1.

Table 1. Experiment characterization and phenological observations

	Winter wheat	Sunflower	Soybean
Variety/hybrid	Trivale	Hybrid PG 4	Raluca TD
Sowing date	22.10.2020	05.05.2021	28.04.2021
Raised date	11.11. 2020	24.05.2021	14.05.2021
Maturity	03.07.2021	14.09.2021	25.09.2021
First treatment application (phenophase)	07.04.2021 (end of twinning)	05.05.2021 (1st pair of leaves)	22.05.2021 (2rd trifoliate leaf)
Second treatment application (phenophase)	28.04.2021 (elongation)	23.05.2021 (4-5 leaves)	29.05.2020 (elongation)
Third treatment application (phenophase)	16.05.2021 (heading)	04.06.2021 (7 leaves)	07.06.2021 (4th trifoliate leaf)
Basal fertilization*	100 kg/ha with complex NPK 20:20:0		

*Basal fertilization was done with complex fertilizer NPK 20:20:0 and 100 kg/ha brought 20 kg/ha N and 20 kg/ha P_2O_5

To determine the effectiveness of biostimulants, the following crops were chosen for testing: winter wheat, sunflower and soybeans. The details of the experiment are presented in Table 1. The determinations of the parameters total biomass, spikes biomass, seeds biomass and 1000 grain weight were performed by weighing and the infrared analysis (Perkin Elmer Inframatic 9500 analyzer) was used to determine protein, starch and wet gluten.

The experiment was developed on albic luvisol with clay texture, having the characteristics presented in the Table 2.

Table 2. Physico-chemical characteristics of the soil

Crops	**Humus**	**Nitrogen**	**Mobile phosphorous (P_{AL})**	**Mobile potassium (K_{AL})**	**C_{org}**	**Mobile forms of cations in solution of ammonium acetate + EDTA at pH = 7**				**pH**
						Zn	Cu	Fe	Mn	
	(%)	(%)	(mg/kg)	(mg/kg)	(%)	(mg/kg)				
Wheat	4.29	0.157	64	208	2.49	1.1	2.0	93.8	30.2	5.35
Soybean	4.53	0.163	83	189	2.63	1.7	2.4	120.4	52.3	5.64
Sunflower	4.71	0.163	58	218	2.73	1.4	2.2	115.0	46.7	5.01

Statistical analysis

Signs following the values in the tables mean significant differences compared to other treatments at levels of p <0.05* p <0.01** according to the tests of the least significant differences (LSD).

RESULTS AND DISCUSSIONS

Wheat (*Triticum aestivum* L.) is one of the largest growing cereal crops worldwide and its fertilization leads to yields that ensure food security.

The application of plant biostimulators to wheat crop has led to an increase in biomass and, implicitly, in the production. Significant increases compared to the unfertilized control were obtained for both the mass of the grains and the spikes (Table 3). Regarding the composition of wheat grain in protein and gluten, Fert-A led to higher values of these parameters than the unfertilized control.

Our results were in line with previous studies by Szczepanek et al. (2018) on the effect of applying seaweed products for wheat. It was also observed that the results obtained are influenced by a number of factors such as the number and timing of applications, soil characteristics, climatic conditions.

The data obtained by Stamatiadis et al. (2021) for wheat crop led to the conclusion that increased soil N uptake and/or remobilization to the reproductive organs was a key process of *A. nodosum* mode of action.

Table 3. Efficacy of FERT-H and FERT-A for wheat crop

Variants	**Total biomass, kg/ha**	**Spikes biomass, kg/ha**	**Seeds biomass, kg/ha**	**1000 grain weight, g**	**Protein %**	**Starch %**	**Wet gluten %**
Control	5520	2650	1730	34.2	7.9	72.7	12.8
FERT - H	7150**	4050**	2770**	35.1*	7.6	74.4	12.2
FERT - A	7730***	3860**	2600**	35.0*	8.0	72.2	14.2

**, *indicates statistical significance at 1% and 5%

It can be seen that the increase in biomass in wheat crops led to the effect of "dilution" in terms of protein content in the case of the variant to which the product FERT - H was applied (Table 3). The results concerning the sunflower crop, except those for 1000-grain weight indicated significant and distinct significant differences between treatments and control variant (Table 4). The results obtained in the case of seed production were significantly higher than the unfertilized control. The differences between the two biostimulants products were not significant.

The use of different doses of a biostimulator based on *Ascophyllum nodosum* has led to increases in root and stem masses corresponding to the concentrations used in treatments (Santos et al., 2019).

Table 4. Efficacy of FERT-H and FERT-A for sunflower crop

Variants	Total biomass, kg/ha	Calatidium biomass, kg/ha	Seeds biomass, kg/ha	1000-grain weigh, g
Control	11600	5333	2890	67.7
FERT - H	11933	6533**	3360*	66.7
FERT - A	13867*	6310*	3320*	65.9

**, *indicates statistical significance at 1% and 5%

The application of the product FERT - A to the sunflower crop led to the increase of calatidium biomass and seeds biomass but to the decrease of the parameter "1000-grain weigh" related to the control (Table 4).
The parameters determined for the application of biostimulants to soybean crop were higher and distinctly statistically significant compared to the unfertilized control (Table 5).
The differences between the two biostimulants were not statistically significant, higher productions being obtained for the FERT-H variant.
Experiments conducted by Briglia et al. (2019) have shown that the application of biostimulators based on various combinations of seaweed and plant extracts formulated with selected micronutrients, such as Mn, Zn, Mo, on the metabolism of soybean nitrogen, transport of metal ions (mainly zinc and iron), sulphate reduction and amino acid biosynthesis were positively regulated.

Table 5. Efficacy of FERT-H and FERT-A for soybean crop

Variants	Total biomass, kg/ha	Pods biomass, kg/ha	Seeds biomass, kg/ha	1000-grain weigh, g	Protein %	Oil %	Fiber %
Control	4767	2780	1480	117	33.8	24.8	5.9
FERT - H	5833**	3460**	2010**	125	35.5	24.8	5.7
FERT - A	5467*	3350**	1880**	119	35.6	25.3	5.6

**, *indicates statistical significance at 1% and 5%

The application of the two biostimulants with organic substances lead to increased production compared to the unfertilized control, that ranged between 50% and 60% for the wheat crop, 8% and 9% for the sunflower, respectively, between 24% and 38% for the soybean. The highest productions were observed in the case of the FERT-H biostimulant variant (Figure 1).

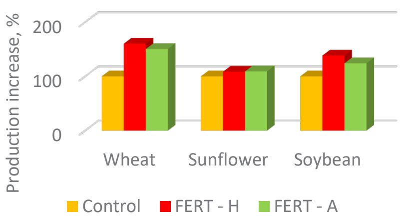

Figure 1. Production increases obtained for wheat, sunflower and soybean crops depending on the biostimulant applied

The production obtained by applying plant biostimulants based on algae (FERT - A) and soy protein hydrolyzate (FERT - H) showed increases for the three crops tested. In the case of sunflower cultivation, production increases were close, i.e. 8% for the product with organic content from algae and 9% for the one based on hydrolyzate. In contrast, in the case of wheat and soybean crops, the highest increase was obtained in the case of the FERT - H variant (60% for wheat and 38% for soybeans).

CONCLUSIONS

The production of wheat, sunflower and soybeans obtained as a result of the application of biostimulants FERT - H and FERT - A led to increases in production compared to the untreated control.
It was noticed, that biostimulators with natural organic matter content (algae/soy hydrolyzate) can influence crop nutrition leading to increased product quality. Some seed quality indices for the three crops declined as production increased, with the phenomenon of dilution occurring.

In conclusion, the application of biostimulators can be considered a sustainable choice in terms of environmental protection but also economic and is a solution in the current crisis of mineral fertilizers.

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COMPARATIVE STUDY OF ESSENTIAL OILS OBTAINED FROM TWO BASIL TAXA

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Abstract

The objective of this study was to evaluate the essential oils (EOs) obtained from two medicinal plants belonging to the genus Ocimum sp. These were compared in terms extraction yield and analysis of EOs compounds using GC/MS (content, chemical composition and quantitative dosage of some compounds: linalool, estragole and eugenol). Ocimum basilicum L., fam. Lamiaceae with 2 cultivars: Yellow basil (Ocimum basilicum L., 'Aromat de Buzău' variety), Purple basil (Ocimum basilicum cv. purpurascens, 'Seraphim' variety) and Holy basil (Tulsi) was used in the experiments. Extraction yields obtained: 5 ml EO/1 kg plant material for Yellow basil, 1 ml EO/1 kg plant material for Purple basil and 0.9 ml EO/1 kg plant material for Tulsi. Twenty-six compounds of the Yellow basil, sixteen compounds of the Purple cultivar and twenty-eight compounds in Tulsi and were identified using GC/MS. Linalool (46.70%-48.52%), Estragole (31.50% for the 'Aromat de Buzău' variety) and Eugenol (13.18% for the 'Seraphim' variety and 35.85% for the Tulsi) were dosed quantitatively and identified as the main and common compounds, for the essential oils obtained from the two species of Basil.

***Key words**: Ocimium basilicum, Ocimum sanctum, yield, essential oils, GC/MS.*

INTRODUCTION

The genus *Ocimum* belongs to the *Lamiaceae* family, commonly called Basil, is known and appreciated for its diversity throughout the world. It includes more than 30 species of plants and shrubs, originating in the tropical and subtropical regions of Asia, Africa, Central and South America (Simon et al., 1999). Basil is an important source of essential oils and aromatic compounds (Simon et al., 1990), it is an attractive culinary and ornamental plant with specific aroma and fragrance (Morales et al., 1996). For the future, a growth of the *Ocimum* essential oil market is expected to grow, from 86.5 million USD from 2019 to 2023, with an annual growth rate of 8%, and Europe will have the largest market share (Technavio, 2019). With such a high market potential, *Ocimum* essential oil, is of particular economic importance to developing countries in terms of foreign exchange earnings (Gurav et al., 2021).
Basil has been classified according to different geographical origins into several chemotypes:
- European chemotype (found in Italy, France, Bulgaria, Egypt, South Africa), with the main compounds linalool and methyl chavicol (estragole);
- Tropical chemotype (found in India, Pakistan and Guatemala), rich in methyl cinnamate;
- Reunion chemotype (found in Thailand, Madagascar, Vietnam), characterized by high concentrations of methyl chavicol (estragole);
- Eugenol-rich chemotype (found in North Africa, Russia) (Simon et al., 1999; Telci et al., 2006).

Among the species of this genus, *Ocimum basilicum* L. - Basil, is cultivated in many countries and is the most important crop for obtaining essential oils worldwide. Basil is used as a medicinal plant, and the essential oil is widely used in the food industry as a flavouring agent and in the perfumery industry. It is considered an important source of aromatic compounds that has a number of biological activities (repellent, insecticides, nematocides), antibacterial and antifungal activity, antioxidant activity (Lee et al., 2005; Telci et al., 2006).

Ocimum sanctum (The Queen of Herbs) has been known and cultivated in India for over 3,000 years. It is known as Tulsi and is considered a sacred plant, with special importance in Ayurvedic medicine (Khair-ul-Bariyah, 2013).

Basil essential oils are complex mixtures that can contain over a hundred chemical compounds. However, only a few of them are found in relatively high concentrations: citral, 1,8-cineole, linalool, methyl chavicol (estragole), eugenol, methyl eugenol and methyl cinnamate, while the mixture and the ratio of the compounds contained give the plant specific aroma (Simon et al., 1990; Korocha et al., 2017). Also, the concentration of the main and secondary compounds, the specific ratio between them is important and can form the basis for the commercial production of the specific essential oil (Zheljazkov et al., 2016).

Three major compounds are found in sweet basil grown in the United States: Linalool (7-59%), Estragole (5-29%) and Eugenol (2-12%).

Linalool is a compound found in many essential oils and has the ability to alter the permeability and function of proteins in the cell membrane (Blejan et al., 2021). Has a wide range of biological activities, it has a sedative effect that helps relieve stress and has neurological effects.

Estragole has a sweet, herbaceous, anise-fennel like smell. It is used in the composition of perfumes offering an aromatic note of fruit and anise.

Eugenol is also used in perfumery, but as a dental medicine (local antiseptic) too.

The essential oil obtained from basil has a good antimicrobial and antioxidant activity, it is a good food preservative. With a strong attractiveness to many insects, it can be used as a potential green insecticide used to control harmful insects.

The aim of this study was to evaluate EOs obtained from two medicinal plants belonging to the genus *Ocimum* (*Ocimum basilicum* and *Ocimum sanctum*). They were compared in terms of extraction yield and analysis of compounds using GC/MS (chemical composition, listing of compounds and quantitative dosing of specific compounds: linalool, estragole and eugenol).

MATERIALS AND METHODS

The biological material was represented by 2 Basil taxa:

- Common basil (*Ocimum basilicum* L.) with two Romanian cultivars: Yellow basil - *"Aromat de Buzău"* variety and Purple basil - *"Seraphim"* variety;
- Holy basil or Tulsi (*Ocimum sanctum* sin. *Ocimum tenuiflorum*), of Indian origin, the cultivar with purple leaves.

The study included varieties that have a relatively high yield of herba, supported by medium-tall plants with a high number of branches. All varieties were grown on experimental plots within INMA Bucharest (Băneasa area), on a reddish brown forest soil, in the climatic conditions of 2019, and the seedlings necessary for the establishment of crops were purchased from SCDL Buzău.

EOs were obtained by hydrodistillation method (distillation with water vapor under pressure) using equipment of French origin. The aerial part of the plants, which were in the flowering phase at the time of harvest, was processed. Extraction yield was calculated using the formula:

$$\text{Extraction yield (ml/kg)} = V/M$$

V = volume of essential oil obtained from the green plant sample (ml);

M = mass of medicinal plant sample (kg).

The chemical composition of EOs, the concentration of the compounds was determined by gas-chromatography coupled to mass spectrometry (GC-MS). The conditions for performing the gas-chromatography were the following: Agilent Technologies gas-chromatograph type 7890 A GC system, MS Agilent Technologies type 5975 C Mass Selective Detector; HP 5MS 30 m x 0.25 mm x 0.25 µm (5% Phetylmethylsiloxane) column; injector temperature 250ºC, detector temperature 280ºC; temperature regime 25^0C

(10 degrees/min) up to 280^{0}C (const. 5.5 min); mobile phase - helium 1 ml/min; injected volume - 0.1 μl essential oil; split ratio - 1:100.

RESULTS AND DISCUSSIONS

Extraction yield of EOs

For processing, the harvested plant material was left to wither for 5 hours, so as to reduce its moisture and volume. However, in order not to diminish the quality of the oil and the extraction yield, the material must be processed within 6-8 hours after harvesting, as an additional delay can cause significant losses. Hydrodistillation was used as method, using a plant of French origin, and the whole process took place at Horting Bucharest. Inflorescences, leafy branches and shoot tips, without foreign and organic bodies, were used for processing; with impurities max. 3% represented by browned or discoloured flowers, content in active substances min. 35%.

From the plant product was obtained using the distillation plant, the hydrolate (mixture of essential oil and flower water). The obtained EOs were decanted and filtered, then stored in dark bottles, in a cool, dry place.

Extraction yields obtained:

- 5 ml oil/1 kg plant material for *"Aromat de Buzău"* variety;
- 1 ml oil/1 kg plant material for *"Seraphim"* variety;
- 0.9 ml oil/1kg plant material for *Tulsi.*

It should be mentioned that both the quantity but especially the quality of the essential oil and the flower waters obtained differ, depending on the variety, the type of soil but also on the agroclimatic conditions in the year of production.

Data from the literature show that for basil varieties in Romania, the level of essential oil in the plant is between 0.2% and 0.6% (Benedec et al., 2009). The yield of essential oil obtained in Bosnia and Herzegovina was 0.4% (Stanojević et al., 2017)

EOs compositions

The biochemical characterization of the three essential oils of basil was performed based on the retention time (RT) and was compared with the main compounds using the Kovats retention rate (Skoog et al., 2004). The compounds of interest (linalool, estragole and eugenol) have been confirmed (Adams, 2007) using standards Linalool (97% purity), Estragole (98% purity) and Eugenol (99% purity), purchased from Sigma-Aldrich and are presented as percentages in Table 1.

Table 1. Quantitative dosing of 3 compounds (Linalool, Estragole, Eugenol) from essential oils obtained from 2 Basil taxa

Compound name[a]	Yellow basil Variety *"Aromat de Buzău"* (g, %)	Purple basil Variety *"Serafim"* (g, %)	Holy basil *Tulsi* (g, %)
Linalool	*46.70*	*48.52*	2.27
Estragole	*31.50*	1.35	2.92
Eugenol	-	13.18	*35.85*

- identification based on the co-injection of high purity compounds

The characterization of the 3 essential oils was done by GC-MS, allowing the identification and quantification of the compounds, and the results are presented as percentages in Table 2.

The chemical composition of the essential oil obtained from Yellow Basil cultivar, *"Aromat de Buzău"* variety is presented in table 2. By means of GC-MS, 26 compounds were identified, representing 99.74% of the total separated compounds. Linalool (27.59%) and Estragole (34.42%) were the major compounds. It should be noted the presence of other compounds as well, but in smaller quantities: Germacrene (4.62%), β-Caryophylene (4.22%), Azulene (3.94%), Isoledene (3.06%). The main classes of compounds identified were: monoterpenes oxygenated (48.96%), monoterpenes hydrocarbons (25.51%), sesquiterpenes (25.07%), but also phenols (0.20%).

Subsequent dosing of the 3 compounds of interest (linalool, estragole and eugenol) using high purity standards showed that Linalool is the major compound with 46.70% and Estragole 31.50%. Eugenol could not be dosed because it was not identified in the chromatogram (Table 2).

The chemical composition of the essential oil obtained from Purple basil cultivar, the *"Seraphim"* variety is shown in Table 2. By means of GC-MS, 16 compounds were identified, representing 99.99% of the total separated compounds. Here, too, the compound Linalool was the majority with 32.56%, followed by β-caryophyllene with 24.83% and Eugenol (12.28%). It should also be noted the presence of other compounds, but in smaller quantities: Eudesmadiene (7.91%), Guaiene (5.94%), Cineole (4.12%), etc. The main classes of compounds identified were: sesquiterpenes (53.76%), monoterpenes oxygenated (33.22%) but also phenols (13.01%).

The dosage of the 3 target compounds (linalool, estragole and eugenol), using high purity standards showed that Linalool is the major compound with 48.52% followed by Eugenol 13.18% and Estragole 1.35% (Table 1).

The chemical composition of the essential oil obtained from *Tulsi* is presented in Table 2. By means of GC-MS, 28 compounds were identified, representing 94.10% of the total separated compounds. Here, the majority compound was β-caryophyllene with 47.16%, followed by Eugenol (23.24%) and Guaia with 10.24%. The presence of the compounds α-caryophyllene (2.45%), Germacrene-D (1.19%), Elemene (1.13%) should be noted, but in a smaller amount. The main classes of compounds identified in Tulsi oil were: sesquiterpenes (70.13%), phenols (20.80%) but also monoterpenes oxygenated (1.68%). The dosage of the 3 compounds followed (linalool, estragole and eugenol), using high purity standards showed that this time the compound Eugenol is the majority compound with 35.85%, and Estragole and Linalool quantitatively, were dosed 2.92% respectively 2.27% (Table 1).

The literature (Qing et al., 2016) mentions that in basil oil were identified over 200 chemicals such as monoterpenes, sesquiterpenes, triterpenes, flavones and aromatic compounds. The major compounds for basil oil include linalool, estragole (methyl chavicol), anethole, eugenol and methyl eugenol, which vary in quantity depending on the chemotype, which also confirms the results obtained in this study. It should be mentioned that for the 2 basil taxa analysed, all three varieties contain in the essential oil the following 6 compounds: cineole, linalool, estragole, β-caryophyllene, germacrene, elemene. But their concentration varies, both between the two basil taxa but also between the analysed varieties. Thus, the concentration for linalool varies from 2.27% in Tulsi, to 46.70% in *"Aromatul de Buzău"* and 48.52% in *"Serafim"*. On the other hand, regarding the Estragole concentration, there are significant differences both between the two taxa (2.92% in Tulsi, but also between the two varieties of Basil (31.50% in the *"Aromat de Buzău"* variety and only 1.35 % in the purple variety *"Seraphim"*. Eugenol was dosed most quantitatively (35.85%) in *Tulsi*, and in the *"Seraphim"* variety the concentration was 13.18%. Another 7 compounds were identified as common (α-Pinene, Cineol, α-, β-Caryophyllene, Germacrene-D, Elemene, Eudesmadiene) in all three essential oils analysed, but in small quantities.

GC/MS analysis of essential oils obtained from the two taxa of basil (leaves and inflorescences), led to the identification of three main classes of compounds:

for the Yellow basil cultivar (*"Aromat de Buzău"* variety), out of a total of 99.74%, the main classes of compounds were oxygenated monoterpenes with 48.96%, monoterpene hydrocarbons with 25.51% followed by sesquiterpenes with 25.07%;

for the Purple basil cultivar (*"Seraphim"* variety) out of a total of 99.99%, the following classes of compounds were identified: sesquiterpenes 53.76%, monoterpenes oxygenated 33.22%, but also phenols 13.01%;

for Tulsi out of a total of 94.10% of the identified compounds, the main classes were 70.13% sesquiterpenes followed by 20.80% phenols.

Based on the study conducted by Zheljazkov in 2016, on 38 essential oils obtained from Basil, according to their composition, they were divided into 7 groups/chemotypes. According to this classification and based on the results obtained and presented in Tables 1 and 2, the basil varieties analysed in this study can be classified as follows:

The Yellow basil cultivar, *"Aromat de Buzău"* variety, can be included in:

Linalool chemotype (19-73%) - with dosed linalool 46.70%;

Chemotype Estragole (8-29%) - Linalool (8-53%) - dosed 31.5% and 46.70% respectively.

Purple basil cultivar, *"Seraphim"* variety:

Linalool chemotype (19-73%) - with 48.52% dosed linalool;

Linalool chemotype (28-66%) - *Eugenol* (5-29%), with dosed linalool 48.52% and 13.18% eugenol.

Tulsi with the *Eugenol chemotype* - dosed 35.85% in the essential oil.

Similar studies by Carović-Stanko et al., 2011; Koroch et al., 2017, on different varieties of *O. basiculum*, showed that they fall into two main groups rich in methyl chavicol (estragole) and linalool, which confirms the results obtained in this study.

Table 2. Chemical composition of essential oils obtained from two Basil taxa (*Ocimum basilicum* vs. *Ocimum sanctum*)

No.	Compound name[a]	Yellow basil EO *"Aromat de Buzău"* variety		Purple basil EO *"Seraphim"* variety		Holy basil EO *"Tulsi"*	
		RT	Area %	RT	Area (%)	RT	Area (%)
1	*α-Pinene*	*9.11*	*0.24*	*9.17*	*0.49*	*9.15*	*0.16*
2	Myrcene	13.17	0.18	nd	Nd	nd	nd
3	Limonene	14.43	0.19	nd	Nd	nd	nd
4	*Cineol*	*14.70*	*2.22*	*14.73*	*4.12*	*14.68*	*0.24*
5	Carene	17.02	0.44	nd	Nd	nd	nd
6	Octanal	nd	nd	nd	Nd	18.37	0.24
7	Cubebene	24.33	0.19	nd	Nd	nd	nd
8	Camphor	24.97	1.17	24.95	1.01	nd	nd
9	Pinocamphene	nd	nd	nd	Nd	24.98	0.43
10	Pinanone	nd	nd	nd	Nd	25.74	1.14
11	**Linalool**	**26.05**	**27.59**	**26.04**	**32.56**	**26.02**	**0.17**
12	Alanine	nd	nd	nd	Nd	26.67	0.16
13	Bornyl acetate	26.73	0.74	nd	Nd	nd	nd
14	Farnesene	nd	nd	26.83	0.53	nd	nd
15	Azulene	26.95	3.94	nd	Nd	nd	nd
16	Guaiene	nd	nd	26.96	5.94	nd	nd
17	*ß-Caryophyllene*	*27.05*	*4.22*	*27.05*	*24.83*	*27.04*	*47.16*
18	*α-Caryophyllene*	*28.82*	*1.22*	*28.81*	*1.80*	*28.82*	*2.45*
19	**Estragole**	**28.98**	**34.42**	**28.99**	**0.64**	**28.97**	**0.26**
20	Ɉ-Terpineol	nd	nd	29.59	0.60	nd	nd
21	*Germacren-D*	*29.77*	*4.62*	*29.75*	*2.94*	*29.74*	*1.19*
22	Guaiodiene	29.91	2.65	29.90	2.11	nd	nd
23	Eudesma	nd	nd	nd	Nd	29.95	0.53
24	Selinene	nd	nd	nd	Nd	30.08	0.62
25	*Elemene*	*30.33*	*1.34*	*30.32*	*1.52*	*30.30*	*1.13*
26	Cariofilene	30.46	0.16	nd	Nd	nd	nd
27	Chamigrene	nd	nd	nd	Nd	30.71	0.75
28	Isoledene	30.91	3.06	nd	Nd	nd	nd
29	Guaia	nd	nd	nd	Nd	30.95	10.24
30	*Eudesmadiene*	*30.98*	*2.89*	*30.97*	*7.91*	*30.96*	*0.53*
31	2-Hexanoilfuran	nd	nd	nd	Nd	31.86	0.30
32	Nerol	32.94	0.28	nd	Nd	nd	nd
33	Phenol	nd	nd	nd	Nd	34.72	0.15
34	Caryophyllene oxid	nd	nd	35.67	0.71	35.65	1.19
35	Cubenol	37.18	0.55	nd	Nd	37.62	0.72
36	Spathulenol	38.45	0.16	nd	Nd	38.43	0.17
37	Ɉ-Cadinol	39.33	5.67	nd	Nd	nd	nd
38	**Eugenol**	nd	nd	**39.33**	**12.28**	**39.31**	**23.24**
39	Guaiol	nd	nd	nd	Nd	40.23	0.18
40	Eudesmenol	nd	nd	nd	Nd	40.37	0.25
41	Mururol	40.41	0.24	nd	Nd	nd	nd
42	2-Allylphenol	42.42	0.20	nd	Nd	nd	nd
43	Ledene oxid	nd	nd	nd	Nd	42.96	0.15
44	Aromadendrene	nd	nd	nd	Nd	43.86	0.17
45	Ethylene oxid	nd	nd	nd	Nd	45.99	0.18
46	Phytol	46.95	1.16	nd	Nd	nd	nd
Total compounds		**99.74%**		**99.99%**		**94.10%**	
Monoterpene hydrocarbons		25.51		-		-	
Monoterpenes oxygenated		48.96		33.22		1.68	
Sesquiterpenes		25.07		53.76		70.13	
Phenols		0.20		13.01		20.80	
Others		-		-		1.50	

[a] - Compounds identified based on retention index; nd - not detectable.

Chemotaxonomic studies of essential oils from European basil varieties (Grayr et al., 1996; Ahlam et al., 2017) and two different varieties of basil from Iran (Pirmoradi et al., 2013) have shown that methyl chavicol (estragole) and linalool are the main compounds.

In other studies, the main compound found in essential oils from other varieties of basil growing in different geographical areas is methyl-eugenol (Parmeshwar et al., 2021), while the presence of methyl cinnamate among the main chemical constituents of basil oil "either as a chemotype or as a subtype" has been detected in basil varieties in Serbia (Beatovic et al., 2015).

Comparing the data obtained in this study with those in the literature (Ilic et al., 2019), the results showed the complex chemical composition of essential oils and highlighted the presence of biologically active compounds important for various branches of the pharmaceutical, chemical and food industries. Although there were differences between essential oils, the results showed that all are rich in biochemical compounds that are responsible for biological activities, but further studies are needed to determine their biological activities and their applicability as possible food additives.

The differences in the chemical composition of the analysed essential oils can be explained as a consequence of the morphological characteristics of the studied plants but also of the agroclimatic conditions of 2019.

CONCLUSIONS

In this study, the essential oil obtained from two basil taxa was researched: common basil with two cultivars (Yellow basil and Purple basil) and Holy basil or Tulsi.

The content of essential oil for the evaluated varieties varied from 5 ml of oil/1 kg of vegetable material for the *"Aromat de Buzău"* variety, to 1 ml for the *"Seraphim"* variety and 0.9 ml of oil for *Tulsi*.

GC/MS analysis showed differences in the chemical composition of each essential oil and in the concentration of each chemical compound in the chromatogram. As number, the compounds identified ranged from 26 in the *"Aromat de Buzău",* 16 in the purple variety (*"Seraphim"*), and 28 compunds in the *Tulsi* oil. This variation did not depend on the values of the quantitative characters, the colour of the leaves or flowers.

The concentration of the main compounds in the 3 essential oils varied as follows: in the *"Aromat de Buzău"* variety the main compounds are linalool (46.70%) and estragole (31.50%), in the *"Seraphim"* variety the linalool (48.52%) and eugenol (13.18%) compounds predominated and for *Tulsi* the main compound was eugenol, dosed 35.85%.

Ocimum sp. genotypes evaluated are divided into the following chemotypes:

- Yellow basil cultivar, *"Aromat de Buzău"* variety falls into the Linalool chemotype, but also into the Linalool-Estragole chemotype;
- Purple basil cultivar, *"Seraphim"* variety falls into the Linalool chemotype and the Linalool-Eugenol chemotype;
- *Tulsi* cultivar falls into the Eugenol chemotype.

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NITROGEN AND PHOSPHORUS FERTILIZERS AFFECTING THE QUALITY AND QUANTITY OF THE DURUM WHEAT

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Abstract

The experiment was based on the block randomized method in four replications, after cotton predecessor in Field Crops Institute, Bulgaria in the period 2018/19-2019/20. Were tested: N_{40}, N_{80}, N_{120}; N_{160}; P_{40}, P_{80}, P_{120} and P_{160}. As a control variant was adopted N_0P_0. Based on the results obtained, we can conclude that the maximum nitrogen rate did not lead to the best results. The norm of 120 kg N ha was the most effective in most parameters – grain yield (76.2%); test weight (113.3%); grain vitreous (32.36%); gluten content (50.2%), respectively compared to the control. Thousand kernel weight was most affected by N_{160} (13.3%). Protein content had the same values in N_{120} and N_{160} (35.1%), and this effect does not justify the high rate of N_{160}. Phosphorus fertilization showed a weaker effect for all studied traits, and grain yield did not have significantly higher values. The other parameters were most affected by fertilization with P_{80}: thousand kernel weight (7.7%); test weight (2.0%); grain vitreous (9.69%); gluten content (22.3%), respectively. Protein content had the same values at P_{80} and P_{160} (9.0%).

Key words: *environmental conditions, nitrogen, phosphorus, fertilization.*

INTRODUCTION

Durum wheat constitutes one of the most pivotal cereal crops for global security (Toukabri et al., 2021). Is grown on 17 million ha worldwide with a globule production of 33.6 million tons in 2020 (Royo et al., 2021). Demand for wheat is projected to continue to grow over the coming decades, particularly, in the developing world to feed an increasing population (Desta & Almayehu, 2020). Regardless of its tight connection to the dishes of the tradition, durum wheat today is cultivated in developed countries mainly as a cash crop to feed the booming food industry (Sall et al., 2019).
Conventional agriculture is the preferred form of agriculture by most farmers in the world. This technological option (Shopova et al., 2014) provides opportunities for higher crop yields. The production of wheat requires intensive use of farms inputs especially nitrogen (N) fertilizer in order to achieve sufficient yield and good drain quality (Tedone et al., 2018). A significant amount of N applied was lost to environment via nitrification, denitrification, leaching, and volatilization (Cao et al., 2017). Nevertheless, farmers tend to use more mineral and organic N fertilizers than biologically necessary to ensure the highest possible yield (Leslie et al., 2017). A consequence of this trend is a deeply unbalanced soil nutrient composition that ultimately leads to a reduction in crop yield potential (Tonfack et al., 2009). Therefore, reducing the amounts of N fertilizer used in cereal-based cropping systems can be considered as a major driver of sustainability (Zekri et al., 2018). Guerrero et al. (2021) emphasize that, plant response to N is limited to a threshold, N fertilization above this level does not increase crop yield any further. The question of optimal nitrogen fertilizer use has a long history and is still relevant from several perspectives (Mayer-Aurich & Karatay, 2019).
Phosphorus is an essential plant nutrient that is required in large quantities (Neocleous & Savvas, 2019). In fear for P deficiency, excess P fertilizers are routinely applied by farmers for producing wheat (Milhoub et al., 2019). However, the same authors report that wheat plant take and use a small amount of phosphorus applied. Overuse of P fertilizer is a globally recognized problem and more efficient

and sustainable cropping systems are needed (Heuer et al., 2017). Indeed, the greater part of P remains in insoluble from in soil and, hence, unavailable for the plant (Cherchali et al., 2019).

The aim of our study was to examine the responsiveness of durum wheat to increasing N and P rates and the impact on qualitative and quantitative traits.

MATERIALS AND METHODS

The experiment was based on the block randomized method in four replications with a plot size of 10 m^2, after cotton predecessor in Field Crops Institute-Chirpan, Bulgaria (42°11′58″N, 25°19'27″E). The data represent 2018/2019 and 2019/2020. Durum wheat Saya variety was sown with 550 germinating kernels. N and P mineral fertilizers were tested in the form of ammonium nitrate (34.4%) and triple superphosphate (46%), respectively, in the following rates: N_{40}, N_{80}, N_{120}; N_{180}; P_{40}, P_{80}, P_{120} and P_{180}. The control was the unfertilized variant (N_0P_0). Phosphorus fertilizer together with ⅓ of nitrogen fertilizer were incorporated into the soil with the last autumn tillage, and ⅔ of nitrogen were imported in tillering phase.

The soil type is Pellic Vertisols. Humus horizon 80-115 cm is observed, and the humus stock is 300 t/ha in one meter depth. The reaction of the soil is 6.5-7.4 pH. The presence of total N is 0.20% and decreases to 0.13% at a depth of up to 40 cm. Up to a depth of 20 cm no $CaCO_3$ is available, while in the layer up to 40 cm it is 0.25%.

The analysis of variance (ANOVA) was performed as a two-factor analysis to assess the impact of environmental conditions and mineral fertilization. Differences were compared using the lowest significance (LSD) at 0.1% probability level. The correlation relationships of the studied parameters were established with the software product Statistica 13.0 software (TIBCO, Software, 2018).

The average values of were studied: grain yield (GY) - kg/ha; thousand kernel weight (TKW) - g; test weight (TW) - kg/hl; grain vitreous (GV) - %; protein content (PC) - %; gluten (G) - %.

RESULTS AND DISCUSSIONS

During the durum wheat vegetation, the two years studied had similar values in terms of the sum of temperatures from April to harvest (Table 1). The first year studied was cooler from the sowing of wheat to the tillering phase. Otherwise, the two years had a higher sum of temperatures than the multy-year period. Regarding precipitation, 2019/20 had well-distributed precipitation in the active wheat vegetation, while 218/19 had a well-defined drought (March) and over moisturization in June.

Table 1. Temperature sum and rainfall during the triticum durum vegetation for 2018/2020 and multy-year period

Year	Mouths								Σ
	XI	XII	I	II	III	IV	V	VI	
Temperature sum, Σ˚C									
1928-2020	216.0	63.6	-3.6	58.6	191.9	355.3	507.7	624.9	2014
2018/19	225	21	54	113	293	335	533	682	2256
2019/2020	336	111	45	154	257	314	516	615	2348
Rainfall, mm									
1928-2020	46.9	51.7	43.7	37.7	39.2	44.2	60.5	65.5	389
2018/19	82	24	29	25	3	51	21	123	358
2019/2020	82	22	2	56	67	62	50	63	404

Grain yield

The sum of squares showed that 76.23% of the total variation was due to mineral fertilization (factor A) in the formation of GY (Table 2). For environmental conditions (factor B) dispersion - showed 13.68%. The interaction of factors represented 6.38% of the total variation and showed a significant influence on the change in GY. The coefficient of variation (5.91%) showed that there was no strong variation between the different fertilizer rates. Grain yield ranges from 2,137 kg/ha to 4,298 kg/ha (Table 3). N fertilizer rates had a significant effect, with the greatest effect observed with N_{120} fertilization (76.2% above control). Shchuklina et al. (2021) reported a similar trend of decreasing GY with increasing N rate. In contrast to our results, Bielski et al. (2020) report that GY in triticale increases with increasing N rate. Phosphorus fertilizer not only has no significant effect, but two of the variants have a lower GY than the control, P_{40} and P_{120}, respectively. May et al. (2008) also report that GY decreases with the application of more P. Gao and Grant (2012) concluded that there was no statistically significant major effect on grain yield from different amounts of P fertilization. On the other hand, in a study of N and P self-fertilization, Lakew (2019) reported that a significant effect on GY was observed in bread wheat.

Table 2. Effect of mineral fertilization on triticum durum yield and yield parameters (mean squares - % of total)

Source of variance	df	Grain yield	Thousand kernel weight	Test weight	Vitreous	Protein content	Gluten content
Replicate	17	96.29***	97.31***	95.47***	100.0***	97.73***	97.39***
A	8	76.23***	46.41***	47.77***	56.60***	79.72***	80.67***
B	1	13.68***	26.85***	5.67***	28.06***	7.82***	7.54-02^{NS}
AxB	8	6.38***	24.06***	42.04***	15.34***	10.19***	16.64***
Error	51	3.12	2.68	3.87	4.72-04	2.22	2.40
VC, %		5.91	1.83	0.33	5.30-02	2.45	3.66
Accuracy indicator, %		2.96	1.30	0.24	3.75-02	1.75	2.58

Thousand kernel weight

The two sources of variation were very significant for TKW (Table 2). Differences in fertilizer rates explain 46.41% of the total variation, and the impact of the environment - 26.85%. The interaction of the two factors was also very significant (24.06%), which ultimately led to a total variation of 97.31%. Thousand kernel weight ranged from 43.1 g to 50.4 g (Table 3). TKW was most affected by N_{160} (13.3% above control). A similar effect of N fertilization was observed by Namvar and Khandan (2013). However, the application of 80 kg N/ha had a similar effect. The effect of this variant resulted in a TKW of 50.3 g, which was 13.0% more than the control. Litke et al. (2017) reported that nitrogen fertilization affects TKW, which confirms our results. Fertilization with P_{160} showed a statistically significant increase in values of 7.7% compared to the control. The same trend is observed by Sial et al. (2018). The authors reported an increase in TKW with increasing P rate. In contrast to our results, Chen et al. (2019) reported that as P rate increases, the TKW decreases.

Test weight

The sum of the squares for the main effect (factor A) explains 47.77% of the total variance in the formation of test weight (Table 2), while the differences between the years explain 5.67%. The complex action of the factors also represented a significant part of the variance - 42.04%. TW values ranged from 75.8 kg/hl to 78.0 kg/hl (Table 3). All fertilization rates included in the study were shown to increase the values, but with the greatest impact was N_{120}, exceeding the control by 2.9%. Campiglia et al. (2014) confirmed our results by finding that N fertilization significantly affects TW. On the other hand, the results obtained by us contradict the study of Fortunato et al., (2019), who reported that with increasing N rate TW values increase. Fana et al. (2012), however, observed the same trend of decreasing values with increasing N rate. The same authors confirm our results for the positive impact of the independent application of P fertilizer and for the increase of the values with the increase of the rate.

Grain vitreous

The sum of the squares in ANOVA for fertilization amounts to 56.60% of the main effect and this factor has the most significant effect on the vitreousness of durum wheat (Table 2). The impact of environmental conditions was also very significant with 28.06%. The interaction of the two factors was proven with high reliability (P = 0.1%). The GV of the grains ranges from 46.5% to 68.3% (Table 4). There was a tendency to increase the values to the rate of N fertilization 120 kg

N/ha, and when the norm increased to 160 kg N/ha, the values decreased. This result contradicts the results of the study by Gerba et al., (2013), who reported that as the fertilizer rate increases, the values also increase. A similar effect was observed with P fertilization. Moreover, the high rates of 120 and 160 kg P/ha were below the control values.

Protein content

The sum of the squares showed a very significant influence on both factors in the formation of the protein (Table 1). Fertilization was by 79.72%, while the influence of the year was by 7.82%. PC ranged from 11.1% to 15.0% (Table 4). All N and P fertilization rates had a proven effect. The greatest effect on protein accumulation was reported by N_{120} and N_{160}. Both variants had the same value, exceeding the control by 35.1%. A number of authors report that as the rate increases, the values increase (Ali et al., 2019; Novak et al., 2019; Woyema et al., 2012). P fertilization had also a large effect, but there was a tendency for the PC to decrease as the rate increased. These results are inconsistent with the study of Chen et al. (2020), who report that P alone has no effect on grain protein in bread wheat.

Table 3. Grain yield (kg/ha), thousand kernel weight (g) and test weigh (kg/hl) average for test period

Fertilization		Grain yield, kg/ha	% of control	Thousand kernel weight, g	% of control	Test weight, kg/hl	% of control
Control		2,439	100.0	44.5	100.0	75.8	100.0
N_{40}		3,197***	131.1	47.9***	107.6	76.8***	101.3
N_{80}		3,796***	155.6	50.3***	113.0	77.5***	102.2
N_{120}		4,298***	176.2	48.5***	109.0	78.0***	102.9
N_{160}		3,778***	154.9	50.4***	113.3	77.0***	101.6
P_{40}		2,324^{NS}	95.3	45.2^{NS}	101.6	77.3***	102.0
P_{80}		2,552^{NS}	104.6	43.1^{NS}	96.9	76.7***	101.2
P_{120}		2,137^{NS}	87.6	44.8^{NS}	101.8	76.5***	100.9
P_{160}		2,517^{NS}	103.2	47.4***	107.7	76.3**	100.7
LSD	*5%*	*178.3*	*7.3*	*1.3*	*3.0*	*0.4*	*0.5*
	1%	*237.6*	*9.7*	*1.8*	*4.1*	*0.5*	*0.7*
	0.1%	*310.1*	*12.7*	*2.4*	*5.4*	*0.7*	*0.9*

NS - no significant; *, **, *** significant at P=5%, P=1% and P=0.1%

Table 4. Grain vitreous (%), protein content (%) and gluten content average for test period

Fertilization		Grain vitreous, %	% of control	Protein content, %	% of control	Gluten content, %	% of control
Control		51.6	100.0	11.1	100.0	21.5	100.0
N_{40}		57.1***	110.66	13.4***	120.7	24.1**	112.1
N_{80}		64.2***	124.42	13.9***	125.5	29.1***	135.4
N_{120}		68.3***	132.36	15.0***	135.1	32.3***	150.2
N_{160}		66.8***	129.46	15.0***	135.1	31.9***	148.4
P_{40}		52.7***	102.13	12.6***	113.5	24.9***	115.8
P_{80}		56.6***	109.69	12.1***	109.0	26.3***	122.3
P_{120}		51.1^{NS}	99.03	11.9**	107.2	22.5^{NS}	104.7
P_{160}		46.5^{NS}	90.12	12.1***	109.0	23.0*	107.0
LSD	*5%*	*0.04*	*0.08*	*0.5*	*4.5*	*1.4*	*6.5*
	1%	*0.06*	*0.12*	*0.7*	*6.3*	*2.0*	*9.3*
	0.1%	*0.08*	*0.16*	*0.9*	*8.1*	*2.7*	*12.6*

NS - no significant; *, **, *** significant at P=5%, P=1% and P=0.1%

Gluten content

The change in the gluten content in the grain was mostly due to fertilization – 80.67% of the total variation (Table 1). This was the only trait that was not affected by the environmental condition. However, the interaction of AxB was highly proven. GC ranged from 21.5% to 32.3% (Table 4). Increasing the N rate led to an increase in the values to the norm of 120 kg N/ha, and the higher dose led to a decrease. The same trend was observed for P fertilization. A number of studies support the positive effects of nitrogen on GC. Dinkinesh et al. (2020) observed an increase in GC to the norm of 122 kg N/ha. When increased to 183 kg N/ha, the gluten content decreases. On the other hand, Kizilgeci et al. (2021) reported that the values increase with increasing N rate. Regarding phosphorus fertilization Agapie and Bostan (2020) conclude that unilaterally applied phosphorus does not bring significant changes.

Under the action of N fertilization, the correlation revealed strong and proven relationships between most of the studied parameters (Table 5). The most closely related were GV and GC (0.993***). Holmurodova and Urinova (2021) confirm this result by reporting that there is direct relationship between the glassiness of the grain and the amount of protein and gluten in it.

Under the action of P fertilization, only two proven correlations were found between the TW and the PC (0.928 **) and a strong negative relationship between the TKW and the GV (-0.950**), respectively.

Table 5. Correlation coefficients between the studed traits

	GY	*TKW*	*TW*	*V*	*PC*	*GC*
			N fertilization			
GY	1.000					
TKW	0.804^{NS}	1.000				
TW	0.971**	0.736^{NS}	1.000			
V	0.975**	0.846*	0.897**	1.000		
PC	0.946*	0.871*	0.866*	0.959***	1,000	
GC	0.947*	0.814*	0.849*	0.993***	0.941**	1.000
			P fertilization			
GY	1.000					
TKW	0.009^{NS}	1.000				
TW	-0.218^{NS}	-0.102^{NS}	1.000			
V	0.088^{NS}	-0.950**	0.363^{NS}	1.000		
PC	-0.078^{NS}	0.188^{NS}	0.928**	0.091^{NS}	1.000	
GC	0.346^{NS}	-0.418^{NS}	0.745^{NS}	0.662^{NS}	0.710	1.000

***0.01%; **0.05%; *0.1%

CONCLUSIONS

Based on the results obtained, we can conclude that the increase in N fertilizer rates did not lead to maximum results. The rate of 120 kg N/ha was the most effective in most parameters - GY (76.2%); TW (113.3%); GV (32.36%); GC (50.2%), respectively. Only TKW was most affected by N_{160} (13.3%). PC had the same values for N_{120} and N_{160} (35.1%), and this effect does not justify the additional imported N fertilizer at the high rate.

Phosphorus fertilization had a significantly lower effect for all studied traits. Moreover, GY did not have a significant increase in values.

The other parameters were most affected by P_{80} fertilization: TKW (7.7%); TW (2.0%); GV (9.69%); GC (22.3%), respectively. PC had the same values at P_{80} and P_{160} (9.0%), and this effect does not further justify the imported P fertilizer at the high rate.

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ECONOMIC EVALUATION OF THE PRODUCTIVITY OF COMMON WHEAT VARIETIES

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Abstract

The study was conducted in the period 2017-2019, in the Department of Plant Breeding at the Faculty of Agriculture at the Trakia University, Stara Zagora, Bulgaria. The subject of the study are seven varieties of common wheat - Syngenta (Ingenio, Bologna, Dalara, Moyson, Falado, Gabrio and Pibrak) and variety Factor from the Bulgarian selection of common wheat. The aim of the present study is to assess the productivity and ecological plasticity of common wheat varieties by analyzing the main economic indicators. The economic evaluation of the results was performed according to the following indicators: GO - Gross output (euro/ha); Y - Yield of common wheat for grain (kg/ha); SPP - stock purchase price (euro/kg); P - profit (euro/ha); PC - Production costs (euro/ha); CP - Cost price (euro/kg) and RP - Rate of profitability (%). As a result of the economic analysis it was found that the varieties Falado (26.02%) and Gabrio (25.01%) have the highest profitability rate. This makes them the most adaptable to specific soil and climatic conditions. The cost of the grain is estimated at 0.13 euro/kg for Falado and Gabrio. Dalara and Moyson (0.14 euro/kg) are also characterized by low cost. Factor variety appears to be unprofitable and low productive in specific soil and climatic conditions.

***Key words**: common wheat, productivity, Anova, economical analysis.*

INTRODUCTION

Climate change is a global problem for crops. The ecological plasticity of different varieties and lines is the subject of a number of studies. One of the main goals of modern selection is to create high-yielding varieties that realize their full potential in different climatic conditions and have good flour milling and baking qualities. According to Penchev et al. (2004) wheat varieties are characterized by relatively low ecological plasticity, so it is necessary to study the productive potential of each variety in different agro-ecological regions. The selection of a suitable varietal structure is a very important component in connection with the increasing climate stress for plants, which often compromises the expected harvest. It is the set of varieties with different ecological plasticity that can guarantee good results in different regions of the country. High-yielding varieties show lower ecological plasticity, they are more sensitive to stress factors (Yanchev et al., 2005). Döringa et al. (2015) investigated the effects of increased genetic diversity on the yield and content of crude protein in the grain of winter wheat varieties and lines (*Triticum aestivum* L.). Overall, the results show that the use of increased genetic diversity in crops can yield wheat crops with improved yield stability and good yield reliability in a variable and unpredictable cultivation environment. Therefore, the cultivation of several varieties of wheat, with different genetic origins, with different tolerance to abiotic conditions is recommended to each producer.

Kucek et al. (2019) evaluate the effectiveness of the genotype in individual years by determining the stability in yield and protein content. The complex influence of the year and location is the subject of a study by Šíp et al. (2013). They establish the effect on common wheat varieties by grain yield and quality parameters. The correct varietal structure depending on the specific agro-ecological conditions of the region can significantly increase the yields and quality of products Ilieva (2011). The use of increased genetic diversity in crops can give wheat crops with improved yield stability and good yield reliability in a variable and unpredictable cultivation environment (Döringa et al., 2015; Bonchev et al., 2019; Bonchev, 2020). For the period 1996-2007, Marijanović et al. (2010) found differences in wheat yield from 3.62 to 5.00 t/ha for the region of Croatia. Differences in productivity depend on a complex relationship between wheat yields and weather characteristics (precipitation and average air temperatures). The increase in temperature is the main factor contributing to the increasing drought index, according to Kheiri et al. (2017).

For a period of 14 years, they analyzed the influence of climatic factors, temperature and precipitation. The effects of precipitation decrease with higher temperature changes, according to Pirttioja et al. (2015), analyzing the fluctuations in temperature and precipitation in the period 1981-2010. The model includes 26 varieties of spring and winter wheat (*Triticum aestivum* L.), grown in a wide range of climate conditions (Finland, Germany and Spain). Despite the complex relationship between wheat yields and weather characteristics (rainfall and average air temperatures), there are indications of moderate well-distributed rainfall combined with mild winters are more conducive to growing wheat than excess rainfall, especially in autumn and cold winters (Marijanović et al., 2010). Precipitation variability has a higher relationship with wheat yield at small scales (0.5°, 2°/2.5°) than at larger scales (4°/5.0°); but wheat yield has a good relationship with temperature at all levels. Li et al. (2010). During the grain filling stage, wheat yield in China is significantly affected by temperature, reported Jiayu et al. (2018). Each element of the argot technique of wheat contributes to the formation of the cost of production from weed control to harvesting techniques (Yadav et al., 2009; Dixit et al., 2011; Tihanov, 2018; Tihanov, 2019). Grain production is a strategic and structural sector of the economy of many countries, ensuring their food stability. What is the efficiency of production and what are the data on the cost of grain from varieties grown in specific soil and climatic conditions? All this can be useful for forecasting the production costs of wheat in different areas. The aim of the present study is to assess the productivity and ecological plasticity of common wheat varieties by analyzing the main economic indicators.

MATERIALS AND METHODS

The study was conducted in the period 2017-2019, in the Department of Plant Breeding at the Faculty of Agriculture at the Trakia University, Stara Zagora, Bulgaria. The subject of the study are seven varieties of common wheat - Syngenta (Ingenio, Bologna, Dalara, Moyson, Falado, Gabrio and Pibrak) and variety Factor from the Bulgarian selection of common wheat. The research is based on the method of fractional plots. The size of the experimental plot is 10 m^2. Sowing was carried out in the optimal time for the region from 10 to 25 October. The cultivation of the crop was carried out using standard agricultural techniques for the region, according to the technology of wheat cultivation. After the predecessor corn is carried out deep plowing and then 2-3 cultivations to keep the area free of weeds. The last treatment was carried out immediately before sowing to create a loose layer for better contact between soil and seeds. The economic evaluation of the different options was made after the development of a technological map for the production cultivation of corn for grain. Production costs and material investments (seeds, fertilizers, plant protection products, irrigation water) were calculated at current market prices as of October 2020. The efficiency of the individual options is determined by a system of indicators including average yield, total production, production costs, cost and rate of return. The economic evaluation of the results was performed according to the following indicators: GO – Gross output (euro/ha); Y – Yield of common wheat for grain (kg/ha); SPP – stock purchase price (euro/kg); P – profit (euro/ha); PC – Production costs (euro/ha); CP – Cost price (euro/kg) and RP – Rate of profitability (%). Statistical processing was performed with Anova. The controlled selection of varieties that successfully meet the environmental conditions is a condition for obtaining high yields. Study of the adaptability and ecological plasticity of varieties is usually an important condition in choosing the appropriate variety composition. Economic evaluation is the indicator by which the correct selection of the appropriate varieties for a certain region can be most easily specified.

Meteorological characteristics of the period

The hydrothermal conditions during the three harvest years appear to be dynamic and not very favorable for wheat. Limiting factors for plant development are temperature and soil moisture. The growth and development of cereals during the years of research takes place in different weather conditions. Table 1 presents the average daily air temperatures for the study period.

Table 1. Temperatures and precipitations during the experiment in the region of Stara Zagora, Bulgaria

Years	IX	X	XI	XII	I	II	III	IV	V	VI
Temperature, ^0C										
2016/2017	20,2	12,6	7,3	0,2	-4,2	2,6	9,3	11,7	17,3	26,6
2017/2018	20,7	12,4	8,0	4,2	2,4	3,6	6,7	15,7	19,1	21,8
2018/2019	19,7	14,4	7,8	2,0	2,3	4,5	9,8	11,6	17,4	23,4
1930-2019	*19,1*	*13,3*	*7,5*	*2,9*	*1,9*	*3,1*	*6,5*	*12,0*	*17,2*	*21,1*
Rainfalls										
2016/2017	14,5	23,5	40,6	0,9	81,6	44,8	28,5	38,1	44,2	72,0
2017/2018	28,1	103,1	51,0	56,5	19,0	**115,0**	89,9	2,9	**99,3**	85,2
2018/2019	19,9	40,8	76,2	21,6	39,9	15,3	5,3	57,9	63,5	**108,7**
1930-2019	*36,2*	*45,9*	*47,3*	*54,3*	*40,8*	*37,5*	*39,1*	*45,8*	*60,6*	*64,8*

The analysis of the data shows the trends in the change of temperatures during the vegetation period of the crop. In October, the period after sowing, agro-meteorological conditions are determined by temperatures that are below the climatic norm for the month, during the first two economic years. Low temperatures prolong the period of crop emergence. In the third economic year, temperature sums were registered 7.6% higher than the norm. In 2018 and 2019, the temperature sums were close to the norm (for the period 1930-2019) and favor the development of plants. There was a tendency to increase the average daily temperatures in the last two economic years. The total temperature in the second experimental year was 8.8% higher than the norm for many years.

RESULTS AND DISCUSSIONS

The amount and distribution of precipitation over the three years was characterized by extremely uneven distribution of precipitation (Table 1). The average of annual precipitation for the period 1930-2019 was 472.3 mm. In the first economic year (2016-2017) the amount of precipitation was 17.7% less than the norm for the multiannual period. Water deficit characterizes the initial stages of crop development. The winter months are extremely important in terms of moisture storage of the one-meter soil layer and are the basis for future yields next year. In the last year (2018-2019) the amount of precipitation was close to the norm, only 4.9% lower. The data show an excess of 37.6% of precipitation in the second year. During the second harvest year in October, 103.1 mm were measured.

Common wheat productivity

The productivity of common wheat varieties is dynamic and depends on the stress of meteorological factors, the level of agricultural techniques and the adaptability of the varieties. In the first year, the highest yield was registered for the Falado variety - 7106.0 kg, ha. Productivity is higher by 44.7% compared to the Factor variety. The Gabrio variety (7015.8 kg, ha) is also characterized by high yields. In the second marketing year, the Dalara variety showed the best results (6004.1 kg, ha). The lowest production is from the Moyson variety - 4944.8 kg, ha.

The Falado and Gabrio varieties again showed high results in the last year of the field study. The dynamics of the productivity of the common wheat varieties is presented in Figure 1. The average productivity analysis for the period showed that the yields of the Falado variety are 44.7% higher than the Factor variety. The Gabrio variety follows with 42.9%, on average for the three-year period. Higher productivity was also found at Dalara variety (34.2%).

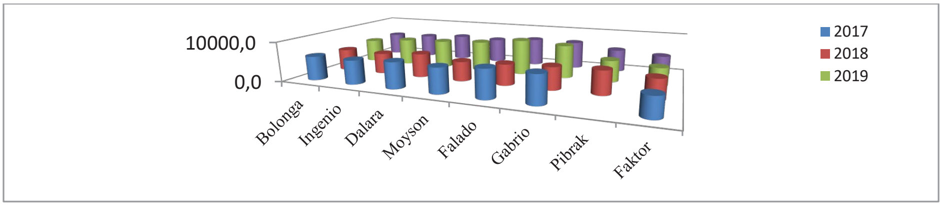

Figure 1. Productivity of common wheat varieties for the period 2017-2019

Table 2 presents the results from the analysis of variance. Values of different sums of squares (SS) - intergroup (Between Groups), intragroup (Within Groups) and total (Total), their degrees of freedom (df), mean squares (MS), the empirical value of F - statistics, critical value at significance level 0.05 F crit = F0.05 (2.15) of the Fisher distribution and p-value. Appendix F criterion proves the different genetic potential of the group of varieties according to the studied indicators with a high degree of statistical significance in the yield indicator

Table 2. Dispersion analysis of the results

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	8471346,985	3	2823782	2,976785	0,052587	3,027998382
Within Groups	21817832,91	23	948601,4			
Total	30289179,89	26				

Economical analysis

Economic evaluation of the results was carried out by the following indicators: total production, profit, cost of production and the resulting rate of profitability.

Economic processing is accomplished by the following formulas: GO = Y x SPP; P = GO – PC; CP = PC/Y; RP= CP/GO x 100, where: GO – Gross output (euro/ha) Y – Yield of common wheat for grain (kg/ha) SPP – stock purchase price (euro/kg) P – profit (euro/ha) PC – Production costs (euro/ha) CP – Cost price (euro/kg) RP – Rate of profitability (%). Production costs include material costs, mechanical and transport services. The cost of production is average for the region for 2020.

The economic analysis shows the level of economic indicators in the studied varieties of common wheat during the three-year period and the average for the period. In the first year of the field experiment, the Pibrak variety was not included because it has not yet been introduced in the country.

The same agro-technical operations (sowing, fertilization, plant protection treatments, etc.) were carried out for all varieties. After the predecessors, who vacated the field early and in the presence of sufficient moisture, plowing was carried out to a depth of 18-20 cm.

Until sowing, the area was kept clean by disking. The last treatment before sowing wasdone at a depth of 6-8 cm to create a loose layer with a firm bed under it. Nitrogen fertilization has been carried out to ensure optimal development and reach the yield potential of the crop. In the spring, when the temperatures rose, when the vegetation and wheat were resumed, the crops were treated with herbicides.

In the first experimental year, the results show that the cost of grain was lowest for the varieties Falado and Gabrio (0.13 euro/kg). This leads to the formation of a higher rate of return. The data in Table 3 show that the rate of return is 26.62% for Falado and 25.01% for Gabrio, respectively. The lowest rate of return was achieved for the variety Factor (-12.53%). The cost of grain in Factor is 0.18 euro/kg.

The second year of the field study turned out to be unfavorable for wheat. Despite the yields from 4944.8 kg/ha (Mojson) to 6004.1 kg/ha (Dalara), the economic analysis shows low levels of profit in more of the varieties. Negative values were obtained for the cultivar Moyson (-106.8 euro/ha), Factor (-72.6 euro/ha), Ingenio (-60.44 euro/ha), Falado (-52.78 euro/ha) and Bologna (-32.76 euros/ha). The cost of grain this year varies in the range of 0.15-0.18 euro/kg. The varieties Pibrak and Dalara (0.15 euro/kg) stand out with the lowest cost.

When establishing the values of profitability from Table 4, it can be seen that the highest profitability rate is calculated, respectively, in the dalera variety is 6.98% and for the pibak variety is 5.63%. The yield of 5671.5 kg/ha for the Gabrio variety forms a rate of profitability of 1.06%. Productivity of other varieties of common wheat leads to higher-cost grain and a negative rate of profitability

The soil and climatic features in 2019 (Table 5) turn out to be suitable for growing the Falado and Gabrio varieties. The high yields of 8359.6 kg/ha and 8929.9 kg/ha ensure the production of low-cost grain (0.10-0.11 euro/kg). The varieties are highly profitable and many times exceed the profitability of Pibrak and Factor. The latter are characterized by a negative rate of profitability.

On average for the three-year study period, the varieties Falado and Gabrio are the most productive, with 7106.09 kg/ha and 7015.63 kg/ha, respectively (Table 6). The profit for both varieties is in the range of 224.54-239.01 euro/ha. The average cost for these varieties is 0.13 euro/kg for the study period. Falado and Gabrio are also characterized as the most profitable for the whole period, with profitability levels of 26.62% and 25.01%. For Dalara and Moyson, the cost of the grain was found to be 0.14 euro/kg. Also, these varieties are characterized by a positive rate of return, ranging from 12.65% to 17.37%.

The production of the Ingenio, Bologna and Pibrac varieties is low profitable, with 7.31%, 3.11% and 1.46%, respectively. On average for the period, the results for the Factor variety show a negative rate of profitability of 12.53% and the highest levels of grain cost of 0.18 euro/kg.

From this point of view, the study is particularly relevant because it makes it possible to assess the profitability of each variety of common wheat in different climatic conditions. These calculations show how eco-plastic each variety isAs a result of the obtained results the correct selection of the adaptive varieties can be made.

Table 3. Economic evaluation of the results for common wheat, 2017

Variants	Yield	Gross output	Production costs	Profit	Cost price	Rate of profitability
	kg/ha	euro/ha	euro/ha	euro/ha	euro/kg	%
Bologna	6053,5	968,56	897,96	70,60	0,15	7,86
Ingenio	6022,3	963,56	897,96	65,60	0,15	7,31
Dalara	6587,0	1053,92	897,96	155,96	0,14	17,37
Mojson	6322,4	1011,58	897,96	113,62	0,14	12,65
Falado	7106,0	1136,96	897,96	239,00	0,13	26,62
Gabrio	7015,8	1122,52	897,96	224,56	0,13	25,01
Pibrac	-	-	-	-	-	-
Factor	4909,3	785,48	897,96	-112,48	0,18	-12,53

Table 4. Economic evaluation of the results for common wheat, 2018

Variants	Yield	Gross output	Production costs	Profit	Cost price	Rate of profitability
	kg/ha	euro/ha	euro/ha	euro/ha	euro/kg	%
Bologna	5407,5	865,20	897,96	-32,76	0,17	-3,65
Ingenio	5234,5	837,52	897,96	-60,44	0,17	-6,73
Dalara	6004,1	960,65	897,96	62,69	0,15	6,98
Mojson	4944,8	791,16	897,96	-106,80	0,18	-11,89
Falado	5282,4	845,18	897,96	-52,78	0,17	-5,88
Gabrio	5671,5	907,44	897,96	9,48	0,16	1,06
Pibrac	5928,4	948,54	897,96	50,58	0,15	5,63
Factor	5158,5	825,36	897,96	-72,60	0,17	-8,08

Table 5. Economic evaluation of the results for common wheat, 2019

Variants	Yield	Gross output	Production costs	Profit	Cost price	Rate of profitability
	kg/ha	*euro/ha*	*euro/ha*	*euro/ha*	*euro/kg*	*%*
Bologna	5899,0	943,84	897,96	45,88	0,15	5,11
Ingenio	6810,1	1089,62	897,96	191,66	0,13	21,34
Dalara	7170,2	1147,24	897,96	249,28	0,13	27,76
Mojson	7699,6	1231,94	897,96	333,98	0,12	37,19
Falado	8929,9	1428,79	897,96	530,83	0,10	59,11
Gabrio	8359,6	1337,54	897,96	439,58	0,11	48,95
Pibrac	5460,3	873,64	897,96	-24,32	0,16	-2,71
Factor	4660,1	745,62	897,96	-152,34	0,19	-16,97

Table 6. Economic evaluation of the results for common wheat, 2017-2019

Variants	Yield	Gross output	Production costs	Profit	Cost price	Rate of profitability
	kg/ha	*euro/ha*	*euro/ha*	*euro/ha*	*euro/kg*	*%*
Bologna	5786,66	925,87	897,96	27,91	0,16	3,11
Ingenio	6022,29	963,57	897,96	65,61	0,15	7,31
Dalara	6587,10	1053,94	897,96	155,98	0,14	17,37
Mojson	6322,24	1011,56	897,96	113,60	0,14	12,65
Falado	7106,09	1136,97	897,96	239,01	0,13	26,62
Gabrio	7015,63	1122,50	897,96	224,54	0,13	25,01
Pibrac	5694,34	911,09	897,96	13,13	0,16	1,46
Factor	4909,29	785,49	897,96	-112,47	0,18	-12,53

CONCLUSIONS

As a result of the economic analysis it was found that the varieties Falado (26.02%) and Gabrio (25.01%) have the highest profitability rate. This makes them the most adaptable to specific soil and climatic conditions.

The cost of the grain is estimated at 0.13 euro/kg for Falado and Gabrio. Dalara and Moyson (0.14 euro/kg) are also characterized by low cost.

Factor variety appears to be unprofitable and low productive in specific soil and climatic conditions.

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RESEARCH ABOUT INFLUENCE OF VARIETY, CULTURE SUBSTRATE AND NUTRIENT SPACE ON POTATO MINITUBERS PRODUCTION

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Abstract

This study was conducted to determine the minituberization capacity of three Romanian potato varieties. The three-factor experiment included the following factors: A - culture substrate with two graduations: a_1 - 80.00% red peat, 9.90% black peat and 10.10% perlite, a_2 - 84.03% red peat, 7.9% black peat and 8.06% perlite; B: nutrition space, with two graduations: b_1 - 1.5 l, b_2 - 2 l; C: variety, with three graduations: c_1 - Marvis; c_2 - Castrum; c_3 - Ervant. Examination of the results on the number and weight of minitubers/plant suggests the high capacity of the Castrum variety for the production of minitubers, when using increased space nutrition and the substrate consisting of a smaller concentration of red peat (80.00%). Regarding the minitubers number, when it was used the substrate with a higher concentration of red peat (84.03%) the Castrum variety was distinguished in a bigger nutrition space (2 l).

Key words: *potato minitubers, variety, nutrition space, substrate.*

INTRODUCTION

Plant propagation through the method of tissue culture, a facet of biotechnology, has developed an important industry with considerable potential for the future (Vasil and Vasil, 1986, Yoon Kab Seog, 2000, Zimmerman et al., 1986, qupted by Yoon Kab Seog, 2000).
By the conventional method, the potato is often the target of pathogens, such as fungi, bacteria and viruses, which leads to poor quality and low yield (FAO, 2008).
For seed potatoes production it is essential to use a healthy and high-quality organic material, in order to obtain an increase in potato production at an optimal level (Parrot, 2010). Seed tuber quality is the most important determinant factor for production (Struik and Wiersema, 2012).
Development of a virus eradication technology and establishment of an *in vitro* collection of virus-free germplasm is an important premise for healthy seed potatoes production (Mozafari and Pazhouhandeh, 2000).
Starting from the meristem culture, with or without the application of thermotherapy and/or chemotherapy, healthy plants are obtained in a short period of time, by using micropropagation. The production of potato seed material is based on the use of pathogen-free microplants and establishment of nuclear stock (germplasm collection) and then minitubers production in protected areas.
Minituber production through planting of micropropagated plantlets in soil can be regarded as a quick effective approach for potato seed tuber production (Ahloowalia, 1994).
Minitubers are principally used for the production of pre-basic or basic seed by direct field planting (Ritter et al., 2001).

MATERIALS AND METHODS

The experiment was conducted in the Tissue Culture Laboratory of National Institute of Research and Development for Potato and Sugar Beet Brasov, Romania. The technology of minitubers producing is based on rapid multiplication Rapid multiplication has as its main objective the obtaining of disease-free biological material and starts from the meristem located at the apex of growth. Meristeme culture involves the following steps: selection of biological material estimated to be programmed for *in vitro* multiplication; preparation of biological material and culture medium; their sterilization; meristematic

sampling followed by inoculation; culture maintenance (Figure 1).
To obtain minitubers, the starting point was represented by meristem culture, which was prelevated from studied varieties. After 6-8 month from meristem inoculation plantlets were developed. To ensure the phytosanitary quality, *in vitro* material is tested by the DAS ELISA technique and healthy *in vitro* material was transferred in April-May into "insect-proof" space (Figure 2).
Statistical analysis was performed to determine the influence of genotype, culture substrate and nutrition space in obtaining minitubers number/plant and their weight. The three-factor experiment (2 x 2 x 3), on 6 repetitions, included the following factors: Experimental factor A - the culture substrate with two graduations: a_1 - 80.00% red peat, 9.90% black peat and 10.10% perlite (considered control); a_2 - 84.03% red peat, 7.9% black peat and 8.06% perlite; Experimental factor B: nutrion space, with two graduations: b_1 - 1.5 l (considered control); b_2 - 2 l; Experimental factor C: variety, with three graduations: c_1 - Marvis; c_2 - Castrum; c_3 - Ervant (as control).
The experience included 12 variants. In the Figure 3 is presented the scheme of experimental variants. The experimental conditions were those specific to the isolated "insect-proof" space.

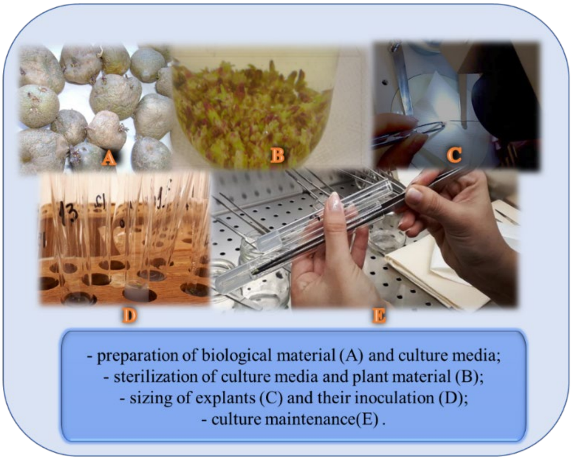

Figure 1.The necessary steps for initiating the meristem culture

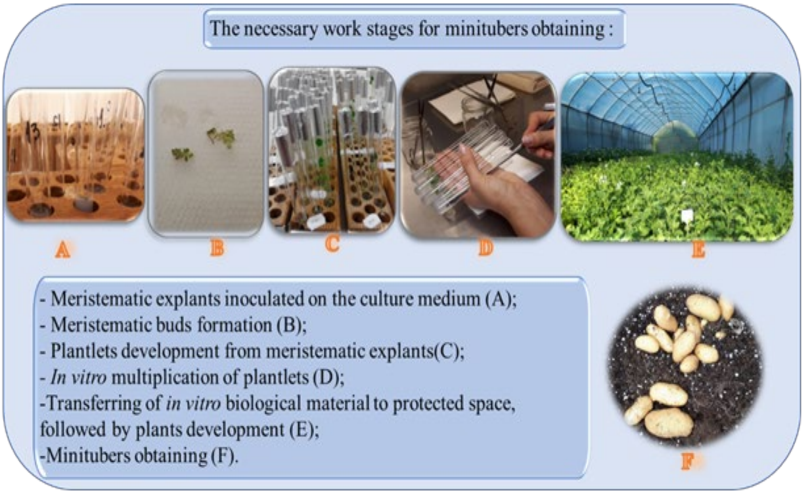

Figure 2. Steps for minitubers obtaining

R_1	a_1						a_2					
	b_1			b_2			b_1			b_2		
	c_1	c_2	c_3	c_1	c_2	c_3	c_1	c_2	c_3	c_1	c_2	c_3
R_2	a_1						a_2					
	b_1			b_2			b_1			b_2		
	c_1	c_2	c_3	c_1	c_2	c_3	c_1	c_2	c_3	c_1	c_2	c_3
R_3	a_1						a_2					
	b_1			b_2			b_1			b_2		
	c_1	c_2	c_3	c_1	c_2	c_3	c_1	c_2	c_3	c_1	c_2	c_3
R_4	a_1						a_2					
	b_1			b_2			b_1			b_2		
	c_1	c_2	c_3	c_1	c_2	c_3	c_1	c_2	c_3	c_1	c_2	c_3
R_5	a_1						a_2					
	b_1			b_2			b_1			b_2		
	c_1	c_2	c_3	c_1	c_2	c_3	c_1	c_2	c_3	c_1	c_2	c_3
R_6	a_1						a_2					
	b_1			b_2			b_1			b_2		
	c_1	c_2	c_3	c_1	c_2	c_3	c_1	c_2	c_3	c_1	c_2	c_3

Figure 3. The scheme of experimental variants

RESULTS AND DISCUSSIONS

From the analysis of the influence of the culture substrate over minitubers/plant and on weight of them, insignificant differences are observed, the two types of substrates not influencing the parameters studied. On a more detailed analysis of the minituberization process, by using the culture substrate with a higher concentration of red peat, we find a higher value of the number of minitubers (5.89), compared to the control substrate, with a positive difference close to the first threshold of differences limit. Also, the positive effect of the substrate with a higher % of red peat is reflected in obtaining a higher value of the minitubers weight (44.94), compared to the control substrate (Table 1).
By comparing the experimental differences with the calculated limit differences in studying over influence of nutrition space on minitubers number/plant, the beneficial effect of increased nutrition space is noted, leading to a statistically positive significant difference (1.83 minitubers). Examination the results over the weight of minitubers/plant highlights the positive influence of the increased nutrition space expressed by a very significant positive difference (23.71 g) (Table 2).
The study of variety influence on minitubers weight/plant draws our attention to Castrum and Marvis varieties which had a very high capacity in minituberization, determining the obtaining of statistically assured results, with a very significant positive difference for Castrum variety (36.95 g/plant) and a distinctly significant positive difference for the Marvis variety (25.89 g/culture vessel). The number of minitubers/plant ranged from 4.33 (Marvis variety) to 6.21 (Castrum variety), whose differences are statistically insignificant (Table 3).
The combined influence of the culture substrate and the nutrition space minitubers number/plant highlights the substrate consisting of a higher percentage of red peat (84.03%), in an increased nutrition space (2 l), leading to a significant positive difference (2.22) (Table 4).
Castrum variety is distinguished with high values of minitubers number for both culture substrates, followed by the Ervant variety which on both experimented substrates had produced a larger number of minitubers, compared to the Marvis variety (Table 5).
Increasing the nutrient space strongly influences the minitubers formation for Castrum and Marvis varieties, whose distinctly significant (2.75) and significant (2.17) positive differences it detaches from the low nutrition space (Table 6).
Examination of the combined influence of the culture medium and the nutrient space on minitubers weight reveals the beneficial effect of the increased nutrient space on a substrate with a higher % of red peat, resulting in a very significant positive difference (33.37 g) (Table 7).
Statistical interpretation of obtained results regarding minitubers weight shows that from combined interaction of the culture substrate and the variety resulted in significant (27.42) and very significant differences for Marvis and Castrum varieties, when it was used the 80.00% red peat, 9.90% black peat and 10.10% perlite substrate and significant and distinctly significant differences for the same varieties by applying the substrate 84.03% red peat, 7.9% black peat and 8.06% perlite (Table 8).
From the analysis of varieties behavior on minitubers weight obtained on nutrition spaces the Castrum variety can be noticed, which determines obtaining of a distinctly significant positive difference for the reduced nutrition space (Table 9).

Table 1. Influence of the culture substrate on minitubers number and on minitubers weight/plant (g)

Culture substrate (a)	Minitubers number/plant	Diff./ Sign.	Minitubers weight/pl. (g)	Diff. (g)/Sign.
80.00% red peat, 9.90% black peat and 10.10% perlite (a_1) (Ct)	4.72	-	38.58	-
84.03% red peat, 7.9% black peat and 8.06% perlite (a_2)	5.89	1.17 ns	44.94	6.37 ns

LSD 5% = 1.56; 1% = 2.45; 0.1% = 5.24. LSD 5% = 14.66 g; 1%= 22.99 g; 0.1% = 49.12 g.

Table 2. Influence of culture space on minitubers number/plant and on minitubers weight/plant (g)

Nutrition space volume (l) (b)	Minitubers number/plant	Diff./Sign.	Minitubers weight/plant (g)	Diff. (g)/Sign.
1.5 (b_1) (Ct)	4.39	-	29.90	-
2 (b_2)	6.22	1.83 *	53.61	23.71 ***

LSD 5% = 1.40; 1% = 2.00; 0.1% = 2.89. LSD 5% = 10.27 g; 1%= 14.60 g; 0.1% = 21.14 g.

Table 3. Influence of variety on minitubers number/plant and on minitubers weight/plant (g)

Variety (c)	Minitubers number/plant	Diff./Sign.	Minitubers weight/plant (g)	Diff. (g)/Sign.
Marvis (c_1)	4.33	-1.04 ns	46.70	25.89 **
Castrum (c_2)	6.21	0.83 ns	57.76	36.95 ***
Ervant (c_3) (Ct)	5.38	-	20.81	-

LSD 5% = 1.48; 1% = 1.97; 0.1% = 2.59. LSD 5% = 16.08 g; 1%= 21.49 g; 0.1% = 28.26 g.

Table 4. The combined influence of culture substrate and nutrition space on minitubers number/plant

Culture substrate (a)/ Nutrition space volume (l) (b)	80.00% red peat, 9.90% black peat and 10.10% perlite (a_1)		84.03% red peat, 7.9% black peat and 8.06% perlite (a_2)		a_2-a_1/ Semn.
	Minitubers number/plant	Diff./ Semn.	Minitubers number/plant	Diff./ Semn.	
1.5 (b_1) (Ct)	4.00	-	4.78	-	0.78 ns
2 (b_2)	5.44	1.44 ns	7.00	2.22 *	1.56 ns

LSD 5% = 1.99; 1%= 2.82; 0.1% = 4.09. LSD 5% = 2.10; 1%= 3.14; 0.1% = 5.72.

Table 5. The combined influence of the culture substrate and variety on minitubers number/plant

Culture substrate (a)/ Variety (c)	80.00% red peat, 9.90% black peat and 10.10% perlite (a_1)		84.03% red peat, 7.9% black peat and 8.06% perlite (a_2)		a_2-a_1/ Semn.
	Minitubers number/plant	Diff./ Semn.	Minitubers number/plant	Diff./ Semn.	
Marvis (c_1)	3.33	-1.33 ns	5.33	-0.75 ns	2.00 ns
Castrum (c_2)	6.17	1.50 ns	6.25	0.17 ns	0.08 ns
Ervant (c_3) (Ct)	4.67	-	6.08	-	1.42 ns

LSD 5% = 2.09; 1% = 2.79; 0.1% = 3.67. LSD 5% = 2.30; 1%= 3.28; 0.1% = 5.49.

Table 6. The combined influence of space nutrition and variety on minitubers number obtained / plant

Nutrition space volume (l) (b)/ Variety (c)	1.5 (b_1)		2 (b_2)		b_2-b_1/ Semn.
	Minitubers number/plant	Diff./ Sign.	Minitubers number/plant	Diff./ Sign.	
Marvis (c_1)	3.25	-1.83 ns	5.42	-0.25 ns	2.17 *
Castrum (c_2)	4.83	-0.25 ns	7.58	1.92 ns	2.75 **
Ervant (c_3) (Ct)	5.08	-	5.67	-	0.58 ns

LSD 5% = 2.09; 1% = 2.79; 0.1% = 3.67. LSD 5% = 2.00; 1%= 2.74; 0.1% = 3.74.

Table 7. The combined influence of the culture medium and nutrient space
on the average weight of the mini-tubers / plant (g)

Culture substrate (a)/ Nutrition space volume (l) (b)	80.00% red peat, 9.90% black peat and 10.10% perlite (a_1)		84.03% red peat, 7.9% black peat and 8.06% perlite (a_2)		a_2-a_1 (g) / Semn.
	Minitubers weight/pl. (g)	Diff. (g)/ Sign.	Minitubers weight/pl. (g)	Diff. (g)/ Sign.	
1,5 (b_1) (Ct)	31.55	-	28.26	-	-3.29 ns
2 (b_2)	45.60	14.05 ns	61.63	33.37 ***	16.03 ns

LSD% = 14.52 g; 1%= 20.64 g; 0.1% = 29.89 g. LSD 5% = 17.86 g; 1%= 27.06 g; 0.1% = 51.60 g

Table 8. The combined influence of the culture medium and the variety on minitubers weight/plant (g)

Culture substrate (a)/Variety (c)	80.00% red peat, 9.90% black peat and 10.10% perlite (a_1)		84.03% red peat, 7.9% black peat and 8.06% perlite (a_2)		a_2-a_1 (g) / Sign.
	Minitubers weight/pl. (g)	Diff. (g)/ Sign.	Minitubers weight/pl. (g)	Diff. (g)/ Sign.	
Marvis (c_1)	43.45	27.42 *	49.96	24.36 *	6.51 ns
Castrum (c_2)	56.25	40.22 ***	59.27	33.67 **	3.02 ns
Ervant (c_3) (Ct)	16.03	-	25.60	-	9.57 ns

LSD 5%=22.74 g; 1%=30.39g; 0.1%=39.96 g. LSD 5%=23.51 g; 1%=33.21 g; 0.1%=53.62 g

Table 9. The combined influence of nutrition space and variety on minitubers weight / plant (g)

Nutrition space volume (l) (b) / Variety (c)	1.5 (b_1)		2 (b_2)		b_2-b_1 (g) / Sign.
	Minitubers weight/pl. (g)	Diff. (g)/ Sign.	Minitubers weight/pl. (g)	Diff. (g)/Sign.	
Marvis (c_1)	30.57	17.67 ns	62.84	34.09 **	32.28 **
Castrum (c_2)	46.27	33.39 **	69.25	40.50 ***	22.98 *
Ervant (c_3) (Ct)	12.88	-	28.75	-	15.88 ns

LSD 5%=22.74 g; 1%= 30.39 g; 0.1% = 39.96g. LSD 5%= 20.11 g; 1%= 27.25 g; 0.1% = 36.65 g.

Increasing nutrition space favors Castrum and Marvis varieties, an increase reflected by the achievement of very significant and distinctly significant positive differences. The variety/nutrition space interaction highlights the distinctly significant and significant differences for the Marvis and Castrum varieties, obtained by comparing the two types of culture spaces (Table 9).

Examination of the results on the number and weight of minitubers/plant suggests the high capacity of Castrum variety for the production of minitubers, grown in increased nutrient space and on the substrate consisting of 80.00% red peat, 9.90% black peat and 10.10% perlite.

Regarding the number of minitubers, the experimentation on the second type of culture substrate highlights the Castrum variety by using the increased culture space. For this substrate, the Marvis variety records the highest value of the weight of the mini-tubers (74.75 g), followed by the Castrum variety (71.85 g), in an increased nutrition space (Figure 4).

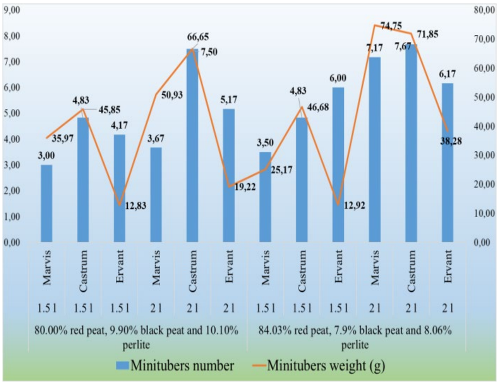

Figure 4. The number and minitubers weight

The Castrum variety stands out for both analyzed parameters (6.21 minitubers/plant and 57.76 g/plant).

CONCLUSIONS

Increased nutrition space had a positive influence in minituberization, both for minitubers number, but also, in the total weight of the obtained minitubers/pl.

Regarding the influence of the culture substrate in minituberization, it is found that by using as a substrate the red peat in a higher percentage, high values are obtained for the minitubers number/pl. as well as for their weight/pl.

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THE INFLUENCE OF TEMPERATURE ON VARIOUS FIELD CROPS SEEDS GERMINATION

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Abstract

The quality control of the biological material is done systematically through analyses: genetic, physical, physiological and the sanitary conditions, as well as regarding to respect the quality parameters standards. Depending on testing results, the seeds are or not accepted for sowing. The influence of environmental factors on seeds germination for sowing is very important. The temperature influences the activity of involved enzymes in seeds germination metabolism. The minimum, optimal and maximum temperatures differ from one species to another, so this must be taken into account when it is organizing the seeds sowing. The purpose of this paper is to present results of the temperature influence on the seeds germination for sowing, for 10 field crops species, as follows: Triticum aestivum, Hordeum vulgare, Hordeum distichon, Zea mays conv. dentiformis, Zea mays conv. sacharata, Sorghum bicolor var. eusorghum, Brassica napus spp. oleifera. Helianthus annuus, Lupinus albus and Cicer arietinum, from the profile market. The influence of temperature on the germination process showed that there were normal seedlings, which are taken into account to express germination, but there were also abnormal seedlings or dead seeds (that did not germinate). Thus, at exposure for one hour at temperature of 40^{o}C, for the species such as: Triticum aestivum, Hordeum vulgare, Hordeum distichon, Brassica napus ssp. oleifera, germination was reduced with 10-25%. In the experiment with exposure for one hour at temperature of -7^{o}C, the species such as: Helianthus annuus or Lupinus albus, completely lost their ability to germinate.

***Key words**: field crops, seeds germination, seeds quality, sowing, temperature.*

INTRODUCTION

Investments in competitive agriculture, increased productivity and high yields can be optimized by farmers' access to high quality seeds for agricultural crops (Balafoutis et al., 2017). The seed is the foundation of the crops, therefore the importance of its quality is decisive in order to obtain a good result from the quantitative and qualitative of production. Seed is the most important natural factor for increasing yields and represents the natural way of transmitting the plants characters from one generation to another, being considered the basis of plant life and the most important link for starting a new cycle production (Bewley et al., 2014). In the embryo, the seed holds a number of valuable components that together with the characteristics of species and sanitary conditions must ensure in the field a uniform emergence and rapid growth of vigorous, healthy plants capable of producing high-yield crops.

In Romania, the Ministry of Agriculture and Rural Development through the Central Laboratory for Quality Seeds and Planting Material and through the Territorial Inspectorates for Seed and Planting Quality certifies batch identity seeds in the field and laboratory testing of the quality of seeds used for sowing, as well and the authorization of economic operators to carry out these specific activities. According to the Romanian legislation in force (Law No. 266/2002 (r2) on production, processing, control and quality certification, seed marketing and planting material, as well as testing and registration of plant varieties, republished in 2014) seed is defined as any material for reproduction or planting: seeds, fruits, planting material produced by any method of propagation, intended for multiplication or for the production of food or industrial consumption.

The certification of the seeds quality for sowing is carried out in the framework organized by the specialized and accredited Laboratories for this purpose by the Romanian Ministry of Agriculture and Rural Development. These Laboratories perform control and verification operations in the main phases of the multiplication process, conditioning, packaging, labelling and sealing of seeds for sowing and ensure that products, processes and services comply with specific official technical rules and regulations.

Food and Agriculture Organization (FAO) in 2011, in "Seeds in Emergencies: a technical handbook" stated that seed testing provides essential information for determining the quality of a shipment of seed and comprises such parameters as germination, physical purity and moisture content. This ensures that it meets the technical specifications of the order and that quality seed is being provided to vulnerable farmers (FAO, 2011). Seed growers need to be aware of the requirements and the technical regulations necessary for the production of a crop intended for obtaining certified seed and to ensure that all operations are carried out strictly in accordance with the specific regulations and in a timely manner.

In this context, seed germination is defined as the test that determines the maximum germination potential of the seeds in the seed lot, which can be used to compare the quality of different lots and also to assess the sowing value in the field (www.incs.ro/activitate.htm). The ability to germinate can be influenced by a number of factors related to, among others, the genetics and purity of the species tested, the health of the crop from which the seeds come, the harvesting technology, but also by factors such as humidity and temperature, from the moment the seed is sown (Kameswara Rao et al., 2017).

The temperature is one of the main factors conditioning the seeds germination process (Oliveira et al., 2020). It affects the water absorption rate and the biochemical reactions that control germination, influencing both the germination percentage and its speed index. In general, species demonstrate physiological variations when exposed to different temperatures, and for this very reason evaluating this germination aspect is important (Filho, 2017; Araújo et al., 2016). Temperature is one of the primary factors affecting the percentage and speed of germination, which directly works via seed imbibition and the biochemical reactions that regulate the metabolism involved in the germination process (Filho, 2017). The correct assessment of the resistance of plants to high temperatures is particularly important for the rational use of varieties and hybrids, as well as optimization methods for selecting valuable genotypes. This task is becoming more and more important in connection with the danger of global warming.

Therefore, the purpose of this paper is to demonstrate the influence of temperature on seeds germination belonging to different crops.

MATERIALS AND METHODS

The present experiment of the influence temperature on the seeds germination included the following crops: winter wheat (*Triticum aestivum*), 6-row barley (*Hordeum vulgare*), 2-row barley (*Hordeum distichon*), maize (*Zea mays* conv. *dentiformis*), sweet maize (*Zea mays* conv. *sacharata*), sorghum (*Sorghum bicolor* var. *eusorghum*), sunflower (*Helianthus annuus*), *rape seed* (*Brassica napus* spp. *oleifera*), white lupines (*Lupinus albus)* and chickpeas (*Cicer arietinum*), from the profile market.

The experiments were carried out in the period 2020-2021, within the Field Crops Production Laboratory, Faculty of Agriculture, University of Agronomic Sciences and Veterinary Medicine of Bucharest.

The sampled seeds were stored at a temperature of 10-12°C until the date of the experiment and they were produced in 2020. The experiment started after minimum 3 months after harvesting of each species.

Temperature, like the other factors influencing the seeds germination, acts within intervals of minimum, optimal and maximum, different for each plant species, variety or hybrid.

To achieve the proposed objective, the seeds germination was tested at different temperature conditions, as follows: minimum germination of each species; optimum temperature

(20-22°C); one hour exposure to thermal shock of -8ºC, then germination at optimum temperature; one hour exposure to thermal shock of +40ºC, then germination at optimum temperature.

In Table 1, it is included the requirements for the minimum germination temperature and the European standards regarding the germination, for the commercialization of the certified seed.

Table 1. Minimum germination temperature (ºC) and Germination Standards (% of pure seeds) (according the Council Directive of 14 June 1966 on the marketing of cereal seed (66/402/EEC) and Council Directive 2002/57/EC of 13 June 2002 on the marketing of seed of oil and fibre plants)

Species	Minimum germination temperature (ºC)	Standards of minimum germination (% of pure seed)
Triticum aestivum	1-3	85
Hordeum vulgare	1-3	85
Hordeum distichon	1-3	92
Zea mays conv. *dentiformis*	8-10	90
Zea mays conv. *sacharata*	8-10	90
Sorghum bicolor var. *eusorghum*	11-13	85
Helianthus annuus	6-8	85
Brassica napus ssp. oleifera	1-3	85
Cicer arietinum	2-4	80
Lupinus albus	2-5	80

The germination substrate was filter paper. Other tools were: Petri dishes, paper towels, labels, tweezers, thermometer, distilled water, germinator, airtight seed containers, magnifying glasses and tweezers. The germination substrate was kept at sufficient humidity without excess. In order to maintain optimum humidity and to avoid further wetting, which can lead to further variation in results, the relative humidity of the air surrounding the seed has been kept as close to saturation as possible. Distilled water was used.

For wheat, barley, rapeseed, sorghum, were counted 4 replications of 100 seeds and for the rest of species with 50 seeds.

Germination test results fall into at least four major categories: normal seeds/seedlings that will develop into healthy plants and all other seeds/seedlings that include abnormal seedlings, dead seed and hard seed (FAO, 2011). Normal seedlings possess the essential structures that are indicative of their ability to produce a normal plant under favourable conditions. These seedlings possess a normal and healthy shoot (hypocotyl, cotyledons or epicotyl) and root (primary and secondary). Abnormal seedlings will not eventually develop into a healthy plant. Abnormal seedlings are all those that cannot be classified as normal. They often lack a shoot and/or a root. Dead seeds are those that absorb water, decay and will not produce a seedling during the germination test. Since these are seeds that do not absorb water, they do not swell and do not start the germination process. This is a problem with a limited number of species that include some legumes.

Germination results are percentage reported in germination capacity of normal seedlings, based on the average of the four replications of 100 seeds. Germination capacity means the percentage of the pure seed with the ability to germinate and that can develop into normal seedlings in 7-8 days, under appropriate conditions of optimum moisture, temperature and light. Germination energy is expressed by the percentage of germinated seeds in a period equal to 1/3-1/2 of the duration established for the germination capacity.

During the experiments, observations were made 3 days after germination of the seeds, to determine the germination energy, at optimal conditions. After 7 days to determine the germination capacity in all experiments.

Seeds were considered to be germinated when the tip of the radical (2 mm) had grown free of the seed coat (Auld et al., 1988).

The Germination Percentage (G%) was calculated by the following formula as described by Association of Official Seed Analysis (AOSA, 1990): Germination percentage (G%) = (Germinated seeds/Total seeds) x 100 and Germinative Energy = (Seeds count on 4th day/Total seeds) x 100 (Ikram et al., 2014).

RESULTS AND DISCUSSIONS

The seeds quality intended for sowing is determined by a whole chain of factors, such as: natural environment conditions, cultivation works, maintenance works, seeds harvesting, conditioning, packaging, storage and marketing. From the moment the seed is received for official testing, it acquires a special biological value, attested by a quality certificate, and finally it acquires an economic value that ensures the economic efficiency that keeps visible any production activity.

Results for seed germination under minimum germination temperature conditions. In order to comply with the working protocol, each species was tested according to the minimum germination temperature of EU Council Directives 2002/57/EC and 66/402/EC.

If sowing takes place earlier, the seeds are soaked in water and cannot germinate due to too low a temperature, thus becoming a favourable environment for the development of pathogens and pests, producing uneven and hollow emergence.

If sowing takes place later, moisture can be lost from the surface layer of the soil, which can lead to an uneven and hollow emergence, and on the other hand, the vegetation is delayed, the plants reaching maturity later.

For the success of crop, it is especially important to sow when the minimum germination temperature is reached in the soil.

According to the data in Table 2, all the seeds had the germination capacity over standards minimum germination, except for the chickpea in which no seed germinated even after 8 days.

The best value was determined for 2-row barley (98%), both for germination energy and for germination capacity, where the standard shows that the germination energy must be over 92%.

Tao et al., in 2016, show that final germination of all these varieties of rape seeds was more than 98% and time to final germination was less than 3 days at 23ºC (Tao et al., 2018).

At the seeds of wheat, barley and rapeseed at the minimum germination temperature, the germination energy of 80% and the germination capacity of 91% were obtained. Of the four replications 2-9 seeds did not germinate.

In the case of thermophilic species (maize, sorghum, sunflower) the germination energy was lower (57-68%) than in the winter species, and in the case of lupine the germination energy was about 50%.

For the chickpea seeds no germinating were registered.

Abnormal seedling has also been obtained from sunflower and maize seeds, respectively 1 abnormal seedling. Also, the number of dead seeds ranged from 2-9 (Table 2).

Table 2. Seed germination results under minimum germination temperature

Species	Minimum germination temperature (ºC)	Germination Energy (after 3 days) (%)	Normal seedlings (number)	Abnormal seedlings (number)	Dead seeds (number)	Hard seeds (number)	Germination Capacity (after 7 days) (%)
Triticum aestivum	1-3	87	97	0	5	-	97
Hordeum vulgare	1-3	81	91	0	9	-	91
Hordeum distichon	1-3	98	98	0	2	-	98
Zea mays conv. *dentiformis*	8-10	62	42	1	7	-	94
Zea mays conv. *sacharata*	8-10	68	48	0	2	-	96
Sorghum bicolor var. *eusorghum*	11-13	65	95	0	5	-	95
Helianthus annuus	6-8	57	47	1	2	-	94
Brassica napus ssp. *oleifera*	1-3	83	93	3	3	-	93
Cicer arietinum	2-4	0	0	0	0	50	0
Lupinus albus	2-5	52	42	0	0	8	84

Results for seed germination under optimum germination temperature conditions. At the optimum temperature, which is about 20-22ºC for all species, germination energy was observed about 1-3 days after germination (Table 3). The results showed that the optimal temperature can influence the duration of germination by comparison with the minimum germination temperature, respectively reduces germination time by about 2-3 days. Seed germination proceeds most rapidly at the temperature of 20-22°C.

After 3 days, the germination energy was between 71 and 94%, compared to the result obtained at minimum temperature, when after 3 days, only 2-row barley germinated over 98%.

For this experiment, germination values were obtained above the limits of the EU standards, which proves that the seeds meet the commercial standards as certificated seeds for sowing. The best value was obtained in wheat, on average 99%. Also, legumes have the hard seeds, 50 for chickpea and 8 of lupine.

Table 3. Seed germination capacity results under optimum germination temperature

Species	Germination Energy (after 3 days) (%)	Normal seedlings (number)	Abnormal seedlings (number)	Dead seeds (number)	Hard seeds (number)	Germination Capacity (%)
Triticum aestivum	87	99	0	1	-	99
Hordeum vulgare	81	94	0	6	-	94
Hordeum distichon	98	98	0	2	-	98
Zea mays conv. *dentiformis*	82	48	0	4	-	96
Zea mays conv. *sacharata*	88	49	0	2	-	98
Sorghum bicolor var. *eusorghum*	85	97	0	3	-	95
Helianthus annuus	87	49	2	0	-	98
Brassica napus ssp. *oleifera*	83	96	0	4	-	93
Cicer arietinum	0	0	0	0	50	0
Lupinus albus	84	44	0	0	8	84

Results for seed germination under one hour exposure to thermal shock of –8ºC, then germination at optimum temperature. In this experiment, at low temperatures, it observed that the low temperature above –8ºC influences the seeds germination of all species. Thus, among the species, the most resistant proved to be wheat, which had a germination energy of 80%, followed by barley of beer and for forage and lupine, with a germination energy of 60%. The other values were between 30 and 50% (Table 4). Also, the number of deeds seeds was very high, especially for sorghum where the lowest germination of only 35% was recorded. In general, winter cereals and rapeseeds have not been affected by low temperatures, which demonstrate their ability to adapt to very low winter temperatures.

Table 4. Seed germination capacity results under one hour exposure to thermal shock of –8ºC, then germination at optimum temperature

Species	Germination Energy (after 3 days) (%)	Normal seedlings (number)	Abnormal seedlings (number)	Dead seeds (number)	Hard seeds (number)	Germination Capacity (%)
Triticum aestivum	80	95	0	5	-	95
Hordeum vulgare	60	90	0	10	-	90
Hordeum distichon	61	92	0	8	-	92
Zea mays conv. *dentiformis*	50	25	0	25	-	50
Zea mays conv. *sacharata*	30	29	0	21	-	48
Sorghum bicolor var. *eusorghum*	40	35	0	65	-	35
Helianthus annuus	30	35	0	15	-	70
Brassica napus ssp. *oleifera*	30	89	0	11	-	89
Cicer arietinum	0	0	0	0	50	0
Lupinus albus	60	44	0	0	6	44

Results for seed germination under one hour exposure to thermal shock of +40ºC, then germination at optimum temperature. It can be appreciated that the high temperature influenced both the germination energy and the germination capacity.

Thus, in the case of lupine, the germination energy was 0%.

The most resistant proved to be wheat and rapeseed, which kept their germination unchanged even in these conditions, 95%, respectively 93%.

It is noteworthy the chickpeas, which in the other cases had a germination of 0, in the case of the shock of +40ºC had a germination of 70%. In the case of the other species it is found that there have been decreases in the value of germination being 10-20% below the standard. Also, 2-row barley has lost its germination energy by about 53% in case of exposure to high temperature. This shows that the embryo suffers from drying temperatures above +40ºC (Table 5).

Table 5. Seed germination capacity results under one hour exposure to thermal shock of +40ºC, then germination at optimum temperature

Species	Germination Energy (After 3 days) (%)	Normal seedlings (number)	Abnormal seedlings (number)	Dead seeds (number)	Hard seeds (number)	Germination Capacity (%)
Triticum aestivum	75	95	0	5	-	95
Hordeum vulgare	40	80	0	20	-	80
Hordeum distichon	34	78	0	22	-	78
Zea mays conv. *dentiformis*	70	38	0	12	-	76
Zea mays conv. *sacharata*	22	32	0	18	-	64
Sorghum bicolor var. *eusorghum*	40	70	0	30	-	70
Helianthus annuus	40	22	0	28	-	44
Brassica napus ssp. *oleifera*	40	80	0	20	-	93
Cicer arietinum	20	35	0	0	15	70
Lupinus albus	0	40	0	0	10	80

CONCLUSIONS

The experiments showed the major importance of temperature to seeds germination of 10 different field crops species: wheat, 2-rows barley and 6-row barley, maize and sweet maize, sorghum, sunflower, rapeseed, lupine and chickpea.

Of all the species, wheat seeds performed best, regardless of the temperature to which they were subjected, and maintained a germination capacity of over 95%. By comparison, chickpea has a good germination at shock thermic with high temperature, over +40ºC, and in the case of the other cases (minimum and optimal temperature) it did not manifest its germination capacity, the germination being 0%. In this case, it can be argued that sometimes legume seeds need a thermal shock to get out of the dormant phase to germinate. At the opposite pole, lupine lost its germination energy under the conditions of high temperature.

The other species were affected by both high and low temperatures, losing their germination capacity by about 20-30% than in optimal or minimum temperature conditions.

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THE QUALITY OF FRESH AND ENSILED BIOMASS FROM WHITE MUSTARD, *Sinapis alba,* AND ITS POTENTIAL USES

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Abstract

We investigated some biological peculiarities and the quality of fresh and ensiled biomass from white mustard, Sinapis alba, which was cultivated on the experimental land in the National Botanical Garden (Institute), Chisinau. The fresh mass was mowed in the flowering stage, some assessments of the main biochemical parameters: crude protein (CP), ash (CA), acid detergent fibre (ADF), neutral detergent fibre (NDF), acid detergent lignin (ADL), total soluble sugars (TSS) have been determined by near infrared spectroscopy (NIRS) technique PERTEN DA 7200, the concentration of hemicellulose (HC), cellulose (Cel), digestible energy (DE), metabolizable energy (ME), net energy for lactation (NEl) and relative feed value (RFV) were calculated according to standard procedures, the sensorial and chemical characteristics of the prepared silage were determined in accordance with the laboratory standard SM 108. It has been determined that the white mustard fresh mass contained 183-208 g/kg dry matter with 18.3-22.9% CP, 9.2-10.9% CA, 43.9-51.8% NDF, 28.3-34.7% ADF, 4.8-5.6% ADL, 23.5-29.1% Cel, 15.6-17.1% HC, 6.3-8.7% TSS, 63.3-75.9% DMD, 57.3-66.1% DOM, RFV=111-142, 12.22-13.08 MJ/kg DE, 10.03-10.74 MJ/kg ME and 6.04-6.77 MJ/kg NEl. this fact indicates a good quality of the natural feed for ruminants. The white mustard silage was distinguished by homogeneous olive colour, pleasant smell specific of pickled cucumbers with pH = 4.12, it contained 7.4 g/kg acetic acid, 41.8/kg lactic acid, 24.6% CP, 14.1% CA, 41.1% NDF, 28.2% ADF, 2.9% ADL, 25.3 % Cel, 12.9 % HC, 5.3% TSS, 81.7% DMD, 71.3% DOM, RFV=151, 13.11 MJ/kg DE, 10.76 MJ/kg ME and 6.78 MJ/kg NEl. The biochemical methane potential of Sinapis alba substrates reached 295-330 L/kg organic matter.

Key words*: biochemical composition, biochemical methane potential, feed value, fresh mass, silage, Sinapis alba.*

INTRODUCTION

The global population growth has resulted in the intensification of food and energy production, which has been necessary in order to cover the rising demands to maintain the standards of living.

The plants of the family *Brassicaceae* constitute one of the world's most economically important plant groups.

They range from noxious weeds to leaf and root vegetables, to oilseed and condiment crops, fodder, technical and cover crops.

The species of *Brassicaceae* have gained great importance in agricultural systems in the last decades, due to their many environmental and agronomic benefits.

The genus *Sinapis* L. contains 6 species, including white mustard - *Sinapis alba* L. and charlock mustard or wild mustard - *Sinapis arvensis* L., which occur in the local flora of our country.

White mustard, *Sinapis alba* L. (syn. *Brassica hirta* Moench or *Brassica alba* (L.) Rabenh.) is assumed to have its origins in the South-East of the Mediterranean Basin. It was used by ancient civilisations 2000 years BC as an oil, spice and medicinal plant and was introduced into the Western and Northern Europe in the early Middle Ages. *Sinapis alba* is an annual herbaceous plant. Stem branched, bristly, usually clearly coarsely hairy, 50-150 cm tall, vigorous. Leaves are alternate, long, bristly branched, irregularly toothed, petiolate, hairy on both sides. Flowers are small, yellow with four petals, cruciform; stamens tetradynamous; pistil bicarpellate. The fruit is a bristly siliqua, round, ribbed, swollen at the seeds, and with a long ensiform beak, pods spreading in the raceme. The fruit stem is 5 × 14 mm. The fruit is 20-45 × 2-4.5 mm in size and carries a beak of 15-30 mm in size. Beak has 0-1 seed; the lower part of the fruit has 1-4 seeds. Seeds are globular and yellowish. They are about 1.5-

3 mm, minutely pitted, seed coat is thin, endosperm meagre and invisible to the naked eye; embryo large, yellowish, with curved hypocotyls, radicle partially surrounded by two folded cotyledons. *Sinapis alba* plants have extensive root system that penetrates deep into the soil profile, more than 50% of all moisture uptake is from below 1.5 m in the soil profile, and hence can utilize the nitrates that have leached down from other crops. White mustard is highly competitive with weed species (Duke, 1983; Oplinger et al., 1991; Kayaçetin, 2020).

The total area cultivated with mustard species in the world is 616,000 ha, with production of 564,000 tons and yield of 915 kg/ha per year on average. About half of this quantity is produced by Canada and Nepal. The other important mustard growing countries in the world include China, Czech Republic, France, Germany, Myanmar, Pakistan, Russia, Ukraine and USA. Its economic importance is continuously increasing due to many possible uses, such as: seed production, secondary crop, as plant important for nematode control in crop rotation and also as melliferous plant. Yellow mustard seed does not have any odour when crushed in water. The seeds have strong disinfectant properties and can be used as a food preservative. Its essential oil can be used to preserve foods due to its potent antimicrobial activity. Moreover, the seed is used in traditional medicine for its antitumor, antiviral, and analgesic activities, it also has expectorant, stimulant, and antimicrobial activities that are useful for digestive and respiratory diseases (Peng et al., 2014; Kayaçetin, 2020).

White mustard is cultivated in warm regions primarily for seed production, whilst in cool, temperate zones it is grown as a break crop, for forage or as green manure. For animal feed and green manure, the breeding aims concentrate on achieving a high leaf production and resistance to beet nematodes. The cultivars bred to be used as fodder must produce a low mustard oil content. In contrast, the cultivars for spice and mustard production should contain much sinalbin. White mustard, as compared with spring rapeseed, is characterized by a more stable yield and especially by its better resistance to temporary droughts frequent in our regional climatic conditions. White mustard and other cruciferous crops can be successfully used in grass mixtures with spring vetch, peas and other legumes, especially those that need support (Kostenko et al., 2021).

Biofumigation with mustard could be integrated to provide environmentally friendly and affordable control of soil-borne pests and diseases under integrated pest management systems (Santos et al., 2021).

Young seedling leaves, which are rich in vitamin A, C and E, are edible as fresh and tasty salad leaves and are used for medicinal purposes to purify blood (Rahman et al., 2018).

Honey bees, solitary bees, bumblebees, flies etc. frequently visit the flowers of *Sinapis alba* to collect nectar and pollen, and serve as agents of cross pollination. Expert beekeepers could manage to get about 10-50 kg honey per hive during a season or 50-60 kg/ha (Popa & Cîrnu, 1960; Glukhov, 1974; Ion et al., 2018).

White mustard seed oil has garnered interest for its use as a feedstock for biodiesel production and oil meal - a byproduct of the biodiesel industry that can be used for animal feed or further extracted to produce additional oil, thus improving economic benefits (Mitrovic et al., 2020). White mustard straw contained 36.7% cellulose and 21.6% lignin, and may serve as alternative raw material in the production of particle board (Dukarska et al., 2011). Also above-ground biomass has caloric value of 17.09-18.45 MJ/kg and may be used to prepare solid biofuel (Fuksa et al., 2013).

The aim of the current study was to evaluate some biological peculiarities, the quality of fresh and ensiled biomass of white mustard, *Sinapis alba,* as feed for ruminant animals, as well as substrate for the production of biomethane by anaerobic digestion.

MATERIALS AND METHODS

The local ecotype of white mustard, *Sinapis alba*, which was cultivated in the experimental plot of the National Botanical Garden (Institute) of Moldova, Chişinău, N 46°58′25.7″ latitude and E 28°52′57.8″, served as subject of research and the traditional crop alfalfa, *Medicago sativa*, was used as control. The experimental design was a randomised complete block design with four replications, and the experimental plots measured 10 m^2. *Sinapis alba* as primary crop was sown on March 19 and as secondary crop on

June 17, 2020, at a depth of 2.0 cm, in rows at a distance of 15 cm; the sowing density was 100 germinable seeds per m^2.

The plant growth, development and productivity were assessed according to methodical indications. The green mass was harvested in the flowering period, in the primary crop on June 9 and in the secondary crop - on September 8. The green mass yield was measured by weighing. The dry matter content was detected by drying samples up to constant weight at 105°C.

The leaf/stem ratio was determined by separating the leaves and flowers from the stem, weighing them separately and establishing the ratios for these quantities (leaves/stems). For ensiling, the green mass was shredded and compressed in well-sealed containers.

After 45 days, the containers were opened, and the sensorial and chemical characteristics of the prepared silages were determined in accordance with standard laboratory procedures and the Moldavian standard SM 108 for forage quality analysis.

For chemical analysis, plant samples were dried in a forced air oven at 60°C, milled in a beater mill equipped with a sieve with diameter of openings of 1 mm and some of the main biochemical parameters were assessed: crude protein (CP), ash (CA), acid detergent fibre (ADF), neutral detergent fibre (NDF) and acid detergent lignin (ADL), total soluble sugars (TSS), digestible dry matter (DDM), digestible organic matter (DOM) were determined by the near infrared spectroscopy (NIRS) technique PERTEN DA 7200.

The concentration of hemicellulose (HC), cellulose (Cel), digestible energy (DE), metabolizable energy (ME), net energy for lactation (NEl) and relative feed value (RFV) were calculated according to standard procedures. The carbon content of the substrates was determined using an empirical equation according to Badger et al. (1979). The biochemical methane potential was calculated according to the equations of Dandikas et al. (2014).

RESULTS AND DISCUSSIONS

When we sowed the white mustard, *Sinapis alba,* seeds in spring (the plots with primary crop), the emergence of the seedlings was observed on the 8-10 days, and in the plots with secondary crop, the seedlings emerged on the 3-5 days after sowing, under adequate temperature and moisture conditions.

It is a commonly known fact that the bio-morphological characteristics: plant height, stem thickness and leaf/stem ratio have significant impact on the productivity, but also affect the biochemical composition and forage value. The structure of the harvested aerial plant biomass and its yield are shown in Table 1. At the harvest time, the height of *Sinapis alba* plants grown as primary crop was 116.1 cm, while those grown as secondary crop reached 60.4 cm, *Medicago sativa* plants at first cut were 84.5 cm tall, but at the third cut - 53.8 cm. The traditional leguminous forage crops reached 84.5-93.1 cm. *Sinapis alba* had the largest weight of a single plant among the studied species. The forage yield of white mustard grown as primary crop reached 35.6 t/ha green mass or 7.3 t/ha dry matter with 71.6 % leaves and flowers, while as secondary crop - 12.8 t/ha green mass or 3.8 t/ha dry matter with 61.8 % leaves, but the leguminous forage crop *Medicago sativa* at the first cut yielded 27.7 t/ha green mass, 7.2 t/ha dry matter with 52.9% leaves and flowers, while at the third cut - 9.6 t/ha green mass, 2.0 t/ha dry matter with 62.5% leaves, respectively.

Several literature sources have described the productivity of *Sinapis alba* plants. As a result of the research conducted in Serbia, Mikić et al. (2009) found that the white mustard lines of Serbian origin reached plant height of 80-112 cm with 4-17 lateral branches and 22-35 internodes, green forage yield 24.64-64.61 g/plant, including 21.10-50.80 g stem mass and 5.00-13.81g leaf mass. Ahlberg & Nilsson (2015) reported that the productivity of the white mustard as intermediate crop was 3235 kg/ha fresh mass.

Table 1. Some agrobiological peculiarities and the structure of the green mass of the studied species

Plant species	Plant height, cm	Stem, g		Leaf+flower, g		Yield, t/ha	
		fresh mass	dry matter	fresh mass	dry matter	fresh mass	dry matter
Sinapis alba, primary crop	116.1	28.5	5.0	62.1	12.6	35.6	7.3
Sinapis alba, secondary crop	60.4	14.5	3.4	29.2	5.5	12.8	3.8
Medicago sativa, first cut	84.5	6.2	1.6	6.9	1.8	27.7	7.2
Medicago sativa, third cut	53.8	5.9	0.9	5.8	1.5	9.6	2.0

Table 2. The biochemical composition and the nutritive value of the harvested green mass of the studied species

Indices	*Sinapis alba*		*Medicago sativa*	
	primary crop	second crop	first cut	third cut
Crude protein, g/kg DM	229	183	170	141
Ash, g/kg DM	109	92	90	90
Acid detergent fibre, g/kg DM ,	283	347	365	393
Neutral detergent fibre, g/kg DM	439	518	558	579
Acid detergent lignin, g/kg DM	48	56	63	66
Total soluble sugars, g/kg DM	63	87	63	69
Cellulose, g/kg DM	235	291	302	327
Hemicellulose, g/kg DM	156	171	193	186
Digestible dry matter, g/kg DM	759	633	611	509
Digestible organic matter, g/kg DM	661	573	541	459
Relative feed value	142	111	101	94
Digestible energy, MJ/ kg	13.08	12.22	11.96	11.57
Metabolizable energy, MJ/ kg	10.74	10.03	9.82	9.50
Net energy for lactation, MJ/ kg	6.77	6.04	5.83	5.51

Analysing the results of the fresh mass quality of the local ecotype of white mustard *Sinapis alba*, Table 2, we would like to mention that the dry matter contained 183-229 g/kg CP, 92-109 g/kg ash, 283-347 g/kg ADF, 439-518 g/kg NDF, 48-56 g/kg ADL, 63-87 g/kg TSS, 235-291 g/kg Cel, 156-171 g/kg HC, with 63.3-75.2% DMD, 57.3-66.19% OMD, RFV=111-142, 12.22-13.08 MJ/kg DE, 10.03-10.74 MJ/kg ME, 6.04-6.77 MJ/kg NEl, but *Medicago sativa* at the first and third cuts: 141-170 g/kg CP, 90 g/kg ash, 365-393 g/kg ADF, 558-579 g/kg NDF, 63-66 g/kg ADL, 63-69 g/kg TSS, 302-327 g/kg Cel, 186-193 g/kg HC, with 50.9-61.1% DMD, 45.9-54.1% OMD, RFV=94-101, 11.57-11.96-MJ/kg DE, 9.50-9.82 MJ/kg ME, 5.83-5.81 MJ/kg Nel, respectively. The white mustard grown as secondary crop contained a low amount of crude protein and high amount of structural carbohydrates, lignin, which contributed to the reduction of digestibility, relative feed value and energy concentration as compared with the forage harvested in the primary crop. The crude protein decreased and the cell wall composition also increased in the third cut forage of *Medicago sativa*.

Some authors mentioned various findings about the green mass quality of *Brassicaceae* species. According to Medvedev & Smetannikova (1981), the chemical composition of white mustard plants was 19.8% CP, 2.3% EE, 28.1% CF, 36.6% NFE and 13.1% ash. Kamalak et al. (2005) reported that wild mustard, *Sinapsis arvensis,* harvested in early flowering period contained 13.2% CP, 66.5% NDF, 54.4% ADF, 7.4% ash, 72.4% OMD, 10.9 MJ/kg ME, but the fodder harvested in mid-flowering period contained 9.8% CP, 70.7% NDF, 60.8% ADF, 8.6% ash, 69.9% OMD and 10.2 MJ/kg ME. Kshnikatkina et al. (2005) reported that the dry matter from *Sinapis alba* forage contained 148.0-177.6 g/kg dry matter, 21.26-22.18% CP, 1.60-3.31% EE, 19.45-34.00% CF, 14.82-15.80% ash, 0.58-0.90% Ca, 0.06-0.10% P. McLean. (2007) remarked that mustard can be utilised as a grazed forage crop for lambs, and contained 101 g/kg dry matter with 32.2 % CP, 25.4 % DP and 12.6 MJ/kg ME, but clover crops – 191-262 g/kg dry matter, 17.8-19.3 % CP, 12.4-13.8 % DP, 9.5-10.6 MJ/kg ME, respectively. Póti et al. (2014) compared the forage quality of green mass from two brassicaceous species and found that the chemical composition of white mustard was 154 g/kg dry matter, 20.6% CP, 2.9% EE, 19.4% CF, 8.9% ash, 48.2% NFE, 629 g/kg TDN, 11.61 MJ/kg DE, 9.52 MJ/kg ME (ME) and 5.88 MJ/kg net energy for maintenance, but oil radish fodder contained, respectively, 135 g/kg dry matter, 14.8% CP, 3.1% EE, 14.1% CF, 13.0% ash, 55.0% NFE, 616 g/kg total TDN, 11.31 MJ/kg DE, 9.32 MJ/kg ME and 5.70 MJ/kg net energy for maintenance. Lebedev & Vorobeikov (2017) found that in the Leningrad Region, Russia the dry matter productivity of white mustard varied from 12.07 to 17.4 t/ha, the dry matter contained 1.7-2.1% N, 1.0-1.4% P, 1.6-2.6% K. Wilczewski et al. (2018) mentioned that the content of macronutrients in the aboveground biomass of white mustard cultivated as stubble catch crop was 20.2 g/kg N, 3.71 g/kg P, 35 g/kg K, 17.6 g/kg Ca, 2.18 g/kg Mg. Kiliç et al. (2021) studied the feed value and digestibility in some brassica fodder crops and remarked that fodder mustard contained 205 g/kg dry matter, 12.02% CP, 2.26% EE, 33.76% CF, 9.05% ash, 43.29% NFE, 50.42% NDF, 43.84% ADF, 15.61% ADL, 6.58% HC, 28.23%Cel, 64.56% IVTD, RFV 101, but canola fodder – 227.5 g/kg dry matter, 9.60% CP, 2.16% EE, 35.20% CF, 9.05% ash, 44.83% NFE, 50.31% NDF, 41.93% ADF, 10.91% ADL, 9.37% HC, 31.03%Cel, 68.26% IVTD, RFV 104. In our previous research, we found that the rapeseed fresh mass fodder contained 227 g/kg CP, 97 g/kg ash, 285 g/kg ADF, 442 g/kg NDF, 41 g/kg ADL, 170 g/kg TSS, 244 g/kg Cel, 157 g/kg HC 75.2 % DMD, 70.9 % OMD, RFV=140, 13.07 MJ/kg DE, 10.73 MJ/kg ME, 6.75 MJ/kg NEl (Ţoţei, 2021).

Forage preservation is a key element for productive and efficient ruminant livestock farms, which provides a uniform level of high-quality feed for ruminants throughout the year. Silage is as nutritious as green fodders as it preserves the nutrients in the original form and hence it is as good for animal feeding as green fodder itself. The investigated white mustard silage was distinguished by homogeneous olive colour, pleasant smell specific of pickled cucumbers, the consistency was retained, in comparison with the initial green mass, without mould and mucus. As a result of the performed analysis (Table 2), it was determined that the pH index of the *Sinapis alba* silage was 4.74, the concentration of total organic acids is higher, butyric acid has not detected and lactic acid predominates (84.90%).

It has been found that the concentration of nutrients and energy in *Sinapis alba* silage was: 246 g/kg CP, 24.8 g/kg EE, 141 g/kg ash, 282 g/kg ADF, 411 g/kg NDF, 29 g/kg ADL, 63 g/kg TSS, 253 g/kg Cel, 129 g/kg HC, with 81.7% DMD, 71.3% OMD, RFV=151, 13.11 MJ/kg DE, 10.76MJ/kg ME, 6.78 MJ/kg NEl. As compared with the initial fresh mass, the silage from white mustard had high concentration of crude protein and ash, low content of neutral detergent fibre and acid detergent lignin, which had a positive impact on digestibility, relative feed value and net energy for lactation.

Table 3. The quality of the silage from white mustard, *Sinapis alba*

Indices	primary crop
pH index	4.12
Content of organic acids, g/kg	49.2
Free acetic acid, g/kg	3.2
Free butyric acid, g/kg	0
Free lactic acid, g/kg	13.0
Fixed acetic acid, g/kg	4.2
Fixed butyric acid, g/kg	0
Fixed lactic acid, g/kg	28.8
Total acetic acid, g/kg	7.4
Total butyric acid, g/kg	0
Total lactic acid, g/kg	41.8
Acetic acid, % of organic acids	15.04
Butyric acid, % of organic acids	0
Lactic acid, % of organic acids	84.90
Crude protein, g/kg DM	246
Crude fats, g/kg DM	24.8
Ash, g/kg DM	141
Acid detergent fibre, g/kg DM	282
Neutral detergent fibre, g/kg DM	411
Acid detergent lignin, g/kg DM	29
Total soluble sugars, g/kg DM	53
Cellulose, g/kg DM	253
Hemicellulose, g/kg DM	129
Digestible dry matter, g/kg DM	817
Digestible organic matter, g/kg DM	713
Relative feed value	151
Digestible energy, MJ/ kg	13.11
Metabolizable energy, MJ/ kg	10.76
Net energy for lactation, MJ/ kg	6.78
Calcium, % DM	1.57
Phosphorus, % DM	0.24
Carotene, mg/ kg GM	31.67

Literature sources indicate considerable variation in the chemical composition and nutritional value of Brassicaceae silages. According to Medvedev & Smetannikova (1981), white mustard silage contained 15.3 % DM, including 2.7% CP, 0.7% EE, 4.4% CF, 4.9% NFE, 2.6% ash, 22 g/kg DP and 0.1 feed unit /kg, but rapeseed silage – 12.7% DM, including 2.4% CP, 0.1% EE, 1.3% CF, 5.0% NFE, 2.7% ash, 17 g/kg DP and 0.1 feed unit/kg. Herrmann et al. (2016) studied the biochemical composition of silages made of various crops in Germany and remarked that *Brassica napus* silage contained 265 g/kg dry matter with 91.1% organic matter, pH 4.2, 6.6% lactic acid, 1.7% acetic acid, 0.1% butyric acid, 9.9% CP, 8.1% EE, 39.1% NFE, 48.5% NDF, 39.6% ADF and 7.6% ADL, but *Raphanus sativus* var. *oleiformis* silage - 115 g/kg dry matter with 81.1% organic matter, pH 4.4, 10.3% lactic acid, 3.6% acetic acid, 0.7% butyric acid, 14.9% CP, 2.6% EE, 42.0% NFE, 31.0% NDF, 34.7% ADF, 4.3% ADL. Kiliç et al. (2021) found that mustard silage contained 234.3 g/kg dry matter, 14.6% CP, 3.26% EE, 46.78% CF, 9.05% ash, 24.14% NFE, 48.25% NDF, 41.40% ADF, 6.77% ADL, 7.15% HC, 34.33% Cel, 66.84% IVTD, RFV = 110, but canola silage - 243.2 g/kg dry matter, 10.32 % CP, 3.34 % EE, 35.68% CF, 11.10% ash, 39.58% NFE, 50.61% NDF, 44.58% ADF, 9.14% ADL, 5.84% HC, 35.69% Cel, 67.74% IVTD, RFV= 99.

The increasing energy demand that has been noticed worldwide, the risk of depletion of fossil energy sources and their injurious impact on environment led to our coal-based society recognizing the potential of renewable energy sources. Versatile energy sources such as biomass, including biogas production, can play an important role next to solar, wind and hydropower utilization. Renewable energy sources coming from agricultural crops could play an important role in terms of energy supply and positive environmental effects. Biogas has become important as a renewable source of energy, because of its decentralized approach. The use of plant biomass as substrate for biogas production has recently become of major interest in Europe. Plant biomass may be used for anaerobic digestion directly after harvest and as ensiled substrates. Anaerobic decomposition will produce methane, carbon dioxide, some hydrogen and a final product that can be used as a fertilizer. The results regarding the quality of the *Sinapis alba* substrates and the potential for obtaining biomethane are shown in Table 4. The carbon to nitrogen ratio constitutes a basic factor governing the correct course of methane fermentation. Methanogenic bacteria need a suitable ratio of carbon to nitrogen for their metabolic processes, ratios higher than 30:1 were found to be unsuitable for optimal digestion, and ratios lower than 10:1 were found to be inhibitory, due to low pH, poor buffering capacity and high concentrations of ammonia in the substrate. The nitrogen concentration in the tested *Sinapis alba* substrates ranged from 29.3 g/kg to 36.6 g/kg, the estimated content of carbon - from 477.2 g/kg to 504.4%, the C/N ratio varied from 12.2 to 17.2, but the *Medicago sativa* substrates contained 26.6-27.2 g/kg nitrogen, 500.0 g/kg carbon and C/N = 18.4-18.9. Essential differences were observed between the lignin contents. The white mustard substrates contained acceptable amounts of hemicellulose and low amounts of lignin. The biochemical methane potential of tested white mustard substrates varied from 281 l/kg VS to 330 l/kg VS, but in alfalfa substrates - from 263 l/kg VS to 270 l/kg VS The best methane potential was achieved in *Sinapis alba* silage substrate - 330/kg VS, the lowest – in the third cut fresh mass substrate of *Medicago sativa*.

Table 4. The biochemical biomethane production potential of the investigated substrates

Indices	*Sinapis alba*			*Medicago sativa*	
	fresh mass, primary crop	fresh mass, secondary crop	silage, primary crop	fresh mass, first cut	fresh mass, third cut
Minerals, g/kg DM	109.0	92.0	141.0	90	90
Nitrogen, g/kg DM	36.6	29.3	39.4	27.2	26.6
Carbon, g/kg DM	495.0	504.4	477.2	500.0	500.0
Ratio carbon/nitrogen	13.5	17.2	12.2	18.4	18.8
Cellulose, g/kg DM	235	291	253	302	327
Hemicellulose, g/kg DM	156	171	129	193	186
Acid detergent lignin, g/kg DM	48	56	29	63	69
Biomethane potential, L/kg VS	295	281	330	270	263

According to Zubr (1986), the methane potential of mustard substrate was 300 l/kg VS. but – of rapeseed silage substrate - 330 l/kg. Molinuevo-Salces et al. (2013) reported that, in four different locations of Denmark, the methane yields of *Sinapis alba* substrates ranged between 251 and 379 l/kg VS or 72-1077 m^3 /ha net energy yield per hectare, but - from *Brassica napus* 362-448 l/kg VS or 48-470 m^3 /ha and from *Raphanus sativus* 356-474 l/kg VS or 66-948 m^3/ha. Ahlberg & Nilsson (2015) found that the accumulated specific methane yield for the intermediate crops after 30 days BMP tests ranged from 278 to 290 l/kg VS in the white mustard substrates, 297-304 l/kg VS in oilseed radish substrates and 305-343 l/kg VS in hairy vetch substrates. Murphy et al. (2011) reported that oilseed rape produced 2.5-7.8 t/ha dry matter and the measured methane yield was 240-340 m^3/t VS.

Herrmann et al. (2016) mentioned that rapeseed silage substrates had C/N=29, biochemical methane potential 259.2 l/kg VS; the fodder radish silage substrates had C/N=17 and biochemical methane potential 29l.0 l/kg VS, but alfalfa grass mixtures silage: C/N=18 and biochemical methane potential 280.0 l/kg VS. In our previous research (Ţîţei, 2016; 2021), we found that the *Isatis tinctoria* substrates achieved a biochemical methane productivity of 242-251 l/kg VS and *Brassica napus* substrates 309-324 L/kg. Słomka, & Wójcik Oliveira (2021) reported that the concentration of macronutrients in the white mustard substrate depending on the location were 40.66-41.58% organic carbon and 2.6-2.08% nitrogen, C/N=15.5-19.9, whereas its biogas potential amounted to 350–440 m^3/t DM.

CONCLUSIONS

The local ecotype of white mustard, *Sinapis alba,* cultivated under the climatic conditions of the Republic of Moldova, is characterized by optimal growth and development rates. If grown as primary crop, sown in spring, it has a forage productivity of 35.6 t/ha fresh mass or 7.3 t/ha dry matter, and if grown as secondary crop, it yields 12.8 t/ha fresh mass or 3.8 t/ha dry matter.

The forage dry matter contains 18.3-22.9% CP, 9.2-10.9% CA, 43.9-51.8% NDF, 28.3-34.7% ADF, 4.8-5.6% ADL, 23.5-29.1 % Cel, 15.6-17.1 % HC, 6.3-8.7% TSS, 63.3-75.9% DMD, 57.3-66.1% DOM, RFV=111-142, 12.22-13.08 MJ/kg DE, 10.03-10.74 MJ/kg ME and 6.04-6.77 MJ/kg NEl.

White mustard is characterized by pH = 4.12, it contains 7.4 g/kg acetic acid, 41.8/kg lactic acid, 24.6% CP, 14.1% CA, 41.1% NDF, 28.2% ADF, 2.9% ADL, 25.3% Cel, 12.9% HC, 5.3% TSS, 81.7% DMD, 71.3% DOM, RFV=151, 13.11 MJ/kg DE, 10.76 MJ/kg ME and 6.78 MJ/kg NEl.

The biochemical methane potential of fresh mass and silage substrates from white mustard reaches 281-330 L/kg organic matter.

The local ecotype of white mustard may be used as multi-purpose crop to prepare green fodder and silage for ruminants and also as substrate for biomethane production.

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BARLEY YIELD RESPONSE TO AGROCLIMATIC INDICES VARIABILITY

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Abstract

This study analyses the barley genotype's response to different agro-climatic indices used to characterize the effect of genotype and environment on yield potential, providing an overview of different six and two rows winter barley genotypes (varieties and lines). The variability was obtained under two growing conditions (CGC1 - conventional growing condition and LSC2 - late sowing condition) in southeast Romania, and the agro-climatic indices were evaluated based on the number of days from sowing to heading and from heading to physiological maturity. The relationship between barley grain yield data under CGC1 and LSC2 and seven agro-climatic indices was analyzed. According to growing degree days (GDD), bright sunshine hours (BSH), heliothermal units (HTU), photothermal index (PTI), heat use efficiency (HUE), rainfalls sum (RS), rainfall index (RI), barley genotypes had different yield potential and agro-climatic indices. A high level of yield will always be obtained by the six-row and two-row winter barley which efficiently use the heat, this agro-climatic index (HUE) being positively correlated under both studied conditions with yield.

Key words: *agro-climatic indices, barley, grain yield, growing condition, phenological stages.*

INTRODUCTION

The temperature and photoperiod were considered primary factors with a major influence (Heurer et al., 1978) and the reaction of plants to the environmental factors has been known since the XVII century. Later, in 1800, it was known that the plants grown under a longer duration of sunlight (bright sunshine hour) will have accelerated growth.

The yield of a genotype is a complex process that begins at sowing and ends at maturity (Slafer and Rawson, 1994), and is marked by critical periods characterized especially by a high-water quantity consumption, such as elongation of the stem, the formation of the number of fertile flowers which contribute to the number of grains in the ear (Miralles and Slafer, 2007).

According to this, the agronomical potential of a genotype is a trait that depends on a large number of morphological, physiological, and environmental characteristics (Alam et al., 2007). Yield stability in the various environment is a desirable feature for all crops and genotype classification is important for each breeding program (Sabaghnia et al., 2013) while the interaction between genotype x environment is of major importance because it provides information about the effect of this on the agronomical performance of cultivars and in the same time, has the main role in prioritizing the stability of the breeding material (Saad et al., 2013).

Also, rainfalls are one of the most important climatic parameters involved in obtaining a high yield (Ekaputa, 2004).

The cumulative effect of daily temperatures can be estimated by an index called growing degree days (GDD) very important for plant growth and development (Schwartz et al., 2006) and shows the necessary useful temperature accumulation.

The relationship between plant growth, maturity, and average air temperature can find out with this simple tool (Basu et al., 2012), and also the phenology can be studied with

positive temperature degrees because each species has a predefined temperature required to reach certain stages of development (Bishnoi et al., 1995) and influences the level of yield.
Growing degree day (GDD) is often used to describe the growth and development processes of plants from emergence to physiological maturity (Siebert & Ewert, 2012, Zartash et al., 2020, Shi et al., 2021).
To determine the maturity date of different crops (Bierhuizen, 1973), the system of heat units was highly adopted. Sreenivas et al. (2010) stated that both heliothermal units (HTU) and heat use efficiency (HUE) are the mathematical derivations of growing degree days (GDD) and could be the main principle for understanding the plant phenology stages.
How efficiently the heat is used by plants for obtaining a certain level of yield is shown by the indicator namely heat use efficiency (HUE). Haider et al., in the 2003 year expressed this indicator as kg ha^{-1} $^{0}C^{-1}$ day^{-1}, and subsequent the quantification of HUE (Pramanik & Sikder, 2020) for the evaluation of crop yield potential in different growing conditions has become necessary.
Another thermal index is the pheno-thermal index (PTI) counts as the ratio between GDD and the number of growth days (Amgain, 2011) and helps to evaluate the relative performance of different genotypes under drought conditions (Pramanik & Sikder, 2020). Response to the climatic and the soil type (Rajput, 1980) can be studied with the heliothermal units (HTU) as the product between GDD and bright sunshine hours (BSH), which represent the number of bright sunshine hours per day.
There are no reports to describe the relationship between winter barley yield and agroclimatic indices, or the knowledge of the relationships between winter barley varieties, registered in the 1992-2019 period and released by NARDI Fundulea, and thermal indices under different growing conditions from the southeast region of Romania.
In this context, the paper presents an analysis of the response of barley yield to agroclimatic indices variability, to evidence the associations between agroclimatic indices and the studied traits, the potential directions for the breeding program, and implicitly the study of old and new barley genetic resources behavior.

MATERIALS AND METHODS

Two separate experiments were conducted at the National Agricultural Research and Development Institute (NARDI) Fundulea under different growing conditions namely CGC1 - conventional growing condition and LSC2 - late sowing condition in the experimental field of winter barley breeding. Nine varieties and 4 lines of six-row winter barley genotypes (Dana, Cardinal FD, Univers, Ametist, Smarald, Simbol, Onix, Lucian, Serafina, F 8-19-2010, F 8-3-2001, F 8-18-2009, F 8-11-2009) and 3 varieties and 9 lines two-row winter barley genotypes (Andreea, Artemis, Gabriela, DH 220-5, DH 314-1, DH 315-10, DH 315-12, DH 320-3, DH 320-6, DH 333-6, DH 334-8, F 8-101-2009) in six different environments, on the cambic chernozem soil, in the 2012-2014 period were tested. The biological material was released by NARDI Fundulea from 1992 (Dana variety) to 2018 (Lucian variety tested as a line from 2010) except Serafina variety which is a foreign genetic resource and the used varieties/lines for this experiment are characterized by the different yield, plant height, and one thousand kernel weight.
Conventional growing condition (CGC1-three years) has represented the optimal sowing period and the late sowing condition (LSC2 - delayed emergence, three years) which was obtained by postponing the sowing date from the usual date (middle of October), outside the optimal season (middle of November) each year. A fertilizer dose of 150 kg/ha N:P:K and 100 kg/ha urea each year in the autumn and the spring respectively were applied.
The studied phenological stages were visually identified on each plot (emergence-heading and heading-physiological maturity).
As measurement traits, days to heading (HD) was recorded as the number of days from emergence (E) to the day when 75% of plants had emerged from flag leaf and the days to physiological maturity (PM) were recorded as the number of days from heading to the day when all the plants have no green tissue (stem, leaves, spikes, and awns).
Plant height (PH) expressed in cm was measured at maturity from above the soil to the tip of the spike (the main tiller without awns)

on three selected plants diagonally distributed on each plot. The studied barley plant development stages were emergence-heading (E-H) and heading-physiological maturity (H-FM).

The experimental plots were mechanically harvested, with a special machine for experimental fields. The weight of each plot was determined in the laboratory on the electronic balance, each genotype was threshed and a sample for further analysis was subtracted.

The one thousand kernel weight (TKW) was determined with the Contador grain counter (all the analyses were made in three replications and expressed in g).

All the weather parameters used to compute the various agroclimatic indices were recorded and provided by the meteorological station located in the vicinity of the winter barley experimental field and then in the EXCEL program were counted for two developmental plant stages, E-H and H-PM.

From daily acquired meteorological data (minimum temperature, maximum temperature, bright sunshine hours, and rainfalls) the following agroclimatic indices were derived: the growing degree days (GDD), bright sunshine hours (BSH), heliothermal units (HTU), photo-thermal index (PTI), heat use efficiency (HUE) at maturity, rainfall sum (RS), rainfall index (RI) which were calculated, according to the following formulas:

$GDD = \Sigma (T_{max} + T_{min})/2 - T_b$

$D\_T < 0^oC = \Sigma (T < 0^oC)$

$HTU = \Sigma (GDD \times BSH)$

$PTI = \Sigma (GDD \div NDBP)$

$HUE = Yield \div GDD$

$RS = \Sigma mm$

$RI = RS/N\_D$, where:

GDD = growing degree days (°C day);

T_{max} = maximum temperature (ºC);

T_{min} = minimum temperature (ºC);

Tb = base temperature (0ºC);

HTU= heliothermal units (°C day);

BSH= bright sunshine hours (hours/day);

HUE= heat use efficiency (kg ha^{-1} $^oC^{-1}$ day^{-1});

PTI = feno-thermal index (^0C day);

BSH = number of bright sunshine hours/day;

RS = rainfall sum (mm) for each development phenophase;

NDBP = number of days between the studied phenophases;

D_T< 0ºC = number of days with temperatures lower than 0ºC;

D_E-H = number of days from emergence to heading;

D_H-PM = number of days from heading to physiological maturity.

The ANOVA statistical program was used to perform the analysis of variance and the relationship between barley grain yield data under CGC1 and LSC2 and seven agro-climatic indices were analyzed based on descriptive statistics (mean, standard error, standard deviation, range, the minimum, and maximum value for emergence-heading E-H in BBCH 00-50, heading-physiological maturity H-PM in BBCH 51-90 and maturity M) and Pearson correlations.

RESULTS AND DISCUSSIONS

The analysis of variance showed a different behavior of six-row and two-row winter barley genotypes depending on studied factors and their interactions (Table 1).

Therefore, analysis of variance components for yield, and TKW, during the 2012-2014 period (six-row and two-row winter barley genotypes) revealed an insignificant influence of barley genotypes only in the case of six-row winter barley regarding the yield obtained and a significant influence of year, growing condition and their interactions on yield and TKW under CGC1 (Table 1).

In the case of two-row winter genotypes, all the sources of variation (year, genotype, and growing condition) and their interaction had a significant influence on both the yield and TKW. The only exception was the Y x G x Gc interaction which had an insignificant influence on yield.

Also, data showed a different magnitude of growing conditions influence comparing six-row with two-row winter genotypes. Postponing the sowing date by one month led to the conclusion that for two-row winter barley the most important factor for a high weight of seed (TKW) is the growing condition followed by the Y x Gc interaction compared with six-row barley where the Gc is followed by genotype.

Table 1. Analysis of variance for yield and TKW, 2012-2014 period

Source of variation	six-row winter genotypes		two-row winter genotypes	
	Yield	TKW	Yield	TKW
Year	76.66xx	35.81xx	19.17xx	28.02xx
Genotype	**1.18ns**	**62.16xx**	3.67xx	40.17xx
Y x G	2.53xx	7.79xx	1.93x	6.87xx
Growing condition	4.34x	**250.21xx**	5.19x	**305.98xx**
Y x Gc	45.0xx	50.31xx	15.73xx	**55.04xx**
G x Gc	2.84xx	25.10xx	2.13x	7.17xx
Y x G x Gc	2.41xx	3.70xx	**1.60ns**	2.46x

*significant at P < 0.05, **significant at P < 0.01, ns-not significant.

Table 2. Descriptive statistics – six-row winter barley under conventional growing conditions (CGC1)

Parameters	Mean	Standard error	Standard deviation	Range	Minimum	Maximum	Count
Emergence-heading (E-H) - BBCH 00-50							
D_E-H	205.67	0.20	0.71	2.33	**204.67**	**207.00**	13
GDD	1211.98	3.89	14.02	44.90	**1192.23**	**1237.13**	13
BSH	878.79	2.19	7.91	25.10	867.13	892.23	13
D_T< 0°C	158.33	0.20	0.71	2.33	**157.33**	**159.67**	13
PTI	5.89	0.01	0.05	0.15	5.83	5.98	13
HTU	7722.21	44.23	159.49	489.71	**7494.51**	**7984.22**	13
RS	231.16	0.33	1.20	4.47	**229.43**	**233.90**	13
RI	1.12	0.01	0.01	0.02	1.11	1.13	13
Heading- physiological maturity (H-PM) - BBCH 51-90							
D_H-PM	42.31	0.12	0.44	1.67	**41.33**	**43.00**	13
GDD	777.63	2.71	9.75	35.57	**757.03**	**792.60**	13
BSH	363.85	1.79	6.44	23.70	350.70	374.40	13
D_T< 0°C	42.31	0.12	0.44	1.67	41.33	43.00	13
PTI	2.12	0.01	0.03	0.11	2.06	2.17	13
HTU	6983.02	38.50	138.80	529.26	6704.47	7233.73	13
RS	156.70	1.44	5.21	14.67	**146.53**	**161.20**	13
RI	0.44	0.01	0.02	0.06	0.40	0.46	13
Maturity (M)							
HUE	2.83	0.05	0.19	0.58	2.59	3.17	13
Yield	5617.38	111.88	403.40	1226.85	5087.04	6313.89	13
P_H	110.69	2.66	9.60	30.00	93.00	123.00	13
TKW	36.03	0.81	2.90	8.93	31.81	40.74	13

The number of days required to attain phenophase from emergence to heading stage (D_E-H) for six-row winter barley (Table 2) under conventional growing conditions (CGC1) ranged from 204.67 to 207.0 days and from heading to physiological maturity (D_H-PM) from 41.33 to 43.0 days, while under late sowing condition (LSC2) the number of days (Table 3) varied between 181.67-186.0 days from the first phenophase and for the second phenophase from 42.67 to 46.0 days.

Among the dates of sowing, the genotypes grown under CGC1 took the maximum days to reach physiological maturity (246-250 days compared with 224-232 days under LSC2) and maximum GDD (1949.26-2029.73 compared with 1799.33-1928.30 under LSC2).

The registered number of days with temperatures above 0^0C showed that in the case of the six-row winter barley sown in October (Table 2), there were more days with temperatures below 0^0C compared to the one sown in November (157-160 days under CGC1 and 134-139 under LSC2 at E_H phenological stage, Table 3), which can have a negative effect on the plant depending on the habit of the barley varieties that have different requirements for vernalization and photoperiod.

Table 3. Descriptive statistics – six-row winter barley under late sowing condition (LSC2)

Parameters	Mean	Standard error	Standard deviation	Range	Minimum	Maximum	Count
Emergence-heading (E-H) - BBCH 00-50							
D_E-H	184.13	0.38	1.38	4.33	**181.67**	**186.00**	13
GDD	1009.46	6.82	24.60	74.13	968.90	1043.03	13
BSH	786.19	3.86	13.91	45.20	759.93	805.13	13
D_T< 0ºC	136.79	0.38	1.38	4.33	**134.33**	**138.67**	13
PTI	5.48	0.03	0.09	0.27	5.33	5.61	13
HTU	7074.95	69.03	248.89	774.06	6645.70	7419.77	13
RS	225.24	0.81	2.91	9.30	**221.93**	**231.23**	13
RI	1.22	0.00	0.01	0.04	1.21	1.25	13
Heading-physiological maturity (H-PM) - BBCH 51-90							
D_H-PM	44.54	0.30	1.08	3.33	**42.67**	**46.00**	13
GDD	861.69	5.03	18.13	54.83	830.43	885.27	13
BSH	394.19	2.93	10.57	30.03	378.73	408.77	13
D_T< 0ºC	44.54	0.30	1.08	3.33	42.67	46.00	13
PTI	2.70	0.02	0.06	0.18	2.59	2.77	13
HTU	8035.96	56.18	202.56	556.89	**7787.28**	**8344.17**	13
RS	174.34	1.75	6.32	20.50	**158.87**	**179.37**	13
RI	0.52	0.01	0.03	0.09	0.46	0.55	13
Maturity (M)							
HUE	2.81	0.04	0.16	0.60	2.40	3.00	13
Yield	5247.6	79.9	288.1	1091.3	4478.7	5570.0	13
P_H	100.2	1.8	6.5	26.0	86.0	112.0	13
TKW	41.52	0.77	2.76	8.29	36.73	45.02	13

The six-row winter barley varieties benefited from a longer sunlight duration (BSH) in the E-H stage under CGC1 and the one sown in November had a longer duration in the H-PM stage (LSC2).

Regarding the pheno-thermal index PTI (^{0}C day), it did not differ much depending on the date of sowing, but the heliothermal units HTU (°C day) registered higher values for barley with six rows optimally sown in the E-H stage (7494-7984) and the one sown in November higher values in the H-PM stage (7787-8344).

Another factor that significantly influences barley yield is not only the amount of precipitation but also its uniform or uneven distribution. From this point of view, whether it was sown in October or sown in November, barley benefited on average from different amounts of rainfall during the growing season (229-234 mm in E-H stage and 146-161 mm in H-PM under CGC1 compared with 221-231 mm in E-H stage and 158-179 mm in H-PM stage under LSC2 (Tables 2 and 3).

Heat use efficiency (HUE) was much better in the case of barley from the first crop condition, which ensured higher yields (from 5087 to 6314 kg/ha) compared to that grown in the second condition (from 4478-5570 kg/ha). Also, the height of the plants was 10 cm higher on average (110 cm) than the barley sown later (100 cm) with a variation of one thousand kernel weights from 31.81-40.74 g (CGC1) to 36.73-45.02 g (LSC2).

Among the dates of sowing, the two-row winter genotypes grown under CGC1 took the maximum days to reach physiological maturity (244-250 days compared with 225-235 days under LSC2) and maximum GDD (mean values of E-H plus H-PM between 1932.33-2034.07 compared with mean values of E-H plus H-PM between 1799.33-1931.17 under LSC2).

Regarding two-row winter barley, the number of days required to attain phenophase from emergence to heading stage (E-H) under conventional growing conditions (CGC1) ranged almost similar from 204.33 to 207.67 days (Table 4) and from heading to physiological maturity (H-PM) from 40.33 to 42.67 days. Under late sowing conditions (LSC2) the number of days varied between 184.0-187.67 days (Table 5) from the first phenophase (more than six-row winter barley with 2-3 days) and for the second phenophase from 41.0 to 44.0 days (less than six-row winter barley with 1-2 days).

The registered number of days with temperatures above 0^0C showed that in the case of the two-row winter barley sown in October (Table 4), there were more days with temperatures below 0^0C compared to the one sown in November (157-160 days under CGC1 and 136-140 under LSC2 at E-H phenological stage (Table 5).

Table 4. Descriptive statistics - two-row winter barley under conventional growing conditions (CGC1)

Parameters	Mean	Standard error	Standard deviation	Range	Minimum	Maximum	Count
Emergence-heading (E-H) - BBCH 00-50							
D_E-H	206.22	0.32	1.10	3.33	**204.33**	**207.67**	12
GDD	1226.85	5.21	18.06	50.77	1199.40	1250.17	12
BSH	886.50	2.41	8.36	24.47	872.87	897.33	12
D_T< 0ºC	158.89	0.32	1.10	3.33	**157.00**	**160.33**	12
PTI	5.95	0.02	0.06	0.16	5.86	6.02	12
HTU	7900.62	45.40	157.27	421.21	**7673.53**	**8094.74**	12
RS	231.95	0.78	2.71	7.53	227.77	235.30	12
RI	1.12	0.01	0.01	0.03	1.11	1.14	12
Heading- physiological maturity (H-PM) - BBCH 51-90							
D_H-PM	41.42	0.18	0.64	2.33	**40.33**	**42.67**	12
GDD	757.53	4.20	14.56	50.97	732.93	783.90	12
BSH	356.40	1.83	6.33	20.63	348.03	368.67	12
D_T< 0ºC	41.42	0.18	0.64	2.33	**40.33**	**42.67**	12
PTI	2.05	0.01	0.04	0.15	1.99	2.13	12
HTU	6816.89	38.43	133.12	405.53	6666.99	7072.53	12
RS	151.19	1.71	5.92	16.50	140.80	157.30	12
RI	0.42	0.01	0.02	0.05	0.39	0.44	12
Maturity (M)							
HUE	2.73	0.05	0.18	0.51	2.47	2.98	12
Yield	5419.68	99.25	343.82	970.37	4933.33	5903.70	12
P_H	100.25	2.84	9.85	30.00	85.00	115.00	12
TKW	42.04	0.84	2.91	9.26	37.02	46.28	12

Table 5. Descriptive statistics - two-row winter barley under late sowing condition (LSC2)

Parameters	Mean	Standard error	Standard deviation	Range	Minimum	Maximum	Count
Emergence-heading (E-H) - BBCH 00-50							
D_E-H	185.72	0.33	1.14	3.67	**184.00**	**187.67**	12
GDD	1040.51	4.90	16.97	51.80	1017.97	1069.77	12
BSH	799.82	3.06	10.60	33.37	785.67	819.03	12
D_T< 0ºC	138.39	0.33	1.14	3.67	**136.67**	**140.33**	12
PTI	5.60	0.02	0.06	0.18	5.52	5.70	12
HTU	7353.06	46.83	162.23	529.19	7119.75	7648.94	12
RS	230.36	1.00	3.47	10.10	224.47	234.57	12
RI	1.24	0.00	0.01	0.04	1.22	1.26	12
Heading-physiological maturity (H-PM) - BBCH 51-90							
D_H-PM	42.69	0.30	1.03	3.00	**41.00**	**44.00**	12
GDD	826.88	6.02	20.86	63.17	798.23	861.40	12
BSH	378.24	3.11	10.76	31.23	364.10	395.33	12
D_T< 0ºC	42.69	0.30	1.03	3.00	41.00	44.00	12
PTI	2.57	0.02	0.06	0.16	2.50	2.66	12
HTU	7729.55	69.63	241.20	789.79	7368.62	8158.41	12
RS	167.75	1.62	5.60	15.77	158.87	174.63	12
RI	0.50	0.01	0.02	0.06	0.47	0.53	12
Maturity (M)							
HUE	2.79	0.08	0.27	0.72	2.45	3.17	12
Yield	5222.8	148.0	512.8	1370.4	4578.7	5949.1	12
P_H	91.1	1.6	5.6	16.0	84.0	100.0	12
TKW	46.20	0.81	2.82	8.18	41.99	50.17	12

The two-row winter barley varieties benefited from a longer sunlight duration (BSH) in the E-H stage under CGC1 (872-897 hours) and the one sown in November had a longer duration (364-395 hours) in the H-PM stage (LSC2).

The pheno-thermal index PTI (^{0}C day), did not differ as in the case of six-row winter barley, depending on the date of sowing, but the helio-thermal units HTU (°C day) registered almost the same trend, with higher values for two-row barley optimally sown in the E-H stage (7673-8094) and under the LSC2 higher values in the H-PM stage the minimum value was above the minimum value from E-H stage (7368) and the maximum value was higher (8158).

Also, the amount of rainfall had influenced depending on the time of sowing, therefore the two-row barley benefited on average from different amounts of rainfall during the growing season (227-235 mm in the E-H stage and 140-157 mm in H-PM under CGC1 compared with 224-234 mm in E-H stage and 158-174 mm in H-PM stage under LSC2 (Tables 4 and 5).

The use of heat (HUE) was more efficient in the case of a few two-row winter barley from the first crop condition, which ensured higher yields (from 4933 to 5903 kg/ha) compared to that grown in the second condition (from 4578 kg/ha).

Also, the height of the plants was 9 cm higher on average (100 cm) than the one sown later (91 cm) with a variation of one thousand kernel weights from 37.02-46.28 g (CGC1) to 41.99-50.17 g (LSC2).

The analysis of the Pearson correlation revealed for six-row barley under the E-H stage (CGC1, green color-left side down) a strong correlation between yield (Y) and total quantity of rainfall fallen (0.63**) during vegetation period (RS) and between one thousand kernel weight and plant height (0.70***).

In the case of two-row barley genotypes (blue color - right side up), besides the correlations between the studied agroclimatic indices, yield is negatively correlated with D_E-H, GDD, D_T< 0ºC, RS, and RI.

The P_H is negatively correlated with HTU (-0.47) but TKW is positively correlated with RS, P_H, D_E-H, GDD, BSH, and D_T< 0ºC (Table 6).

Table 6. Pearson correlation - six-row barley (green color-left side down) and two-row barley genotypes (blue color - right side up), E-H under CGC1

Two-row barley correlations emergence-heading (E-H) under conventional growing conditions (CGC1)											
	D_E-H	**GDD**	**BSH**	**D_T< 0ºC**	**PTI**	**HTU**	**RS**	**RI**	**Yield**	**P_H**	**TKW**
D_E-H	1	**0.98*****	**0.94*****	**0.99*****	**0.95*****	**0.89*****	**0.93*****	**0.82*****	**-0.49**	-0.10	**0.64****
GDD	**0.98*****	1	**0.98*****	**0.98*****	**0.99*****	**0.96*****	**0.94*****	**0.82*****	**-0.48**	-0.26	**0.52***
BSH	**0.96*****	**0.99*****	1	**0.94*****	**0.99*****	**0.99*****	**0.87*****	**0.73*****	-0.44	-0.36	**0.48***
D_T< 0ºC	**0.99*****	**0.98*****	**0.96*****	1	**0.95*****	**0.89*****	**0.93*****	**0.82*****	**-0.49**	-0.10	**0.64****
PTI	**0.95*****	**0.99*****	**0.99*****	**0.95*****	1	**0.98*****	**0.92*****	**0.81*****	-0.46	-0.35	0.44
HTU	**0.94****	**0.99*****	**0.99*****	**0.94*****	**0.99*****	1	**0.85*****	**0.72*****	-0.42	**-0.47**	0.36
RS	**0.57****	**0.65****	**0.65****	**0.57****	**0.67****	**0.66****	1	**0.97*****	**-0.60**	0.12	**0.48***
RI	-0.04	0.05	0.06	-0.04	0.10	0.09	**0.78*****	1	**-0.64**	-0.05	0.40
Yield	0.23	0.26	0.26	0.23	0.27	0.26	**0.63****	**0.59****	1	-0.15	-0.32
P_H	0.36	0.19	0.15	0.36	0.10	0.07	0.06	-0.11	0.26	1	**0.51***
TKW	0.17	0.04	0.01	0.17	-0.03	-0.05	0.04	-0.03	0.33	**0.70*****	1
Six-row barley correlations emergence-heading (E-H) under conventional growing conditions (CGC1)											

**significant at P < 0.01, * **significant at P < 0.001

Under CGC2 (H-PM stage), for six-row winter barley, negative correlations between RS, RI, P_H, and BSH and RI, P_H, and HTU had been found. RS and RI were strongly correlated with P_H and TKW, which revealed the importance of the quantity and distribution of rainfall after heading. Also, the yield was very strongest correlated with HUE (0.99***) and TKW with P_H (0.70***).

Two-row barley correlations (blue color- right side up) analysis of heading-physiological maturity stage (H-PM) under conventional growing conditions (CGC1) had shown positive correlations between yield and BSH (0.50*) and P_H with PTI (0.53*), this being the first difference between six-row and two-row winter barley under CGC1 (Table 7).

Table 7. Pearson correlation – six-row barley (green color-left side down) and two-row barley genotypes (blue color- right side up), H-PM under CGC1

Two-row barley correlations heading- physiological maturity (H-PM) under conventional growing conditions (CGC1)												
	D_H-PM	GDD	BSH	D_T< 0°C	PTI	HTU	RS	RI	HUE	Yield	P_H	TKW
D_H-PM	1	**0.94*** **	**0.91*** **	**0.99*** **	**0.99*** **	**0.92*** **	**0.53***	0.44	0.30	0.38	0.44	0.01
GDD	**0.98*** **	1	**0.78*** **	**0.94*** **	**0.95*** **	**0.90*** **	**0.73*** **	**0.63** **	0.09	0.22	0.45	0.27
BSH	**0.87*** **	**0.83*** **	1	**0.91*** **	**0.89*** **	**0.94*** **	0.18	0.06	0.45	**0.50***	0.27	-0.24
D_T< 0°C	**0.99*** **	**0.98*** **	**0.87*** **	1	**0.99*** **	**0.92*** **	**0.53***	0.44	0.30	0.38	0.44	0.01
PTI	**0.96*** **	**0.91*** **	**0.88*** **	**0.96*** **	1	**0.92*** **	**0.55** **	0.46	0.27	0.35	**0.53***	0.12
HTU	**0.90*** **	**0.88*** **	**0.98*** **	**0.90*** **	**0.86*** **	1	0.39	0.26	0.27	0.37	0.29	0.00
RS	-0.08	-0.01	-0.54	-0.08	-0.16	-0.46	1	**0.99*** **	-0.34	-0.21	0.43	**0.62** **
RI	-0.20	-0.14	-0.63	-0.20	-0.26	-0.58	**0.99*** **	1	0.35	-0.23	0.43	**0.63** **
HUE	-0.11	-0.08	-0.05	-0.11	-0.13	0.01	-0.15	-0.16	1	**0.99*** **	-0.18	-0.42
Yield	-0.03	0.01	0.01	-0.03	-0.08	0.07	-0.13	-0.15	**0.99*** **	1	-0.15	-0.32
P_H	-0.30	-0.23	-0.62	-0.30	-0.31	-0.56	**0.68** **	**0.70*** **	0.26	0.26	1	**0.51***
TKW	-0.10	-0.07	-0.38	-0.10	-0.10	-0.35	**0.59** **	**0.60** **	0.33	0.33	**0.70*** **	1
Six-row barley correlations heading- physiological maturity (H-PM) under conventional growing conditions (CGC1)												

**significant at P < 0.01, * **significant at P < 0.001

Table 8. Pearson correlation – six-row barley (green color-left side down) and two-row barley genotypes (blue color right side up), E-H under LGC2

Two-row barley correlations emergence-heading (E-H) under late growing conditions (LSC2)											
	D_E-H	GDD	BSH	D_T< 0°C	PTI	HTU	RS	RI	Yield	P_H	TKW
D_E-H	1	**0.99*** **	**0.99*** **	**0.99*** **	**0.99*** **	**0.97*** **	**0.80*** **	**0.56** **	-0.25	0.11	**0.58** **
GDD	**0.99*** **	1	**0.98*** **	**0.99*** **	**0.99*** **	**0.99*** **	**0.80*** **	**0.57** **	-0.25	0.11	**0.57** **
BSH	**0.99*** **	**0.98*** **	1	**0.99*** **	**0.98*** **	**0.99*** **	**0.70*** **	0.44	-0.28	0.04	**0.56** **
D_T< 0°C	**0.99*** **	**0.99*** **	**0.99*** **	1	**0.99*** **	**0.97*** **	**0.80*** **	**0.56** **	-0.25	0.11	**0.58** **
PTI	**0.99*** **	**0.99*** **	**0.98*** **	**0.99*** **	1	**0.99*** **	**0.80*** **	**0.57** **	-0.23	0.12	**0.58** **
HTU	**0.99*** **	**0.99*** **	**0.99*** **	**0.99*** **	**0.99*** **	1	**0.71*** **	0.45	-0.27	0.05	**0.56** **
RS	**0.78*** **	**0.82*** **	**0.72*** **	**0.78*** **	**0.83*** **	**0.77*** **	1	**0.95*** **	0.07	0.28	**0.51***
RI	0.31	0.37	0.23	0.31	0.40	0.30	**0.84*** **	1	0.23	0.32	0.40
Yield	-0.33	-0.34	-0.32	-0.33	-0.34	-0.35	-0.07	0.19	1	-0.10	-0.13
P_H	0.01	-0.01	0.02	0.01	-0.01	0.00	-0.25	-0.38	-0.45	1	**0.68** **
TKW	-0.35	-0.35	-0.38	-0.35	-0.34	-0.37	-0.38	-0.25	-0.31	**0.81*** **	1
Six-row barley correlations emergence-heading (E-H) under late growing conditions (LSC2)											

**significant at P < 0.01, * **significant at P < 0.001

Table 9. Pearson correlation – six-row barley (green color-left side down) and two-row barley genotypes (blue color- right side up), H-PM under LGC2

Two-row barley correlations heading- physiological maturity (H-PM) under late growing conditions (LSC2)												
	D_H-PM	GDD	BSH	D_T< 0°C	PTI	HTU	RS	RI	HUE	Yield	P_H	TKW
D_H-PM	1	**0.89*** **	**0.96*** **	**0.99*** **	**0.93*** **	**0.79*** **	**0.65** **	0.43	**0.56** **	**0.62** **	0.08	0.16
GDD	**0.93*** **	1	**0.96*** **	**0.89*** **	**0.99*** **	**0.98*** **	**0.73*** **	**0.48***	0.45	**0.57** **	0.07	0.38
BSH	**0.95*** **	**0.97*** **	1	**0.96*** **	**0.97*** **	**0.92*** **	**0.66** **	0.39	**0.49***	**0.59** **	0.18	0.32
D_T< 0°C	**0.99*** **	**0.93*** **	**0.95*** **	1	**0.93*** **	**0.79*** **	**0.65** **	0.43	**0.56** **	**0.62** **	0.08	0.16
PTI	**0.98*** **	**0.97*** **	**0.96*** **	**0.98*** **	1	**0.94*** **	**0.67** **	0.41	**0.54***	**0.64** **	0.01	0.25
HTU	**0.74*** **	**0.92*** **	**0.90*** **	**0.74*** **	**0.82*** **	1	**0.68** **	0.41	0.36	**0.49***	0.13	0.46
RS	**0.74*** **	**0.61** **	**0.58** **	**0.74*** **	**0.67** **	0.34	1	**0.94*** **	0.09	0.19	0.10	**0.57** **
RI	**0.59** **	0.42	0.38	**0.59***	**0.50***	0.13	**0.97*** **	1	-0.09	-0.02	0.03	**0.51***
HUE	0.36	0.29	0.28	0.36	0.40	0.17	0.10	0.04	1	**0.99*** **	-0.11	-0.23
Yield	0.35	0.35	0.33	0.35	0.41	0.30	0.01	-0.08	**0.98*** **	1	-0.10	-0.13
P_H	0.32	0.40	0.35	0.32	0.29	0.38	**0.60** **	**0.57** **	-0.47	-0.45	1	**0.68** **
TKW	**0.69** **	**0.69** **	**0.72*** **	**0.69** **	**0.64** **	**0.63** **	**0.67** **	**0.56** **	-0.32	-0.31	**0.81*** **	1
Six-row barley correlations heading- physiological maturity (H-PM) under late growing conditions (LSC2)												

**significant at P < 0.01, * **significant at P < 0.001

Compared to the six-row winter barley sown under CGC1, at the one sown under LSC2, the yield correlates negatively with P_H (-0.45) but there is the same strong correlation between TKW and P_H (0.81***) as in the case of genotypes sown in CGC1. Other different correlations were found for two-row winter barley at the E-H stage in the LSC2 condition where TKW correlates with almost all parameters studied, except RI and yield compared with CGC1 (Table 6 and 8) where the parameter is not correlated with PTI and HTU.

Six-row winter barley correlations at heading-physiological maturity (H-PM) stage under late growing conditions (LGC2) had been shown a different behavior regarding P_H which is dependent on rainfall (0.60**) and is negatively correlated with HUE (-0.47) and yield (-0.45).

On the other hand, the TKW is strongly correlated with all parameters (Table 9) except yield and HUE.

At the heading-physiological maturity stage (H-PM) under late growing conditions (LGC2), apart from the correlations between the studied agroclimatic parameters, the correlations for barley with two rows were different. The yield was positively correlated with almost parameters (the second difference between two-row winter barley sown under CGC1 and LGC2), P_H did not correlate with the agroclimatic indices (Table 9) and TKW presented the same correlations compared with the same development stage (H_PM) of barley under CGC1.

CONCLUSIONS

Agroclimatic indices can be used as selection indices for high-temperature tolerance barley genotypes due to significant correlations between the growing degree days (GDD), pheno-thermal index (PTI), heliothermal units (HTU), and bright sunshine hours (BSH).

The number of days and growing degree days to attain the studied phenophases are different between six-row and two-row winter barley. The differences between the photothermal indices for the two phenological stages can be used to study the biomass accumulated in different stages to promote genotypes with a high harvest index and a smaller plant height.

A high level of yield will always be obtained by the six-row and two-row winter barley which efficiently use the heat, this agroclimatic index (HUE) being positively correlated under both conditions with yield.

The only similar correlation between six-row and two-row barley is TKW with P_H and yield is influenced by BSH in the case of two-row winter barley while for the six-row barley, yield is not correlated with BSH (under optimal time sowing). Under late growing conditions, the six-row winter barley TKW is conditioned by almost agroclimatic indices, while for two-row winter barley yield depends on all indices, less RS from the H-PM stage.

Furthermore, new research is required to estimate the duration of each oldest, old and new six and two-row winter barley variety and line phenological stage, and also, to cope with the climate changes, a wide range of barley genetic resources and environment evaluation is required.

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MONITORING OF BARLEY NET BLOTCH (*Pyrenophora teres* Drechsler) IN BULGARIA

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Abstract

Worldwide, net blotch caused by Pyrenophora teres Drechsler is a major foliar disease of barley (Hordeum vulgare L.) causing economic losses by reducing the yield and grain quality. Two forms P. teres f. maculata and P. teres f. teres have been identified as similar morphologically, however, different at the genetic and pathophysiological levels. The aim of the current study is to monitor the distribution of barley net blotch in Bulgaria. The total surveyed area during the investigation is 5212 dka. The lowest prevalence of the disease is in the regions of Imrenchevo and Chirpan, respectively 14.35% and 15.2%. The manifestation of net blotch is strongest in the region of Kamburovo - 82.2%. Based on the studied samples from different regions the species D. teres predominates in Bulgaria, while D. maculata is much rarer. The conidia of D. teres are light brown, cylindrical, with 3 to 8 partitions and dimensions - 69.5-181 x 15.28-24.1µm. The conidia of D. maculata are oblong-cylindrical with 3 to 5 partitions and with dimensions - 65-143 x 10.2-19.3 µm.

***Key words**: Barley breeding, Hordeum vulgare, net blotch, pathogen resistance, Pyrenophora teres.*

INTRODUCTION

Worldwide, net blotch caused by *Pyrenophora teres* Drechsler [anamorph *Drechslera teres* (Sacc.) Shoem] is a major foliar disease of barley (*Hordeum vulgare* L.) causing economic losses by reducing the yield and the grain quality. Two forms *P. teres* f. *maculata* and *P. teres* f. *teres* have been identified as similar morphologically, however, different at the genetic and pathophysiological levels (Campbell et al., 1999; Liu et al., 2011; Akhavan et al., 2016).

P. teres f. *teres* forms dark-brown and longitudinal necrotic lesions, which can turn into chlorotic (Lightfoot & Able, 2010), while *P. teres* f. *maculata* is responsible for dark brown circular or elliptical spots with chlorosis on the surrounding leaf tissues (Gupta and Loughman, 2001; Jayasena et al., 2004). *Pyrenophora teres* f. *teres* (net form of net blotch (NFNB) and *Pyrenophora teres* f. *maculata* (spot form of net blotch (SFNB) are morphological very similar, while the disease symptoms are different (Akhavan et al., 2016). The pathogen of NFNB can be easily identified based on symptomatology, while SFNB presents symptoms without a net-spot (Marshall et al., 2015), which closely resemble those caused by *C. sativus* (Rehman et al., 2020).

Nowadays there are no studies on the prevalence of the disease in Bulgaria. The first data are given by Nakova (2009), according to reticular spots are little known as a disease in Bulgaria. The disease first appeared on a mass scale in the area of the town of Yambol in 2005 - on 5000 ha of crops, on a 0.2 to 0.5 ha patch. in the tillering phase.

The pathogenic factor and the quantity of primary inoculum from infected residues depend on several factors. Firstly, the environmental conditions and more specifically, long periods of wet increase the primary inoculum levels (Mclean et al., 2009). Secondly, the disease levels vary greatly depending on the cultural practice applied. Crop rotation, avoiding barley monoculture and eliminating or reducing primary inoculum in the field are means preventing the pathogen's development (Liu et al., 2011).

Geschele (1928) has first demonstrated the resistance to *P. teres* f. *teres* to be

quantitatively inherited (Clare et al., 2020). The genetic control of resistance to *P. teres* in barley has been first conducted in United States in 1955 (Afanasenko et al., 2007). The first gene *Pt1* conferring the barley resistance to *P. teres* is found by Schaller (1955). Later, two additional loci, designated *Pt2* and *Pt3* were identified by Mode & Schaller (1958). Initially, the genetics conferring resistance to *P. teres* f. *maculata* contained three major designated loci and therefore has been considered less complex to compare the *P. teres* f. *teres* – barley interaction (Clare et al., 2020).
The aim of the current study is to monitor the distribution of barley net blotch in Bulgaria.

MATERIALS AND METHODS

Spread of *Pyrenophora teres* in Bulgaria

A number of barley production areas in Bulgaria were evaluated for plants two leaf spot fungi reactions. The surveyed barley crops were located in the South Central, South Eastern and Northern parts of the country, typical areas for breeding the culture. The distribution was determined by examining the crops on randomly selected plants. The type of lesions occurring on plants was an indicator of susceptibility or resistance of cultivars to net blotch and spot-type net blotch in the field.
Cultivars susceptible to *P. teres* showed typical net-blotch lesions, having dark-brown striations extending both longitudinally and transversely within the lesions. In the case of spot-type net blotch, lesions varied from dark-brown spots to solid stripes, spreading longitudinally between leaf veins.
Periodic observations and macroscopic analyses were performed in order to detect the forms of the pathogen during the critical stages of barley to disease. The Tekauz scale for NFNB (net type) and SFNB (spot form) was used to determine the degree of infestation of the two forms of net blotch. The grades of 1-3 denote specimens resistant to SFNB, and 5-9 for susceptible in a different range. Respectively, values from 1 to 5 are conventionally considered as resistant forms to NFNB and 5 to 10 as sensitive (Figure 1).
The percentage of diseased plants compared to healthy ones was reported. The calculations were performed according to the formula of Chumakov (1974):

$$P = a/A*100,$$

Where: P - distribution, %
a - diseased plants
A - total number of reported plants
Observations of barley phenotype reactions to net blotch and fungus symptomatic manifestations were carried out under the field conditions, on different varieties of naturally infected plants. Field surveys described symptoms such as changes in plant habitus; change in colour, shape and size of lesions: chlorosis or yellowing, necrotic spots. Leaf samples, with symptoms of disease, were taken for isolation.

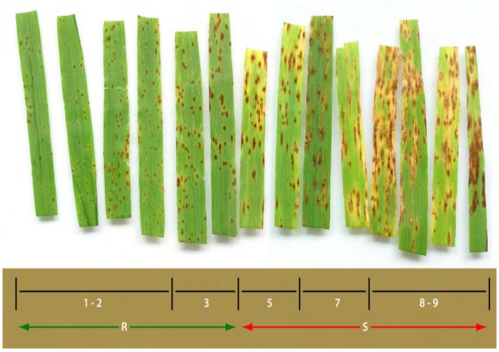

Figure 1. Tekauz's scale for determining the degree of attack by *Pyrenophora teres*

The presence of pathogens was proven macroscopically, microscopically on the basis of isolates on nutrient media by the accepted technique of biological analysis. Isolations were performed by naturally infected plant parts on Water agar (WA) and Potato Dextrose Agar (PDA).
Small pieces of infected tissues are cut from the border zone between the diseased and healthy part and then washed with running tap water. Isolates were prepared on PDA. From the pure cultures prepared, sporulation is examined, and pathogenicity tests are carried out by inoculation of healthy barley plants.
The obtained isolates pathogenicity was proven by inoculating barley plants in controlled conditions. Each variant was in three repetitions. The plants were grown in pots, on a sterile substrate. The plants were pulverized with the prepared spore suspension. The variants were placed in a humid chamber, periodically sprayed with water to maintain high humidity. Daily symptoms monitoring,

description and comparison with the control variants sprayed with sterile water was conducted. Re-isolation and microscopic analysis were performed as well. Plants were placed in a growth chamber at 25°C, RH 70% and periodically sprayed with water to maintain high humidity. If symptoms
appear, reisolation and microscopic analysis are carried out.

From the isolates, with proven pathogenicity, monospore cultures were obtained for morphological studies. Identification of the phytopathogen that cause the disease is performed macroscopically based on symptoms characteristics, and microscopically by morphological characters of the spores (Tafradjiiski et al., 1973). Morphological identification is based on the type of colonies (color, shape, type of mycelium), type of shape and size of spores.

The software products used during the study were “MS Excel Analysis Tool Pak Add-Ins” 2019 (https://support.office.com) and “R-4.0.3” in combination with “RStudio-0.98” and package installed “Agricolae 1,2-2” (Mendiburu, 2015).

RESULTS AND DISCUSSIONS

Net blotch has become a major foliar disease of barley not only in Bulgaria, but in many countries of the world (Backes et al., 2021). Based on the pathogen life cycle, three sources can form the primary inoculum of which infected seeds, crop debris, and straw residue. It is known that net blotch propagates efficiently on wild plants and, there is a huge reservoir of the pathogen in the wild host populations, which could occasionally or continuously serve as a source of initial inoculum to epidemics in the field (Ronen et.al., 2019). Therefore, the first step to control net blotch is the deletion of the primary inoculum of *P. teres* by sowing healthy seeds (Jalli, 2011).

Different areas are observed to determine the prevalence of barley disease *Drechslera teres* and *Drechslera maculata* in the country. The analysis of the data shows that the attack by regions varies widely. The results of the 2021 survey on the distribution of *Drechslera teres* and *Drechslera maculata* on barley in different regions of the country are shown in the Table 1 and Figure 2.

The total surveyed area in Bulgaria for the period of investigation was 5212 dka. On the surveyed areas was observed 40.54% spread of the disease. The variation was very pronounced between the different regions of the country.

Table 1. Distribution of *Drechslera teres* and *Drechslera maculata* on barley in some parts of the country in 2021

№	Region	Area (dka)	Diseased plants (%)
1	Aleksandrovo	150	37.45
2	Levka	22	48.25
3	Elhovo	140	22.3
4	Okop	210	19.5
5	Aheloy	60	36.2
6	Stozher	80	18.95
7	Karnobat	750	38.9
8	Chirpan	500	15.2
9	Imrenchevo	200	14.35
10	Milanovo	200	33.03
11	Lilyak 2	250	43.45
12	Izvorovo 1	350	52.50
13	Izvorovo 2	350	28.95
14	Kamburovo	150	82.2
15	Lilyak 2	300	55.64
16	Padarino	200	68.49
17	Zimnitsa	550	51.06
18	Dragoevo	450	50.00
19	Pleven Region	150	37.86
20	Vratza region	150	56.48

The standard deviation is 18.08%. The analysis of the reported data (Table 1) showed that the attack of the pathogen by regions varies widely.

Figure 2. *Pyrenophora teres* distribution of barley crops on the territory of Bulgaria

The lowest prevalence of the disease is in the regions of Imrenchevo (North Eastern

Bulgaria) and Chirpan (South Central part of the county), respectively 14.35% and 15.2%.
The manifestation of net form and spot form of net blotch was strongest in the region of Kamburovo (North Eastern) - 82.2%. Based on the studied samples from different regions, it was found that the species *Drechslera teres* (*Pyrenophora teres* f. *teres* - *Ptt*) predominates in the country while *Drechslera maculata* (*Pyrenophora teres* f. *maculata* - *Ptm*) is much rarer.
Gray fluffy mycelium with radial growth is formed on the PDA. Conidia are light brown, cylindrical, with 3 to 8 partitions and dimensions - 68.5-178 x 13.5-22.5μm (Figure 3).

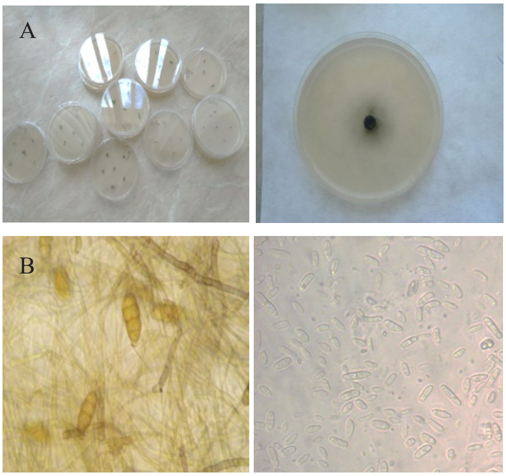

Figure 3. Conidia of *Pyrenophora teres* Drechsler [anamorph *Drechslera teres* (Sacc.) Shoem] on a petri dish (A) and from microscopic examination (B)

Similar results are also confirmed by Lammari et.al. 2019, in which Ptt is the dominating type of net blotch in Algeria and was prevalent in almost all provinces surveyed, while Ptm was found less frequently.
The differentiation of these forms has been reported from other authors in Sweden (Jonsson et al., 1997), France (Arabi et al., 2003), Western Australia (Gupta & Longhman, 2001), South Africa (Lowu et al., 1996), and Western Canada (Akhavan et al., 2016).
Surveys of foliar diseases in barley (Hordeum vulgare) crop throughout Victoria Australia indicated spot form of net blotch caused by *Pyrenophora teres* f. *maculata* had the highest incidence, being present in more than 90% of crops surveyed (McLean et. al., 2010).

In 2021, 20 isolates of *Drechslera teres* and *Drechslera maculata*, which are pathogenic for the culture, were obtained from different regions and different cultivars. All inoculations were prepared of naturally infected leaves, on AA and PDA.
The spores of *Drechslera teres* form in groups of 2 to 3, and emerge through the stomata. The conidia of *D. teres* are light brown, cylindrical, with 3 to 8 partitions and dimensions - 69.5-181 x 15.28-24.1μm (Figure 3). The conidia of *D. maculata* are oblong-cylindrical with 3 to 5 partitions and with dimensions - 65-143 x 10.2-19.3μm.
Light brown spots in the form of a network were observed. The mass manifestation of the disease is in the growth stage of tillering at a temperature of 18 to 20ºC and precipitation. Depending on the variety, small, dark brown rounded to elliptical spots were formed on the leaf blade, surrounded by a lighter crown, or the characteristic brown-red spots, interspersed with transverse and longitudinal lines, which give them a reticulated appearance.
The leaves wither from the top to the base and die in a short time. At high humidity, the sporulation of the fungus was formed on the spots, in the form of a dark spore-bearing deposit (Figure 4).

Figure 4. Pathogenicity of isolates evaluated under controlled condition with high humidity

Several methods for disease assessment are applied for monitoring of *P. teres* infection. The evaluation of the disease in the laboratory and under controlled condition, where *P. teres* isolates is sprayed with a sprayer on the leaves at different stages of growth after sowing in order to follow the disease development. After pathogen inoculation, the barley plants are placed in a hood to increase the humidity level, allowing the pathogen to improve its development (Backes et al., 2021). The disease can also be followed on detached leaves, a rapid technique of assessment under controlled conditions (El-Mor et al., 2017).

A reliable method used for monitoring and scoring of resistance to barley net blotch, so called ''summer hill trial'' was developed in which winter barley is sown at the beginning of August at optimum conditions for *P. teres* infection and in order to other diverse pathogen infections with *Rhynchosporium commune*, *Puccinia hordei* or *Blumeria graminis* f. sp. *hordei* to be avoided (König et.al. 2013).

During this study, we were able to confirm field observations in controlled conditions on barley plants using the fungal isolates. The seedling symptoms rate under artificial inoculation of commercial barley varieties formed the varietal structure in the country was 100%.

CONCLUSIONS

Pathogenicity tests and morphological studies as well as analyses indicated that the described symptoms were caused by the forms of *Pyrenophora (Drechslera) teres*. Recognized as the causal agent of net blotch, *Pyrenophora teres* is responsible for major losses of barley crop yield. The consequences of this leaf disease are due to the impact of the infection on the photosynthetic performance of barley leaves.

The susceptibility of barley cultivars currently being grown in Bulgaria, variable distribution and *P. teres* barley pathosystem, indicates that incorporating resistance and identifying new resistant germplasm should remain a high priority.

It's still challenged the better understanding of local isolate pathogenicity, epidemiology, and host–pathogen interactions, which are needed to breed more resistant cultivars

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CULTIVATION POTENTIAL OF CHIA (*Salvia hispanica* L.) IN CLUJ COUNTY

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Abstract

Chia (Salvia hispanica) is an annual herbaceous species from the Lamiaceae family. It is a tropical short-day species, native to Mesoamerica. Chia seeds are considered a "superfood" due to nutritional characteristics. Aim of this research was to assess the cultivation potential of chia in local climate (Cluj-Napoca, Romania). The research was conducted on four Salvia hispanica accessions cultivated in the experimental field from Agro-Botanical Garden of the University of Agricultural Sciences and Veterinary Medicine of Cluj-Napoca. In field conditions, growth cycle lasted between 150-170 days. According to BBCH scale were identified eight principal growth stages. Fruit development and fruit maturation were the longest. In September, seeds were harvested for analysis. The average thousand seeds mass was 1.43 g, average protein content 17.06 g/100 g and average fat content was 31.32 g/100 g. Plants developed a specific habitus and had a complete life cycle, producing fruits with viable seeds at the end of summer. Average seed germination was 92.88%. Quality of seeds was comparable with the one from literature, indicating to the potential for cultivation of chia in continental temperate conditions of Cluj county, Romania.

***Key words**: food, proteins, lipids, germination, quality, phenology.*

INTRODUCTION

Salvia hispanica L. is an annual short-day herbaceous species from the family *Lamiaceae* that is native to Mesoamerica (Iannucci & Amato, 2021). The edible seeds were used as food by Mayan and Aztec in pre-Columbian times (Baginsky et al., 2016; de Falco et al., 2017). Today, chia seeds find wide utilization in food industry, as supplements or in cosmetology (Motyka et al., 2021). The nutritional value of chia seeds is given by their rich chemical composition, such as high content of polyunsaturated omega-3 fatty acids, essential amino acids, polyphenols derived from caffeic acid and vitamins (de Falco et al., 2017; Motyka et al., 2021; Rentería-Ortega et al., 2021). Aside of the nutritional benefits, chia can be considered a good candidate for the development of functional foods, and important food ingredient due to textural properties. In this regard, chia can be used in baked goods as hydrocolloid and egg substitute (Zettel & Hitzmann, 2018). Chia can also be used as food additive - thickener, as fat substitute, stabilizer and emulsifier in various food applications (Kulczyński et al., 2019; Rentería-Ortega et al., 2021). The inclusion of chia seeds in human diet could be considered an innovative therapeutic approach in the prevention and treatment of various ailments and diseases (Kulczyński et al., 2019). This is due to the fact that chia seeds demonstrated anti-inflammatory and antioxidant properties in addition to anti-diabetic, cardioprotective, anti-atherosclerotic and antihypertensive potential (Motyka et al., 2021; Motyka et al., 2022). Among non-food applications, there are results that indicate to the potential use of chia essential oil in controlling phytopathogenic bacteria and fungi (Elshafie et al., 2018). Based on these considerations, the extended uses and application possibilities of chia seeds will most likely increase the demand for this crop in the coming years (Zettel & Hitzmann, 2018).

Under favourable conditions, chia plants can grow up to one meter in height. Leaves have elongated shape, size 3-4 × 4-8 cm and serrate margins; leaves are inserted opposite. Flowers are hermaphrodite from white to purple having typical labiate morphology and reaching 3-4 mm in size. Flowers are arranged in verticillasters on inflorescence axis (Hrnčič et al., 2020; Motyka et al., 2022). The plant produces a dry indehiscent fruit of 1-2 mm in length, oval in shape and ranging in colour from white-gay to black; the white colour in seeds is a recessive trait (Motyka et al., 2022). Four nutlets are produced per flower, and act as seed units (Geneve et al., 2017). The hydrated chia seed forms a continuous and transparent capsule with an average thickness of about 0.4 mm, having a gel-like consistency and complex ultra-structure (Muñoz et al., 2012). Myxocarpy in chia might play some important ecological roles (Geneve et al., 2017). There are a series of traits selected for cultivation that distinguishes the cultivars from wild *S. hispanica* genotypes, but the most important is early flowering (Grimes et al., 2018) and the closed cups (Motyka et al., 2022). In Figure 1 it can be observed a *S. hispanica* plant alongside the characteristic speckled dark seeds.

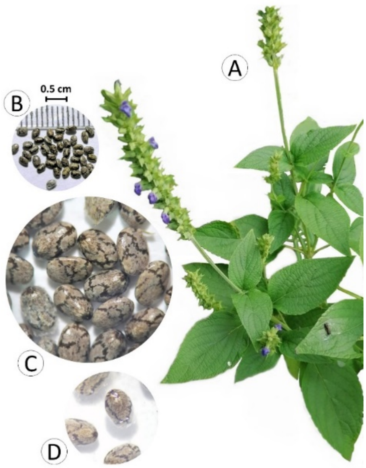

Figure 1. Characteristics of *S. hispanica*: A) chia plant, B-C) dry seeds, D) seeds swelling in water (Original)

Originating in tropical climate of southern Mexico and Guatemala (Motyka et al., 2022), the growth and development of this species is mainly influenced by day length and temperature. For successful cultivation, chia crop requires well distributed rainfall during early growth and dry conditions during seed maturation and harvest (Iannucci & Amato 2021). This plant species is not frost-tolerant, but has extended in cultivation well beyond its native range (Bochicchio et al., 2015; Grimes et al., 2018; Iannucci & Amato 2021). However, technical information about cultivation of this species remains relatively scarce (de Oliveira et al., 2019). In its natural habitats this species grows in mountain areas. In culture, thrives in acidic soils but can grow in soil with ranging pH 6.5-8.5 (Motyka et al., 2022). The optimum growth temperatures for this crop are between 16–26°C (Grimes et al., 2018).

Because this valuable plant species is a promising crop, cultivation beyond its native geographic range could be a viable possibility to cover the increasing market demands. Locally sourced chia could provide a steady flow of raw material representing an attractive option for local growers and food sector alike. However, before recommending this species for cultivation in local conditions, the agronomic suitability and feasibility of this crop must be determined.

Aim of this research was to identify the cultivation potential of chia (*S. hispanica*) in temperate conditions from Cluj county, Romania. Two objectives were defined:

- description of the plant phenology under local climatic conditions in order to determine the agronomic suitability for cultivation;
- determination of some seed characteristics after harvest, in order to find out the preliminary qualitative parameters with importance for feasibility of this crop locally.

MATERIALS AND METHODS

The experiment was conducted in the year 2020 in the Agro-Botanical Garden of the University of Agricultural Sciences and Veterinary Medicine (UASVM) from Cluj-Napoca, Romania. The Agro-Botanical Garden UASVM Cluj-Napoca is situated in temperate continental climate. The soil has loam-clay texture, pH 6.72, a low humus content (1.35%), very well supplied with macronutrients: N 0.461%, P 68 ppm, K 312 ppm (Vârban et al., 2021). Climatic conditions during the experimental interval, according to data registered by the UASVM Cluj-Napoca weather station are presented in Figure 2. Monthly average temperature was over 10°C between May and October. It can be observed that high precipitation levels were registered in June. Between June and September there were days when maximum temperature reached ≥30°C, but highest temperature was registered in the month of August of 2020. September was characterized by low precipitation levels (Figure 2).

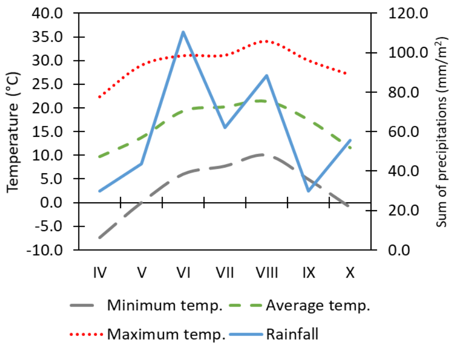

Figure 2. Climatic conditions during the experiment (April-October, 2020) in Cluj-Napoca, Romania (Original)

The biologic material was represented by dark chia seeds, obtained by Agro-Botanical Garden UASVM Cluj, from four botanical gardens, as presented in Table 1.

Table 1. Provenance of *Salvia hispanica* accessions

Botanical Garden[1]	IPEN code[2]
Jardin botanique de Besançon, France (BESN)	XX-0-CLA-1913
Jardin des Plantes Nantes, France (NTM)	XX-0-CLA-1914
"Anastasie Fătu" Botanical Garden of Iaşi, Romania (IAGB)	XX-0-IAGB-20179769G
Späth-Arboretum der Humboldt-Universität zu Berlin, Deutschland (BHU)	XX-0-BHU-2018-0262

[1]Acronymin in parentheses indicates the Garden IPEN code
[2]International Plant Exchange Network (Index Seminum, 2021)

The seeds were sown in heated greenhouse on 12 March 2020. Germination took place in 10 days. At two true leaves, the seedlings were pricked in larger pots. In the month of May (2020) seedlings were planted in the experimental field from the Agro-Botanical Garden UASVM Cluj-Napoca, Romania. Seedlings were planted at a distance of 50 cm between rows and 30 cm between plants on a row, as recommended for species from the family *Lamiaceae*, according to literature (Muntean et al., 2014; Muntean et al., 2016).

In the accordance with the objectives of the research the following determinations were conducted:

- identification of main growth stages and their duration;
- seeds characteristics after harvest: thousand seeds mass and chemical parameters (moisture, lipids, protein and ash);
- germination percentage of the seeds.

Aspect of the chia crop can be seen in Figure 3.

Figure 3. Aspect from the experimental field (Original)

Delimitation of phenophases followed the BBCH scale description (Meier, 2001), and the specific growth stages defined for chia by Pérez Brandán et al. (2019). For each accession were determined the growing degree days (GDD) and sum of rainfall, calculated according to Vârban et al. (2021) for the entire growth cycle length. Thousand seeds mass was determined according to standard procedure (Muntean et al., 2014). Germination was determined according to SR 1634/1999, using 100 seeds in four replicates. Germination was determined after 4 months from harvest (January 2021), and calculated as percentage of germinated seeds per total number of seeds placed for germination on moist blotting paper after 4, 7, 14 and 18 days (Muntean et al., 2014). Chemical characterization of seeds was conducted at the Faculty of Food Science and Technology from UASVM Cluj-Napoca. Proximate compositions were determined according to the standards (https://e-standard.eu.): moisture was determined according to SR ISO 712:1999. Nitrogen (N) content was determined by the Kjeldahl method, and crude protein was calculated using 5.7 as N conversion factor for protein of vegetable products (SR ISO 1871/2002). The lipid content was determined according to SR ISO 6492:1999 and ash (mineral content) was determined according to Romanian official methods STAS 90/1988 (Rusu et al., 2021).

RESULTS AND DISCUSSIONS

Regarding the phenology of the accessions studied in 2020, it was found that the vegetation period lasted between 150-170 days. The longest vegetation period was registered by the accession from Iași (Romania) of 170 day, while the shortest for the two accessions from France of only 150 days (from Botanical Gardens of Besançon and Nantes, respectively). The length of growth season for accession from Berlin was 155 days.
Regarding the length of the phenophases, it was observed that in all accessions the phenophase of fruit development (stage 7), fruit ripening (stage 8) and senescence (stage 9) were the predominant ones, both in number of days (Figure 4) as well as percentage from the vegetation period (Table 2).

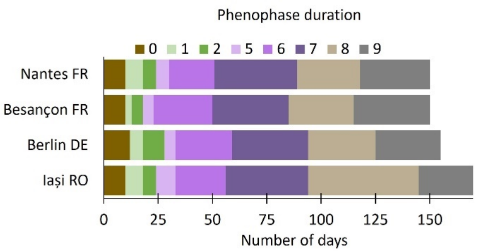

Figure 4. Phenophase duration in number of days for four accessions of *Salvia hispanica*

Seed harvesting is conducted in this phenophase. The phenophase of flowering (stage 6) was also quite long, lasting between 21-27 days (Figure 4). The share of phenophases (%) for the studied accessions are presented in Table 2. The phenophases of leaf appearance and branching of the stem were short. In the case of the accession from the Botanical Garden of Besançon, France, the phenophase of fruit development and senescence were predominant.

Table 2. Phenophase duration (%) from growing season of four *Salvia hispanica* accessions

Principal growth stage according to BBCH scale	Besançon FR (BESN)	Nantes FR (NTM)	Iași RO (IAGB)	Berlin DE (BHU)
0. Germination	6.7	6.7	5.9	7.7
1. Leaf appearance	2.0	5.3	4.7	3.9
2. Shoot appearance	3.3	4.0	3.5	6.5
5. Inflorescence growth	3.3	4.0	5.3	3.2
6. Flowering	18.0	14.0	13.5	16.8
7. Fruit development	23.3	25.3	22.4	22.6
8. Ripening	20.0	19.3	30.0	20.0
9. Senescence	23.3	21.3	14.7	19.4
GDD	2383.7	2697.9	2630.9	2670.8
Rainfall (mm)	328.92	341.86	333.48	341.10

In the case of accession from Nantes, France, the predominant phenophase was represented by fruit development (25.33%). The accession from Iași (Romania) had the longest vegetation period, while the longest phenophase was the fruit ripening, which represented 30% of the vegetation period. The shortest phenophase duration was registered for the accession of Besançon, the appearance of leaves (stage 1). There was also considerable overlapping between phenophases, particularly between vegetative and reproductive growth stages (Figure 5).

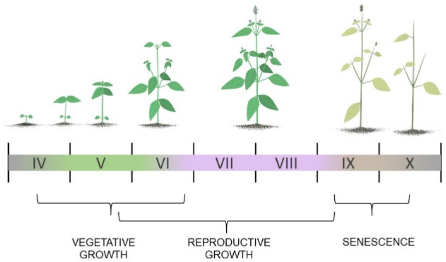

Figure 5. Growth stages of chia in Cluj county

The formation and ripening of the fruit began during last part of August, followed by senescence, which took place during September and October. In all accessions, growth cycle ended in October. Senescence process was gradual, lasting >30 days except for the accession from Iași, with a senescence of 25 days. The fruits were harvested in September. During the entire growth season, the growing degree days ranged between 2383.7-2697.9°C while sum of rainfall accumulated ranged between 328.92-341.86 mm/m^2 (Table 2). In summary, in conditions from Cluj county (2020), the chia plants completed their phenological cycle, reaching physiological maturity and forming fruits. Images with vegetative and reproductive growth stages of chia are presented in in Figure 6. There were three vegetative stages (that includes germination, leaf and shoot appearance) (Figure 6 A-E) and four reproductive growth stages represented by inflorescence growth, flowering, fruit development and ripening (Figure 6 F-J).

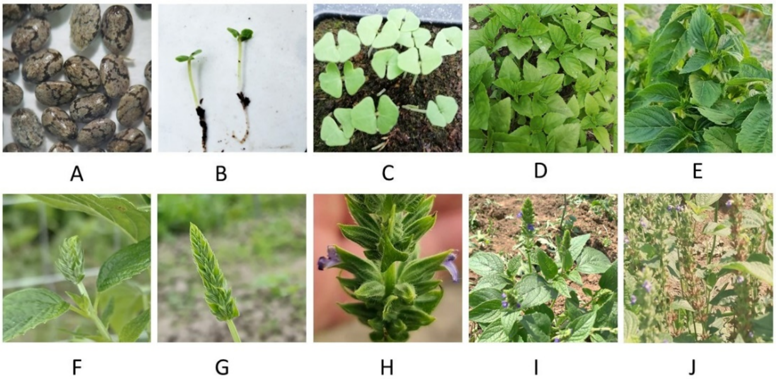

Figure 6. Examples of phenological stages of chia in Cluj county according to BBCH scale: A) dry seed, principal growth stage 0; B-C) cotyledons unfolded, principal growth stage 1; D) appearance of true leaf pairs, principal growth stage 1; E) shoot appearance, principal growth stage 2; F-G) inflorescence growth, principal growth stage 5; H-I) flowering, principal growth stage 6; J) fruit development, principal growth stage 7 (original)

The results for thousand seeds mass (TSM) are found in Table 3. The mass of 1000 seeds of *S. hispanica* registered values between 1.39 and 1.48 g. The thousand seeds mass registered significantly higher values for accession from Iași compared to the accession from Berlin and Besançon. Regarding the germination percentage, on average it increased from 82.31% after four days to 90.06% after 14 days but mean value varied by accession (Table 4).

Table 3. Thousand seeds mass (TSM) of *Salvia hispanica*

Provenance	Mean TSM	±SD	±SE	Duncan test
Besançon FR, (BESN)	1.40	0.054	0.019	a
Nantes FR, (NTM)	1.44	0.052	0.018	ab
Iași RO, (IAGB)	1.48	0.046	0.016	b
Berlin DE, (BHU)	1.39	0.064	0.023	a

[1]SD - standard deviation; SE - standard error; differences between means followed by same letters are not significant

Table 4. Germination (%) of *Salvia hispanica* seeds (Mean ± SD)

Provenance	After 4 days	After 7 days	After 14 days	After 18 days
Besançon FR, (BESN)	85.50 ± 2.65 b	86.00 ± 2.45 bc	91.75 ± 4.65 b	94.00 ± 2.16 a
Nantes FR, (NTM)	80.50 ± 2.38 ab	81.75 ± 2.22 ab	84.25 ± 3.69 a	90.25 ± 1.71 a
Iași RO, (IAGB)	86.25 ± 1.71 b	87.25 ± 1.71 c	92.00 ± 3.56 b	94.25 ± 2.22 a
Berlin DE, (BHU)	77.00 ± 5.48 a	80.25 ± 3.30 a	92.25 ± 3.59 b	93.00 ± 4.08 a
Average	82.31 ± 4.94	83.81 ± 3.73	90.06 ± 4.92	92.88 ± 2.92

[1]SD - standard deviation; differences between means followed by same letters are not significant (Duncan test)

Statistical analysis revealed that accessions from Iași and Besançon registered significantly higher germination percentage after four days compared to the accession from Berlin. After four and seven days, the accession from Berlin presented the lowest germination among the accessions studied, but after 14 days presented the highest germination. After 18 days, all four accessions registered a germination >90%. At this point there were no more significant differences between mean germination percentage among accessions (Table 4). Seed quality is particularly important for this species, considering that it is found in relationship with the nutritional values. The highest fat content was identified in the accession from Besançon followed by the accession from Iași. Similar protein content was identified for the accessions from Nantes and Iași. Compared with data from literature can be observed that seeds moisture situates within middle range (Tables 5, 6). Fat content of seeds obtained in conditions from Cluj county is similar with the one reported for chia crops from Brazil (da Silva et al., 2017), Bolivia (Ayerza, 2016) and Chile (da Silva Marineli et al., 2014). The protein content of seeds was lowest in this study for accessions Besançon and Berlin (Table 5), and these levels are lower (<15%) than those from literature, where roughly the reported range is 18-25% (Table 6).

Table 5. Chemical characteristics of *Salvia hispanica* seeds (Mean) in Cluj county

Provenance	Humidity (g/100 g)	Lipids g/100 g dry substance	Proteins g/100 g	Ash (total mineral substances) g/100 g
Besançon FR, (BESN)	6.33	32.20	15.56	5.30
Nantes FR, (NTM)	6.88	30.22	18.35	5.20
Iași RO, (IAGB)	6.30	32.10	18.35	5.30
Berlin DE, (BHU)	6.48	30.74	15.96	5.10

Table 6. Characteristics of *Salvia hispanica* seeds according to literature

Country of source material	Moisture (%)	Lipids (%)	Proteins (%)	Ash (%)	Source
Mexico – Jalisco	5.80	18.30	18.80	4.70	Rodríguez et al., 2021
Mexico	6.82	35.13	24.11	-	Grancieri et al., 2019
Brazil – Rio Grande do Sul	7.14	32.16	18.18	4.56	da Silva et al., 2017
Brazil – Mato Grosso	5.62	30.17	19.72	5.07	da Silva et al., 2017
Ecuador	5.71	16.06	19.78	4.82	Carrillo et al., 2018
Ecuador	-	33.30	18.90	-	Ayerza, 2016
Bolivia	-	31.80	23.90	-	Ayerza, 2016
Chile	5.82	30.22	25.32	4.07	da Silva Marineli et al., 2014

For the other two accessions (Nantes, Iași), the protein content although situates within lower range compared to literature data (Table 6), resembles the levels registered by some chia crops from Mexico - Jalisco (Rodríguez et al., 2021), Brazil - Rio Grande do Sul (da Silva et al., 2017) and Ecuador (Ayerza, 2016). The ash content of the seeds from this study is similar with the one reported for chia from Brazil - Mato Grosso (da Silva et al., 2017), however most sources from literature report a level of ash <5% for chia (Table 6). In large part, nutritional and health benefits of chia seeds are due to their lipid fraction (polyunsaturated fatty acids, chiefly α-linolenic acid) besides other constituents (Rentería-Ortega et al., 2021). Other non-food applications are also linked to the lipid fraction of chia seeds; for example, lipids from chia seeds can be used to obtain nanoemulsions and nanoliposomes with pharmaceutical applications (Motyka et al., 2022). Regarding the protein content, seeds obtained in Cluj county presented low levels. However, this is not the chief attribute that seeds are used for, but they do represent an important nutritional parameter. According to literature, the most important storage protein found in chia seeds is globulin, that constitutes up to 52% of the total protein content, followed by albumins (17%), glutelins (14%), and prolamins (12%) alongside a few other with lower abundance (Motyka et al., 2022).

Although the chia plants completed their phenological cycle in conditions from Cluj county, viability of the seeds is important because it can ensure seed production for establishing the crop, locally. There were no significant differences between accessions after 18 days, since all four accessions reached a germination percentage >90%. A study conducted on chia seeds in Brazil testing different germination temperatures (25-30 °C), reported a germination percentage after 4 days of 19-57% and after seven days between 72-88% (de Oliveira et al., 2019). The germination percentage obtained in this study is higher compared to this cited study after four days, but values after seven days are comparable. Another study from Brazil reported a mean germination of 96% after 14 days (at 25 °C), but under lower temperature conditions (at 18 °C), the germination percentage decreased to 67% (Possenti et al., 2016). Based on research of chia seed germination under different stressors, was proposed the characteristic pectinaceous mucilage formed around hydrated chia seeds enhances germination, and in addition could potentially provide an ecological advantage in arid or semiarid conditions, in salinized soil or with irregular soil moisture (Geneve et al., 2017). Interestingly, germination of the seeds might enhance nutraceutical potential of chia, with potential application in the design of novel foods (Beltrán-Orozco et al., 2020). Several applications of chia are associated with the mucilaginous layer of hydrated seeds. The viscoelastic properties and solubility are given by its chemical composition. Analysis revealed that this mucilage is a polymer consisting mainly of sugars (xylose, glucose, arabinose and galactose) and a considerable amount of uronic acids (Rentería-Ortega et al., 2021).

Life cycle of chia crop starts with germination, since these plants are propagated by seed. After germination, the plant enters the seedling stage. This stage is critical, and recognized as highly important for the establishment of the crop (Iannucci & Amato 2021). From seedling stage until physiologic maturity the chia plants undergo a succession of vegetative and reproductive phenophases until approaching the end of their life cycle once with senescence onset. A study conducted across a climatic gradient in Chile suggests that chia might have a quantitative-type sensitivity to day length (Baginsky et al., 2016), and this can be explained based on their origin. However, due to breeding efforts, were obtained genotypes with early flowering, that no longer limit the chia cultivation to latitudes lower than 25 degrees near the equator. Instead such genotypes due to earlier flowering in summer when day length is longer than 12 h, allows the time for maturation before frost, very advantageous for the cultivation in temperate climates (Grimes et al., 2018). Considering that chia plants are cultivated for seeds, relationships as well as conditioning factors between reproductive growth stages and yields are the most important.

A study conducted in Australia, indicated that the critical period for grain yield of chia starts from 550 degree-days before flowering (Diez et al., 2021). In Chile, highest yields were associated with latitudes with longer day lengths. It was determined a required day length threshold of 11.8 h for the beginning of flowering of chia plants. The study indicated that when plants were exposed to shorter days, the flower initiation was more precocious, but in the case of inadequate day length chia plants began to flower when they accumulated 600-700 ºC day degrees, calculated with the base >10 °C (Baginsky et al., 2016).

In temperate continental conditions from Cluj county, the life cycle of chia ended between September and October, lasting between 150-170 days. Similarly, in conditions from southwestern Germany, plants reached the harvest maturity between 15 September and 7 November, after 127-170 days from sowing (Grimes et al., 2018). However, this duration can be considered long compared to the ones reported in the geographical regions proximal to the centre of origin for this species. In Chile, chia crops reached maturity and completed the phenological cycle at 84-110 days after sowing (Baginsky et al., 2016). Also, the mean growing cycle length of chia ranged from 113 days in Bolivia to 110 days in Ecuador (Ayerza, 2016), therefore shorter than the one obtained in this study. Regarding the growing degree days accumulated in conditions from Cluj county, in the experimental year (2020) all accessions accumulated >2000 °C GDD, with

the base of calculation >10 °C. These values are higher compared to data from literature, but in this case were calculated for the entire life cycle until the end of stage 9 (senescence). Plants reached physiologic maturity in September, therefore a month earlier. In conditions from southwestern Germany, chia accumulated 910.2-1143.9°C growing degree days until the end of their growth cycle (Grimes et al., 2018). In Chile, growing degree days accumulated varied with latitudinal gradient, ranging between 927.7-1393.0 °C for those that reached maturity and completed their phenological cycle (Baginsky et al., 2016).
Regarding yields, under favourable conditions for this crop, there was reported yield of >2900 kg/ha in Chile (Baginsky et al., 2016). In Australia chia yields ranged between 1418 to 2148 kg/ha (Diez et al., 2021). In climatic conditions from Germany, yields reached as high as 1290 kg/ha (Grimes et al., 2018). Because productivity of this crop is related to feasibility and the prospects for successful cultivation, these are the next aspects to be assessed. Based on this study, it was demonstrated that chia plants can complete their life cycle, reaching physiological maturity and producing viable seeds in local conditions of Cluj county, Romania. This preliminary study indicates that interested growers could obtain seeds of comparable dietary quality with the ones obtained from crops in regions and countries of high favourability for this crop. In addition, based on the germination study it was determined that seeds obtained were viable reaching a germination percentage of >90%. Therefore, the preliminary screening concerning the possibility of cultivation of chia locally, established that this might be a promising crop. The results are justifying further studies and prompting the next steps into defying in more detail the cultivation potential. Following the results of this study, the first three necessary requirements were met, such as: plants completed their life cycle reaching physiologic maturity, seed produced had acceptable chemical properties and seeds were viable. In the prospects of cultivation this indicates that not only seeds of acceptable quality could be obtained locally, but growers could also have locally produced seeds for starting their crops. However, there still remain key aspects and further details that have to be studied and defined, and these should be subject for further research.

CONCLUSIONS

Salvia hispanica known as chia, is a species native to the tropical and sub-tropical region of Mexico and Central America that experiences increasing demand due to nutritional and textural properties of their seeds with wide applications in food industry.
This research reports on the potential cultivation of this species in the temperate continental conditions from Cluj county, Romania. Four accessions of *S. hispanica* were studied in order to determine the suitability for cultivation based on phenology in local conditions and some seeds characteristics after harvest.
Based on BBCH were identified eight growth stages between April and October 2020: germination, leaf appearance, shoot appearance, inflorescence growth, flowering, fruit development, ripening, senescence. The principal growth stages 3 and 4 were omitted because are not characteristic of this species. Plants had a complete life cycle lasting 150-170 days and produced fruits with viable seeds at the end of summer (average germination of 92.88%). At harvest, the average thousand seeds mass was 1.43 g, average protein content 17.06 g/100 g and average fat content 31.32 g/100 g. Quality of seeds obtained in continental temperate conditions of Cluj county, Romania, was comparable with the one obtained in native range of this species, indicating to the potential for cultivation of chia in the local climate. High temperatures during the summer registered from last few years in Cluj county could be favourable for fruit development and ripening of chia.

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EFFECTS OF DIFFERENT SOWING DENSITY IN WINTER WHEAT IN ECOLOGICAL PRODUCTIONS IN TWO DIFFERENT LOCATIONS IN ROMANIA

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Abstract

Straw cereals, especially wheat (Triticum aestivum), are the most widely cultivated plant in the world, grown in over 100 countries, and are a prime commercial source. The uses of straw cereals are many and varied. The grains are used for a range of milling products from which a rich assortment of bakery products, pastries and biscuits are made, which constitute basic foods for 35-55% of the world's population, providing 50-55% of calories consumed worldwide, along with other grains grown. The processing of wheat in high-capacity mills results in large quantities of bran, which is a valuable concentrated feed (rich in protein, lipids and mineral salts) and germs high in vitamins, which is a natural provitamin but also lipids with uses in cosmetics.Straw left over from harvesting can be used to make pulp, bulk feed or bedding for various categories of animals, organic fertilizer after a period of composting or incorporated as such into the soil after harvest, and by briquetting can be used as fuel. The agronomic importance is given by: integral mechanization of the crop; early release of the land and the possibility of summer plowing, being a good precrop for most crops; according to the early varieties, it allows the location of successive crops in certain areas.In this respect, a field experiments were established in the year 2020 at the Agricultural and Development Research Station Secuieni (ADRS Secuieni) located in North Romania (Neamț County) and at Experimental Trials of Saaten Union Romania at Drajna Nouă located in South-East (Călărași County). The experimental variants were represented by the nine winter wheat varieties (Trublion, Centurion, Katarina, Glosa, Aspekt, Izvor, Avenue, Solehio, Alcantara) and one hybrid wheat (Hyxperia) in three repetitions in both locations, with the following graduations: a) 250 germinable kernels/sm; b) 360 germinable kernels/sm; c) 500 germinable kernels/sm. The obtained results indicate that at medium density the production results are superior to the variants of low and high density, which implies giving us more profitability.

Key words*: wheat, ecological system, sowing rate, wheat varieties, hybrid wheat.*

INTRODUCTION

Winter wheat (*Triticum aestivum*) is a rustic and drought-tolerance plant, with very good adaptability to different climatic and soil conditions, from south to north areas.

In Romania, the areas cultivated with wheat have undergone minor changes in recent decades. Thus, in 1938, 2.5 million ha of wheat were cultivated with wheat, and the areas were gradually reduced to 2.1 million ha during 1979-1981. In recent years, surface oscillations can be reported, around this value (2.1-2.2 million ha) (Bîlteanu, 1998).

The three main groups of grain classification according to protein content are: feed wheat (below 12.5%), baking wheat (12.5-14.5%) and durum wheat or premium wheat (>14.5%) (Tabără et al., 2008).

Wheat cultivation offers the following advantages:

- kernels has a high content of carbohydrates and proteins, corresponding to the requirements of the human body;
- kernels has a good shelf life over long periods of time;
- the grains are easily transported over long distances;
- wheat grains have different alternatives for capitalization;
- wheat grains are an important source of trade on the world market;

- wheat can be grown in different soil and climatic conditions, ensuring satisfactory yields wherever it is grown;
- cultivation technology is completely mechanized and well developed, without special problems;
- wheat is a very good precrop for most crops;
- according to the early wheat varieties, successive crops can be sown, especially if the varieties are irrigated (Ion, 2010).

The vegetation period of autumn wheat lasts, in the conditions of our country, about 9 months (270-290 days). During this period, from germination to maturity, wheat plants go through certain phenological phases (stages), which are recognized by changes in the external appearance of plants and which are accompanied by internal changes in plant biology. Usually, it is difficult to strictly delimit these phases, because they partially overlap, or run in parallel.

It is generally accepted to divide the vegetation period of wheat plants into the following phenological phases: germination (emergence); rooting; twinning; straw formation (elongation); sprouting-flowering-fertilization; grain formation and ripening. In turn, the presented phases are grouped in the vegetative stage (period), characterized by the development of the vegetative organs of plants (from germination to twinning) and the generative (reproductive) stage, characterized by the development of inflorescence, flowers and berry formation (from beginning of straw elongation and until full ripening) (Axinte et al., 2006).

Practically, choosing the good agricultural practices, especially related to the soil management, is a key factor in granting food, clean water, feed, energy, safe climate, diverse ecosystem services and biodiversity for future generations (Mușat et al., 2021).

The yields obtained, by applying ecological system, show that differentiated results can be obtained, the choice of the working variant in relation to the crop plant being decisive (Guș et al., 2004).

In last years, ecological system of winter wheat has gained more and more ground. Organic wheat is one of the best listed and most sought-after organic products on the world market.

For organic farming, wheat varieties grown in conventional agriculture are also used.

Beneficial effects of organic farming at farm level:

- Restoring the natural balance of water and nutrients and infesting weeds, diseases, insects and other pests.

The restoration of natural balances is achieved, both by using classical technological measures (fertilization, soil work, etc.) and by using ecological measures (rotation, associated and intercropping crops, agroforestry curtains, hedges, grassy strips, etc.), soil improvement measures (green manure, mulching, conservation work, etc.) and plant protection (preventive, biological, biotechnical methods, etc.).

- Sustainable growth of soil fertility Organic farming has the healthiest methods and means of restoring and preserving soil fertility by stimulating the activity of soil microorganisms and the use of compost, green manure and long rotations with perennials and annuals with rich and/or deep root system.
- Decreasing soil erosion. The reduction of soil erosion is achieved as a result of soil improvement (increasing the organic matter content and improving the structure) and its better coverage (mulching, protection crops, etc.).
- Better water conservation in the soil. High soil organic matter content leads to better water retention and conservation in the soil, which has the effect of reducing irrigation needs.
- Respecting the intrinsic needs of animals regarding food, shelter, movement (http://madr.ro/docs/dezvoltare-rurala/rndr/buletine-tematice/PT4.pdf-page 11).

In the case of ecological system, soil fertility must be maintained as follows:

- cultivation or tillage practices maintain or increase soil organic matter, improve soil stability and biodiversity, and prevent soil compaction and erosion;
- practicing multiannual crop rotation, including legume crops and green manures;
- the application of fertilizers of animal origin or organic matter, both preferably composted, from organic production;
- use of biodynamic preparations.

If these measures do not cover the nutritional needs of the plants, the fertilizers and soil amendments listed in Annex I to EC Regulation 889/2008 may be used.

The following are prohibited in organic farming:

- hydroponic production (cultivation method which consists of placing the roots of the plants in a solution of mineral nutrients or in an inert medium, such as perlite, gravel or mineral wool, to which is added a solution of nutrients);
- administration of nitrogen (from animal fertilizers) in quantities greater than 170 kg/year/ha agricultural area;
- use of nitrogen-based inorganic fertilizers (N);
- composts of household waste that have not been sorted or have not been composted;
- raw materials containing GMOs or other derivatives thereof;
- slaked lime (calcium oxide) or slaked lime (calcium hydroxide); only calcium carbonate (in the form of chalk, marl, powdered calcium rock, sand deposit with calcareous impregnated algae (marl), phosphate chalk) or industrial lime obtained from the manufacture of sugar or salt (https://www.srac.ro/files/documente/Ghid-03% 20ECO% 20e1% 20r0% 20Ghid% 20practic% 20_Productia% 20vegetala.pdf).

The sources of organic agriculture are represented by the three currents that have emerged in Europe. The first is the one that appeared in Germany in 1924 under the impetus of Rudolf Steiner, with the name of biodynamic agriculture. The second current, published in Britain in 1940, was based on the theory developed by Sir Albert Haward and Lady Eve Balfour under the name of organic agriculture. Last but not least, the third current, called organo-biological agriculture, was developed in Switzerland by Hans Peter Rush and H. Müller

In the 1940s, in Switzerland, Hans Peter Rush and Muller H. emphasized the autarky of producers and the interest of short market circuits. These ideas have resulted in a method that the authors have called organic farming that focuses on renewable resources to ensure food security for the population. Organic farming is defined as a productive system that avoids the use of synthetic fertilizers, pesticides, plant growth regulators, feed additives in animal husbandry. Technological elements are allowed and practiced various sowing processes, use of plant resources after harvest, manure, legumes, green manure, mechanical cultivation, use of rock dust - a mineral source for maintaining high fertility, biological and physical control pests, diseases and weeds. The fundamental aims of this model of organic farming are: - long-term maintenance of soil fertility, - avoidance of all forms of pollution that can be caused by agricultural techniques, - production of sufficient quantities of food of high nutritional quality, - minimization of use fossil energy - non-recoverable energy in agricultural practice, - raising animals in living conditions in accordance with their physiological needs. At present, the principles of organic farming are increasingly conquering the food market, becoming an inseparable component of the agricultural policy of economically developed countries, which have an organization of organic farming through laws, ordinances and regulations. Organic farming (sustainable). The system of industrial agriculture, with its accompanying shortcomings, tends to be replaced by "organic farming" ("sustainable farming") (Toncea et al., 2012).

It has begun to take on a clearer outlook since the last decade in our country as well. Agriculture has been "ecological" since its inception, but in recent years the application of systematic vision and modern technologies to agriculture has been sought. Organic farming promotes the cultivation of the land through those means that ensure a balance between agroecosystems and the environment (generating "specific agroclimaxes") (Puia and Soran, 1981).

It is based on the use of those means and six methods offered by society, by the scientific and technical achievements that ensure the obtaining of large, constant and high-quality productions, in the conditions of environmental protection. Organic farming is in fact becoming synonymous with the agriculture of the coming years, which ensures the integrity of the biosphere, maximizing the production capacity of agroecosystems and obtaining good quality products (Ionescu et al., 1978).

It will require more conscientious and imaginative work and will ensure an abundance of food while reducing fossil energy consumption, maintaining or increasing the natural fertility of soils, improving man's living environment and protecting the environment as a whole. Organic farming, agriculture that is being born now for the future, is and must be thought of on an ever-widening, efficient and generous scale, ensuring the prosperity of society and nature on all the meridians of the globe. The structure of the new curricula and analytical programs in higher agronomic education must respond to the guidelines on the development of agriculture on ecological principles and in our country. For this reason, agricultural scientific research in our country must act on a systemic basis, both in the field of creating varieties (hybrids) of plants and animal breeds, and in improving the technologies of plant cultivation and animal husbandry, non-polluting, the protection of flora and fauna, the preservation of ecological balances and the protection of the environment (Toncea et al., 2012).

The characteristics to be followed in the choice of a wheat variety are its adaptability to the pedoclimatic conditions of the area, the increased tolerance to the specific pathogenic pressure and the efficient use of nitrogen, in order to maximize yields (Roman et al., 2009).

Taking in consideration these aspects, the objective of the present paper is to put into evidence the effects of different winter wheat sowing density in two different locations from Romania.

MATERIALS AND METHODS

Researches were carried out in field experiments at the Agricultural and Development Research Station Secuieni (ADRS Secuieni) located in North Romania (Neamț County) and at Experimental Trials of Saaten Union Romania at Drajna Nouă located in South-East (Călărași County) in the years 2020.

The researches were performed under rainfed conditions on a soil of cambic chernozem type for both locations (Secuieni and Drajna).

Secuieni: the soil has a medium nitrogen supply (20.7 ppm $N\text{-}NO_3$); well supplied with phosphorus (74.8 ppm, P_{AL}); poor potassium supply (142.6 ppm, K_2O); well supplied with calcium and magnesium (1.6 meq/100 g/soil); humus - 2.44% and pH (in water) = 5.55.

Drajna: the soil has a high nitrogen supply (45.0 ppm $N\text{-}NO_3$); well supplied with phosphorus (80.1 ppm, P_{AL}); medium potassium supply (160.2 ppm, K_2O); well supplied with calcium and magnesium (2.2 meq/100 g/soil); humus - 3.15% and pH (in water) = 6.1.

Experimental design

The experiment was based on the method of subdivided plots into 3 replications, with the following factors:

- Factor A - variety, with 10 graduations:
  - a_1 = Trublion;
  - a_2 = Centurion;
  - a_3 = Katarina;
  - a_4 = Glosa;
  - a_5 = Aspekt;
  - a_6 = Izvor;
  - a_7 = Avenue;
  - a_8 = Solehio;
  - a_9 = Alcantara;
  - a_{10} = Hyxperia.

- Factor B - plant density, with 3 graduations:
  - b_1 = 250 germinable kernels/sm;
  - b_2 = 360 germinable kernels/sm;
  - b_3 = 500 germinable kernels/sm.

- Factor C - locations, with 2 graduations:
  - c_1 = Secuieni;
  - c_2 = Drajna.

Crop management

The preceding crop was peas in both locations. The technology was the same in Secuieni and Drajna.

Seed treatment was with Bordeaux mixture in a concentration of 5%, substance, spring fertilizer with manure. All studied variants were sown on 28 of October in both locations. The sowing was performed mechanized.

During the vegetation period no phytosanitary treatments were performed.

For disease and insect control were apply two times the product Ortimag - 100 ml/100 l water, insecto-fungicide homologated for ecological agriculture.

The productivity elements were evaluated at 10 plants chosen at random from each experimental variant.

The calculation and interpretation of the results was done based on the analysis of variance (Săulescu and Săulescu, 1967).

The percentage of protein contain in the wheat seeds was determined with the device Nir

Noise Instruments Quick Analyzer, Agri Check Plus model.

Climatic data

In terms of temperature in the experimental year 2020, winter wheat plants benefited throughout the vegetation period from temperatures higher than the multiannual average value in both location (Figure 1 is for Secuieni location and Figure 2 is for Drajna location).

In terms of water, in 2020, in Drajna location there were excess rainfall in May (+6.8 mm) and June (+12.3 mm), while in April, July and August a cumulative deficit of -98.1 mm was registered, compared to the multiannual averages of the area. In July, it can be said that the total drought was installed, when only 2.5 mm of rainfall was recorded, the rainfall being practically absent. In August, 12.1 mm of rainfall was recorded, of which 12.0 mm in the second decade (Figure 3).

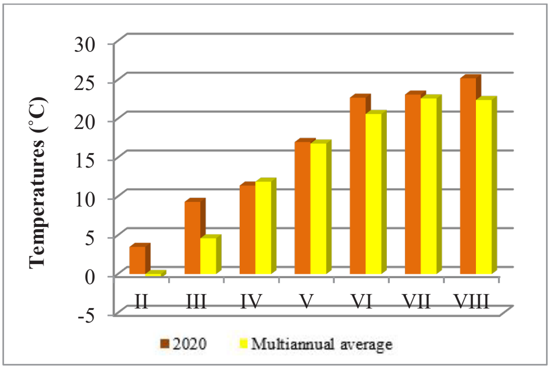

Figure 1. Evolution of average monthly temperatures at ARDS Secuieni in the year 2020

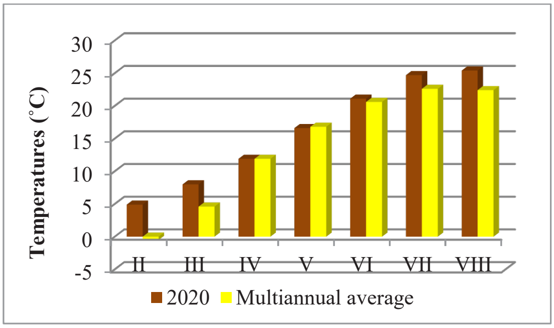

Figure 2. Evolution of average monthly temperatures at Drajna in the year 2020

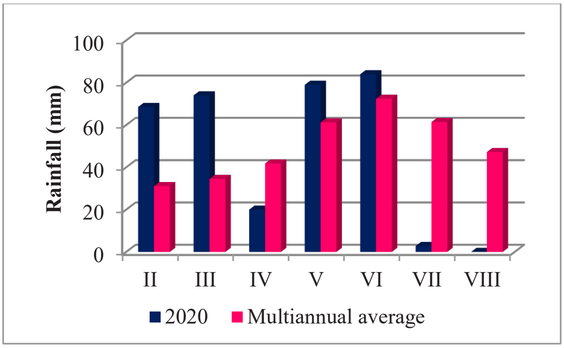

Figure 3. Evolution of rainfall at Drajna in the years 2020

RESULTS AND DISCUSSIONS

Due to the architecture of the winter wheat plant, a high density of the plants is a phenomenon that can cause significant production losses for same varieties. The use of high density can result in overcrowded plants prone to falling, low tillering capacity, high diseases pressure, late flowering, prolongs the vegetation period and consequently reduces productivity.

The percentage of emerged plants by variants had significant differences as follows: the variant with lower sowing rate registered the highest emergence percentage reported to the same sown period (18.8%) and in the medium density, the emergence was later (9.9%) (Table 1).

Table 1. Emergence of the winter wheat varieties plants in different sowing rate (ARDS Secuieni, Drajna in 2020)

No.	Variety	Sowing rate (g.k./sm)	Sowing date	Emergence date in Secuieni	No. of days for emergence in Secuieni	Emergence date in Drajna	No. of days for emergence in Drajna	Average days for emergence
1	Trublion	250	28.10.2020	20.11.2020	22	15.11.2020	17	19.5
	Trublion	360	28.10.2020	20.11.2020	22	16.11.2020	18	20
	Trublion	500	28.10.2020	19.11.2020	21	15.11.2020	17	19
2	Centurion	250	28.10.2020	19.11.2020	21	14.11.2020	16	18.5
	Centurion	360	28.10.2020	20.11.2020	22	14.11.2020	16	19
	Centurion	500	28.10.2020	19.11.2020	21	15.11.2020	17	19
3	Katarina	250	28.10.2020	17.11.2020	19	12.11.2020	14	16.5
	Katarina	360	28.10.2020	17.11.2020	19	14.11.2020	16	17.5
	Katarina	500	28.10.2020	19.11.2020	21	12.11.2020	14	17.5
4	Glosa	250	28.10.2020	21.11.2020	23	13.11.2020	15	19
	Glosa	360	28.10.2020	20.11.2020	22	14.11.2020	16	19
	Glosa	500	28.10.2020	23.11.2020	25	14.11.2020	16	20.5
5	Aspekt	250	28.10.2020	19.11.2020	21	16.11.2020	17	19
	Aspekt	360	28.10.2020	18.11.2020	20	19.11.2020	21	20.5
	Aspekt	500	28.10.2020	18.11.2020	20	17.11.2020	19	19.5
6	Izvor	250	28.10.2020	18.11.2020	24	14.11.2020	16	20
	Izvor	360	28.10.2020	23.11.2020	25	16.11.2020	18	21.5
	Izvor	500	28.10.2020	21.11.2020	23	14.11.2020	16	19.5
7	Avenue	250	28.10.2020	19.11.2020	21	14.11.2020	16	18.5
	Avenue	360	28.10.2020	18.11.2020	20	15.11.2020	17	18.5
	Avenue	500	28.10.2020	19.11.2020	21	15.11.2020	17	19
8	Solehio	250	28.10.2020	18.11.2020	20	15.11.2020	17	18.5
	Solehio	360	28.10.2020	18.11.2020	20	16.11.2020	18	19
	Solehio	500	28.10.2020	16.11.2020	18	14.11.2020	16	17
9	Alcantara	250	28.10.2020	20.11.2020	22	16.11.2020	18	20
	Alcantara	360	28.10.2020	21.11.2020	23	20.11.2020	22	22.5
	Alcantara	500	28.10.2020	19.11.2020	21	18.11.2020	20	20.5
10	Hyxperia	250	28.10.2020	19.11.2020	21	14.11.2020	16	18.5
	Hyxperia	360	28.10.2020	17.11.2020	19	16.11.2020	18	18.5
	Hyxperia	500	28.10.2020	19.11.2020	21	14.11.2020	16	18.5

The average of tillers capacity of winter wheat varieties counted in winter period, before winter, had significant differences as follows: the variants with medium sowing rate 360 g.k./sm registered the highest number of tillers reported to the same period (3.7 tillers/sm) and in the higher density sowing rate, 500 g.k./sm, number of tillers were lower (3.3 tillers/sm) (Table 2).

On average, the lowest percentage of plants affected by disease (1.66%) was recorded at 250 g.k./sm sowing rate and the highest percentage plants affected by diseases (3.26%) (Table 3).

On average per plant density with the increase of plant density increased the percentage of plants affected by diseases and decrease in plant density from 500 g.k./sm to 250 g.k./sm decrease the plants affected by disease (Table 3).

Table 2. Density in autumn and number of tillers of winter wheat varieties plants in different sowing rate (ARDS Secuieni, Drajna in 2020)

No.	Variety	Sowing rate (g.k./sm)	Sowing date	Density in autumn (plants/sm), Secuieni			No. of tillers in Secuieni	Density in autumn (plants/sm), Drajna			No. of tillers in Drajna	Average of tillers
				R_1	R_2	R_3		R_1	R_2	R_3		
1	Trublion	250	28.10.2020	210	232	220	3	208	215	207	4.5	3.75
	Trublion	360	28.10.2020	296	280	299	4.2	348	350	317	4.7	4.45
	Trublion	500	28.10.2020	480	457	466	3.3	490	468	470	3.1	3.2
2	Centurion	250	28.10.2020	249	241	232	2.9	250	230	235	4.8	3.85
	Centurion	360	28.10.2020	340	320	324	3.6	350	355	349	4.5	4.05
	Centurion	500	28.10.2020	480	457	466	3.3	490	468	470	3.1	3.2
3	Katarina	250	28.10.2020	247	249	250	2.2	249	232	218	3.1	2.65
	Katarina	360	28.10.2020	349	355	358	2.6	350	325	312	3.8	3.2
	Katarina	500	28.10.2020	490	478	485	3.5	499	470	480	3.5	3.5
4	Glosa	250	28.10.2020	192	178	169	2.2	248	250	219	2.5	2.35
	Glosa	360	28.10.2020	310	292	286	2.4	308	301	315	2.5	2.45
	Glosa	500	28.10.2020	487	490	495	2.6	480	500	495	3.8	3.2
5	Aspekt	250	28.10.2020	237	243	247	2.4	240	241	249	3.8	3.1
	Aspekt	360	28.10.2020	345	333	356	2.3	340	312	350	4.1	3.2
	Aspekt	500	28.10.2020	491	476	498	2	495	478	456	3.2	2.6
6	Izvor	250	28.10.2020	246	249	235	2.8	246	249	235	2.8	2.8
	Izvor	360	28.10.2020	332	348	320	1.9	330	335	350	2.7	2.3
	Izvor	500	28.10.2020	444	419	428	2.4	415	490	430	2.6	2.5
7	Avenue	250	28.10.2020	238	210	244	3.6	238	210	244	3.6	3.6
	Avenue	360	28.10.2020	316	288	288	2.7	320	290	300	3.8	3.25
	Avenue	500	28.10.2020	464	432	473	2.2	490	471	456	3.5	2.85
8	Solehio	250	28.10.2020	242	236	228	4.2	242	236	228	4.8	4.5
	Solehio	360	28.10.2020	342	312	351	3.2	350	320	341	4.7	3.95
	Solehio	500	28.10.2020	488	496	491	3.4	490	499	475	3.6	3.5
9	Alcantara	250	28.10.2020	199	220	189	2.6	199	220	189	4.9	3.75
	Alcantara	360	28.10.2020	284	340	312	2.4	312	350	359	4.5	3.45
	Alcantara	500	28.10.2020	356	352	378	2.3	360	450	380	3.9	3.1
10	Hyxperia	250	28.10.2020	228	200	198	4.2	228	200	198	6.1	5.15
	Hyxperia	360	28.10.2020	236	329	347	2.8	302	330	350	6.1	4.45
	Hyxperia	500	28.10.2020	438	460	467	3.4	450	480	456	3.2	3.3

Table 3. Disease resistance of the winter wheat plants at different sowing rate (ARDS Secuieni, Drajna in 2020)

No.	Variety	Density (g.k./sm)	*Puccinia striiformis* resistance		*Septoria tritici* resistance		*Erysiphe graminis* resistance	
			Drajna	Secuieni	Drajna	Secuieni	Drajna	Secuieni
1	Trublion	250	1	2	2	3	1	2
	Trublion	360	1	1	1	2	2	2
	Trublion	500	2	2	3	5	4	3
2	Centurion	250	2	2	2	2	1	1
	Centurion	360	1	1	1	2	2	2
	Centurion	500	2	3	4	3	4	4
3	Katarina	250	2	1	2	3	1	2
	Katarina	360	1	1	1	2	2	2
	Katarina	500	2	2	3	5	4	3
4	Glosa	250	1	1	2	2	1	2
	Glosa	360	1	1	1	2	2	2
	Glosa	500	3	4	3	4	3	2
5	Aspekt	250	1	1	1	1	1	1
	Aspekt	360	1	2	2	2	1	2
	Aspekt	500	3	4	3	2	4	4
6	Izvor	250	1	1	2	2	1	2
	Izvor	360	1	1	1	2	2	2
	Izvor	500	2	3	3	3	3	2
7	Avenue	250	1	2	2	3	1	2
	Avenue	360	1	1	1	2	2	2
	Avenue	500	3	6	3	5	4	3
8	Solehio	250	1	2	2	3	1	2
	Solehio	360	2	1	1	2	2	2
	Solehio	500	4	5	3	3	2	4
9	Alcantara	250	2	2	2	2	1	2
	Alcantara	360	2	1	1	1	2	2
	Alcantara	500	3	4	3	3	2	2
10	Hyxperia	250	2	2	2	2	1	2
	Hyxperia	360	2	2	1	1	2	2
	Hyxperia	500	4	5	3	3	4	6

Notes: 1 - resistant .... 9 - sensible

Regarding the percentage of lodging plants, the tendency can be observed that we cannot had lodging in all sowing density and varieties, but in high density we can observe that the plants are toller (average 86.81 cm) then in lower density (82.87 cm) (Table 4).

Table 4. Lodging resistance of the winter wheat plants at different sowing rate (ARDS Secuieni, Drajna in 2020)

No.	Variety	Sowing rate (g.k./sm)	Plant height (cm)	Lodging resistance
1	Trublion	250	77.00	1
	Trublion	360	76.60	1
	Trublion	500	80.30	1
2	Centurion	250	89.00	1
	Centurion	360	91.80	1
	Centurion	500	95.20	1
3	Katarina	250	71.60	1
	Katarina	360	75.20	1
	Katarina	500	77.10	1
4	Glosa	250	81.60	1
	Glosa	360	83.10	1
	Glosa	500	89.60	1
5	Aspekt	250	90.00	1
	Aspekt	360	95.20	1
	Aspekt	500	95.20	1
6	Izvor	250	92.80	1
	Izvor	360	92.20	1
	Izvor	500	95.20	1
7	Avenue	250	77.20	1
	Avenue	360	71.40	1
	Avenue	500	75.30	1
8	Solehio	250	86.40	1
	Solehio	360	92.80	1
	Solehio	500	90.80	1
9	Alcantara	250	84.00	1
	Alcantara	360	88.80	1
	Alcantara	500	83.80	1
10	Hyxperia	250	79.10	1
	Hyxperia	360	83.20	1
	Hyxperia	500	85.60	1

Notes: 1 - resistant .... 9 - sensible

As in the case of morphological elements of the winter wheat plants, the productivity characters (number of ears per s.m., length of ear, number of grains per ear, weight of the seeds per ear) varied depending on the previous crop, sowing rate and soil type, tillage variants (Table 5). Also, the smallest values of the productivity characters were registered in the case of the variant in high density. The protein, gluten and amidon content of the seeds is not influenced by sowing rate (Table 6).

Table 5. Number of ears/sm, ear lengh, number of kernels/ear, kernels weigh (ARDS Secuieni and Drajna, 2020)

No.	Variety	Sowing rate (g.k./sm)	No. of ears/sm, Secuieni	No. of ears/sm, Drajna	Ear lengh (cm), Secuieni	Ear lengh (cm), Drajna	No. of kernels/ear, Secuieni	No. of kernels/ear, Drajna	Kernels weigh/ear (g), Secuieni	Kernels weigh/ear (g), Drajna
1	Trublion	250	780	800	7.90	8.20	46	45.00	1.33	1.20
	Trublion	360	896	840	8.10	7.10	43	46	1.40	1.50
	Trublion	500	856	750	7.70	7.50	40	41	1.32	1.15
2	Centurion	250	576	620	7.20	7.50	45	48.00	1.52	1.40
	Centurion	360	832	750	7.40	7.00	39	45	1.44	1.52
	Centurion	500	784	795	6.50	7.10	30	40.00	1.28	1.12
3	Katarina	250	524	642	7.10	6.80	41	45.00	1.31	1.32
	Katarina	360	664	701	8.40	7.60	49	46	1.50	1.50
	Katarina	500	628	529	8.30	8.30	46	48	1.40	1.10
4	Glosa	250	676	512	7.00	6.20	56	45.00	1.38	1.20
	Glosa	360	844	789	7.40	8.00	49	51	1.50	1,20
	Glosa	500	752	810	8.20	8.30	44	49	1.26	1.25
5	Aspekt	250	748	815	7.90	8.90	44	50.00	1.26	1.25
	Aspekt	360	808	820	8.50	5.60	42	53	1.73	1.30
	Aspekt	500	844	650	8.00	7.10	39	48	1.45	1.02
6	Izvor	250	704	690	7.40	8.00	37	41.00	1.41	0.98
	Izvor	360	820	800	7.90	8.10	37	39	1.43	1.15
	Izvor	500	836	820	8.00	3.00	40	43	1.11	1.30
7	Avenue	250	752	680	7.00	7.80	32	38.00	0.97	1.10
	Avenue	360	824	789	7.60	8.30	33	35	1.10	1.30
	Avenue	500	820	750	7.80	7.90	39	40	1.35	1.50
8	Solehio	250	708	680	6.80	7.20	28	32.00	0.99	0.89
	Solehio	360	876	720	7.20	7.50	29	38	1.11	0.90
	Solehio	500	864	750	6.80	6.80	32	35	1.07	1.30
9	Alcantara	250	732	789	8.90	8.90	47	42.00	1.39	1.50
	Alcantara	360	792	825	8.80	7.90	41	35	1.47	1.11
	Alcantara	500	804	650	7.40	8.10	33	38	1.14	1.30
10	Hyxperia	250	756	862	7.90	9.10	37	48.00	1.18	1.50
	Hyxperia	360	872	856	8.40	8.60	45	41	1.55	1.32
	Hyxperia	500	764	750	7.70	8.30	39	35	1.47	0.80

Table 6. Protein, gluten and amidon content of the seeds at different sowing density (ARDS Secuieni and Drajna, 2020)

No.	Variety	Sowing rate (g.k./sm)	Protein content (%)	Gluten content (%)	Amidon content (%)
1	Trublion	250	12.6	25.1	68.9
	Trublion	360	12.8	25.7	68.6
	Trublion	500	12.6	25.2	69.1
2	Centurion	250	13.8	28.1	68.7
	Centurion	360	13.6	27.6	68.6
	Centurion	500	13.7	27.8	69.1
3	Katarina	250	13.3	26.8	68.8
	Katarina	360	13.1	26.4	68.8
	Katarina	500	12.7	26.6	69.5
4	Glosa	250	13	26.1	68.4
	Glosa	360	13.1	26.3	68.1
	Glosa	500	12.9	25.8	68.3
5	Aspekt	250	12.2	24.3	69
	Aspekt	360	12.2	24.3	69
	Aspekt	500	11.8	23.5	69.8
6	Izvor	250	12.8	25.7	68.6
	Izvor	360	13.4	27.1	68.9
	Izvor	500	12.2	24.4	69.4
7	Avenue	250	12.5	25.1	76.7
	Avenue	360	12.3	24.4	62.9
	Avenue	500	11.9	23.7	69.1
8	Solehio	250	11.6	23	70.2
	Solehio	360	11.4	22.4	70.1
	Solehio	500	11	21.5	70.8
9	Alcantara	250	13	26	68.7
	Alcantara	360	12.6	25.2	69.1
	Alcantara	500	12.4	24.9	69.5
10	Hyxperia	250	12.8	25.7	68.5
	Hyxperia	360	12.6	25.2	68.6
	Hyxperia	500	12.1	24.1	69

The highest seed yields were registered in the case of variant with lower sowing rate, while the smallest seed yields were registered in the case of the variant with higher sowing rate. The lower TGW was for one variety in higher sowing rate (29.6 g and 30.8 g, for both locations) and the higher TGW (43.8 g) was in lower sowing rate at Secuieni and 43.1 g at Drajna, variant with medium sowing rate - 360 g.k./sm (Table 7).

Table 7. Seed yields obtained at different sowing rate and locations (ARDS Secuieni and Drajna, 2020)

No.	Variety	Sowing rate (g.k./sm)	Average of yield STAS (kg/ha), Secuieni	Average of yield STAS (kg/ha), Drajna	TGW (g) average, Secuieni	TGW (g) average, Drajna	HLM (kg/hl) average, Secuieni	HLM (kg/hl) average, Drajna
1	Trublion	250	8,536	8,280	37.3	36.2	70.5	71.8
	Trublion	360	9,187	8,911	34	35.1	71.0	72.3
	Trublion	500	8,300	8,051	32.9	30.8	69.9	70.7
2	Centurion	250	11,120	10,786	43.8	42.3	78.0	75.9
	Centurion	360	10,769	9,560	41	43.1	76.8	75.4
	Centurion	500	8,921	8,653	43.3	40.2	75.3	76.3
3	Katarina	250	7,669	7,439	33.20	35.4	77.0	76.2
	Katarina	360	7,545	7,319	35.90	36.9	72.2	76.4
	Katarina	500	7,499	7,274	29.60	34.5	76.0	77
4	Glosa	250	8,397	8,145	37.5	39.4	75.4	77.1
	Glosa	360	7,786	7,552	32.7	37.0	75.9	75.4
	Glosa	500	8,281	8,033	35	37.8	74.0	76.1
5	Aspekt	250	8,350	8,500	35.1	41.1	79.0	71.7
	Aspekt	360	8,900	7,890	38.3	39.8	80.1	74.1
	Aspekt	500	7,950	7,712	38.6	35.0	78.9	74.2
6	Izvor	250	8,239	7,992	34.2	38.3	79.2	78.2
	Izvor	360	9,356	8,075	42.8	41.2	78.0	75.8
	Izvor	500	8,481	8,227	35.1	38.9	78.6	78.4
7	Avenue	250	7,923	7,685	30.09	33.2	75.1	70.5
	Avenue	360	8,312	8,063	31.4	35.8	72.3	73.6
	Avenue	500	8,827	8,750	30.8	32.3	74.9	72.3
8	Solehio	250	9,448	7,560	35.9	35.9	73.8	75.5
	Solehio	360	9,950	5,630	34.9	38.5	74.2	76.3
	Solehio	500	8,860	8,950	35.4	36.5	75.2	75.9
9	Alcantara	250	8,003	7,763	32.6	35.2	74.5	72.2
	Alcantara	360	8,588	8,960	34.9	36.8	74.9	74.3
	Alcantara	500	8,573	7,560	33.3	34.2	73.5	73.9
10	Hyxperia	250	9,840	9,545	35.4	40.1	78.3	70.6
	Hyxperia	360	9,510	9,225	32.6	38.5	75.8	69.7
	Hyxperia	500	7,970	7,731	35.9	36.9	73.9	71.6

CONCLUSIONS

Taking in consideration the architecture of the plant and the way the plant growth and develop, it is very important to find for winter wheat the optimal sowing density adapted for each variety. An optimal sowing rate can be obtained by reducing the sowing density and obtaining high yields on the main plants and fertile tillers. Some variety has very good tillering capacity and in this case, it is recommended to adapt the sowing rate.

The use of high density can result in overcrowded plants prone to falling, low tillering capacity, high diseases pressure, late flowering, prolongs the vegetation period and consequently reduces productivity.

Increasing sowing rate is associated with decreasing of yield, while decreasing the plant density is associated with increasing of yield.

The yields obtained, on average over the varieties and locations of experimentation, were of 7,386 kg/ha for Katarina variety in high density (500 g.k./sm) and 10,953 kg/ha for Centurion variety in lower density of 250 g.k./sm. So, the highest seed yields were registered in the case of variant with lower sowing rate, while the smallest seed yields were registered in the case of the variant with higher sowing rate.

The large differences in yields are explained by the differences in plant density at harvest, but also by the way of growth and development of plants throughout the vegetation period function of the space of nutrition.

The lower TGW was for one variety in higher sowing rate (29.6 g) and the higher TGW (43.8 g) was in lower sowing rate.

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WATER CONSUMPTION AND EFFICIENCY OF IRRIGATION OF MAIZE HYBRIDS OF DIFFERENT FAO GROUPS IN THE SOUTHERN STEPPE OF UKRAINE

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Abstract

The results of research on the influence of irrigation methods and regime on the processes of total water consumption and irrigation efficiency in the cultivation of maize hybrids of different FAO groups in the Southern Steppe of Ukraine are presented. It is confirmed that the method of irrigation, the genotype of the hybrid significantly affects the formation of water regime of the soil and the productivity of corn. The use of drip irrigation provides the highest levels of grain yield (16.09-16.72 $t \cdot ha^{-1}$) at the lowest specific water consumption for the formation of the unit of yield (water use efficiency) – 365.90-376.13 $m^3 \cdot t^{-1}$, the highest payback of irrigation water by yield increase (3.95-4.16 $kg \cdot m^{-3}$) when using FAO 400-440 hybrids adapted to irrigation conditions. According to the absolute parameters of irrigation water consumption, surface drip irrigation is the most economical. Hybrids with adequate response to the level of soil moisture and provide grain yield: without irrigation - 2.89-3.01 $t \cdot ha^{-1}$ (drought-resistant), with water-saving irrigation regime - 9.45-9.51 $t \cdot ha^{-1}$ (homeostatic type), with the optimal irrigation regime - 14.85-16.72 $t \cdot ha^{-1}$ (intensive type).

***Key words**: irrigation methods, water consumption, maize, hybrids, water use efficiency.*

INTRODUCTION

Climate change is leading to an increase in areas of insufficient natural moisture, which puts agriculture at risky production conditions. This is especially true of the Southern Steppe, where there is an annual shortage of natural moisture. In this region, soil and air droughts have recently become more frequent, which does not allow to realize the yield potential of agricultural crops, in particular corn. Among cereals, corn is one of the most productive and important crops in the world. It is quite drought–resistant and responds well to improved soil moisture, so much of the area in southern Ukraine is sown with corn on irrigated lands, where it provides two to three times higher yields (Vozhehova et al., 2021).

Only thanks to irrigation, the south of Ukraine remains a zone of guaranteed production of high-quality corn grain. Of great importance is the choice of environmentally friendly technologies, technical means of irrigation, and hybrids of corn of different FAO groups with an appropriate response to agri-environmental growing conditions (Shatkovsky et al., 2020).

The need for rational use of water resources in irrigated agriculture and increase the productivity of reclaimed lands logically follows from the economic essence and features of irrigation as the main factor in increasing soil fertility in conditions of insufficient moisture.

Obtaining high yields of irrigated crops is ensured by conducting a range of agro-ameliorative techniques and measures. Irrigation regime serves in this complex as the core in which other agronomic techniques are formed. Violation of the irrigation regime causes an antagonistic ratio of elements of soil fertility, resulting in a sharp decrease in watering efficiency (Lobell and Field, 2007).

Irrigation regime is primarily determined by soil and climatic conditions and biological characteristics of crops. It is also significantly influenced by the method and technique of irrigation, water supply, hydromodule of irrigation, hydrogeological and geomorphological conditions, the level of agricultural technology, the degree of drainage of the territory and others. All this leads to the use of almost different options for irrigation. In a particular agro–climatic zone, it must meet the water needs of plants throughout their growth, ensure high crop yields and increase the fertility of irrigated lands, preventing erosion, waterlogging and salinization of the soil (Silber et al., 2003).

With the optimization of all components of the irrigated agriculture system, it is possible to obtain consistently high yields of crops annually. Thus, by improving the water and nutrient regimes of the soil at a high technological level of agriculture, it is possible to increase yields by 2-3 times, and in dry years - by 4-5 times (Barlog & Frckowiak-Pawlak, 2008).

An important component of the agricultural system is the method of irrigation, which, along with improving the moisture content of plants, enhances the action of other factors in the direction of increasing yields and increasing net income. In addition, it is important to study the characteristics of water consumption of plants, as these experimental data can be used to optimize artificial moisture by supplying the required amount of water during periods of maximum need (in the so-called "critical periods" of plant growth and development) (Gadzalo et al., 2020).

In the modern practice of irrigated agriculture in Ukraine, two main methods of irrigation are used – sprinkling and drip surface irrigation. Drip surface irrigation is spreading rapidly in arid conditions and in Ukraine, where it is currently used on more than 70 thousand hectares. This method of irrigation allows you to quickly adjust soil moisture, but the technical efficiency and cost-effectiveness of this method is still poorly understood (Romashchenko et al., 2016).

The timeliness of the next vegetative watering is the main condition in the development and implementation of the irrigation regime. Several methods are used to set the timing of irrigation of crops, including corn for grain. The most scientifically sound and proven in production is the method of assigning the next term of watering by soil moisture. Of great importance is the correct installation of the lower threshold of moisture, at which time it is recommended to water again. The threshold is expressed as a percentage of LM (lowest moisture content) of the soil - the amount of water retained by the soil in natural (field) conditions after complete drainage of gravitational moisture. The size of LM characterizes the water holding capacity of the soil. The main criterion in determining the timing of vegetative irrigation is the lower limit of optimal soil moisture, which varies in the range of 60-90% of the lowest moisture content (LM). Soil drying, in which soil moisture exceeds this limit, leads to a sharp decrease in crop yields (Gheysari et al., 2021; Allen et al., 1998).

The amount of annual precipitation and their seasonal distribution are crucial for agricultural production (Sun et al., 2010). It was found that low water content in the soil during sowing slows down the germination process, reduces the percentage of germination and sowing density (Passioura et al., 2006; Domínguez et al., 2011). However, if plants use too much water before flowering, further water stress caused by lower rainfall leads to premature aging of the plant, low yields or poor grain quality (Angus & van Herwaarden, 2001).

Water use efficiency (WUE) of plants depends on the quantities, timing and watering rates. Deficit irrigation, defined as the use of water below the total needs of plants, is an important tool to reduce the use of water for irrigation. Improving the efficiency of irrigation through the use of scarce irrigation is an important management practice, especially in regions with severe water shortages. Increasing the frequency of irrigation with a reduced rate can increase the evaporation of moisture from the soil surface, affect yields, as well as WUE, which must be taken into account when planning a method of irrigation (Zhang et al., 2010; Garcia y Garcia et al., 2009).

Studies conducted by Oktem A. (2008) to determine the ratio of yield and quality of maize grown under drip irrigation in Sanliurfa

(Turkey), showed, that the yield response factor (ky) or the ratio of decrease in relative yield to decrease in relative water consumption varied from 0.82 to 1.43, and the water-saving rate ranged from 10.9 to 31.1%. The relationship between cob yields and irrigation was statistically significant ($P < 0.01$), and yields decreased with increasing irrigation deficit. Maximum values of leaf area index were obtained at full irrigation, whereas the lowest values were found at 30% water deficiency. The values of the deficit irrigation stress index increased with decreasing water application. (Oktem, 2008).

An important element of water consumption is the genotypic characteristics of corn. A field survey to obtain the characteristics of seed and grain maize using the CROPWAT model allowed the calculated water demand for irrigation (IWR) of these two types of maize. Water needs for irrigation of seed and grain corn during the growing season were 470.1 and 488,5 mm respectively. However, there were large differences in the sequence of water consumption for these two types of corn. Prior to mid – July, evapotranspiration and IWR of seed corn were 14.3% and 20.1% higher, respectively, than those of field corn. In September, the IWR of the two corn types began to decrease, with a value of 82.3 mm for seed corn, which was 32.1% lower than the IWR of field corn (108.7 mm) during the same period , but significant differences in watering time and water quantity during one-time watering of seed and grain corn in the study area was not (Tan & Zheng, 2017).

In the irrigation regime of corn, it is important to consider the depth of water absorption. It was found that in the Great Plains of China, corn showed significant plasticity relative to the depth of water absorption. It mainly absorbed water from a depth of 0-10 cm (23.4-46.7%), 10-20 cm (33.3-35.8%) and 20-40 cm (20.9-26.3%) in the early stages of growth, and then changed the sources of water absorption - absorbed it from a depth of 10-20 cm (22.3-24.7%), 20-40 cm (23.7-28.1%) and 40-60 cm (25.7-39.0%) at later stages of growth (Sun et al., 2010).

In the study, water was applied to sweet corn as 100, 90, 80 and 70% of evaporation from corresponding to 2-, 4-, 6- and 8- day irrigation frequencies, respectively. The highest values of total water efficiency (TWUE) were 1.38 and 1.24 kg m^{-3} at 4-day watering frequency in two different years, respectively. The highest values for irrigation water use efficiency (IWUE) was 1.66 kg m^{-3} at 4-day irrigation frequency and 1.59 kg m^{-3} at 6-day irrigation frequency. The results of this research indicate that a 2-day irrigation frequency, with 100% ET water application by a drip system, will be optimal for sweet corn grown in semi-arid regions similar to that in Turkey where the work was conducted (Oktem et al., 2003).

In the work of Lv et al. (2011) changes in water consumption of wheat and corn under different humidification conditions (optimal level of irrigation and water conservation) were studied. The efficiency of water use and the potential of water savings in the irrigation of corn and wheat are analyzed. Grain yield at the optimal level of irrigation was higher compared to the water–saving irrigation regime, with higher water efficiency. Thus, optimization of irrigation can simultaneously achieve a stable yield and high water efficiency (Lv et al., 2011).

Yield and water consumption are two important indicators of water conservation and high-yield farming (Gornott & Wechsung, 2016; Liu et al., 2018). Studies of water consumption by crops of different stages of growth of corn at relative soil moisture 60%, 70% and 80% showed that the maximum corn grain yield was obtained by maintaining the lower soil moisture limit of 70%, but with a shortage of water resources for conventional irrigation should recommend a lower limit of relative soil moisture, i.e. 60% (Wang et al., 2015).

Studies of Ertek A. & Kara B. (2013) and to determine the effects of different levels of irrigation (I_{100}: full irrigation; I_{85}: 15% deficit; I_{70}: 30% deficit; I_{55}: 45% deficit and I_{40}: 60% deficit) on yield and yield components, sugar and protein content in fresh sweet corn showed that the lowest and the highest plant water consumptions (E_t) were found in I_{40} (240-406 mm) and I_{100} (348-504 mm) treatments in both years. Water scarcity has affected the yield of fresh maize, the components of the crop, the quality and efficiency of water use. The lowest fresh ear yields were determined in I_{40} treatments in both years, respectively. The highest fresh ear yields were obtained from I_{100}. Maize fresh ear yields were significantly affected by water deficits. Low irrigation levels decreased the ear yields. However, it was clearly observed that I_{70} treatment could be a water-saving treatment without a significant decrease in yield. In addition, the highest protein content and sugar amount was also observed in I_{70} treatment (Ertek & Kara, 2013).

The limiting factor in the productivity of grain corn in the steppe of Ukraine is the unfavorable water regime of soils (Dudka, 2013). Possible areas for obtaining high and sustainable yields in these conditions are the creation of new drought–resistant hybrids and the development of more efficient methods of adaptive cultivation technologies aimed at maximizing moisture conservation (Vozhehova et al., 2022; Marchenko, 2019). The increase in yield from the optimization of water regime is the most significant and ranges from 100 to 380% compared to non-irrigated conditions (Shatkovskyi, 2015). High irrigation efficiency has contributed to the expansion of irrigated areas under corn in Ukraine to 175 thousand hectares (Fomichov, 2019), and the main method of irrigation is sprinkling. Therefore, the use of new irrigation methods and optimization of soil water regime is the main stabilizing factor in maize cultivation.

An important factor in increasing the grain yield of corn with different moisture content is the use of modern innovative maize hybrids, created by special breeding programs and have a genotypically adaptive response to specific agri-environmental conditions (Dziubetskyi & Cherche, 2017).

Therefore, substantiation of optimal methods of moisture supply and selection of hybrids that adequately respond to soil moisture is an important issue to increase the efficiency of agricultural production in the arid conditions of southern Ukraine.

MATERIALS AND METHODS

The research was conducted during 2018-2020 in the research field of the Institute of Irrigated Agriculture of the NAAS of Ukraine, located in the agro-ecological zone of the Southern Steppe of Ukraine. The soil of the experimental area is dark chestnut, slightly saline, medium loamy. The total amount of annual precipitation is on average according to long-term data - 373 mm, including during the growing season of corn - 150 mm.

Soil moisture was determined by thermostatic weighting method in four replicates. Soil samples were taken in layers 10 cm at a depth of 0-50 cm after five days to determine the timing of irrigation and 0-100 cm to calculate the total water consumption of corn.

Total water use of the crops - by the method of water balance without considering the recharge of groundwater (Allen et al., 1998; Vozhehova, 2012).

The total water use for the growing season, as well as for the separate interphase periods of the crops in the crop rotation, was determined by the method of water balance by the formula (1) (Allen et al., 1998; Vozhehova, 2012):

$$E = M + O + (Wh - Wk), \quad (1)$$

where: E - total water use, $m^3 \cdot ha^{-1}$; M - irrigation rate, $m^3 \cdot ha^{-1}$; O - precipitation, $m^3 \cdot ha^{-1}$; Wh - moisture content in the active soil layer at the beginning of the growing season, $m^3 \cdot ha^{-1}$; Wk - moisture content in the active soil layer at the end of the growing season, $m^3 \cdot ha^{-1}$.

The coefficient of water use of crops in the crop rotation on irrigated lands was determined by the formula (2) (Allen et al., 1998; Vozhehova, 2012):

$$WUE = E/Y, \quad (2)$$

where: WUE - water use efficiency, $m^3 \cdot t^{-1}$; E - total water use for the growing season, $m^3 \cdot ha^{-1}$; Y - yield of the crop, $t \cdot ha^{-1}$.

To establish the indicators of total water consumption and irrigation efficiency of maize hybrids of different FAO groups under different irrigation methods used: sprinkler irrigation, drip surface irrigation, natural moisture. Repeat four times, sown area of the second order - 75 m^2, accounting - 50 m^2. To establish the rate of response of maize hybrids of different FAO groups to irrigation regimes, we used a pre–surprise humidity level of 60, 80% for sprinkler irrigation and 80, 85% for drip irrigation.

The research used modern innovative hybrids of corn, which were created under special programs for drought resistance and adaptability to irrigation (Dziubetskyi & Cherchel, 2017; Marchenko, 2019).

Agricultural techniques for growing maize hybrids in the experiments were generally accepted for the southern part of Ukraine.

The predecessor is soy. Processing of research results was carried out by the method of analysis of variance using a package of computer programs Agrostat (Ushkarenko et al., 2014).

The aim of our research was to determine the response of maize hybrids of different FAO groups to different methods of irrigation and moisture.

RESULTS AND DISCUSSIONS

Proper design of water regime and its regulation in accordance with agri-environmental conditions are based on information about the biological needs of crops in moisture. Thus, the key issue of the irrigation regime is the total water consumption, which means the amount of moisture consumed by plants for transpiration and evaporation from the soil surface. Total water consumption is a complex indicator that reflects the amount of water consumed by the crop for transpiration and formation of biological mass of plants, as well as for physical evaporation from the soil. Total water consumption is not a constant indicator, it varies considerably depending on the weather conditions of the growing season, the moisture content of plants, the level of agricultural technology, etc (Xue, 2017).

Our observations in 2018-2020 showed that the total water consumption of crops varies depending on the hybrid composition (factor A). On average, by FAO hybrid groups, the maximum total water consumption of maize plants 2923-6560 $m^3 \cdot ha^{-1}$ was found in FAO hybrids 420-440 by all methods of sowing moisture. According to the factor B (method of moisture supply), the highest indicator was found for sprinkler irrigation - 4216-6560 $m^3 \cdot ha^{-1}$ depending on the FAO group (Table 1).

Table 1. Simple water consumption of maize hybrid plants of different FAO groups and its components

Method of moisture supply of crops	Total water consumption, $m^3 \cdot ha^{-1}$	Components of the water consumption balance					
		moisture used from soil reserves		precipitation		irrigation rate	
		$m^3 \cdot ha^{-1}$	%	$m^3 \cdot ha^{-1}$	%	$m^3 \cdot ha^{-1}$	%
FAO hybrids 180-190							
Without watering, control	2719	1240	46	1479	54	0	0
drip irrigation	3959	830	21	1479	37	1650	42
sprinkling	4216	877	21	1479	35	1860	44
hybrids 250-290							
without watering, control	2801	1314	47	1487	53	0	0
drip irrigation	4464	847	19	1487	33	2130	48
sprinkling	4732	885	19	1487	32	2360	49
FAO hybrids 300-380							
without watering, control	2847	1360	48	1487	52	0	0
drip irrigation	5647	910	16	1487	26	3250	58
sprinkling	5812	945	16	1487	26	3380	58
FAO hybrids 420-440							
without watering, control	2923	1386	47	1537	53	0	0
drip irrigation	6052	915	15	1537	23	3600	59
sprinkling	6560	956	15	1537	25	4067	62

The maximum total water consumption of 6052-6560 $m^3 \cdot ha^{-1}$ in the soil layer 0-100 cm on average for 2018-2020 was established in FAO hybrids 420-440 under drip irrigation and sprinkling.

The maximum amount of moisture used by crops of maize hybrids from soil reserves was observed in the option without watering – 46-48%.

It was found that when growing hybrids of corn without irrigation, water consumption of hybrids is due to rainfall and soil moisture and depended on the FAO group. In late–maturing hybrids, the rate of utilization of soil moisture and precipitation increased due to the lengthening of vegetation by 58-146 $m^3 \cdot ha^{-1}$. The share of precipitation and soil moisture in the total water consumption of hybrids of all

FAO groups was almost the same – 52-54% and 46-48%.

The total water consumption of hybrids increased mainly due to irrigation. In the water balance, the share of irrigation moisture increased from 42% in precocious hybrids to 62% in late–ripe FAO 440 hybrids. FAO 180-190 hybrids showed less dependence on soil moisture reserves and precipitation.

During the cultivation of maize under irrigation, the total water consumption of FAO 320-380 and FAO 420-440 hybrids over the years of research increased compared to control areas, almost doubled and amounted to 5647-5812 and 6052-6560 $m^3 \cdot ha^{-1}$ in accordance. At the same time, the irrigation rate in the total water consumption of FAO 320-380 hybrids and FAO 420-440 hybrids accounted for an average of 58 and 62%. The use of soil moisture by FAO 320-380 hybrids was 16%, and precipitation was used by 26%, which is almost twice less than the crops of hybrids of the same FAO group without irrigation. FAO 420–440 hybrids had a similar structure of moisture use, which indicates that these hybrids are predominantly dependent on artificial irrigation.

Under irrigation, the amount of precipitation during the growing season is a significant (23, 37%) share of the balance of total water consumption of maize hybrids. The share of precipitation use is much higher in FAO hybrids 180-290 (32, 37%), which indicates a lower need for moisture in hybrids with a shortened growing season. Thus, in years with a high level of natural moisture supply, the need for irrigation of these hybrids decreases.

The efficiency of moisture use, as shown by the experience of domestic and foreign researchers, can be determined on the basis of the indicator of moisture efficiency - WUE (water use efficiency) (Allen, 1998) and payback of irrigation water by increasing grain yield under irrigation. All these parameters are determined by the value of total water consumption, irrigation rate and crop yield. Thus, the coefficient of water consumption characterizes the total amount of moisture consumed per unit yield; the coefficient of irrigation efficiency characterizes the consumption of irrigation water per unit increase in yield from irrigation and moisture efficiency – the amount of crop produced per unit of moisture used.

Our research has shown that improving the conditions of moisture supply by artificial irrigation leads to a decrease in WUE in maize hybrids of different FAO groups (Table 2).

According to factor A (hybrid) the smallest water use efficiency , on average over the years of research, was observed in hybrids of FAO 420-440 Hileia and DN Olena - 365.90 and 376.13 $m^3 \cdot t^{-1,}$ respectively. The method of irrigation had a significant impact on the total water consumption. The minimum values of this indicator by factor B (irrigation method) – 365.90 $m^3 \cdot t^{-1}$ recorded in the hybrid Hileya under drip irrigation. The method of irrigation by sprinkling increased the water consumption coefficient by 15-19%. Without irrigation, WUE increased sharply in FAO 180-190 almost twice to 814.07 to 826.44 $m^3 \cdot t^{-1}$. Even greater WUE growth was observed in later FAO 300–380 hybrids from 1330.37-1388.78 $m^3 \cdot t^{-1}$ to 1554.79-1873.72 $m^3 \cdot t^{-1}$ in FAO 420–440. On average, for all irrigation methods, the lowest WUE rates were observed for drip irrigation.

WUE indicators of maize hybrids indicate an increased level of moisture efficiency for the formation of 1 ton of grain under drip irrigation using intensive maize hybrids. Stepovyi, Pyvykha (FAO 180-190) maize plants use moisture most efficiently with natural moisture supply. These hybrids are created according to special selection programs for drought resistance, so they are suitable for growing without watering.

An indicator such as the payback of irrigation water by the additionally obtained grain harvest due to irrigation is also quite important (see Table 2). On the average for three years of researches on all hybrids with carrying out vegetative watering this indicator varied from 2.87 $kg \cdot m^{-3}$ at watering by sprinkling, to 4,16 $kg \cdot m^{-3}$ on drip irrigation, which indicates the prospects for the use of drip irrigation.

This indicates the need to grow maize hybrids on irrigated lands of the relevant FAO groups. With natural moisture, it is necessary to use hybrids with high drought resistance. The drought resistance coefficient of such hybrids should be in the range of 0.3-0.4 (see Table 2), only FAO hybrids 180-190 can provide grain yield without irrigation in the range of 3-3.5 $t \cdot ha^{-1}$, with an additional increase in grain yield increased in hybrids with a longer growing season. The highest payback of irrigation water was observed in FAO 420-440 hybrids 3.95-4.16 kg·m^{-3}, created for irrigated agriculture.

Table 2. Water use efficiency, drought resistance and payback of irrigation water of maize hybrids of different FAO groups depending on irrigation methods (average for 2018-2020)

The method of moisture supply (factor A)	Hybrid (factor B)	Crop capacity, t·ha^{-1}	Total water consumption, m^3·ha^{-1}	Water use efficiency, m^3·t^{-1}	Drought resistance coefficient	Payback of irrigation water by increasing grain yield, kg·m^{-3}
FAO hybrids 180-190						
Without watering, control	DN Pyvykha	2.89	2719	826.44	–	–
	Stepovyi	3.01	2719	814.07	–	–
drip surface	DN Pyvykha	8.84	3959	447.85	0.327	3.61
	Stepovyi	9.01	3959	439.40	0.334	3.64
sprinkling	DN Pyvykha	8.52	4216	494.84	0.339	3.03
	Stepovyi	8.34	4216	505.52	0.361	2.87
hybrids 250-290						
Without watering, control	DN Halateia	2.55	2801	1098.43	–	–
	Skadovs`kyi	2.47	2801	1134.01	–	–
drip surface	DN Halateia	10.55	4464	423.13	0.242	3.76
	Skadovs`kyi	10.73	4464	416.03	0.230	3.88
sprinkling	DN Halateia	10.14	4732	466.67	0.251	3.22
	Skadovs`kyi	10.25	4732	461.66	0.241	3.30
FAO hybrids 300-380						
Without watering, control	DN Demetra	2.05	2847	1388.78	–	–
	Tronka	2.14	2847	1330.37	–	–
drip surface	DN Demetra	14.53	5647	388.64	0.141	3.84
	Tronka	14.05	5647	401.92	0.152	3.66
sprinkling	DN Demetra	13.87	5812	419.03	0.148	3.50
	Tronka	13.55	5812	428.93	0.158	3.38
FAO hybrids 420-440						
Without watering, control	Hileia	1.56	2923	1873.72	–	–
	DN Olena	1.88	2923	1554.79	–	–
Drip surface	Hileia	16.54	6052	365.90	0.094	4.16
	DN Olena	16.09	6052	376.13	0.117	3.95
sprinkling	Hileia	16.05	6560	408.72	0.097	3.56
	DN Olena	15.56	6560	421.59	0.121	3.36
LSD_{05}, t·ha^{-1} factor A	0.13					
factor B	0.15					
AB interaction	0.17					

The fundamental direction of increasing the yield of corn is the introduction of new hybrids of intensive type, because the grain productivity of the hybrid is a genetic trait, and not every hybrid will be able to recoup the cost of harvesting under irrigation.

Today, in a fairly wide range of hybrids of this grain crop grown in Ukraine, only some have the genetic ability (potential) to ensure the proper cultivation technology to obtain high yields at 14-17 t·ha^{-1}.

An important role in increasing yields and improving the quality of corn grain belongs to the correct selection of hybrids for cultivation (Lavrynenko et al., 2015).

To establish the response of newly created hybrids to soil moisture regime and irrigation methods, studies were conducted with options: 1) irrigation by sprinkling with a pre-irrigation soil moisture level of 65% LW (pre-irrigation moisture level 65%, water-saving regime); 2) irrigation sprinkling pre-irrigation moisture level 80% LW; 3) drip irrigation with a pre-irrigation soil moisture level of 80% LW; 4) drip irrigation with pre-irrigation moisture level 85% (pre-irrigation moisture level 85%, optimal mode). Such irrigation regimes and irrigation methods correspond to the most typical parameters of corn cultivation technologies on irrigated lands (Table 3).

Table 3. Grain yield (t·ha^{-1}) of modern maize hybrids under different irrigation methods and irrigation regime

Hybrid	FAO	Irrigation by sprinkling, RPVG 65% HB	Irrigation by sprinkling, RPVG 80% HB	Drip irrigation, RPVG 80% HB	Drip irrigation, RPVG 85% HB
DN Pyvykha	180	8.32	8.52	8.84	9.03
Stepovyi	190	7.87	8.34	9.01	9.38
DN Halateia	260	8.45	10.14	10.55	10.78
Skadovs`kyi	290	9.51	10.25	10.73	10.89
DN Demetra	300	8.14	13.87	14.53	14.85
Tronka	390	9.08	13.55	14.05	14.49
DN Olena	420	8.35	16.05	16.54	16.72
Hileia	420	8.94	15.56	16.09	16.36
LSD_{05}		0.23	0.28	0.31	0.33

Hybrids of FAO 180-190 DN Pyvykha, Stepovyi showed stability of yield under different irrigation regimes. The use of FAO hybrids 180-190 is expedient under conditions of water-saving irrigation regimes on irrigated lands with low hydromodule.

Hybrids of FAO 260-290 DN Halateia and Skadovs`kyi show the maximum yield under drip irrigation of pre-irrigation moisture level 85% LW 10.78-10.89 t·ha^{-1} and reduce the yield under water–saving irrigation - 65% LW. But the reduction in yield is not critical, so it is permissible to grow FAO 260-290 hybrids on irrigation systems with low hydromodule.

The hybrids of DN Demetra and Tronka (FAO 300-390) showed a strong reaction of the hybrids to the ecological gradient of cultivation. The yield of hybrids of this type decreases sharply with the use of water-saving irrigation regimes. These hybrids are of the intensive type and dramatically reduce grain yields compared to FAO 190-280 hybrids. The use of FAO 300-390 hybrids under water–saving irrigation regimes is impractical and may lead to poor yields. The genotypic productivity potential of these hybrids can be revealed only under the conditions of intensive technologies. For pre-irrigation moisture level 85% and drip irrigation grain yield of hybrids Tronka, DN Demetra reached 14.49-14.85 t·ha^{-1}.

In the FAO group 400-420 hybrids of corn of intensive type DN Olena, Hileia provide grain yield of 15.56-16.72 t·ha^{-1} under drip irrigation and sprinkling. Hybrids of this type should not be used on irrigated lands with low hydromodule and water-saving irrigation regimes, as this leads to significant crop losses and they become uncompetitive with modern FAO hybrids 190-280.

The conducted research confirmed the perspective direction of research of scientists (Romashchenko et el 2015; Repilevsky and Ivaniv, 2021) in the direction of improving the irrigation regime of crops taking into account the reduction of irrigation water costs, increasing the efficiency of irrigation in climate change in the direction of aridity. Irrigation, in combination with other agricultural practices, is a key factor in intensifying growth corn in the south of Ukraine. The south of Ukraine has a strong potential for grain production, but suffers from insufficient natural moisture. Therefore, today an important area of stabilization of crop production is the scientific justification of artificial moisture supply of plants through the use of new irrigation methods and the use of varietal productivity potential of modern varieties and hybrids adapted to specific agri-environmental conditions and technologies (Dziubetskyi & Cherchel, 2017; Prysiazhnuk et al., 2016). Created new innovative maize hybrids have broad adaptive capabilities, but the process of determining agronomic indicators of varieties and hybrids requires the development of varietal technologies to provide specific recommendations for production (Gadzalo, 2020; Babych, 2014; Kokovikhin & Bilyaeva, 2017). The presented research materials extend the direction of research that combines breeding and genetic development and improvement of varietal technologies with the definition of adaptation parameters of new genotypes and further recommendations for production.

CONCLUSIONS

On the basis of the conducted researches it is confirmed that irrigation, in a complex with other agricultural receptions, is the key factor of intensification of growth processes and formation of productivity of grain corn crops.

Studies have shown that the maximum total water consumption of 6052-6560 $m^3 \cdot ha^{-1}$ in the soil layer 0–100 cm on average for 2018-2020 was established in FAO hybrids 420-440 under drip irrigation and sprinkling .

It was investigated that on average for three years of research on all hybrids with vegetative irrigation the payback rate of irrigation water ranged from 2.87 kg m^{-3} for sprinkling to 4.16 kg m^{-3} on drip irrigation, which indicates the prospects of using drip irrigation.

The maximum grain yield was shown by maize hybrids of intensive type DN Olena, Hileia under drip irrigation of pre-irrigation moisture level 85% - 16.36-16.72 $t \cdot ha^{-1}$.

When growing maize hybrids with a longer growing season, the payback of irrigation water increased compared to early and middle-early groups. This gives grounds to recommend drip irrigation as the best method of irrigation for growing corn in the steppes of Ukraine with a severe shortage of water resources. Maize hybrids of different FAO groups with selectively programmed response to water-saving and optimal irrigation regimes have been established. You are divided into drought-resistant homeostatic hybrids that can be used in non-irrigated conditions.

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HERBICIDAL WEED CONTROL IN WINTER WHEAT (*Triticum aestivum* L.)

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Abstract

During 2019-2020 and 2020-2021 on the experimental field of the Agricultural University of Plovdiv, Bulgaria, a field experiment with winter wheat variety 'Enola' was performed. The trial included the following herbicidal treatments: Quelex + Trend 90 (37.5 g ha^{-1} + 0.1%); Quelex + Trend 90 (50 g ha^{-1} + 0.1%); Quelex + Aminopielik 600 SL (37.5 g ha^{-1} + 0.4 l ha^{-1}); Quelex + Aminopielik 600 SL (50 g ha^{-1} + 0.4 l ha^{-1}); Quelex + Mustang 306,25 SC (37.5 g ha^{-1} + 0.3 l ha^{-1}); Derby super one + Trend 90 (33 g ha^{-1} + 0.1%); Mustang 306,25 SC (0.6 l ha^{-1}); Sekator OD (1.25 l ha^{-1}); Sekator OD (1.50 l ha^{-1}) and Biathlon 4D + Dash (55 g ha^{-1} + 0.5 l ha^{-1}). The herbicides were applied in phenophase tillering of the winter wheat (BBCH 21-29). The application of Quelex + Mustang 306,25 SC (37.5 g ha^{-1} + 0.3 l ha^{-1}) and Quelex + Aminopielik 600 SL(50 g ha^{-1} + 0.4 l ha^{-1}) ensured excellent efficacy against Anthemis arvensis L., Papaver rhoeas L., Consolida orientalis J.Gay, Vicia hirsuta L., Galium aparine L., Sinapis arvensis L., Lamium purpureum L., and Fumaria officinalis L.. The wheat biological yield as well as the supplementary biometrical indicators for the concrete two treatments was the highest.

Key words*: winter wheat, herbicides, weeds, efficacy, biometry.*

INTRODUCTION

Providing plenty of food to eat the population of the Earth is an inalienable concern for humanity. All branches of biological science work intensively and purposefully to solve a large number of problems and tasks (Georgiev et al., 2019; Nenova, 2019; Nenova et al., 2019; Petrova et al., 2019; Nenova, 2017; Shopova & Cholakov, 2015; Shopova & Cholakov, 2014).

The winter wheat (*Triticum aestivum* L.) is the main grain crop in Bulgaria. The weeds are the main competitors of winter wheat for water, nutrients, and light. The weeds also cause indirect damage, as many of the species are hosts of diseases and pests (Kalinova et al., 2012). The high weeds infestation can decrease the yields by up to 70% (Atanasova & Zarkov, 2005; Bekelle, 2004).

In addition to weeds, the lack of nutrients, which is often caused by them, also harms the formation of crop yields (Ivanov et al., 2019; Manolov & Neshev, 2017; Neshev & Manolov, 2016; Kostadinova et al., 2015; Manolov et al., 2015; Neshev & Manolov, 2014; Neshev et al., 2014; Goranovska et al., 2014).

In modern agriculture, weed control is mainly performed by the chemical method. A number of authors study the selectivity and efficacy of different herbicides in crops (Glazunova et al., 2021; Marinov-Serafimov & Golubinova, 2016; Marinov-Serafimov & Golubinova, 2015; Mitkov, 2014; Mitkov et al., 2014; Mitkov et al., 2010; Tityanov et al., 2010; Tityanov et al., 2009; Mitkov et al., 2009; Atanasaova, 2002).

The choice of a proper herbicide, optimal time, and application rate is one of the most important and responsible moments in wheat management (Petrova, 2017; Penchev & Petrova, 2015; Petrova & Sabev, 2014; Abbas et al., 2009a; Khalil et al., 2008; Sherawat & Ahmad, 2005).

For successful weed control in wheat, several herbicidal products are evaluated and applied. Mitkov et al. (2017a) study Sekator OD and Biathlon 4 D for control of dicotyledonous weeds. The herbicide products were applied in two terms – 1st – 2nd stem node (BBCH 30-32) and flag leaf (BBCH 37-39) of the wheat. The highest efficacy was recorded after the application of Biathlon 4 D + Dash at a rate of 0.14 kg ha^{-1} + 1.0 l ha^{-1} applied 1st – 2nd stem node of the crop. Chopra et al., (2008) found that carfentrazone at a rate of 20 g ha^{-1} and metsulfuron at a rate of 4 g ha^{-1} control the broadleaf weeds 83.7 and 84.1% respectively. For control of the broadleaf weeds Abbas et al. (2009b) recommend the usage of Buktril Super EK - 835 ml ha^{-1} and Starane-M - 875 ml ha^{-1}. WangCang et al. (2016), reported that the combinations of 29% fluroxypyr - 111.31 g ha^{-1} + 5% carfentrazone-ethyl - 3.31 g ha^{-1}, florasulam - 7.50 g ha^{-1} + carfentrazone-ethyl - 15.00 g ha^{-1} had excellent efficacy against *Descurainia sophia*, *Capsella bursa-pastoris*, and *Galium aparine*. For the most efficient control of *Galium* sp. fluroxypyr should be applied.

High efficacy against *Galium aparine* after the combined treatment of carfentrazone + MCPP, triosulfuron + dicamba, and amidosulfuron + iodosulfuron was recorded (Cirujeda et al., 2008).

For control of *Descurainia sophia* L. in winter wheat (*Triticum aestivum* L.) Wang et al., (2021) recommend the treatments with MCPA-Na + carfentrazone-ethyl and bipyrazone+fluroxypyr.

According to Zargar et al. (2021), it is better to achieve weed control in the autumn than in spring. Herbicide application at the early tillering stage of crops reduced the dry weight of broadleaf weeds by 60% to 90% and of monocot weeds by 55% to 85% (Meriem & Rafika, 2021).

It was found that tribenuron-methyl provided the greatest wild mustard suppression (75%) and also caused the highest reduction in wild mustard biomass (3.3 g), stem number (6), seed number (880), and germination percentage (33%) (Zargar et al., 2021).

Besides differentiated, the control of the mono- and dicotyledonous weeds in wheat could be performed simultaneously. For *Apera spica-venti, Echinochloa crus-galli* and some dicotyledonous weeds Szemendera et al., (2008) found that Pledge 50 WP (flumioxazine) can be applied. If there is mixed weed infestation with *Apera spica-venti*, *Lolium* sp., *Avena fatua*, *Myosotis arvensis*, *Capsella bursa-pastoris, Thlaspi arvense*, etc.

Krato and Raffel (2018) observed that treatment with Avoxa (pinoxadene+pyroxulam + cloquintocet-mexyl) at a rate of 1.8 l ha^{-1} may be performed.

The study aims to establish herbicidal weed control in winter wheat (*Triticum aestivum* L.).

MATERIALS AND METHODS

During 2019-2020 and 2020-2021 a field trial with winter wheat variety "Enola" was performed. The experiment was situated on the experimental field of the department of "Agriculture and herbology" at the Agricultural University of Plovdiv, Bulgaria. The trial was conducted by the randomized block design in 3 replications. The size of the harvesting plot was 20 m². Variants of the trial were: 1. Untreated contol; 2. Quelex (104.232 g/kg halauxifen-methyl + 100 g/kg florasulam) – 37.5 g ha^{-1} + Trend 90 (90 % isodecyl alcohol ethoxylate + 10 % water) – 0.1%; 3. Quelex – 50 g ha^{-1} + Trend 90 – 0.1%; 4. Quelex – 37.5 g ha^{-1} + Aminopielik 600 SL (600 g/l 2.4 D amine salt) – 0.4 l ha^{-1}; 5. Quelex + Aminopielik 600 SL – 50 g ha^{-1} + 0.4 l ha^{-1}; 6. Quelex – 37.5 g ha^{-1} + Mustang 306.25 SC (6.25 g/l florasulam + 300 g/l 2.4 D ester) – 0.3 l ha^{-1}; 7. Derby Super One (150 g/kg florasulam + 300 g/kg aminopyralid) – 33 g ha^{-1} + Trend 90 – 0.1%; 8. Mustang 306.25 SC – 0.6 l ha^{-1}; 9. Sekator OD (25 g/l iodosulfuron-methyl-sodium + 100 g/l amidosulfuron sodium + 250 g/l mefenpyr-diethyl) – 1.25 l ha^{-1}; 10. Sekator OD - 1.50 l ha^{-1} and 11. Biathlon 4D (54 g/kg florasulam + 714 g/kg tritosulfuron) – 55 g ha^{-1} + Dash (0.5 l ha^{-1}).

As the studied herbicides are entire with broadleaf weed spectrum of control, for removing the grass weeds pressure, the application of Axial 050 EC (50 g/l pinoxaden) at a rate of 900 ml ha^{-1} as background treatment to the whole experimental area was applied. The spraying was done in the tillering stage of the crop in spring.

The preceding crop of winter wheat during both experimental years was sunflower (*Helianthus annuus* L.). After the preceding crop harvesting twice disking and twice harrowing on 10 cm of depth was performed.

To the whole experimental area before sowing of the winter wheat, fertilization with 300 kg ha^{-1} with NPK (15:15:15) 300 kg ha^{-1} NH_4NO_3 as spring dressing.

Artificial weed infestation with previously collected weed seeds by spreading to the whole area of the trial was performed. The infestation was done with *Anthemis arvensis* L., *Papaver rhoeas* L., *Galium aparine* L., *Sinapis arvensis*

L., *Lamium purpureum* L., *Veronica hederifolia* L., *Consolida orientalis* (J.Gay) Sch., *Lamium purpureum* L., *Fumaria officinalis* L., and *Vicia hirsuta* L.

The application of the herbicide products was done in tillering stage of the crop (BBCH 21-29) with spraying solution 250 l ha^{-1}.

The efficacy of the herbicides was evaluated on the 14th, 28th, and the 56th day after treatments by the 10-score scale of EWRS (Zhelyazkov et al. 2017).

The selectivity of the herbicides was examined on the 7th, 14th, 28th, and 56th day after application by the 9-score scale of EWRS (Zhelyazkov et al. 2017).

The following parameters of the winter wheat were determined: Height of the plants at the end of the vegetation, length of the central ear, number of grains per ear, the mass of the grain per ear, 1000 grain weight, and grain yield.

The reported biometric indicators were processed with the software package SPSS 19 - module two-factor analysis of variance for Windows 10. The difference between the evaluated treatments was statistically analyzed by ONE WAY ANOVA by using Duncan's multiple range test. Statistical differences were considered proved at $p<0.05$.

RESULTS AND DISCUSSIONS

On the experimental field, only annual broadleaf weeds during both vegetation seasons of the winter wheat were observed. The weeds were presenters of three biological weed groups. The highest population was from the group of the winter-spring weeds - *Anthemis arvensis* L., *Papaver rhoeas* L., *Consolida orientalis* (J.Gay) Sch. and *Vicia hirsuta* L., followed by the group of the early-spring weeds – *Galium aparine* L., *Sinapis arvensis* L., *Lamium purpureum* L., and two presenters of the ephemerals – *Veronica hederifolia* L. and *Fumaria officinalis* L.

One of the sensitive weeds to the evaluated herbicides and rates was *A. arvensis*.

The average results show that on the 14th day after application the efficacy against the weed varied from 57.5 to 78.2%.

On the 28th day after treatment, all studied variants showed very good efficacy. It was reported that after application of Biathlon 4D + Dash (55 g ha^{-1} + 0.5 l ha^{-1}) and Quelex + Mustang 306,25 SC (37.5 g ha^{-1} + 0.3 l ha^{-1}) during the second reporting date the efficiency against *A. arvensis* was 99.4%.

On the third reporting date, on average for the two years, 100% efficacy for all herbicide-treated variants except Quelex + Trend 90 (37.5 g ha^{-1} + 0.1%) was reported (Table 1). Effective control against *A. arvensis* was also found from Kieloch (2005) after the application of Herbaflex 585 SC (isoproturon 500 g/l+beflubutamid 85 g/l).

Against the weed *P. rhoeas* the highest control on the 14th day after application of Quelex + Mustang 306,25 SC (37.5 g ha^{-1} + 0.3 l ha^{-1}) was recorded - 81.3%. Similar efficacy was found for the treatments with Quelex + Aminopielik 600 SL (50 g ha^{-1} + 0.4 l ha^{-1}) - 78.2% and Mustang 306,25 SC (0.6 l ha^{-1}) - 75.7%.

Table 1. Efficacy of the studied herbicides against *Anthemis arvensis* L., %

Variants	2020			2021			Average		
	14th day	*28th day*	*56th day*	*14th day*	*28th day*	*56th day*	*14th day*	*28th day*	*56th day*
1.	-	-	-	-	-	-	-	-	-
2.	60.0	95.0	98.8	55.0	90.0	97.5	57.5	92.5	98.2
3.	76.3	97.5	100	70.0	92.5	100	73.2	95.0	100
4.	70.0	98.8	100	65.0	95.0	100	67.5	96.9	100
5.	78.8	98.8	100	72.5	95.0	100	75.7	96.9	100
6.	80.0	100	100	75.0	98.8	100	77.5	99.4	100
7.	75.0	97.5	100	70.0	92.5	100	72.5	95.0	100
8.	78.8	97.5	100	72.5	92.5	100	75.7	95.0	100
9.	78.8	98.8	100	72.5	95.0	100	75.7	96.9	100
10.	81.3	97.5	100	75.0	92.5	100	78.2	95.0	100
11.	78.8	100	100	72.5	98.8	100	75.7	99.4	100

On the 28th day, on average for the period, the same tendency was observed. In treatment 6 the efficiency against *P. rhoeas* reached 100%, and for treatments 5 and 8 - 96.9% and - 96.3% respectively.

At the last reporting date, 100% control against *P. rhoeas* in variants 3, 4, 5, 6, 8, and 11 was found. The lowest efficiency was for Sekator OD at a rate of 1.25 l ha^{-1} - 79.9% (Table 2). Idziak et al., 2012 found that the mixture of pinoxaden with florasulam, applied alone or with different herbicides (fluroxypyr, tribenuron-methyl, dicamba with triasulfuron, 2.4-dichlorophenoxy acetic acid with dicamba) provides effective control of the weed *Papaver rhoes, Galium aparine, Myosotis arvensis, Capsella bursa-pastoris,* and *Stellaria media*, *Matricaria inodora.*

Table 2. Efficacy of the studied herbicides against *Papaver rhoeas* L., %

Variants	2020			2021			Average		
	14th day	*28th day*	*56th day*	*14th day*	*28th day*	*56th day*	*14th day*	*28th day*	*56th day*
1.	-	-	-	-	-	-	-	-	-
2.	57.5	90.0	97.5	52.0	85.0	92.5	54.8	87.5	95.0
3.	73.8	96.3	100	70.0	92.5	100	71.9	94.4	100
4.	71.3	95.0	100	68.5	90.0	100	69.9	92.5	100
5.	81.3	98.8	100	75.0	95.0	100	78.2	96.9	100
6.	83.8	100	100	78.8	100	100	81.3	100	100
7.	68.8	91.3	97.5	62.5	86.3	92.5	65.7	88.8	95.0
8.	78.8	97.5	100	72.5	95.0	100	75.7	96.3	100
9.	47.5	78.8	81.3	40.0	75.0	78.5	43.8	76.9	79.9
10.	51.3	85.0	88.8	45.0	80.0	85.0	48.2	82.5	86.9
11.	58.8	92.5	100	52.5	87.5	100	55.7	90.0	100

For *Galium aparine* L. control the highest results for the treatments with Quelex + Trend 90 (50 g ha^{-1} + 0.1%), Quelex + Aminopielik 600 SL (50 g ha^{-1} + 0.4 l ha^{-1}) and Quelex + Mustang 306,25 SK (37.5 g ha^{-1} + 0.3 l ha^{-1}) were achieved.

On average for the period on the 14th day, the efficiency varies from 61.2 to 80.7%, the highest being in variants 5 and 6.

On day 28, the efficacy against the weed increased and ranged from 85% with Sekator OD at a rate of 1.25 l ha^{-1} to 96.9% with Quelex + Aminopielik 600 SL at a rate of 50 g ha^{-1} + 0.4 l ha^{-1}.

Table 3. Efficacy of the studied herbicides against *Galium aparine* L., %

Variants	2020			2021			Average		
	14th day	*28th day*	*56th day*	*14th day*	*28th day*	*56th day*	*14th day*	*28th day*	*56th day*
1.	-	-	-	-	-	-	-	-	-
2.	67.5	90.0	96.3	62.5	85.0	91.0	65.0	87.5	93.6
3.	77.5	97.5	100	75.0	92.5	100	76.3	95.0	100
4.	75.0	92.5	98.8	70.0	87.5	95.0	72.5	90.0	96.9
5.	81.3	98.8	100	80.0	95.0	100	80.7	96.9	100
6.	81.3	97.5	100	80.0	92.5	100	80.7	95.0	100
7.	65.0	88.8	95.0	60.0	85.0	90.0	62.5	86.9	92.5
8.	71.3	92.5	96.3	65.0	87.5	91.0	68.2	90.0	93.7
9.	66.3	87.5	93.8	62.5	82.5	90.0	64.4	85.0	91.9
10.	66.3	90.0	97.5	62.5	85.0	92.5	64.4	87.5	95.0
11.	63.8	90.0	96.3	58.5	85.0	91.0	61.2	87.5	93.7

On the 56th day, the average efficiency of all variants is from very good to excellent. The efficacy against *G. aparine* was 100% for the treatments of Quelex + Trend 90 (50 g ha^{-1} + 0.1%), Quelex + Aminopielik 600 SL (50 g ha^{-1} + 0.4 l ha^{-1}) and Quelex + Mustang 306,25 SK (37.5 g ha^{-1} + 0.3 l ha^{-1}). In the other variants of the third reporting date, the control against the glue varied from 91.9 to 96.9% (Table 3). Successful control with the *G. aparine* was also established after the application of Aminopielik Gold 530 EW (450 g/l 2,4-D + 80 g/l fluroxypyr) (Skrzypczak and Pudełko, 2004).

Average for the period on the 14th day after treatments against the weed *S. arvensis* the efficacy of Quelex + Trend 90 (50 g ha^{-1} + 0.1%) and Quelex + Aminopielik 600 SL (50 g ha^{-1} + 0.4 l ha^{-1}) was 82.5%. The efficacy of the other treatments varied from 64.4 to 75.3%.

On the 28th day, the highest efficacy was observed for Quelex + Trend 90 (50 g ha^{-1} + 0.1%) – 96.9%. It is worth noting that the use of Quelex + Aminopielik 600 SL at rates of 37.5 g ha^{-1} + 0.4 l ha^{-1} and 50 g ha^{-1} + 0.4 l ha^{-1} and Mustang 306.25 SK at a rate of 0.6 l ha^{-1} provided 93.8% control of *S. arvensis*.

On the 56th day after application, the efficacy in all variants was approximately excellent. Only in the Quelex + Trend 90 variant at the rate of 37.5 g ha^{-1} + 0.1% the efficacy against *S. arvensis* was 95.7%. In the other variants, the control varied from 97.5 to 100% (Table 4)

High efficacy of Mustang 306.25 SK, Secator OD, and Derby super WG against *S. arvensis* was also found by Petrova, 2017.

Table 4. Efficacy of the studied herbicides against *Sinapis arvensis* L., %

Variants	2020			2021			Average		
	14th day	*28th day*	*56th day*	*14th day*	*28th day*	*56th day*	*14th day*	*28th day*	*56th day*
1.	-	-	-	-	-	-	-	-	-
2.	75.0	92.5	96.3	70.0	87.0	95.0	72.5	89.8	95.7
3.	85.0	98.8	98.8	80.0	95.0	100	82.5	96.9	99.4
4.	77.5	95.0	97.5	73.0	92.5	97.5	75.3	93.8	97.5
5.	85.0	95.0	98.8	80.0	92.5	100	82.5	93.8	99.4
6.	78.8	93.8	100	74.0	90.0	100	76.4	91.9	100
7.	75.0	91.3	98.8	70.0	85.0	100	72.5	88.2	99.4
8.	70.0	95.0	100	68.5	92.5	100	69.3	93.8	100
9.	66.3	92.5	100	62.5	87.0	100	64.4	89.8	100
10.	76.3	91.3	100	72.5	85.0	100	74.4	88.2	100
11.	75.0	93.8	100	70.0	90.0	100	72.5	91.9	100

The biological efficacy of the studied herbicidal products against *V. hederifolia* was among the lowest in comparison to those of the other weeds in the research. Average for the period the highest efficacy against the weed on the 14th day after treatment with Quelex + Mustang 306.25 SK (37.5 g ha^{-1} + 0.3 l ha^{-1}) – 76.3%, followed by Quelex + Aminopielik 600 SL (50 g ha^{-1} + 0.4 l ha^{-1}) - 75.1% was found.

The efficacy of Derby Super One + Trend 90 (33 g ha^{-1} + 0.1%) was barely 31.9%.

On the 28th day the highest efficacy was found to be for Quelex + Aminopielik 600 SL (50 g ha^{-1} + 0.4 l ha^{-1}) and Quelex + Mustang 306,25 SK (37.5 g/da + 0.3 l ha^{-1}) - 91.9%.

On average for the period on the 56th day against *V. hederifolia* was 100% for the Quelex + Aminopielik 600 SL (50 g ha^{-1} + 0.4 l ha^{-1}) treatment. The lowest efficacy was reported for treatment 7-46.9% (Table 5).

Table 5. Efficacy of *the* studied herbicides against *Veronica hederifolia* L., %

Variants	2020			2021			Average		
	14th day	*28th day*	*56th day*	*14th day*	*28th day*	*56th day*	*14th day*	*28th day*	*56th day*
1.	-	-	-	-	-	-	-	-	-
2.	36.3	45.0	50.0	32.5	40.0	47.5	34.4	42.5	48.8
3.	63.8	71.3	73.8	60.0	68.8	70.0	61.9	70.1	71.9
4.	62.5	88.8	95.0	58.5	85.0	92.5	60.5	86.9	93.8
5.	76.3	93.8	100	73.8	90.0	100	75.1	91.9	100
6.	77.5	93.8	98.8	75.0	90.0	95.0	76.3	91.9	96.9
7.	33.8	42.5	48.8	30.0	37.5	45.0	31.9	40.0	46.9
8.	66.3	88.8	95.0	62.5	85.0	92.5	64.4	86.9	93.8
9.	42.5	51.3	53.8	40.0	48.8	52.5	41.3	50.1	53.2
10.	47.5	61.3	63.8	42.5	57.5	60.0	45.0	59.4	61.9
11.	38.8	50.0	52.5	35.0	45.0	50.0	36.9	47.5	51.3

According to Kierzek and Adamczewski (2005) the mixture of 2.4 D + dicamba applied alone and with adjuvants (RA 2003, Olbras Super 90 EC, Olbras 88 EC or Atpolan 80 EC at 1.0 l ha^{-1}) was very effective to approximately all existing weeds in their study. The adjuvants have increased the efficacy of 22.4 D + dicamba, especially against *Veronica hederifolia, Papaver rhoeas,* and *Galium aparine*.

Compared to the *V. hederifolia* the weed *C. orientalis* was more sensitive to the studied herbicides. During the first reporting date, the average efficiency for the period varied from 60 to 81.9%.

On the 28th day, the efficacy increased, and for the treatmrnt, with Quelex + Mustang 306.25 SK at raytes of 37.5 g ha^{-1} + 0.3 l ha^{-1} reached 100%. For the other variants, the efficiency varies from 88.2% to 96.9%.

On the 56^{th} day after treatment, in 2021, 100% control was reported for all herbicide variants, except for variants 7 and 11, where the efficacy was 98.8%.

On average for the period during the third reporting date the control with the *C. orientalis* in variants 3, 4, 5, 6, 8 was 100%, in variants 2, 9, 10 is 99.4%, and in variants 7 and 11-98.2% (Table 6).

Table 6. Efficacy of the studied herbicides against *Consolida orientalis* (J. Gay) Sch., %

Variants	2020			2021			Average		
	14^{th} day	*28^{th} day*	*56^{th} day*	*14^{th} day*	*28^{th} day*	*56^{th} day*	*14^{th} day*	*28^{th} day*	*56^{th} day*
1.	-	-	-	-	-	-	-	-	-
2.	62.5	92.5	98.8	57.5	88.8	100	60.0	90.7	99.4
3.	80.0	95.0	100	75.0	90.0	100	77.5	92.5	100
4.	78.8	93.8	100	72.5	90.0	100	75.7	91.9	100
5.	82.5	98.8	100	78.5	95.0	100	80.5	96.9	100
6.	83.8	100	100	80.0	100	100	81.9	100	100
7.	63.8	91.3	97.5	58.8	85.0	98,8	61.3	88.2	98.2
8.	66.3	97.5	100	60.0	94.0	100	63.2	95.8	100
9.	68.8	91.3	98.8	62.5	85.0	100	65.7	88.2	99.4
10.	71.3	92.5	98.8	67.5	88.8	100	69.4	90.7	99.4
11.	66.3	92.5	97.5	60.0	88.8	98.8	63.2	90.7	98.2

On the 14^{th} day after the herbicidal spraying spraying the weed *L. purpureum* was most successfully controlled by Quelex + Aminopielik 600 SL (50 g ha^{-1} + 0.4 l ha^{-1}) – 89.4%, followed by Quelex + Trend 90 (50 g ha^{-1} + 0.1%), Quelex + Aminopielik 600 SL (37.5 g ha^{-1} + 0.4 l ha^{-1}) and Sekator OD 1.25 l da^{-1}) - 80.7%. On the second reporting date at treatments 3, 4, 5, 6, and 10 the efficacy was 100%. It was observed that on the 56^{th} day the weed's control was excellent for all treatments (Table 7).

Table 7. Efficacy of the studied herbicides against *Lamium purpureum* L., %

Variants	2020			2021			Average		
	14^{th} day	*28^{th} day*	*56^{th} day*	*14^{th} day*	*28^{th} day*	*56^{th} day*	*14^{th} day*	*28^{th} day*	*56^{th} day*
1.	-	-	-	-	-	-	-	-	-
2.	76.3	96.3	100	70.0	95.0	100	73.2	95.7	100
3.	82.5	100	100	78.8	100	100	80.7	100	100
4.	82.5	100	100	78.8	100	100	80.7	100	100
5.	91.3	100	100	87.5	100	100	89.4	100	100
6.	80.0	100	100	75.0	100	100	77.5	100	100
7.	78.8	96.3	100	75.0	95.0	100	76.9	95.7	100
8.	66.3	95.0	100	60.0	92.5	100	63.2	93.8	100
9.	82.5	98.8	100	78.8	100	100	80.7	99.4	100
10.	81.3	100	100	77.5	100	100	79.4	100	100
11.	80.0	98.8	100	75.0	100	100	77.5	99.4	100

In the control against *F. officinalis* on the first reporting date, the efficacy of Quelex + Mustang 306.25 SK at rates of 37.5 g ha^{-1} + 0.3 l ha^{-1} was the highest - 82.5%, followed by Quelex + Aminopielik 600 SL at rates of 50 g ha^{-1} + 0.4 l ha^{-1} - 75.7%.

On the 28th day, the highest efficacy of the weed for treatment 6 was reported. On average for the period on the 56th day 100% efficacy after the use of Quelex + Mustang 306,25 SK (37.5 g ha^{-1} + 0.3 l ha^{-1}), Quelex + Aminopielik 600 SL (50 g ha^{-1} + 0.4 l ha^{-1}), Quelex + Aminopielik 600 SL (37.5 g ha^{-1} + 0.4 l ha^{-1}), Quelex + Trend 90 50 g ha^{-1} + 0.1%) was reported. Limited control of *Fumaria officinalis* L. was found for Sekator OD (1.25 l ha^{-1}), Mustang 306.25 SK (0.6 l ha^{-1}), Biathlon 4D + Dash (55 g ha^{-1} + 0.5 l ha^{-1}) and Sekator OD (1.50 l ha^{-1}) (Table 8).

Table 8. Efficacy of the studied herbicides against *Fumaria officinalis* L., %

Variants	2020			2021			Average		
	14th day	*28th day*	*56th day*	*14th day*	*28th day*	*56th day*	*14th day*	*28th day*	*56th day*
1.	-	-	-	-	-	-	-	-	-
2.	62.5	92.5	96.3	60.0	90.0	95.0	61.3	91.3	95.7
3.	75.0	97.5	100	70.0	92.5	100	72.5	95.0	100
4.	67.5	97.5	100	62.5	92.5	100	65.0	95.0	100
5.	78.8	95.0	100	72.5	90.0	100	75.7	92.5	100
6.	85.0	100	100	80.0	97.5	100	82.5	98.8	100
7.	55.0	93.8	97.5	50.0	90.0	98.8	52.5	91.9	98.2
8.	41.3	57.5	57.5	38.5	50.0	52.5	39.9	53.8	55.0
9.	42.5	50.0	55.0	40.0	45.0	50.0	41.3	47.5	52.5
10.	45.0	55.0	61.3	42.5	50.0	57.5	43.8	52.5	59.4
11.	48.8	60.0	60.0	45.0	55.0	55.0	46.9	57.5	57.5

Regarding the weed species *V. hirsute* the herbicidal efficacy on the 14th day after treatments, the efficacy varied between 73.8% - 85.7%.

Excellent 100% efficacy was found for the variants with Quelex + Trend 90 (50 g ha^{-1} + 0.1%), Quelex + Aminopielik 600 SL (37.5 g ha^{-1} + 0.4 l ha^{-1} and 50 g ha^{-1} + 0.4 l ha^{-1}), Quelex + Mustang 306.25 SK (37.5 g ha^{-1} + 0.3 l ha^{-1}) on the 28th day.

On the last reporting date (56 days after treatments) the efficacy of all studied variants reached 100% (Table 9).

Table 9. Efficacy of the studied herbicides against *Vicia hirsuta* L., %

Variants	2020			2021			Average		
	14th day	*28th day*	*56th day*	*14th day*	*28th day*	*56th day*	*14th day*	*28th day*	*56th day*
1.	-	-	-	-	-	-	-	-	-
2.	77.5	96.3	100	70.0	90.0	100	73.8	93.2	100
3.	87.5	100	100	80.0	100	100	83.8	100	100
4.	86.3	100	100	80.0	100	100	83.2	100	100
5.	88.8	100	100	82.5	100	100	85.7	100	100
6.	83.8	100	100	78.5	100	100	81.2	100	100
7.	78.8	96.3	100	72.5	90.0	100	75.7	93.2	100
8.	78.8	97.5	100	72.5	92.5	100	75.7	95.0	100
9.	78.8	96.3	100	72.5	90.0	100	75.7	93.2	100
10.	78.8	96.3	100	72.5	90.0	100	75.7	93.2	100
11.	80.0	98.8	100	75.0	95.0	100	77.5	96.9	100

All studied herbicidal products and rates are selective for the winter wheat variety Enola.

Regarding the indicator plant height, it was found that of all the studied variants, the plants in the untreated control are the shortest.

This difference is statistically proven at a significance level of 5%.

The results show that if there is weed pressure it leads to concurrence with the cultivated plant that leads to growth and development decrease.

On average for the two years of study treatments 2, 3, 4, 5, 6, 7, 8, 10, and 11 did not differ significantly from in plant height ranging from 84.7 cm to 89 cm.

With lower plant height were the treatments with Sekator OD (1.25 l ha^{-1}) and Biathlon 4D + Dash (55 g ha^{-1} + 0.5 l ha^{-1}) - 80.3 and 81.7 cm respectively (Table 10).

Table 10. Height of the plants, length of the central ear, and number of grains per ear of wheat, Enola variety

Variants	2020			2021			Average		
	Height of the plants , cm	length of the dental ear, cm	number of grains per ear	Height of the plants , cm	length of the dental ear, cm	number of grains per ear	Height of the plants , cm	length of the dental ear, cm	number of grains per ear
1.	72.5 f	6.1 f	25.1 f	69.1 f	5.7 d	21.4 e	70.8 d	5.9 f	23.3 e
2.	87.3 bc	8.6 bcd	42.5 bc	83.2 bc	8.0 b	41.9 bc	85.3 abc	8.3 bcd	42.2 bc
3.	88.4 abc	9.5 abc	46.0 b	84.2 abc	8.4 ab	44.1 b	86.3 abc	9.0 ab	45.1 b
4.	89.9 abc	9.6 ab	48.2 b	85.6 abc	8.5 ab	45.7 b	87.8 ab	9.1 a	47.0 b
5.	90.5 ab	9.9 a	57.0 a	86.2 ab	9.0 a	51.4 a	88.4 a	9.5 a	54.2 a
6.	91.1 a	10.0 a	57.4 a	86.8 a	9.1 a	53.3 a	89.0 a	9.6 a	55.4 a
7.	88.0 abc	8.6 bcd	42.8 bc	83.2 bc	8.0 b	42.1 bc	85.5 abc	8.3 bcd	42.5 bc
8.	87.6 bc	9.3 abc	44.0 bc	83.4 abc	8.4 ab	43.1 bc	85.6 abc	8.9 ab	43.6 bc
9.	82.2 e	7.5 e	34.3 d	78.3 e	7.0 c	32.8 d	80.3 c	7.3 e	33.6 d
10.	86.7 cd	8.6 cd	41.3 bc	82.6 cd	7.8 b	40.3 bc	84.7 abc	8.2 cd	40.8 bc
11.	83.6 de	8.1 de	36.1 d	79.7 de	7.8 b	35.8 d	81.7 bc	8.0 d	36.0 d

The values with different letters are with proved difference according to Duncan's multiple range test ($p < 0.05$)

In the indicator of the length of the central ear, a statistical difference between the untreated control and the herbicide-treater variants was recorded. According to the degree of mathematical proof, six separate groups are distinguished – "a", "b", "c", "d", "e" and "f". The lowest results were found for the untreated control – 5.9 cm, belonging to a group *„f”*. The most distant from the group of untreated control – *"f"*. and with the highest value of the studied indicator are the treatments with Quelex + Mustang 306,25 SK (37.5 g ha^{-1} + 0.3 l ha^{-1}), Quelex + Aminopielik 600 SL (50 g ha^{-1} + 0.4 l ha^{-1}), Quelex + Aminopielik 600 SL (37.5 g ha^{-1} + 0.4 l ha^{-1}), Quelex + Trend 90 (50 g ha^{-1} + 0.1%) and Mustang 306,25 SK (0.6 l ha^{-1}), belonging to a group „a”. The was no statistically proved difference also between the treatments with Derby Super One + Trend 90 (33 g ha^{-1} + 0.1%), Quelex + Trend 90 (37.5 g ha^{-1} + 0.1%), Sekator OD (1.50 l ha^{-1}) and Biathlon 4D + Dash (55 g ha^{-1} + 0.5 l ha^{-1}) (Table 10).

The results related to the number of grains from the central ear showed that there are statistically proven differences between the untreated control and the other studied variants in favor of the herbicide-treated ones. The highest grain number was found for the treatments with Quelex + Mustang 306,25 SK (37.5 g ha^{-1} + 0.3 l ha^{-1}) Quelex + Aminopielik 600 SL (50 g ha^{-1} + 0.4 l ha^{-1}) - 55.4 and 54.2 respectively. Lower grain number was recorded for treatments 9 and 11 - 33.6 and 36.0 respectively. The lowest grain number for the untreated control was recorded - 23.3 (Table 10).

Average for the period the central ear grain mass was the lowest for the untreated control – 0.66 g. The obtained result was statistically proved with the other treatments. The highest mass of the grains from the central ear was found to be for treatments 6, 5, 4, and 3 – 2.14, 2.02, 1.91, and 1.75 g respectively. There is no mathematically proven difference between these four options (Table 11).

The indicator 1000 grain weight gives an idea of the size and obesity of the seeds. The obtained results showed that there is a statistically proven difference between the untreated control and the herbicide-treated variants. The untreated control had the lowest value of the studied indicator - 26.32 g. The highest results for treatments 6, 5, 4, 3, 8, 7, and 2 were recorded. Lower values of this indicator, but with a proven higher difference from the control were treatments 10, 11, and 9 - 34.78, 32.38, and 31.70 g respectively (Table 11). Marczewska-Kolasa and Kieloch (2009) also found that the use of herbicides significantly increases the 1000 grain weight than in the untreated control.

Table 11. Mass of the grain per ear and 1000 grain weight of wheat, Enola variety

Variants	2020		2021		Average	
	mass of the grain per ear, g	1000 grain weight, g	mass of the grain per ear, g	1000 grain weight, g	mass of the grain per ear, g	1000 grain weight, g
1.	0.73 g	27.04 f	0.59 g	25.60 f	0.66 f	26.32 e
2.	1.53 def	37.60 cd	1.27 def	34.81 bc	1.40 de	36.21 abc
3.	1.90 abcd	39.00 bc	1.59 abcd	35.93 bc	1.75 abcd	37.47 ab
4.	2.06 abc	40.12 ab	1.75 abc	36.24 bc	1.91 abc	38.18 ab
5.	2.18 ab	40.58 ab	1.85 ab	38.10 ab	2.02 ab	39.34 a
6.	2.30 a	41.19 a	1.97 a	39.85 a	2.14 a	40.52 a
7.	1.70 cde	38.00 cd	1.43 cde	35.25 bc	1.57 cde	36.63 abc
8.	1.83 bcde	38.12 bc	1.50 bcde	35.5 bc	1.67 bcd	36.81 ab
9.	1.27 f	33.5 e	1.01 f	29.89 e	1.14 e	31.70 d
10.	1.45 ef	36.20 cd	1.16 ef	33.35 cd	1.31 de	34.78 bcd
11.	1.30 f	34.00 e	1.02 f	30.75 de	1.16 e	32.38 cd

The values with different letters are with proved difference according to Duncan's multiple range test ($p < 0.05$)

Data on winter wheat yield confirm that there is a positive correlation between the effect of herbicides on weeds and the yield obtained from the crop. As a result of the high weed infestation of the experimental field, a low average yield from the untreated control was reported - 2.75 t ha^{-1} (Table 12). According to the degree of mathematical proof, seven separate groups of treatments were distinguished - "a", "b", "c", "d", "e", "f"and "g". The application of Quelex + Mustang 306,25 SK (37.5 g ha^{-1} + 0.3 l ha^{-1}) had the highest grain yield - 5.34 t ha^{-1}. It is correct to mention that the application of Quelex + Aminopielik 600 SL (50 g ha^{-1} + 0.4 l ha^{-1}) and Quelex + Aminopielik 600 SL (37.5 g ha^{-1} + 0.4 l ha^{-1}) led to high grain yields as well - 5.21 and 5.12 t ha^{-1} respectively. It was found that there was no proven difference between treatments 6, 5, and 4. These variants are from group "a" and are furthest from the group of untreated control "g", ie. with the highest yield (Table 12).

Table 12. Grain yield (t ha^{-1}) of wheat, variety Enola, treated with the tested herbicides

Variants	2020	2021	Average
1. Untreated contol	2.84 e	2.66 e	2.75 g
2. Quelex + Trend 90 (37.5 g ha^{-1} + 0.1%)	4.94 bc	4.72 bc	4.83 d
3. Quelex + Trend 90 (50 g ha^{-1} + 0.1%)	5.11 ab	4.92 ab	5.02 bcd
4. Quelex + Aminopielik 600 SL (37.5 g ha^{-1} + 0.4 l ha^{-1})	5.22 ab	5.01 ab	5.12 abc
5. Quelex + Aminopielik 600 SL (50 g ha^{-1} + 0.4 l ha^{-1})	5.31 ab	5.11 ab	5.21 ab
6. Quelex + Mustang 306,25 SC (37.5 g ha^{-1} + 0.3 l ha^{-1})	5.44 a	5.24 a	5.34 a
7. Derby super one + Trend 90 (33 g ha^{-1} + 0.1%)	4.98 bc	4.79 bc	4.89 cd
8. Mustang 306,25 SC (0.6 l ha^{-1})	5.03 b	4.83 ab	4.93 cd
9. Sekator OD (1.25 l ha^{-1})	4.23 d	3. 99 d	4.11 f
10. Sekator OD (1.50 l ha^{-1})	4.62 cd	4.40 cd	4.51 e
11. Biathlon 4D + Dash (55 g ha^{-1}+0.5 l ha^{-1})	4. 29 d	4.09 d	4.19 f

The values with different letters are with proved difference according to Duncan's multiple range test ($p < 0.05$)

The lowest grain yield among the herbicide-treated variants for the treatments with Sekator OD at a rate of 1.25 l ha^{-1} - 4.11 t ha^{-1} and Biathlon 4D + Dash at a rate of 55 g ha^{-1} + 0.5 l ha^{-1} - 4.19 t ha^{-1} was recorded. There is no proven difference between the two variants at $p < 0.05$. The obtained average yields in these variants can be explained by their lower herbicidal efficiency. However, in variants 9 and 11 the yield was proven to be higher than in the untreated control (Table 12). Increasing in wheat yields after the application of herbicides have been found in other studies as well (Touahar et al., 2021; Yanev et al., 2021; Al-Khazali et al., 2020; Mitkov et al., 2018; Mitkov et al., 2017b).

CONCLUSIONS

The application of Quelex + Mustang 306,25 SK at rates of 37.5 g ha^{-1} + 0.3 l ha^{-1} had 100% efficacy *A. arvensis*, *P. rhoeas*, *G. aparine*, *S. arvensis*, *C. orientalis*, *L. purpureum*, *F. officinalis* and *V. hirsuta*.

The application of Quelex + Aminopielik 600 SL at rates of 50 g ha^{-1} + 0.4 l ha^{-1} showed 100% efficacy against *V. hederifolia* and the other weed species accept *S. arvensis*, where the efficacy was 99.4%.

The most difficult-to-control weed in the study was *V. hederifolia*, followed by *F. officinalis*.

All studied herbicides show excellent selectivity to wheat, Enola variety.

The lowest results for the studied parameters as length of the central ear, number of grains per ear, mass of the grain per ear, 1000 grain weight and grain yield for the untreated control were reported. Statistically proven differences in favor of herbicide-treated variants have been identified.

After the application of Quelex + Mustang 306,25 SK at rates of 37.5 g ha^{-1} + 0.3 l ha^{-1} and Quelex + Aminopielik 600 SL in both evaluated rates (50 g ha^{-1} + 0.4 l ha^{-1} and 37.5 g ha^{-1} + 0.4 l ha^{-1}) the highest values of all indicators, including grain yield were reported.

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INFLUENCE OF LIQUID ORGANIC FERTILIZERS ON THE YIELD STRUCTURE CHARACTERISTICS AND PRODUCTIVITY OF CHICKPEA (*Cicer arietinum* L.)

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Abstract

The aim of this study was to determine the effect of liquid organic fertilizers Naturamin Plus and Amalgerol Essence on the yield structure characteristics and productivity of chickpea (Cicer arietinum L.). The experiment was conducted in the period 2019-2021 in the region of South-Central Bulgaria. The trial was designed by the block method in 4 repetitions and 3 doses of fertilizers were tested in two phases of chickpea development: growth phase (4th leaf) and beginning of flowering. Results obtained for the yield were statistically processed by ANOVA. It was found that the treatment with the tested fertilizers increases the values of the structural elements of yield (number of pods per plant, number of grains per plant, grain mass per plant and 1,000 grain mass). The maximum increase in productivity was obtained with treatment with liquid organic fertilizer Amalgerol Essence in dose 1,000 ml.ha^{-1} - 21.8% more compared to the control. A higher effect on productivity was found when applying the tested fertilizers in the beginning of flowering.

Key words: *chickpea, fertilization, productivity, yield structure characteristics.*

INTRODUCTION

Chickpea (*Cicer arietinum* L.) is a typical grain legume crop, grown since ancient times in the Mediterranean region, and the third most important grain legume crop, after soybean and bean, that is produced worldwide in the present day. Studies show that it's a plant that can be grown in various ecological conditions, including saline soils in arid and semi-arid regions (Krouma, 2009; Rao et al., 2002). It is grown traditionally in Central, West and South Asia, South Europe, Australia and North Africa, where it is an important source of cheap protein with high energy and nutritional value (Zia Ul-Haq et al., 2007). As a legume plant which is harvested early and enriches the soil with nitrogen, chickpea is a good predecessor to winter cereals and many other crops. This is why it plays an important role in the systems for organic farming (Cokkizgin, 2012). Conducted studies (Zhelyazkova, 2016; Zhelyazkova et al., 2016) show that due to the good drought resistance, high and stable yields, this legume crop is suitable for growing in the region of South-Central Bulgaria.

The increasing need for plant protein in order to solve the protein problem for human and animal nutrition, necessitates using the maximum potential of legumes production. A possible way to achieve that is to influence the yield through foliar application of nutrients in critical phases of the development of the cultures. Many authors reported data on the influence of various liquid foliar fertilizers and their combinations on the productivity of chickpea and its structural elements (Ali & Mishra, 2001; Burman et al., 2013; Kolev et al., 1999; Menaka et al., 2018; Montenegro et al., 2010; Valenciano et al., 2011). It's emphasized that the positive effect on the productivity is related to increasing the resistance to unfavorable external factors, stronger development of the plants and increasing the values of the structural elements of the yield (Drostkar et al., 2016; Janmohammadi et al., 2018; Nandan et al., 2014; Venkatesh & Basu, 2011). El-Habbasha et al. (2012) consider that a possibility for receiving high and stable yields from chickpea, grown on sandy soils, with low content of organic matter, low water holding capacity, and deficit of macro- and microelements as a result of losses from leaching, is the integrated application of soil and foliar fertilizing. According to data from

Rathod et al. (2020) foliar treatment of chickpea with micronutrient fertilizers leads to bigger impact on the total biomass and yield, compared to soil fertilizing. Positive effects from the treatment were also the increased content of crude protein and microelements in the seeds of chickpea, as well as the increased yield of protein (Nandan et al., 2014; Rathod et al., 2020; Venkatesh & Basu, 2011). It's emphasized that the effect from applying foliar fertilizers is determined by the chickpea development phase (Bahr, 2007; Bhowmick, 2006; Bhowmick et al., 2013). Kirnapure et al. (2020) reported highest grain yield, straw yield, and total biological yield, as well as rate of profitability, by using two treatments - at vegetative and at the beginning of flowering stage. According to data from Ganga et al. (2014), maximum chickpea grain yield, grown on sandy clay loam soil, was achieved by applying potassium fertilizers at sowing, combined with foliar spraying at pre-flowering stage with a complex of macro- and microelements. Some authors determined there were specifics in the reaction of the different varieties of chickpea to the applied foliar fertilizers (El-Habbasha et al., 2012).

In order to decrease the negative impact on the environment and to comply with the new trends and demands on the market, Shinde & Ravi (2020) applied liquid biofertilizers to optimize the feed rate of chickpea and determined a positive influence on the yield at two treatments (in flowering stage and 15 days after flowering) in combination with soil fertilizing with organic fertilizers. Conducted studies established biofertilizers and growth regulators as an alternative to reducing mineral fertilization and receiving ecologically clean production from chickpea (Seleiman & Abdelaal, 2018).

The aim of the study was to determine the effect of liquid organic fertilizers Naturamin Plus and Amalgerol Essence on the yield structure characteristics and productivity of chickpea (*Cicer arietinum* L.), grown in the region of South-Central Bulgaria.

MATERIALS AND METHODS

The study was conducted in the period 2019-2021 in the fields of the Agricultural cooperation for production and services (ZKPU) "Trakia" in the town Radnevo, situated in the region of South-Central Bulgaria. For the field experiment was used the chickpea variety Balkan.

The experiment was conducted by the block method in 4 repetitions, size of the experimental plot was 10 m^2, in non-irrigated conditions, with predecessor wheat.

The soil type was Haplic Vertisol, containing medium available humus (Table 1), neutral to low alkaline reaction, low in available nitrogen and phosphorus and high in available potassium.

Table 1. Soil characteristics

pH (KCl)	Humus, %	Mineral N, mg.1,000 g^{-1}	N –NH_4, mg.1,000 g^{-1}	N-NO_3, mg.1,000 g^{-1}	Available P_2O_5, mg.100 g^{-1}	Available K_2O, mg.100 g^{-1}
7.2	3.7	37.9	4.6	33.3	1.5	47.3

Tested was the influence of the combined fertilizers: Naturamin Plus (total 400 $g.l^{-1}$ amino acids, free amino acids - 200 $g.l^{-1}$, Nitrogen (N) - 75 $g.l^{-1}$, Iron (Fe) - 12 $g.l^{-1}$, Manganese (Mn) - 7.5 $g.l^{-1}$; Boron (B) - 1.3 $g.l^{-1}$, Copper (Cu) - 1.2 $g.l^{-1}$, Molybdenum (Mo) - 0.5 $g.l^{-1}$, Zinc (Zn) - 2.5 $g.l^{-1}$) in dose 1,500, 2,500 and 3,500 $ml.ha^{-1}$ and Amalgerol Essence (free amino acids, organic Nitrogen (3%) and organic potassium (3%), plant herb extracts, seaweed extract, plant hormones, antioxidants, total organic carbon 22.7%) in does 1,000, 2,000 and 3,000 $ml.ha^{-1}$.

The treatment was in two phases of chickpea development: growth phase (4th leaf) and beginning of flowering. For application was used a small sprayer pump with 300 $l.ha^{-1}$ spraying solution and air temperature up to 20-25°C. Applied was the commonly accepted technology for growing chickpea.

Reported were the parameters: height of the plants at harvest, yield structure characteristics (number of pods per plant, number of grains per plant, grain mass per plant, and 1,000 grain mass) and grain yield at standard humidity (13%). Data processing was performed by a two-way dispersion analysis (Lidanski, 1988), using MS Excel software - 2010.

RESULTS AND DISCUSSIONS

The climate conditions during the period of the study are shown on Table 2. Regarding the rainfall, the years of the study are charactarised as comparatively favorable.

The vegetation sums of the rainfall in both years of the study are over the average multiannual sum. The largest sum of rainfall during the vegetation period was registered in 2019 - 323.2 mm (25.7% above average). During the vegetation on average for the multiannual period the rainfall was distributed unevenly, and the highest values were for the months May and June.

In the years of the study, this unevenness was also well pronounced, especially in 2019. That year was characterized with intense spring drought lasting until the third ten-days of April, and was especially severe in March.

In both years of the trial, the predominant part of the vegetation rainfalls (75-81%) fell in the second half of the vegetation period (May-June).

Table 2. Climate conditions of South-Central Bulgaria

Years	Months													
	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII	I-XII	III-VII
Total rainfall, mm														
2019	40.0	10.6	3.0	62.2	118.8	78.6	60.6	50.6	23.2	30.8	63.4	16.2	558.0	323.2
2021	110.0	37.0	63.2	60.8	41.4	110.0	25.6	14.4	1.0	127.4	22.4	99.0	712.2	301.0
1936 - 2018	41.7	35.8	37.2	45.1	62.8	61.7	51.2	43.5	34.7	42.7	48.9	47.8	553.1	258.0
Average temperature, ^{0}C														
2019	2.3	4.5	8.9	11.6	17.4	23.4	23.9	25.2	20.6	14.2	11.7	4.0	14.0	17.0
2021	3.7	5.1	5.5	10.6	17.7	20.8	25.9	26.1	19.4	11.5	8.0	4.6	13.2	16.2
1936 - 2018	1.0	2.8	6.6	12.0	17.1	21.2	23.7	23.3	19.0	13.0	7.4	2.7	12.5	16.1

The annual air temperature during the vegetation for the multiannual period (1936-2018) was 16.1ºC. Higher deviation from the norm was found in 2019 when the average air temperatures for the vegetation period were with 0.9 ºC above normal.

That year of the study, the average daily temperatures of the air in the beginning phases of plant development (March) were with 2.3ºC above the average multiannual.

In the months May and especially in June 2019, during the flowering and ripening phases, the average monthly air temperatures were above the average multiannual.

In 2021 the average air temperatures for the vegetation period do not differ significantly from the average multiannual.

The yield of grain as a resulting parameter shows best the effect from the applied agricultural technique (Table 3).

The yield in 2021 was characterized with more favorable climate conditions which created the precondition for more optimal growth and reproductive processes and formation of higher yields - average 2,296.74 $kg.ha^{-1}$. The results for the received grain yields show that by years, as well as by average for the period of the study, the lowest yield was received for the untreated control (2,017.11 $kg.ha^{-1}$).

Treatment with liquid organic fertilizers in both testing phases (growth phase and beginning of flowering) had positive influence on the productivity of the chickpea as well.

The highest statistically significant grain yield ($P<0.001$) for the different years and average for the period of the study was received from the variant treated with liquid organic fertilizer Amalgerol Essence in dose 1,000 $ml.ha^{-1}$.

Average for the period of the study, the grain yield from this variant was higher than the control with 13.80% (growth phase) and up to 21.79% (beginning of flowering phase).

Application of higher doses (2,000 and 3,000 $ml.ha^{-1}$) from the same organic fertilizer during the beginning of flowering phase also gave positive differences compared to the basic variant, which are statistically proven.

These differences, however, are smaller than the tested lower dose (1,000 $ml.ha^{-1}$), which leads to the conclusion that the lower dose would be more efficient economically. In treatment of the chickpea in the growth phase

(4th leaf) with the liquid organic fertilizer Amalgerol Essence in dose 3,000 ml.ha^{-1}, difference compared to the untreated variant was not proven.

Table 3. Grain yield of chickpea, treated with leaf fertilizers (Naturamin Plus and Amalgerol Essence) at different stages of their development, by the years and average for the period 2019-2021, kg.ha^{-1}, n=104

Variant	Dose ml.ha^{-1}	Years		Average	
		2019	2021	kg.ha^{-1}	%
Control (untreated)		1,915.04	2,119.17	2,017.11	100.00
Growth phase (4th leaf)					
Naturamin Plus	1,500	2,027.38	2,168.51	2,097.94a	104.01
Naturamin Plus	2,500	2,113.88	2,228.95	2,171.41b	107.65
Naturamin Plus	3,500	2,175.99	2,282.27	2,229.13***c	110.51
Amalgerol Essence	1,000	2,274.32	2,316.53	2,295.42***c	113.80
Amalgerol Essence	2,000	2,099.54	2,220.41	2,159.98**b	107.08
Amalgerol Essence	3,000	2,026.55	2,156.94	2,091.74ab	103.70
Beginning of flowering					
Naturamin Plus	1,500	2,093.50	2,269.97	2,181.74***b	108.16
Naturamin Plus	2,500	2,247.18	2,359.72	2,303.45***c	114.20
Naturamin Plus	3,500	2,385.97	2,456.80	2,421.39***d	120.04
Amalgerol Essence	1,000	2,415.94	2,497.23	2,456.59***d	121.79
Amalgerol Essence	2,000	2,359.91	2,411.93	2,385.92***cd	118.28
Amalgerol Essence	3,000	2,168.90	2,369.16	2,269.03***c	112.49
Average		2,177.24	2,296.74	2,236.99	110.90
LSD.P< 0.05		128.10	45.00	86.55	4.29
LSD.P< 0.01		171.20	60.10	115.65	5.73
LSD.P< 0.001		224.50	78.90	151.70	7.52
SD				167.2	
CV				7.47	
SE				16.4	
Min				1855.14	
Max				2723.45	

*Different letters indicate statistically significant differences among variants at P < 0.05
*, **, *** - Statistically significant differences of the variants and control at P< 0.05; 0.01 and 0.001, respectively

Positive and highly statistically proven (P<0.001) was the difference in treatment with the liquid organic fertilizer Naturamin Plus in dose 3,500 ml.ha^{-1}. The surplus in grain yield compared to the untreated plants was highest at treatment in beginning of flowering phase and was on average 20.04%. In the treatment of chickpea in the growth phase (4th leaf) with liquid organic fertilizer Naturamin Plus in doses 1,500 and 2,500 ml.ha^{-1} the received differences in the grain yield compared to the untreated plants were not statistically proven both by years as well as by average for the studied period.

During vegetation, using liquid leaf fertilizers had a positive effect on the growth parameters of chickpea (Table 4), but the difference compared to the control group was not statistically proven not only by years but also on average for the duration of the experiment.

The yield structure elements of chickpea – number of pods and grains per plant, grain mass per plant, and 1,000 grain mass, are species and variety characteristics and as such are a comparatively constant quantity, however according to a number of authors (Drostkar et al., 2016; Janmohammadi et al., 2018; Nandan et al., 2014; Venkatesh & Basu, 2011) the application of leaf fertilizers, as part of the technology for growing, has an effect on them. Average for the period of the study, the smallest number of pods and grains per plant, grain mass per plant, and 1,000 grain mass was received from the untreated control (Table 4).

Table 4. Morphological structure parameters of chickpea, treated with leaf fertilizers (Naturamin Plus and Amalgerol Essence) at different stages of their development, average for the period 2019-2021, n = 78

Variant	Dose ml.ha^{-1}	Stem height, cm	Pods per plant, number	Grains per plant, number	Grain mass per plant, g	1,000 grain mass, g
Control (untreated)		72.0	33.5	42.8	12.6	383.7
Growth phase (4th leaf)						
Naturamin Plus	1,500	73.8	35.3a	45.0a	13.0a	385.8a
Naturamin Plus	2,500	76.7	36.3a	47.2**a	13.7a	388.9a
Naturamin Plus	3,500	77.0	38.7**b	49.0***ab	14.6ab	393.9***b
Amalgerol Essence	1,000	77.0	39.3***c	49.8***ab	14.9*ab	396.0***b
Amalgerol Essence	2,000	75.3	36.8*a	46.7*a	14.1ab	392.7**ab
Amalgerol Essence	3,000	74.7	36.1a	45.7a	13.7a	390.1*ab
Beginning of flowering						
Naturamin Plus	1,500	74.0	37.0*ab	45.9a	13.1a	385.1a
Naturamin Plus	2,500	74.4	37.7*ab	47.8**a	13.6a	387.4a
Naturamin Plus	3,500	75.0	40.9***c	50.8***b	15.3**b	400.1***c
Amalgerol Essence	1,000	76.7	42.0***c	51.8***b	15.5**b	400.8***c
Amalgerol Essence	2,000	76.7	38.4**b	47.2*a	14.9*ab	392.0**ab
Amalgerol Essence	3,000	74.6	35.9a	45.8a	14.2ab	390.3**ab
Average		75.2	37.5	47.3	14.1	391.3
LSD.P< 0.05		5.3	3.2	3.5	2.1	5.3
LSD.P< 0.01		7.2	4.3	4.7	2.8	7.3
LSD.P< 0.001		9.5	5.7	6.2	3.8	10.2
SD		6.8	5.8	4.3	2.1	6.4
CV		9.0	15.5	9.0	15.2	1.6
SEE		0.8	0.7	0.5	0.2	0.9
Min		61.2	25.6	38.0	10.2	378.0
Max		89.0	49.0	56.0	19.8	405.0

*Different letters indicate statistically significant differences among variants at P < 0.05
*, **, *** - Statistically significant differences of the variants and control at P< 0.05; 0.01 and 0.001, respectively.

The highest and well proven statistically (P<0.001) differences in the values of the yield structure characteristics compared to the control were received when the chickpea was treated in the beginning of flowering with liquid organic fertilizer Amalgerol Essence in dose 1,000 ml.ha^{-1} – 18.98% (6.7 numbers) more pods per plant, 15.11% (6.8 numbers) more grains per plant, 19.23% (2.5 g) more grain mass per plant, and 3.88% more mass for 1,000 grain mass. The differences in the values of the yield structure elements between the varieties treated with Naturamin Plus in dose 3,500 ml.ha^{-1} and Amalgerol Essence in dose 1,000 ml.ha^{-1} were not statistically proven.

In calculating the correlation between grain productivity and the yield structure characteristics in chickpea treated with liquid leaf fertilizers (Table 5) was determined that applying Naturamin Plus in the beginning of flowering phase had strong positive correlation with the number of pods per plant (r = 0.907), number of grain per plant (r = 0.900) and 1,000 grain mass (r = 0.893).

Table 5. Correlation analysis among the yield and morphological structure parameters of chickpea, treated with leaf fertilizers (Naturamin Plus and Amalgerol Essence) at different stages of their development, average for the period 2019-2021

Variant	Dose ml.ha^{-1}	Pods per plant, number	Grains per plant, number	Grain mass per plant, g	1,000 grain mass, g
Control (untreated)		0.834	0.779	0.656	0.412
Growth phase (4th leaf)					
Naturamin Plus	1,500	0.772*	0.643	0.64	0.765*
Naturamin Plus	2,500	0.769*	0.775*	0.469	-0.582
Naturamin Plus	3,500	0.493	0.734*	0.224	0.355
Amalgerol Essence	1,000	0.249	0.204	0.232	0.338
Amalgerol Essence	2,000	0.438	0.633	0.032	-0.283
Amalgerol Essence	3,000	0.652	0.795*	0.729*	-0.842*

Beginning of flowering					
Naturamin Plus	1,500	0.907*	0.449	0.563	0.893*
Naturamin Plus	2,500	0.710*	0.900*	0.670	0.123
Naturamin Plus	3,500	0.526	0.758*	0.574	-0.252
Amalgerol Essence	1,000	0.642	0.373	0.077	0.517
Amalgerol Essence	2,000	0.199	0.049	0.050	0.114
Amalgerol Essence	3,000	0.300	0.277	0.318	-0.349

* - Statistical significance at $P < 0.05$

In treatment of chickpea with the liquid fertilizer Naturamin Plus in the growth phase between the grain yield and the number of pods per plant correlation exists as well, however it has a lower value (r = 0.769-0.772). In growth phase the correlation of the yield with the number of grains per plant (r = 0.734-0.795) was lower as well.

The dispersion analysis showed that stronger and well proven (P<0.000) influence on the grain yield had the phase of treatment - 26.76% from the total variation of the data (Table 6).

Table 6. Influence of factors on the grain yield, average for the period 2019-2021, n=96

Source of variation	Sum of squares	Degree of freedom	Mean squares	F*	P<	%
Factor analysis for treatment phase						
Year	3,034.6	1	3,034.63	19.63	0.000	12,88
Treatment phase	6,304.8	1	6,304.76	40.79	0.000	26.76
Year * Treatment phase	2.3	1	2.34	0.02	0.902	0.01
Degree of random factors	14,221.7	92	154.58			60.35
Factor analysis for type of preparation						
Year	3,034.6	1	3,034.63	13.90	0.000	12.88
Type of preparation	428.8	1	428.83	1.96	0.164	1.82
Year * Type of preparation	15.1	1	15.13	0.07	0.793	0.06
Degree of random factors	20,084.9	92	218.31			85.24

*F - ratio among the variables; P - Statistical significance

The force of influence of the conditions of the year on the grain yield was also well proven (P<0.000), but significantly lower – respectively 12.88%. There is no proven influence on the grain yield by the type of preparation used, and no proven relation between the year and phase of treatment with fertilizers, between the year and the type of preparation.

CONCLUSIONS

Treatment with liquid organic fertilizers had a positive influence on the productivity of chickpea grown in the region of South-Central Bulgaria. Maximum increase in the yield was obtained with treatment of the chickpea in flowering phase with the liquid organic fertilizer Amalgerol Essence in dose 1,000 $ml.ha^{-1}$ (up to 21.8% more grain yield) and Naturamin Plus in dose 3,500 $ml.ha^{-1}$. Using higher doses of the liquid organic fertilizer Amalgerol Essence, the effect on the productivity decreases. The main influence on the grain yield in chickpea had the phase of fertilization and the conditions of the year. There is no proven influence on the grain yield by the type of preparation used. The productivity of chickpea had a strong positive correlation with the number of pods and grains per plant and the 1,000 grain mass. The applied liquid organic fertilizers Amalgerol Essence and Naturamin Plus increased the values of the yield structure characteristics of chickpea (number of pods per plant, number of grains per plant, grain mass per plant, and 1,000 grain mass) by creating possible opportunities for higher productivity. Maximum increase in the values of the yield structure characteristics was obtained with treatment with the liquid organic fertilizer Amalgerol Essence in dose 1,000 $ml.ha^{-1}$. Treatment of chickpea with liquid organic fertilizers had no effect on the height of the plants.

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CHITOSAN TREATMENTS IN ORGANIC VINEYARD AND THEIR IMPACT ON THE COLOUR AND SENSORY PARAMETERS OF FETEASCA NEAGRA WINES

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Abstract

Chitosan is a natural polymer approved for the treatments of organic vineyards based on its fungicide effect. Beside the protection it offers, chitosan has also the potential to modulate polyphenolic content in the black grapes, hence improving the colour of the resulted red wines. The present study on Feteasca neagra variety organically cultivated showed that there was indeed an improvement of the total polyphenolic content and colour of wines obtained from grapes treated with chitosan (5 kg/ha), as compared to the wines from grapes only subjected to the usual treatment based on Bordeaux mixture (5 kg/ha). The study included a mixed treatment, with both chitosan and Bordeaux mixture (5+5 kg/ha). The increase of total polyphenols and colour is apparent in all samples treated with chitosan, being higher when chitosan was used alone than in the case of the mixed treatment. The sensory qualities of the wines were also influenced. While the main sensory parameters of the wines were not significantly affected by the vineyard treatments, the aromatic profiles perceived sensorially showed that the floral scent decreased and the spiciness increased due to chitosan treatment, the effect being more evident in the case of chitosan used alone. These preliminary results suggest that chitosan can be useful for the modulation of the wine quality and style.

Key words: *chitosan vine treatment, wine colour parameters, Feteasca neagra, wine sensory quality.*

INTRODUCTION

Chitosan (poly-D-glucosamine, CAS No. 9012-76-4) is a deacetylated derivative of chitin, being a biopolymer present in the exoskeleton of insects and in crustacean shells, but also in some microorganisms, especially in the fungal cell wall (Ma et al., 2022; Apetroaei et al., 2016).

Because it is a non-allergenic product, with low toxicity, chitosan has multiple uses, as a phytosanitary agent (Iriti et al., 2011), for producing, preserving (Lo'ay and El-Khateeb 2018) or packing food (Oladzadabbasabadi et al., 2022), for filtering and purifying water, in certain products for medical use such as in bandages for wound healing (Kim, 2010).

Being natural and biodegradable, it is authorized for use in organic agricultural treatments, but also for the treatment of (organic) wine, especially because it has a high positive charge at the wine pH and has the physico-chemical property of flocculating, thus being a stabilizing agent.

In plants it is an antifungal protector, but also an elicitor of plant growth (Gutiérrez-Gamboa et al., 2019). Chitosan increases the plant's immune response by producing antioxidant enzymes, more polyphenols (Vitalini et al., 2011), as a result of increased expression of certain genes, etc. For plants, chitosan is also a modulator of water loss (Bittelli et al., 2011). Under conditions of water stress, chitosan reduces perspiration, closing even the stomata, but when there is too much water it can increase the perspiration rate by about 30%.

Chitosan also increases plant firmness (Adamuchio-Oliveira et al., 2020). In response to chitosan, certain phytoalexins such as chitinase and lignin are produced. This is because the plant recognizes chitosan as a component (or derivative) of insects and fungi, so it responds by increasing those substances that can prevent the attack of insects and fungi, such as increased lignin levels, which makes the plants harder to be penetrated. Because pathogenic fungi have more chitin than others, chitosan treatments affect more these fungi and not the useful ones such as mycorrhizal microorganisms.

In this way chitosan can be seriously considered as an alternative to copper treatment in organic and conventional vineyards (Dagostin et al., 2006a, 2006b, 2011).

In this study, in order to improve existing organic farming technologies, chitosan treatments, alone or in combination with Bordeaux mixture, were carried out in the vineyard during 2020 in order to determine whether this new material leads to better grapes and, respectively, higher wine quality. Hereafter, the effect of chitosan vine treatments on the wines produced from organic grapes is assessed, with special focus on colour, polyphenol composition and sensory characteristics.

MATERIALS AND METHODS

An organic Feteasca neagra vineyard cultivated in Murfatlar (Artem et al., 2021a, 2012b, Artem et al., 2020) was used to compare the effect of chitosan treatments with the usual application of Bordeaux mixture.

The phytosanitary protection treatments applied consisted of doses of 5 kg/ha of each substance (chitosan or Bordeaux mixture), applied alone or in combination. Applied together, the two substances were in a dose of 5 kg/ha each, but the sprayings were applied less often, i.e. 6 treatments/year instead of 12, as it was done with the substances used alone.

The wines which resulted in 2020 from the processing of these grapes differently treated are named in correlation with the type of treatment in the vineyard: FN20-Bord, FN20-Chit and FN20-ChiBo, respectively. The variant treated only with Bordeaux juice is considered a control, because this is the classical treatment applied in organic viticulture.

The physico-chemical parameters of wines were measured, to establish the differences between the treatments, but also to evaluate the intrinsic quality of the wines and their compliance with the legislation. The laboratory methods recognized by the OIV (International Vine and Wine Organization, 2021) were used.

To describe the sensory quality of wines and determine the samples with the highest commercial chances, the most used methods are sensory profile analyses, based on specially designed evaluation sheets. Such a score sheet was developed at USAMV and is part of a patent (Antoce and Namolosanu, 2007). With this sheet, the following elements were evaluated:

- general sensory characteristics of wines (acidity, sweet taste, extract, colour intensity and aroma intensity), which is done through the usual tasting techniques, using continuous scales for evaluating the intensity of perception, with maximum values of 10;
- specific sensory wine parameters (parameters that are considered essential for defining typicality and quality, such as colour and flavour). For the evaluation of the specific parameters, scoring scales with discrete values are used, represented in the form of 5 boxes, which can be considered as notes with integer values between 1 and 5. To use them in mathematical models together with the grades obtained on the 10-point scales, these values are multiplied by a factor of 2. Thus, the resulting values are all in the range 0-10. For each score given to a specific flavour parameter, a more detailed description of the flavour is required from tasters. For example, for aromatic fruit notes, where they can be identified, the types of fruit can be detailed, more generally such as notes of citrus, berries, tropical fruits, temperate fruits or even more specifically, identifying exactly the fruit from the respective classes, such as orange, grapefruit, raspberry, currant, plum, etc.

Since sensory analysis with human evaluators cannot accurately determine colour shades and small differences in colour intensity, in order to accurately determine whether there are differences between experimental variants induced by vine treatments, the defined colour parameters were measured by the CIEL*ab* method with the help of a spectrophotometer.

The colour was determined by a Jena AG Specord 250 UV-VIS Analytik spectrophotometer, which runs software version WinAspect 2.2.7 for spectrum recording and data storage, and Chroma software, specially designed for colour analysis. The measurements were performed by measuring the transmittance of the wine every 1 nm on the visible spectrum from 400 nm to 700 nm, with a quartz cuvette with a 1 mm optical path and using as standard D65 light and an observation angle of 10°. The software automatically calculates where the samples place in a uniform colour perception space with three dimensions and the associated CIEL*ab* parameters: L, *a, b*. L represents "brightness" or "luminance" - the higher the value, the more "transparent" the sample. According to the CIEL*ab* system, the parameters obtained are:

- coordinate *a*, which shows the placement of the colour between red and green; if *a*> 0 is red, and if *a* <0 is green;
- coordinate *b*, which shows the placement of the colour between yellow and blue; if *b*> 0 is yellow, and if a <0 is blue;
- the parameter L, representing the brightness of a coloured object judged in relation to the brightness that appears as white; more simply is the degree of transparency or opacity (0 represents opacity, 100 complete transparency);
- the parameter c_{ab} or *c* (chrome), representing the chromaticity of a coloured object judged in relation to white, or more simply, the purity, the saturation or the depth of the colour;
- the parameter h_{ab} or h (angle in radians) representing that descriptor of the appearance by which a colour is identified according to its resemblance to the colour red (0°), yellow (90°), green (180°), blue (270°), or a combination of two of these. Simply put, h is the colour shade.

The variations of the parameters (ΔL, Δc_{ab} and Δh_{ab}) can also be calculated, as well as the total colour difference, ΔE_{ab}, in relation to a reference point (control sample), being expressed in CIEL*ab* units. The formula for calculating $\Delta E_{ab} = ((L_c-L_s)^2 + (a_c-a_s)^2 + (b_c-b_s)^2)^{1/2}$, where c=control and s=sample, provides a value that represents the colour difference.

For analysis, 4 ml of each wine sample was centrifuged for 10 minutes at 4000 rpm and then subjected to spectrophotometric determination.

Measurements were performed in 5 repetitions for which the means and standard deviations were calculated. Analysis of variance (ANOVA) was applied for each parameter and, where significant differences were found, the Tukey test was applied for comparison in pairs.

RESULTS AND DISCUSSIONS

1. Evaluation of the main parameters of wines

The quality of wines obtained with various interventions in the technology of ecological culture was firstly evaluated through the physico-chemical analysis. Table 1 shows the results for the main physico-chemical parameters of the wines produced from grapes obtained from experimental plots treated ecologically with Bordeaux mixture, chitosan or a mixture of the two.

Table 1. The main physico-chemical parameters of the wines resulting from grapes obtained from the experimental plots treated ecologically with various technological interventions

Physico-chemical parameters*	**FN20-Bord**	**FN20-Chit**	**FN20-ChiBo**
Alcohol (%)	15.42±0.05[a]	15.92±0.08[b]	15.78±0.12[b]
Potential alcohol (%)	15.54±0.07[a]	**16.13±1.62[a]**	**16.18±0.13[a]**
Reducing sugars (g/l)	2.10±0.25[a]	3.60±0.34[b]	**6.80±0.22[c]**
Total acidity (g/l tartaric acid)	**4.14±0.25[a]**	3.72±0.12[b]	3.50±0.13[b]
Volatile acidity (g/l acetic acid)	0.39±0.03[a]	0.33±0.03[b]	0.34±0.02[b]
pH	3.7±0.1[a]	3.8±0.1[a]	3.8±0.2[a]
Total extract (g/l)	29.5±0.5[a]	33.0±0.6[b]	**35.8±0.4[b]**
Dry extract (g/l)	27.4±0.1[a]	**29.1±0.4[b]**	**29.0±0.3[b]**
Total polyphenols (g/l)	1.46±0[a]	**1.65±0.3[b]**	**1.60±0.2[b]**

*Different letters show that there is a significant difference at a probability level of 95% (α = 0.05) determined by ANOVA and Tukey test. The averages with the highest values, if significantly different from those in other samples, are marked in bold.

It is noted that the chitosan treatments lead to a higher concentration of sugars in the grapes, so that the alcohol content is slightly higher in those samples. Taking into account both the residual sugars and alcoholic concentration obtained, we find that the samples have a potential alcoholic strength of 15.54% for FN20-Board (control), and significantly higher in FN20-Chit (16.13%) and FN20-ChiBo (16.18%).

Also, chitosan leads to an increase in dry extract, as well as in the concentration of total polyphenols, the higher values of both parameters being directly correlated with the quality of the wine.

The treatment with Bordeaux mixture is correlated with higher values of total acidity.

2. Sensory profile of wines

The evaluation of the quality of wine included the application of the sensory profile analysis, performed with a panel of trained tasters.

The sensory analysis of the general parameters showed only small differences between the samples of organic Fetească neagră grapes sprayed with different substances (Bordeaux mixture, chitosan or a combination of them). Table 2 shows the averages of the scores given by the tasters to evaluate the perception of the main parameters of the wines.

Table 2. Perception of the main general parameters of the wines evaluated by sensory analysis (notes on a scale from 0 to 10, average values ± standard error)

General parameter*	**FN20-Bord**	**FN20-Chit**	**FN20-ChiBo**
Acidity	4.80 ± 1.21[a]	4.53 ± 0.90[a]	3.47 ± 2.74[a]
Sweetness	0.70 ± 0.35[a]	0.50 ± 0.00[a]	**2.03 ± 0.81[b]**
Astringency	4.90 ± 1.15[a]	4.13 ± 1.89[a]	5.00 ± 2.50[a]
Bitterness	1.43 ± 1.21[a]	2.50 ± 0.00[a]	2.38 ± 0.53[a]
Extract	4.57 ± 0.84[a]	4.10 ± 1.39[a]	4.97 ± 0.06[a]
Colour intensity	6.30 ± 1.11[a]	6.07 ± 0.90[a]	6.83 ± 1.11[a]
Aroma intensity	5.53 ± 1.70[a]	4.00 ± 0.87[a]	5.07 ± 1.10[a]

*Different letters show that there is a significant difference at a probability level of 95% ($\alpha = 0.05$) determined by ANOVA and Tukey test. The averages with the highest values, if significantly different from those in other samples, are marked in bold.

Sensorially, the only significantly different main parameter was the sweetness for FN20-ChiBo sample. The sample was clearly perceived as sweeter, fact confirmed by the chemical analysis (Table 1), which shows that this is a semi-dry wine, unlike the other two, which are dry.

From the sensory analysis of the parameters related to the aroma of the wines, however, it was possible to obtain interesting differences between the wines resulting from the application of different viticultural technologies. Tasters were able to identify certain flavour descriptors, which were summarized in Table 3.

Also, the wines were separately analysed using the score sheet designed for evaluation in wine competitions proposed by the International Organization of Vine and Wine (OIV, 2021) and the scores obtained were also included in Table 3, in order to be correlated with the determined flavour attributes.

The samples were also compared with each other, the tasters determining by consensus the sample with the best olfactory intensity (FN20_Bord), the sample with the lowest sensation of structure (FN20_Chit) and, respectively, the most commercial sample, which could be given in consumption without requiring maturation (FN20_ChiBo).

Table 3. The main descriptors of the wines evaluated by sensory analysis and the scores obtained in the evaluation on a scale of 100 points (OIV score sheet).

	FN20-Bord	**FN20-Chit**	**FN20-ChiBo**
Sensory flavour attributes	Bitter cherries	Bitter cherries; smoked	Bitter cherries, sweet cherries, blueberries
Evaluation score (out of 100 points)	82.00	80.67	84.33
Wine description	lively nose, slightly vanilla, good aromatic intensity, but thin	well-structured wine, slightly flat, relatively simple, aromatic, with a high alcohol content, light, drinkable	slightly reductive but fruity, high concentration of alcohol that strengthens the sweet note of residual sugars, very drinkable, with soft tannins, velvety, supple, elegant
Remarks	The sample with the best olfactory intensity	Sample with the slightest sensation of structure	The most commercial sample (can be consumed without passing through a maturation period)

By sensory analysis of specific aroma parameters, the categories of dominant aromas in these wines could be identified, namely: aromatic hints of flowers, fruits, vegetable, complex aromas and spices / toast.

The averages of the values obtained from the tasting panel on the discontinuous scales from 1 to 5 were used to obtain a suggestive diagram, which shows the aromatic imprint (sensory profile of the aromas) of the experimental wine samples (Figure 1).

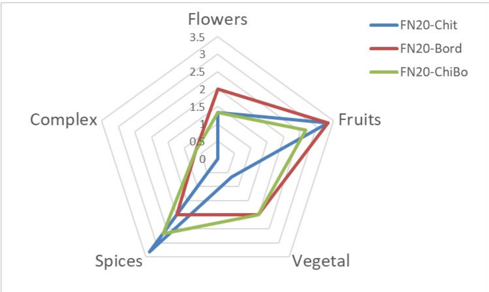

Figure 1. Aromatic profile of Feteasca neagră wines obtained with various interventions in organic cultivation technology

As it can be seen in Figure 1, the wines are relatively simple in aroma, but certain differences can be identified, depending on the treatment carried out in the vineyard. Thus, the chitosan treatments bring a note of burnt, slightly spicy, the Bordeaux mixture creates a greater floral sensation, while the combination Bordeaux mixture-chitosan leads to a wine with a moderate sensory profile, which may be better appreciated by consumers and can be marketed without going through a period of maturation to reduce the note of astringency and the bitterness that young red wines generally have.

In order to better observe the sensory differences between the samples and, especially to determine the parameters with the greatest influence on the discrimination of the samples, the analysis of the principal components was performed, both for the general parameters (Figure 2a) and for specific aroma (Figure 2b).

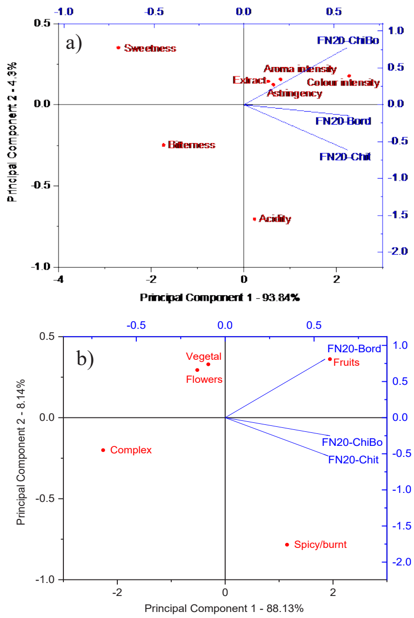

Figure 2. Principal Components Analysis (PCA) for the wines evaluated by sensory analysis: a) main parameters; b) flavour categories

Figure 2a shows that the main physico-chemical parameters, evaluated by tasting, are not substantially influenced by the differences in treatments performed in the vineyard. However, it is noticeable a clearer positioning of the FN20-ChiBo sample in the quadrant determined by the sensory attributes that give quality to the wine, namely "aroma intensity", "colour intensity", "extract", "astringency", which suggests that the combined chitosan-Bordeaux mixture treatment can lead to wines of a higher quality compared to other treatments, in which the substances were used independently. The main components PC1 and PC2 cover a large part of the data variance, of 98.14%, i.e. the evaluated sensory attributes are those that intervene in the creation of the sensory profile of the wine. Attributes related to sensory quality, such as "flavour intensity", "colour intensity", "extract", "astringency", are predominantly included in Principal Component 1, with a variance of 93.84%, while "acidity", " "bitterness" and "sweetness" are equally included in both PC1 and PC2 components. This result shows that PC1 could be considered the axis that includes the most quality-related sensory components, and therefore the order of quality of the wines evaluated, according to these criteria, is, as follows, from the one with the highest quality: FN20-ChiBo, FN20-Bord, FN20-Chit. The sensory analysis on the OIV score sheet shows (Table 3) that the order of the wines according to the sensory quality is also: FN20-ChiBo (84.33 points), FN20-Bord (82.00 points), FN20- Chit (80.67 points).

Figure 2b shows that, for flavour categories, the evaluators determined that the floral aromatic notes are more pronounced in the FN20-Bord variant, the spicier ones in FN20-Chit and FN-ChitBo, and the fruity ones being relatively equally represented in all variants. Obviously, this is a simplification of the aromatic complexity of a wine, but it is known that PCA analysis reduces the number of complex independent variables and embodies them in 2 variables, PC1 and PC2, which depend on all the original independent variables, to a smaller or to a greater extent. Therefore, it should not be understood that the samples do not contain flavours from all the above categories, but the ratio between them makes the perception more inclined in the direction of a category or combination, depending on the sample being evaluated.

3. Specificities regarding the colour of wines

The colour of Fetească neagră wines obtained with various interventions in the organic culture technology was evaluated with the help of spectrophotometry.

In order to evaluate the colour specificities, the CIEL*ab* parameters were obtained, to effectively determine the degree of red (parameter *a*) and yellow (parameter *b*) contained in the wine colour, as well as the brightness L, shade *h* and chromaticity *c*. The average results and standard errors are shown in Table 4 for all determined colour parameters.

Table 4. Results of the colour parameters evaluation and total polyphenolic index of experimental organic wines using spectrophotometry

CIEL*ab* parameter	FN20-Bord	FN20-Chit	FN20-ChiBo
L	56.51 ± 0.20^{b}	**60.19 ± 0.15^{a}**	56.49 ± 0.18^{b}
a	**37.89 ± 0.26^{b}**	33.66 ± 0.20^{a}	36.01 ± 0.25^{c}
b	7.98 ± 0.18^{b}	**9.23 ± 0.18^{a}**	7.57 ± 0.19^{c}
c_{ab}	**38.72** $\pm 0.2^{b}$	34.90 ± 0.18^{a}	36.80 ± 0.23^{c}
h_{ab}	0.21 ± 0.0^{b}	**0.27** $\pm 0.04^{a}$	0.21 ± 0.04^{b}
IPT	45.27 ± 0.10^{b}	**51.64** $\pm 0.18^{a}$	50.36 ± 0.12^{c}

*Different letters show that there is a significant difference at a probability level of 95% (α = 0.05). The statistical analyses applied were the ANOVA and Tukey test. The averages with the highest value, if significantly different from those in other samples, are marked in bold.

It is thus observed that the FN20-Chit sample has the highest degree of transparency, the difference in brightness compared to the other two samples being statistically significant. This may indicate that FN20-Chit is more physically and chemically stable than the other samples.

Regarding the colour parameters *a* and *b*, we can appreciate that the control is significantly redder than the samples with chitosan, the treatment with the latter apparently being correlated with an increase in the degree of yellow in the final colour of the wine. The FN20-ChiBo wine sample shows intermediate values for the red colour, being placed between FN20-Bord and FN20-Chit. The chromaticity or colour saturation, the c_{ab} parameter, follows the same behaviour as the red colour (parameter *a*), FN20-Bord having the most vivid colour, followed by FN20-ChiBo and then FN20-Chit.

In contrast, the colour shade, the h_{ab} parameter, correlated with the presence of yellow (parameter *b*), shows that FN20-Chit has a higher yellow/brown shade, while FN20-ChiBo and FN20-Bord have similar shades, without significant differences. This behaviour of the FN20-Chit sample, with a colour showing a higher yellow participation, is clearly correlated with some oxidizable phenols and the fact that the total polyphenol index is also significantly higher in this sample (Table 1 and Figure 5).

To determine the colour differences that occur in samples from chitosan-treated vineyards, the differences from the FN20-Bord control sample as well as the total colour difference, ΔE, shall be calculated for each parameter. The results are presented in Table 5.

Table 5. Differences in colour parameters of samples with chitosan treatments compared to control samples with Bordeaux mixture FN20-Bord

Differences from FN20-Board	Δ FN20-Chit	Δ FN20-ChiBo
ΔL	3.68	-0.02
Δ*a*	-4.23	-1.88
Δ*b*	1.25	-0.42
ΔC_{ab}	-3.82	-1.92
Δh_{ab}	7.82	2.72
ΔE	**5.75**	**1.92**

Compared to the control sample, the samples from the chitosan-treated vineyards are slightly more transparent (ΔL=3.7) and less coloured (Δ*a*=-4.2; ΔC_{ab}=-3.8) the total colour difference being much greater than 1 (ΔE=5.75), clearly showing that the sample is visibly different. Samples from vineyard plots treated with combinations of chitosan and Bordeaux mixture also show a visibly significant colour difference compared to the control treatment only with Bordeaux mixture, but the colour difference compared to the control is not as high (ΔE=1.92) as in the case of chitosan treatment.

In order to have a clearer picture of the colour of the experimental samples, they can be placed in a two-dimensional space described by parameters *a* and *b* (Figure 3).

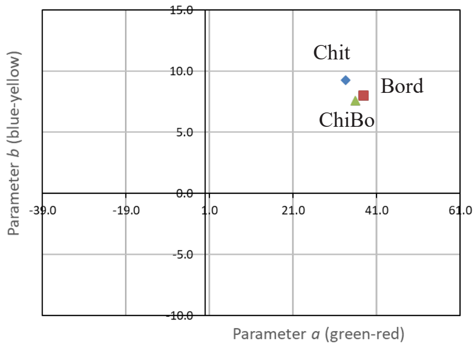

Figure 3. Placement of experimental samples in the two-dimensional colour field parameter *a* vs. parameter *b*

All wines are placed, as expected, grouped in the red-yellow region of the chromatic space. In such a two-dimensional chromatic space (parameter *a* vs. parameter *b*), which does not take into account the brightness and chromaticity of the colour, all samples are grouped in the same region, the apparent colour being a combination of red and yellow. Thus, this diagram clearly demonstrates that the FN20-Border control samples are redder than the others (shift to the right) and the FN20-Chit is yellower than the others (upward movement). Therefore, we can say that the treatments on the vines also influenced the colour of the wines, very possibly by the presence of phenolic compounds (tannins) in higher concentrations in the samples from vines with chitosan treatments.
As for the total polyphenol index (TPI) for our Feteasca neagră wines, which do not have a high phenol load compared to other red wines such as Cabernet Sauvignon, Syrah or Merlot, the values were between 45 and 52 absorbance units (Table 1 and Figure 4).

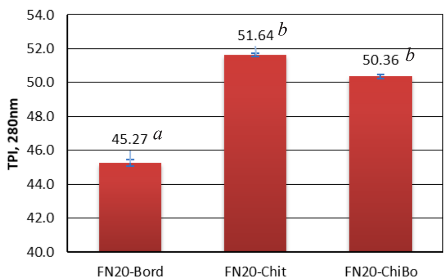

Figure 4. The index of total polyphenols (TPI) for the organic wines obtained with interventions in culture technology

The TPI shows that the treatment with chitosan, both alone and in combination with Bordeaux mixture, leads to an increase in the concentration of phenols in grapes, which is very beneficial for red wines.

CONCLUSIONS

The study shows that the chitosan treatment tends to induce a different and more pleasant sensory profile than that of the control with Bordeaux mixture.
The fact that chitosan treatments in vines bring changes in the chemical composition of plants and grapes obviously has its mark on the quality of the wine, the observed effects on the sensory qualities, aroma and colour being beneficial.
The effect of increasing the total polyphenol content of grapes / wine from vineyards treated with chitosan was also observed in our study.
Consequently, chitosan treatments appear to improve the phenolic content and aromatic profile of the resulting wines, but other experiments of this type still need to be performed until this practice can be recommended.

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SOME PHYSICAL AND TECHNOLOGICAL PROPERTIES OF SEEDS OF NON-TRADITIONAL PLANT SPECIES IN THE REPUBLIC OF MOLDOVA

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Abstract

The goal of our research is to fulfil the potential of non-traditional plant species in the Republic of Moldova, of the families: Asteraceae (Silphium perfoliatum, Cynara cardunculus), Fabaceae (Galega orientalis, Astragalus galegiformis, Medicago sativa) and Poaceae (Sorghum almum, Festuca arundinacea). This study presents the results of the research on the seeds characteristics of these plant species: dimensional parameters, friability, morphological structure, specific apparent weight, the weight of 1000 seeds, dosing instability and degree of seeds crushing in the respective device of the seed drill. Our research has shown that the seeds of the studied plants (except tall fescue) have high indices of dimensional uniformity and friability: angle of repose $\alpha \leq 32.5°$ and flow angle on steel $\alpha_1 \leq 27.8°$, on wood $\alpha_1 = 30.6°$ and on enamel $\alpha_1 = 26.3°$. The obtained indices of the physical properties are necessary to justify the correct choice, calculation and adjustment of the technical means of handling the seeds, and the indices of the technological properties serve as a basis for the correct choice of the seed metering devices for seed drills and the sowing parameters.

***Key words**: dimensions, dosage instability, friability, non-traditional plant species, seed properties.*

INTRODUCTION

Climate change, which is a global phenomenon, imperatively requires the mobilization of plant genetic resources that were previously underused or not used at all in the bioeconomic cycle, but can be successfully used under the new conditions (Cline, 2007; FAO, 2017). Currently, a lot of research is conducted in various countries, aiming at appreciating and using the potential of non-traditional plant species (Mayr et al., 2013; Jasinskas, 2014; Gansberger et al., 2015; Schäfer et al., 2017; Prakash et al., 2019; Kwaśniewski et al., 2020). However, in the above mentioned publications there is little or no information about species that are of interest in the Republic of Moldova. Moreover, the pedo-climatic conditions in the Republic of Moldova influence the properties and characteristics of the plant biomass, including seeds. That is why it is of scientific and practical interest to study the properties of plant species that are non-traditional for the bioeconomic cycle of the Republic of Moldova, of the following families: *Asteraceae* (cup plant - *Silphium perfoliatum*; cardoon - *Cynara cardunculus)*, *Fabaceae* (fodder galega - *Galega orientalis*, milkvetch - *Astragalus galegiformis*) and *Poaceae* (Columbus grass - *Sorghum almum*). The biomass of these non-traditional plants has a high potential for use as feed and raw material for the agricultural and food sector, the pharmaceutical industry, bioenergy production and other branches of the economy. The results of previously conducted research show that the above-mentioned plant species have a productive potential of fresh biomass of 44-100 t/ha (from such biomass, biomethane can be produced with the quota of 270-350 l/kg organic matter), of seeds – 2.5-4.0 t/ha (from which 0.8-1.1 t biodiesel can be obtained) and of energy biomass (calorific value 18.3- 19.0 MJ/kg) - 10-24 t/ha (Țîței & Roșca, 2021).

It is known that the morphological structure and size of the seeds substantially influence their friability (Hailis et al., 1998; Matei & Feher, 2010; Ene & Mocanu, 2016;); therefore, a comprehensive study of this influence in the case of seeds from the families *Asteraceae*, *Fabacea*e and *Poaceae* is necessary.

The result of the large-scale use of plant species of the three above-mentioned families depends to a large extent on the properties of the seeds. Therefore, it is necessary to know the physical and technological properties (characteristics) of the seeds, which have a special importance not only for the harvested plant biomass, but also for the management of the technological operations of conditioning (cleaning, calibration, drying, treatment), storage, transport and sowing. However, there is insufficient information in the above-mentioned bibliographic sources on the properties of the seeds of non-traditional species. Thus, the goal of our research has been to determine the physical and technological properties of the seeds of non-traditional plant species of the families: *Asteraceae*, *Fabaceae* and *Poaceae*.

MATERIALS AND METHODS

The seeds of plant species from the families *Asteraceae* (*Silphium perfoliatum*; *Cynara cardunculus*; *Helianthus annuus*), *Fabaceae* (*Galega orientalis*, *Astragalus galegiformis, Medicago sativa*) and *Poaceae* (*Sorghum almum*, *Festuca arundinacea*) served as research subjects. The studied seeds of non-traditional plant species were collected from the experimental field of the "Alexandru Ciubotaru" National Botanical Garden (Institute), Chisinau (C 46°58′25.7″ N, B 28°52′57.8″ E).

The size of the seeds is an important characteristic of a plant species and indicates, first of all, the potential for obtaining the plant biomass yield. The dimensional parameters of seeds (length, width, thickness ℓ x b x δ) were measured according to standard metods, with a calliper ȘȚ-I-125-0,05 an error of ± 0,05 mm. For each species, 25 seeds were measured from the average sample. The division of seeds samples of each species was performed by the quartering method in accordance with standard metods.

For small seeds, it is recommended to separate the seed fractions using sieves and to determine the fractional distribution, which is an important characteristic trait, determining technological qualities and areas of practical use of seeds (Ene & Mocanu, 2016). For this purpose, 5 samples weighing 150-250 g were taken from the seeds of each species, for which the fractional distribution was determined by sieving with vibrating sieves, using the sieve shaker AS 200 manufactured by the Retsch company (Germany) equipped with a sieve that had square meshes with sizes in the range of 0.25-3.15 mm. The process of separating the fractions of seed material took 15 minutes for each sample, the frequency of the vertical vibrations of the sieves corresponded to position 2 on the scale of the shaking device. Each sample was weighed with the electronic precision balance EW-3000-2M (Kern company, Germany), with an accuracy of 0.01 g.

To determine the weight of 1000 seeds (M_{1000}), a sample was taken and its weight (m) was measured; the result was estimated up to hundredths of gram. After that, the number (N) of the grains in the sample was counted and the value of M_{1000} was calculated according to the formula:

$$M_{1000}= (m/N)*1000 \text{ [g]} \qquad (1)$$

The typification of morphological structures, as well as the dimensional analysis of seeds, is necessary because it allows the correct design and use of technological processes, technical means of handling, planting, harvesting and processing of planting material (seeds, bulbs etc.). According to specialists (Matei & Feher, 2010; Hailis et al., 1998), the shape of the seeds influences their friability the most. The seeds with spherical or near-spherical shape have the highest flow rate. The more the shape of the seeds differs from the spherical shape, the lower the friability. The study of the morphological structure of the seeds was performed based on the classification that divides the seeds into 5 types:

1. Spheroidal: the dimensions of the seed are almost equal
($\ell \simeq b \simeq \delta$) (pea, soybean etc.);
2. Flattened: the width is approximately equal to the length, and the thickness is much smaller
($\ell \simeq b >> \delta$) (lentil);
3. Elliptical: the thickness is equal to the width, but the length is much bigger
($\ell >> b \simeq \delta$) (legume crops);
4. Elongated: all the dimensions differ from each other, the length being the biggest
($\ell > b \neq \delta$) (cereal crops);
5. Pyramidal (triangular).

The flow capacity (friability) of material bodies indicates their ability to move in an inclined plane at an angle to the horizontal plane (flow angle α_1) or to form a natural slope with a certain angle (angle of repose α) relative to the horizontal plane during free fall on a flat surface. The values of the angles α and α_1 are constant characteristics of the planting material of each species and do not change, regardless of the amount of this material. The determination of the angles α and α_1 of the planting material of each species is an important practice in the design of warehouses, transport and conditioning facilities (different types of transport means, elevators, cleaning and drying devices etc.) (Ene & Mocanu, 2016). The determination of the angle of repose α was performed by 2 methods: a) *general* - forming a pile of seeds of a conical shape, wh ich is obtained by pouring them through a funnel and letting them falling freely on a horizontal surface (Figure 1 a, b); b) *local* - applying the digital inclinometer on the inclined surface of the seed cone. To measure the angle α, samples with a volume of 200-250 ml were taken from the majority fractions obtained after sieving and several instruments and accessories were used (depth calliper SG 0-250, instrumental ruler 0-400 mm, funnel, digital inclinometer 360° (accuracy ± 0.20).

The measurement of the angle α with the help of the inclinometer was performed on 4 lines in 2 perpendicular planes, and the parameters of the cone (height h, diameter of the base D) were determined in 2 perpendicular planes. The value of the angle of repose was calculated according to the formula:

$$\text{tg}\,\alpha = 2\,h/D \qquad (2)$$

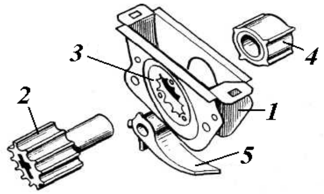
The flow angle α_1 of the seed grains (Figure 1c) was measured using a table with the upper surface rotating vertically. On this surface, plates of steel 10, enamelled steel and wood were successively fixed. The angle α_1 was measured using a digital inclinometer. The measurement test was replicated 10 times when determining the values of the angle α and 5 times - for the angle α_1, which determined the standard deviation and the confidence interval.

The research on the technological properties of the seeds was carried out on a stand based on the cereal seed drill SZ 3.6 (Chervona Zirka company, Ukraine), which has been designed to sow on 24 rows, at a distance between rows of 0.15 m and at a depth in the limit h = 40-80 mm.

a)
b)
c)

Figure 1. Aspects of the process of measuring the angles α and α_1: a), b) cones of seeds (*Silphium perfoliatum*, *Helianthus annuus*), c) the inclined surface with seeds

The seed drill operates at a speed within the limit V = 7-12 km/h and the seeding rate is N = 15-200 kg/ha. The seed drill SZ 3.6 is equipped with individual seed metering devices with grooved cylinders, being intended for sowing a wide range of species (cereals, legumes, vegetables) (Figure 2). For research, the seed drill has been modified in such a way as to provide the possibility to study the dosing process on a single section. For this purpose, the respective dosing section was filled individually by installing a special device made for this research. Respectively, dosed seed samples were taken from the exit of the same section. The weight of each sample was determined with the electronic precision balance EW-3000-2M (Kern company, Germany), with an accuracy of 0.01 g.

a)


b)


Figure 2. Seed metering device with grooved cylinder: a) general view; b) moments of the research process: 1 - frame; 2 - grooved cylinder; 3 - rotating sleeve with grooves; 4 - coupling sleeve; 5 - bottom support

The seed metering devices used for the research were adjusted to two values of the seeding rate (minimum N_{min}, maximum N_{max}), which were obtained as follows: a) minimum seeding rate N_{min}: the minimum values of the working length of the grooved cylinder L_{min} and of the rotations of the same cylinder n_{min} have been set, the transmission ratio in the action mechanism of the grooved cylinder having the maximum value i_{max} = 7.32; b) maximum seeding rate N_{max}: the maximum values of the length of the grooved cylinder L_{max} = 29 mm and of the rotations n_{max} with the minimum value of the transmission ratio i_{min} = 0.77 were set. To dose the small seeds (fodder galega, astragalus, Columbus grass) it was possible to perform a process with a minimum value of working length L_{min} = 5 mm, for larger seeds it was necessary to increase L_{min} up to 9 mm for cardoon seeds and up to 14 mm for cup plant seeds. The seed metering device was operated manually, from the support and drive wheel. The slow rotation of the drive wheel corresponded to the speed of movement of the seed drill within the limit 7-9 km/h (1.9-2.5 m/s). In the performed experiments, the number of rotations of the drive wheel had the following values: in most cases - n = 20 rot., and when the mass of dosed seeds was too small, to increase the measurement accuracy, the number of rotations was n = 30 rot. It should be noted that in the operating instructions of the seed drill SZ 3.6, it is recommended to perform 14 rotations to adjust the seeding rate.

Setting the drive wheel to do 20 rotations limits the movement of the seed drill to a distance of 78.19 m or a sown area of 281.47 m^2.

While processing the data obtained as a result of the experiments, the following indicators were calculated:

1. Average seed weight measured by one device in all the repetitions of the experiment:

$$m_{med}= \sum m_i/n \ [g] \qquad (3)$$

where m_i is the weight of the seeds dosed repeatedly by a device i, [g]; n – the number of repetitions, [unit.], (in each experiment, by 5 repetitions were done);

2. The deviation of the weight of seeds dosed in a repetition i, from the mean value:

$$\Delta m_i = m_i - \overline{m}_{med} \ [g]; \qquad (4)$$

3. The instability of seed dosing during the technological process:

$$I_d= (\overline{\Delta m}_{ir}/m_{med}) \cdot 100 \ [\%]; \qquad (5)$$

where $\overline{\Delta m}_{ir}$ is the arithmetic mean deviation of the seed mass dosed in 5 repetitions from the mean value:

$$\overline{\Delta m}_{ir}=[\sum \Delta m_i]/n= [\sum(m_i- \overline{m}_{med})]/n \ [g]; \qquad (6)$$

The instability of seed dosing can also be estimated based on the formula for calculating the coefficient of variation v:

$$v= (\sigma/ m_{med}) \cdot 100 \ [\%]; \qquad (7)$$

where σ is the standard deviation of the seed weight in different repetitions:

$$\sigma =\sqrt{ [\sum(m_i- m_{med})^2/ (n-1)]} \ [g] \qquad (8)$$

4. The degree of seed crushing (mechanical damage) was calculated from the ratio of the weight of the crushed seeds and the total weight of the sample before the separation of the crushed and undamaged seeds:

$$g= (m_s/ m_{tot}) \cdot 100 \ [\%] \qquad (9)$$

where m_s is the weight of the seeds crushed in a sample [g]; m_{tot} - the total weight of the sample [g].

RESULTS AND DISCUSSIONS

The results of the measurements of the seeds of species of the Asteraceae family show that cardoon *Cynara carduncululs* seeds before calibration were divided into 3 fractions according to their size: the majority fraction exceeded the size of 3.15 mm (mass quota - 62%), the second fraction had a size of 3.15-2.8 mm (30.39%) and the third fraction 2.8-2.0 mm (7.57%). These 3 fractions together made up 99.96% of the total amount of seeds researched, and 0.04% constituted residues, losses, which was much less than the standard value: <2%. For further studies, *Cynara carduncululs* seeds were calibrated, using the majority fraction >3.15 mm (97.5%) (Table1).

The separation of seeds into fractions using the sieve shaker AS 200 is done by vertical vibrations of the sieves, therefore, in this case, the limit size for the passage of seed grains through the square meshes of the sieves is the width of these seeds b. The results of the measurements show that the dimensional characteristics of cardoon *Cynara carduncululs* seeds (fraction> 3.15 mm) have the following values: ℓxbxδ = (7.5 ± 0.9) x (3.65 ± 0.40) x (2.40 ± 0.25) mm (tab.1), the size ratio being ℓ:b:δ = 3.1: 1.5: 1.0. The value of seed width (b = 3.65±0.40 mm) exceeded the mesh size of the sieve (3.15 mm). The sunflower seeds (with shells) (fraction >3.15 mm) had the following dimensions ℓxbxδ = (9.2±1.1) x (5.6±0.3) x (4.2±0.4) mm with the ratio ℓ:b:δ = 2.2: 1.3:1.0.

According to the data presented by Hailis et al., 1998; Manea, 2011; Trubilin et al., 2009, the width of the seeds of the main agricultural crops varies within the following limits: cereals (b = 1-5 mm, wheat, rye, barley, oats, millet), crops that need mechanical weed control (b = 2-12 mm, sunflower), vegetables (b = 1.3-4 mm, tomatoes, onions, radishes, cabbage, carrots). At the same time, the sunflower seeds have, according to the same authors, the following dimensional characteristics: ℓxbxδ = (7.5-15.0) x (2.5-8.6) x (1.7-6.0). The dimensions of the sunflower seeds studied by us fall within the limits identified by the above-mentioned authors.

After sieving, it has been found that the cup plant seeds fit into a single fraction that is larger than 3.15 mm (97.5%). A specific trait of these seeds is that they have a marginal wing, and after peeling the cup plant seeds in a special device (model MDA 1), no significant changes in their fractional distribution were observed.

The factors that influence the flow capacity of seeds are the shape, size and the texture of the surface of the seed grains, their moisture and physical purity, as well as the surface (material, roughness) on which they flow. The flow capacity is higher when the shape of the seeds is close to the spherical shape, their surface is smoother, the humidity - lower and the proportion of impurities - also lower. The studied seeds were previously conditioned according to humidity U and physical purity P. The surfaces on which they flowed were identical (steel 10, wood, enamel) for all seeds. Therefore, it is further necessary to study the influence of the shape and outer surface of the seeds on their friability.

The above-mentioned ratios of the dimensions of cardoon and sunflower seeds ℓ:b:δ, as well as the study of the morphological structure of these seeds (Figure 3) show that they belong to the type 4. Elongated, in which all three dimensions differ from each other, but length has the biggest value (ȴ> b≄δ).

Cynara carduncululs seeds, according to their morphological structure, are identical to sunflower seeds, but, unlike the latter, they do not have a shell.

Silphium perfoliatum seeds, in terms of shape, belong to the type 2. Flattened (ȴ≃b>δ), having a marginal wing (somehow like maple seeds), due to which, after falling, these seeds tend to form a layered pile (Figure 1a, Figure 3). The belonging to types 2 and 4 did not prevent the studied seeds from having high friability.

The studied seeds demonstrated the following values of the friability indicators (Table 1): a) sunflower, control, natural angle of repose α=32.9° ±1.1° (general method) and α=33.2°±2.0° (local method); flow angle on steel α_1=29.3°±0.5°, on wood α_1=31.3°±0.6°, on enamel surface α_1=25.3°±0.4°; b) cardoon, angle of repose α=30.3°±0.9° (general method) and α=31.1° ±0.9° (local method) for cleaned but uncalibrated seeds, and for calibrated seeds (fraction >3.15 mm) α=28.2°±1.3° (general method) and α=29.0°±1.3° (local method);

flow angle on steel α_1= 27.7°±0.8°, on wood α_1=30.6° ±1.1°, on enamel surface α_1= 26,3° ±0,8°; c) cup plant, angle of repose α= 29.4°±1.5° (general method) and α=31.1°±2.1 (local method); flow angle on steel α_1=27.8°±0.3°, on wood- α_1=29.1°±1.5°.

The outer surface of the sunflower *Helianthus annuus* seeds is rough (Figure 3a), which increases the coefficient of friction between the seeds, on the one hand, and between the seeds and the material of the inclined surface, on the other hand. Therefore, the given seeds had higher angle of repose α with 4.2°-4.7° as compared with cardoon seeds, which have smooth surface (Figure 3b). A higher flow angle α_1 is also characteristic of sunflower seeds (Table 1). The cup plant *Silphium perfoliatum* seeds, which have smooth surface, have friability values between those of cardoon and sunflower seeds.

Table 1. Values of physical and technological properties of seeds

Plant species; Material of the surface on which seeds flow	Angle (°) of:			Size, **ℓ·b·δ,** mm/ majority fraction, mm (% mas.)	Specific apparent weight **ρ**$_v$, g/l	Weight of 1000 seeds **(M**$_{1000}$**)**, g
	flow α_1	repose α, method				
		general	local			
Family ***Asteraceae***						
Cynara cardunculus		28.2±1.3	29.0±1.3	(7.5±0.9)x(3.65±0.40)x x(2.40±0.25) /> 3.15 mm (97.5%)	637.52	48.89
Steel 10	27.7±0.8					
Wood	30.6±1.1					
Enamel	26.3±0.8					
Helianthus annuus		32.9 ±1.1	33.2±2.0	(9.2±1.1)x(5.6±0.3)x x(4.2±0.4) /> 3.15 mm (98.7%)	445.18	62.84
Steel 10	29.3±0.5					
Wood	31.3±0.6					
Enamel	26.8±0.4					
Silphium perfoliatum		29.4±1.5	31.1±2.1	/> 3.15 mm (97.5%)	380.82	20.26
Steel 10	27.8±0.3					
Wood	29.1± 1.5					
Family ***Fabaceae***						
Astragalus galegiformis		26.0±1.1	26.9±1.3	/2.0-1.4 mm (83.3%)	802.92	9.33
Steel 10	22.8±0.4					
Wood	26.3± 0.5					
Galega orientalis		32.5±0.1	33.4±0.2	/2,0-1,4 mm (97.3%)	784.24	6.00
Steel 10	27.7±0.3					
Wood	29.8±0.8					
Medicago sativa		30.2±0.4	31.5±0.4	/2.0-1. 4mm (98.3%)	765.19	1.91
Steel 10	27.3±0,4					
Wood	33.6±0.9					
Enamel	26.7± 0.2					
Family ***Poaceae***						
Festuca arundinacea		36.0±0.9	38.7±2.2	(6.4±0.5) x(1.35±0.3)x x(0.8±0.1)	287.13	2.62
Steel 10	30.1±0.2					
Wood	43.2±0.5					
Enamel	26.7±0.3					
Sorghum almum		26.5±0.9	27.2±0.8	/2.0 –1.4 mm (92.0%)	656.00	8.00
Steel 10	19.9±0.3					
Wood	24.2±0.2					

There is a difference between the values of the angle α measured according to the general and the local method, this difference is 0.30 for *Helianthus annuus* and 0.80 for cardoon (Table 1). The lower values of the angle α determined by the general method are probably caused by the lack of a well-defined tip at the seed cone (Figure 1a, b), which decreases the height of the cone and, implicitly, the value of the angle of repose. The local method performed with the digital device provides a high accuracy of the measurement, but the lateral sides of the seed cones are not even, especially in the cup plant seeds (Figure 1a), therefore the deviations of the values of angles α are greater in the case of the local method. Therefore, taking into account that most studies are based on the general method of measuring the angle α, as well as taking into account the above-mentioned facts, we will use in most cases the results obtained by the general method and, if necessary, those obtained by the local method.


a)
b)
c)

Figure 3. The morphology of the seeds of the plants from the Asteraceae family: a) *Helianthus annuus*; b) *Cynara cardunculus*; c) *Silphium perfoliatum*

In order to verify the phenomena mentioned in previous scientific articles (Hailis et al., 1998; Matei & Feher, 2010; Dragoș, 2011), we have studied the friability of cardoon cleaned and uncalibrated seeds (mixture of fractions), as well as calibrated one (fraction > 3.15 mm).

The results obtained (Table 1) confirm the influence of seed purity on their friability: in both methods used (general, local) the angle of repose α is by 2.1° lower than in the case of calibrated seeds. In previous articles (Hailis et al., 1998; Matei & Feher, 2010), values of the angle of repose α of the seeds of different sunflower varieties and hybrids in the limit α=31°- 45° were presented. Analysing these data, we came to the conclusion that the value of the angle of repose of sunflower seeds determined by us in our research (α=31.8°-34.0°) corresponds to the results obtained previously.

The study of seeds from the Fabaceae family demonstrated that alfalfa *Medicago sativa* (control) have a majority fraction of 2.0-1.4 mm (98.3%), and the *Astragalus galegiformis* seeds are represented by 2 fractions: 2.0-1.4 mm (83.3%) and 2.8- 2.0 mm - 16.6%. The share of both fractions together is equal to 99.9%.

In 2019-2020, we researched the influence of weather conditions on the seed size of fodder galega *Galega orientalis*. In the seeds harvested in 2019, two fractions were identified: the majority 2.0-1.4 mm (97.3% mas.) and the secondary fraction 1.4-1.0 mm (2.4%), together, these two fractions made up 99.7% of the mass of seeds. In 2020, the distribution of *Galega orientalis* seeds changed a little: the majority fraction 2.0-1.4 mm (91.9%) and the secondary fraction 1.4-1.0 mm (7.9%). The changes in the distribution of *Galega orientalis* seeds are 2020: long-term hydrological and atmospheric drought.

We would like to mention that the seeds of the species of the *Fabaceae* family have identical dimensional characteristics: their majority fraction falls within the limits of 2.0-1.4 mm, with a share of over 83%.

The seeds of alfalfa, fodder galega and astragalus have many similarities in their shape (Figure 4) and fit in the 3rd category – eliptical, having a thickness approximately equal to the width, and the length being the biggest value ($l >> b \simeq \delta$) similar to the seeds of several leguminous crops. The shape of the seeds, as it was proved by the specialists (Hailis et al., 1998; Matei & Feher, 2010; Ene & Mocanu, 2016), it is the factor that most influences their flow capacity.

The seeds of spherical or almost-spherical shape have the highest flow capacity. The more the shape of the seeds differs from the spherical one, the lower the friability. The above-mentioned authors established that the best flow capacity is characteristic of the seeds of legume crops with rounded, smooth surfaces (peas, beans etc.) (type 1 and 3) and the lowest – of the flattened seeds with a rough surface of vegetable crops (carrots, dill, parsley etc.) (type 2). The seeds of cereal crops (type 4) have intermediate friability.

Our study shows (Table 1) that in the *Fabaceae* family, the astragalus seeds have the highest friability (the angle of repose α=26.0°±1.1° and the flow angle on steel α_1= 22.8°±0.4°, on wood – α_1= 26.3°±0.5°).

The next level of friability, a little lower, was found at alfalfa seeds (angle of repose α=30.2°± 0.4° and the flow angle on steel α_1=27.3°±0.4°, on wood α_1=33.6°±0.9°, on enamelled surface - α_1=26.7°± 0.2°) and fodder galega (α=32.5°±0.1° and α_1 on steel - 27.7°±0.3°, on wood–α_1=29.8°±0.8°). In the 3 studied species of the *Fabaceae* family (astragalus, alfalfa, fodder galega) the seed coat is smooth, hairless (Figure 4), as in the seeds of other legume crops, being one of the reasons why the values of friability are high.

a) b) c)

Figure 4. The morphology of the seeds of the plants from the Asteraceae family: a) *Helianthus annuus*; b) *Cynara cardunculus*; c) *Silphium perfoliatum*

In the *Poaceae* family, the seeds of *Sorghum almum* have the majority fraction with sizes in the range of 2.0-1.4 mm (92.0%) (Table 1), and the second most important fraction falls within the range of 2.8-2.0 mm (7.8%). Together, these two fractions make up 99.8%, the remaining 0.2% includes debris and losses. As a result of the measurements, we identified the dimensional characteristics of the seeds of tall fescue *Festuca arundinacea* which have the following values:

ℓxbxδ=(6.4±0.5) x (1.35±0.3) x (0.8±0.1) mm (Table 1), the ratio of the dimensions being $\ell:b:\delta$ = 8.0: 1.7: 1.0. The highest friability in the *Poaceae* family is characteristic of Columbus grass seeds (the angle of repose = 26.5°±0.9° and the angle of flow on steel α_1=19.9°±0.3°, on wood α_1=24.2°±0.2° (Table 1), and the tall fescue seeds are characterized by the following values of angles α=36.0°±0.9° (general method) and α=38.7°±2.2° (local method), the flow angle on steel α_1=30.1°±0.2°, on wood α_1=43.2°±0.5°, on enamelled surface α_1=26.7°±0.3°. It should be noted that the difference in the values of the angle of repose α measured by the general and local method for most species does not exceed 1°, but in the case of cup plant this difference is 1.7° and in the case of tall fescue Δ = 2.7°. For both plant species, the big difference between the values of the angles α determined by the general and the local method is related to the morphological structure of the seeds. Cup plant *Silphium perfoliatum* has type 2. flattened seeds, with smooth surface (Figure 4), which favours the friability, but the surface of the formed seed cone is not even. The structure of the tall fescue *Festuca arundinacea* seeds (Figure 5) belongs to type 4. elongated ($\ell > b \not\approx \delta$) (identical to the cereals), being covered with paleae (glumes), which increase the coefficient of friction among the seeds and with the contact surfaces. That is why the surface of the cone formed by the tall fescue seeds is not uniform. Unlike the seeds mentioned above, the shape of columbus grass *Sorghum almum* seeds (Figure 5) belongs to type 3. eliptical ($\ell >> b \simeq \delta$) with smooth seed coat, and the cross section of the perennial sorghum seeds is almost round. Despite the fact that most *Sorghum almum* seeds have a peduncle (fruit stalk) at the tip, it does not have a negative effect on the friability of the seeds.

The analysis of the results of the research on the seeds from the 3 families (*Asteraceae*, *Fabaceae*, *Poaceae*) shows that in most of the performed experiments (Table 1) the values of the flow angle α_1 were lower than the values of the angle of repose α. The largest difference between α

and α_1 was identified on the enamelled surface in the case of sunflower (Δ=6.1°) and tall fescue seeds (Δ=9.3°), in other cases this difference was less than 3°-4°. On the wooden surface, the difference α-α_1 had negative values for the seeds of cardoon (Δ=-2.4°), alfalfa (Δ=-3.4°) and tall fescue (Δ=-7.2°). For other studied species the difference α-α_1 had positive values. The obtained results (Table 1) show that, in most of the studied cases, the coefficient of friction among seeds (internal) has higher values than the coefficient of friction between seeds and the sliding surface (external), that is $\alpha > \alpha_1$. The shape and condition of the surface on which the seeds flow influences their friability: on smooth surfaces with low roughness, the friability of the seeds is higher than on those with high roughness.

a) b)

Figure 5. The morphology of seeds of plants of the Poaceae family: a) *Festuca arundinacea*; b) *Sorghum almum*

Therefore, on the enamelled and steel 10 surfaces, seeds have a better flow capacity than on those made of wood (Table 1). The biggest difference between the values of the angle of flow α_1 on wooden surfaces, on the one hand, and on those of steel 10 and enamel, on the other hand, is in alfalfa seeds (Δ=6.9°) and especially, in tall fescue seeds (Δ=16.5°), but in other seeds Δ≤4°.

The results obtained show that the high uniformity of the seed sizes in the studied species, which has been mentioned, has a beneficial influence on the accuracy of measuring the angles of repose and flow: the highest deviation of the angle α was in sunflower, cup plant and tall fescue (±2.0°-2.2°) when using the local method.

In our research the specific apparent weight ρ_v, g/l, was determined by three repetitions; for this purpose, the seeds were poured into a container with a volume of 3 l and then weighed, with an error of ± 1 g. The ρ_v was calculated according to the formula

$$\rho_v = m/V \quad (10)$$

where: m is the weight of seeds [g]; V - the capacity of the container [l].

To determine the mass of 1000 seeds M_{1000}, samples were taken and their weight m was measured to hundredths of grams. After that, the quantity of seeds N was counted in each sample and the weight M_{1000} was calculated according to the formula:

$$M_{1000} = (m/N)*1000 \text{ [g]} \quad (11)$$

The values calculated for the studied seeds (Table 1) of the specific apparent weight ρ_v are of practical interest and are necessary for designing the storage spaces, the organization of the transport, the customization of the equipment and the appreciation of some technological norms.

The weight of 1000 seeds M_{1000} is an important physical indicator of quality when establishing the sowing norm.

The research conducted with the seed drill SZ 3,6 has demonstrated that the seeds of relatively small size (fraction #2.0-1.4 mm) of fodder galega and astragalus had dosing instability values I_d lower than 1.93% seed crushing values of $g_s \leq 0.53\%$ (tab.2).

According to the agro-technical standards (Posâpanov et al., 2007; Mamonov A., 2017), the values of sowing rate instability of different crops need to correspond to the following criteria: cereals - $I_d \leq 2.8\%$; legumes - $I_d \leq 4\%$; grasses - $I_d \leq 9\%$. According to the agro-technical requirements the material prepared for sowing, the quantity of crushed seeds should not exceed 1%, which once again demonstrates the importance of keeping the seed material intact.

The obtained results allow to conclude that dosing fodder galega, astragalus and Columbus grass seeds with the seed metering device with grooved cylinder meets the agrotechnical requirements. The claim that good results can be obtained by dosing the above-mentioned seeds with the grooved cylinder can be supported by the fact that fodder galega, astragalus and Columbus grass seeds (Figures 4, 5) have many similarities in their shape and fall into the category 3. Elliptical, having the following indices of friability: the angle of repose $\alpha \leq 32.5°$ and the flow angle $\alpha_1 \leq 29.8°$ (Table 1).

In the process of research on cardoon and cup plant seeds (*Asteraceae* family), which have the fraction #>3.15 mm, it was established that their characteristics differed when dosed with the grooved cylinder. The highest value of dosing instability in cardoon seeds was 1.91% and the degree of seed crushing was 0.36%, respectively. For cup plant seeds, the above-mentioned indices had the following values: $I_d \leq 6.55\%$ and $g \leq 3.49\%$. The good capacity of dosing cardoon seeds is due to their morphological structure of type 4. Elongated with smooth seed coat (Figure 3b), which causes the high values of friability: the angle of repose $\alpha=28.2°$. Cardoon seeds had the same level of friability, dosage instability and resistance to crushing as the small seeds (fodder galega, astragalus, Columbus grass).

Cup plant seeds, according to the morphological structure, are of type 2. flattened (Figure 3c) and, although they have a sufficiently high level of friability, with the angle of repose $\alpha = 29.4°$, because of the flattened structure with marginal wing, they had greater instability than the seeds of the previous species. The seeding rates of cup plant seeds influence the technological parameters: at the minimum seeding rate - $I_d=6.55\%$ and $g=0.95\%$, and at the maximum – $I_d=1.72\%$ and $g=3.49\%$ (Table 2).

The maximum value of dosing instability of cup plant seeds (6.55%), although it is the highest in our experiments, still does not exceed the allowable value ($I_d \leq 9\%$) expected in the agrotechnical requirements. However, as for the maximum value of the degree of crushing of cup plant seeds, the situation is different (3.49%), because it exceeds the allowed value ($g \leq 1\%$). Therefore, the dosing of the cup plant seeds with the grooved cylinder is possible by using the low values of rotations of the cylinder or by increasing the seeding rate N, taking into account the real values of the degree of crushing of the seeds. Schäfer et al. (2015) adapted a precision seed drill ED 302 (Amazone company, Germany) for sowing cup plant seeds, their dosing being performed in the vacuum chamber on disks with horizontal axes of rotation. The research conducted in open field, with the adapted seed drill, has positive results, the optimal depth of incorporation of the seeds being 5 mm and the distance between rows of 50 cm, and the diameter of the holes on the disks varied within the limit of 1.2-2.2 mm.

Table 2. The results of measurements of dosing instability and degree of crushing of the seeds of the studied species

No.	Plant species	Dosing instability I_d (%) at		Variation coefficient v (%) at		Degree of crushing g (%) at	
		N_{min}	N_{max}	N_{min}	N_{max}	N_{min}	N_{max}
Asteraceae family							
1	*Cynara cardunculus*	1.91	0.17	4.8	0.43	0.07	0.36
2	*Silphium perfoliatum*	6.55	1.72	16.26	4.29	0.95	3.49
Fabaceae family							
3	*Galega orientalis*	0.92	1.93	2.29	4.84	0.53	0.36
4	*Astragalus galegiformis*	1.22	1.43	3.05	3.56	0.39	0.44
Poaceae family							
5	*Sorghum almum*	1.16	0.11	2.91	0.27	0.15	0.18

Note: $\mathbf{N_{min}}$, $\mathbf{N_{max}}$ – the minimal dose and the maximal dose of seeds, respectively

Our calculations showed that the values of the ratio between the coefficient of variation v and the dosage instability I_d vary slightly around $v/I_d \backsimeq 2.5$ for the seeds of all the studied plant species (Table 2). This finding suggests that only one of the indicators is sufficient to calculate the seed dosing instability: the dosing instability I_d or the coefficient of variation v. It is important to take into account the actual values of I_d (or v) and of the degree of seed crushing g when establishing the seeding rate under the real conditions.

CONCLUSIONS

Our research has made it possible to demonstrate that the seeds of the studied species of the families *Asteraceae, Fabaceae* and *Poaceae* (except *Festuca arundinacea*) have high values of dimensional uniformity and friability; the angle of repose $\alpha \leq 32.5°$ and the flow angle on steel $\alpha_1 \leq 27.8°$, on wood $\alpha_1 = 30.6°$, on enamelled surface $\alpha_1 = 26.3°$. One of the basic factors that influenced the friability of the seeds is their morphological structure. In tall fescue, the friability is low because of the morphology (α=36.0° and $\alpha_1 \leq 43.2°$). The studied seeds had friability values (angle of repose α and flow angle α_1) at the same level as the majority of commonly cultivated field crops, which is very important because it allows the use of available buildings and technical means in the agricultural sector.

The comparison of the geometric parameters of the studied seeds and those of the agricultural plants widely used in the local agriculture makes it possible to predict some properties of the studied seeds and to rationally elaborate the technological itineraries, as well as to correctly select the technical means for the implementation of these itineraries.

Currently, as the results of our research suggest, seed metering devices with grooved cylinders, of individual or common type, can be used to sow the researched plants (cardoon, fodder galega, astragalus, Columbus grass). In order to sow cup plant seeds, the given devices need to be adjusted to the minimal values of rotation intensity.

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MODERN BIOTECHNOLOGIES - THE USE OF VERMICOMPOST IN HORTICULTURE

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Abstract

Vermicompost or earthworm humus is a new generation, organic fertilizer, produced with the help of earthworms. It is a concentrated, mineral-organic fertilizer. Earthworm humus obtained from vermicompost is the best fertilizer, as it contains high concentrations of beneficial bacteria and other microorganisms, many biologically-active stimulants for plants, vitamins, amino acids, fulvic and humic acids, added during the digestive process of the earthworm. Vermicompost is one of the fertilizers accepted in the EU for organic farming. The research has been carried out since 2020 in Matca commune, Galați County and focused on the production of vermicompost and its testing on different crops. The experimental variants scheme contains 7 variants with 3 repetitions: Control, Control treated with Cropmax, solid vermicompost - 2 t/ha applied before transplantation, solid vermicompost - 3 t/ha applied before transplantation, liquid vermicompost applied at foliar level in 3 l/ha dose at 14 days, liquid vermicompost applied at foliar level in 5 l/ha dose at 14 days, solid vermicompost - 3 t/ha applied before transplantation and liquid vermicompost applied at foliar level in a 5 l/ha dose at 14 days. For this experiment, the test plant was tomato. From the estimated results, at a density of 30,000 plants/hectare, it was shown that the highest quantity of tomatoes per hectare was obtained in variant V7 (118.33 t/ha; 116.94 t/ha; 123 t/ha), followed, in second, place by variant V3 (112.71 t/ha; 112.5 t/ha; 113.61 t/ha).

Key words*: vermicompost, eartworms, organic fertilizer, soil, tomatoes.*

INTRODUCTION

Vermicompost or earthworm humus is a new generation, organic fertilizer, produced with the help of earthworms. It is a concentrated, mineral-organic fertilizer. Earthworm humus obtained from vermicompost is the best fertilizer, as it contains high concentrations of beneficial bacteria and other microorganisms, many biologically-active stimulants for plants, vitamins, amino acids, fulvic and humic acids, added during the digestive process of earthworm.

Earthworm humus completely replaces any chemical or organic fertilizer and contains 100 times more nutrients and microorganisms beneficial to plants (Atiyeh et al., 2002; Beetz, 1999; Bogdanov, 1996).

Earthworms turn any organic matter into the richest organic fertilizer known to man - the earthworm humus. This humus has a large proportion of all the 16 elements that plants need. Vermicompost considerably improves the structure of the soil, decreasing its density, ncreasing its aeration and nitrogen absorption from the atmosphere, thus helping the plants to grow strong and healthy (Bogdanov, 2004; Canellas et al., 2002; Card et al., 2004).

Vermicompost does not contain or provide living conditions for *E. coli, Salmonella* or other pests. Moreover, it is one of the fertilizers accepted in the EU for organic farming, according to Regulation (EEC) No. 2092/91 and maintained according to art. 16, para. (3), lit. c. of Regulation (EC) No. 834/2007, Annex 1.

Liquid vermicompost is a 100% organic fertilizer extracted from solid vermicompost.

Liquid vermicompost is an active, purely organic humic fertilizer that stimulates plant growth and health, becoming more resistant to sudden changes in temperature or disease (Eastman, 1999; Eastman et al., 2000; Frederickson et al., 1997).

All nutrients available in the extract will be absorbed at cellular level by plants, which leads to the activation of physiological and biochemical processes allowing maximum assimilation of substances that are beneficial to plants (Georg, 2004).

MATERIALS AND METHODS

The research has been carried out since 2020 in Matca commune, Galați County and focused on the production of vermicompost and its testing on different crops.

Preparation of vermicompost

Earthworms live in nests of about 100,000 specimens. They are hermaphroditic, doubling their numbers every 100 days. A nest has an area of 2 sq. m and a thickness of 25 cm.

After the construction of the nest, the substrate for the earthworm bed is prepared, which has a thickness of 25 cm and consists of cattle manure, kept soaked for 4-5 months, and wheat straw for loosening.

After the bed was ready, the earthworms were introduced into the nest. After introduction, a layer of manure of about 10 cm was placed over the earthworms.

The first feeding took place one month after the earthworms were introduced into the nest, after which they were fed with 100 kilograms of manure and straw every 2 weeks.

They had to be watered almost daily especially during the summer. The aeration was done once a month, by loosening the first layer of 10 cm with a fork.

After 6 months, the earthworms were moved to another nest, but the vermicompost was left for another 3 months, after which it was removed, sieved for crushing and loosening, and then the liquid vermicompost extract was made (Table 1).

Before applying the scheme for the experimental variants, an agrochemical and a physical analysis of the soils from the experimental variants was performed (Table 3). The applied methods are methods accredited in Romania.

Table 1. The chemical characteristics of vermicompost

No.	Chemical characteristic	Value	Method of analysis
1	pH 1:2.5 in H_2O	6.7	Potentiometric method
2	Humus, %	6.35	Warkley-Black Method
3	Soluble salts, %	0.303	Conductometric Method
4	Nitric compounds N-NO_3, ppm	1662.5	Colorimetric method with 2,4 fenol-disulfonic acid
5	Ammoniacal compounds N-NH_4, ppm	19.125	Colorimetric method with Nessler reactive
5	Assimilable phosphorus P, ppm	19.05	Colorimetric method with Egner-Riehm-Domingo reactive
7	Assimilable potassium K, ppm	20	Plamphotometric Method
8	Calcium Ca, ppm	22	Titrimetric Method
9	Magnesium Mg, ppm	20	Titrimetric Method
Compost analysis methods used in Romania			

After performing the analysis, the application doses were established in order to test the obtained vermicompost (Table 2).

Table 2. Experimental variants scheme

No.	Variant	Components
1	V1	Control
2	V2	Control treated with Cropmax
3	V3	Solid vermicompost, 2 t/ha applied before transplantation
4	V4	solid vermicompost, 3 t/ha applied before transplantation
5	V5	Liquid vermicompost applied at foliar level in 3 l/ha dose at 14 days
6	V6	Liquid vermicompost applied at foliar level in 5 l/ha dose at 14 days
7	V7	Solid vermicompost, 3 t/ha applied before transplantation and liquid vermicompost applied at foliar level in 5 l/ha dose at 14 days

Table 3. Soils analyses from the experimental variants

No.	Specification	Agrochemical analyses										
		pH	Humus	Nt	P_{AL}	P_{AL}[1]	K_{AL}	Ca_{AL}	Zn	Cu	Fe	Mn	Mg
		pH units	%	%	mg/kg								
1.	V1	7.52	2.13	0.2227	890	630	256	5130	19.7	7.8	14.3	51.4	28.5
2.	V2	7.77	1.78	0.114	906	553	391	5022	19.3	9.3	10.9	40.1	25.2
3.	V3	7.65	2.07	0.106	836	551	246	4696	19	9.4	14.9	45.6	26.3
4.	V4	7.74	2.01	0.115	820	511	367	4370	21	9.6	17.4	44.2	30.8
5.	V5	7.47	1.95	0.113	960	697	373	5674	23.5	9.4	15.8	54.1	32.1
6.	V6	7.29	2.01	0.117	922	724	450	5674	21.7	9.4	13.4	51.2	51.4
7.	V7	7.9	1.78	0.11	1202	667	357	4696	23.1	9.7	14.4	47.3	30.3

[1] - values corrected according to pH values

The plants used for testing were tomatoes - Yigido F1 - that is a hybrid of semi-early tomatoes, with undetermined growth, intended for cultivation in protected areas, with vigorous plants and very high production potential (Seminis presentation catalogue - Universal Group).

Tomato cultivation technology

The tomatoes were sown on 01.06.2020 in alveolar trays of 288 cells. On 17.06.2020, the seedlings were transplanted into pots with a diameter of 9 cm, where they remained until planting.

The planting was done on 15.07.2020, in equidistant rows with a distance of 90 cm between them and 35 cm between plants in a row. Ecologically accredited water-soluble fertilizers have been applied, by drip at a dose of 300 kg/ha, throughout the vegetation period.

The data corresponding to the tomato culture was collected from a number of 10 plants for each variant and the culture had a density of 30,000 plants/ha. The tomatoes were harvested from plants, in 3 repetitions and in accordance with the variants.

RESULTS AND DISCUSSIONS

Before starting the experiment, some physical properties of the soils were checked: bulk density (g/cm^3), total porosity (%), degree of soil compaction (%), fertilized in the previous year with vermicompost, at a harvesting depth of 0-20 cm (Table 4).

Table 4. Physical characteristics of soils used in the tomato cultivation

Variant	Bulk density, BD g/cm^3	Total porosity, TP (%)	Degree of soil compaction, DC (%)
V1	1.3136	50.985	-7.461
V2	1.2833	52.116	-9.844
V3	1.244	53.582	-12.935
V3	1.2783	52.302	-10.238
V4	1.3354	50.172	-5.747
V4	1.3298	50.381	-6,187
V5	1.42	47.015	0.906
V5	1.3561	49.399	-4.119
V6	1.3079	51.198	-7.910
V6	1.3364	50.134	-5.668
V7	1.4173	47.116	0.694
V7	1.3829	48.399	-2.011

Below are the formulas according to which they were calculated: bulk density, total porosity and soil compaction degree.

PMN = 45 + 0.163 * A = 47.445
A = 15
Ad 0-20 cm = 100
YES = dry soil - cylinder country/100
TP = (1- BD / 2.68) * 100
DC = (PMN-TP / PMN) * 100

The results showed that in the experimental variants:

- At V1 - The bulk density is very low (moderately loose soil) with a value of 1.3136 g/cm^3, the total porosity is very high with a value of 50.985% and the degree of compaction /settlement is low (slightly loose soil) with a value of -7.461%.
- At V2 - The bulk density is very low (moderately loose soil) with a value of 1.2833 g/cm^3, the total porosity is very high with a value of 52.116% and the degree of compaction is low (slightly loose soil) with a value of -9.844%.
- In V3 - For both samples, the bulk density is very low (moderately loose soil) with a value of 1.244 g/cm^3 and 1.2783 g/cm^3, in both samples the total porosity is very high with a value of 53.582% and 52.302%. In the first sample, the degree of settlement is very low (moderately loose soil) with a value of -12.935%, and in the other sample, the degree of compaction /settlement is low (slightly loose soil) with a value of -10.238%.
- In V4 - For both samples the bulk density is very low (moderately loose soil) with a value of 1.3354 g/cm^3 and 1.3298 g/cm^3, in both samples the total porosity is high with a value of 50.172% and 50.381%. In both samples the degree of compaction is low (slightly loose soil) with the value of -5.747% and -6.187%.
- In V5 - For both samples the bulk density is low (slightly loose soil) with a value of 1.42 g/cm^3 and 1.3561 g/cm^3, in both samples the total porosity is high, with a value of 47.015% and 49.399%. In both samples the degree of compaction is low (slightly loose soil) with a value of 0.906% and -4.119%.
- In V6 - For both samples the bulk density is very low (moderately loose soil) with a value of 1.3079 g/cm^3 and 1.3364 g/cm^3. In the first test, the total porosity is very high with a value of 51.198%, and in the other sample, the total porosity is high with the value of 50.134%. In both samples the degree of compaction is low (slightly loose soil) with the value of -7.910% and -5.688%.

• In V7 - For both samples the bulk density is low (slightly loose soil) with a value of 1.4173 g/cm^3 and 1.3829 g/cm^3, in both samples the total porosity is high with a value of 47.116% and 48.399%. In both samples the degree of compaction is low (slightly loose soil) with a value of 0.694% and -2.011%.

During the growth season, weekly harvests were conducted. Harvests were performed on previously significant plants, on replicates and on experimental variants (Table 5).

Table 5. Results regarding the number of fruits and yields obtained

Variant	Average number of fruits/plant	Average number of fruits, thousands/ha	Average yield, kg/plant	Average yield, t/ha
V1	22.03	661	3.10	93.01
V2	23.40	702	3.30	99.05
V3	25.23	757	3.76	112.94
V4	24.73	742	3.65	109.47
V5	23.87	716	3.48	104.49
V6	23.70	711	3.46	107.57
V7	27.40	822	3.98	119.42

In Figure 1 the yields obtained for the tomato cultivation are presented, in fruits/plant, for all 7 variants and 3 repetitions.

Figure 1. Results obtained for tomato cultivation fruits/plant

The highest number of fruits was obtained in variant V7 (27.2 pcs; 26.8 pcs; 28.2 pcs), followed in second place by variant V3 (25.3 pcs; 25 pcs; 25.4 pcs).

In Figure 2 the productions obtained for the tomato crop are presented, in kilograms/plant, for all 7 variants and 3 repetitions.

From Figure 2 it can be seen that the highest amount was obtained in variant V7 (3.944 kg; 3.898 kg; 4.1 kg), followed in second place by variant V3 (3.757 kg; 3.75 kg; 3.777 kg).

The estimated yields for tomato crop, in tonnes/hectare, at a density of 30,000 plants hectare, for all 7 variants and 3 repetitions are shown in Figure 3.

From the estimated results at a density of 30,000 plants/hectare, it is shown that the highest quantity of tomatoes per hectare was obtained in variant V7 (118.33 t; 116.94 t; 123 t), followed, in second place, by variant V3 (112.71 t; 112.5 t; 113.61 t).

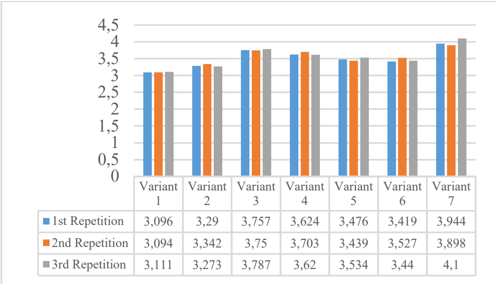

Figure 2. Results obtained for tomato cultivation kilograms/plant

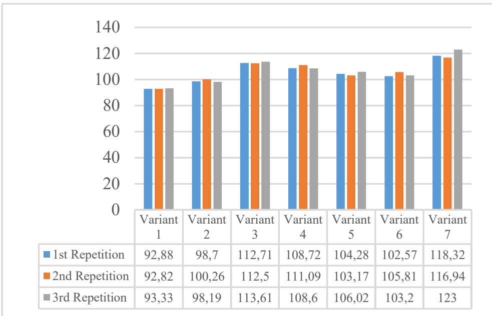

Figure 3. Results obtained for tomato cultivation tons/hectare

After analysing the results obtained in tomatoes, it can be concluded that V7 (solid vermicompost, applied at 3 t/ha before planting and liquid vermicompost applied at foliar level, in a dose of 5 l/ha at 14 days), was the variant with the best results, followed by V3 (solid vermicompost applied at 2 t/ha before planting).

Statistical interpretation of experimental results

In order to highlight the best experimental variants, statistical interpretations were conducted for the number of fruits and the production obtained (Tables 6 and 7). The method used is the analysis of variance.

Table 6. Statistical interpretations for the number of fruits obtained

Variant	Average number of fruits/plant	Differences to Ct 1, fruits/plant	%	Signifi-cance	Differences to Ct 2, fruits/plant	%	Signifi-cance
V1-MCt 1	22.03	-	100.00	-	-	-	-
V2- Ct 2	23.40	+1.37	106.22	*	-	100.00	-
V 3	25.23	+3.20	114.52	**	+1.83	107.82	*
V 4	24.73	+2.70	112.25	**	+1.33	105.68	*
V 5	23.87	+1.81	108.35	*	+0.47	102.00	o
V 6	23.70	+1.67	107.58	*	+0.30	101.28	o
V 7	27.40	+5.37	124.37	***	+4.00	117.09	***
		Diff. to M Ct 1 *LSD 5% = 1.29 fruits/plant* *LSD 1% = 2.37 fruits/plant* *LSD 0.1% = 4.05 fruits/plant*			Diff. to M Ct 2 *LSD 5% = 1.32 fruits/plant* *LSD 1% = 2.67 fruits/plant* *LSD 0.1% = 3.92 fruits/plant*		

Table 7. Statistical interpretation for yield obtained

Variant	Average yield t/ha	Differences between Ct 1, t/ha	%	Signifi-cance	Differences between Ct 2, t/ha	%	Signifi-cance
V1- Ct1	93.01	-	100.00	-	-	-	-
V2- Ct2	99.05	+6.04	106.49	*	-	100.00	-
V 3	112.94	+19.93	121.42	***	+13.89	114.02	**
V 4	109.47	+11.46	117.69	**	+10.42	110.52	*
V 5	104.49	+11.48	112.34	**	+5.44	105.49	ns
V 6	107.57	+14.56	115.65	***	+8.52	108.60	*
V 7	119.42	+26.41	128.39	***	+20.37	120.56	***
		Diff. to Ct 1 LSD 5% = 5.23 t/ha LSD 1% = 8.75 t/ha LSD 0.1% = 12.67 t/ha			Diff. to Ct 2 LSD 5% = 7.56 t/ha LSD 1% = 10.45 t/ha LSD 0.1% = 14.89 t/ha		

The statistical interpretation for the number of fruits obtained shows that the average/variant values ranged between 22.03 and 27.40 fruits/plant. Comparing the untreated control (V1) it is observed that all the variants treated with vermicompost obtained good and very good results.

It is shown that the results obtained for variants V3 (solid vermicompost applied in 2 t/ha before planting) and V4 (solid vermicompost applied in 3 t/ha before planting) offer significant results.

More than that, in variant V7 (solid vermicompost, applied in 3 t/ha before planting and liquid vermicompost applied at foliar level in a dose of 5 l/ha at 14 days) a very significant increase is shown, as compared to all other variants.

If we consider variant V2, which is control treated with Cropmax, the results for the number of fruits are significant at V3 (solid vermicompost applied in 2 t/ha before planting) and V4 (solid vermicompost applied in 3 t/ha before planting) and more significant at V7 (solid vermicompost applied in 3 t/ha before planting and liquid vermicompost applied at foliar level at a dose of 5 l/ha at 14 days).

Therefore, it can be said that variants V3 (solid vermicompost applied in 2 t/ha before planting), V4 (solid vermicompost applied in 3 t/ha before planting) and V7 (solid vermicompost applied in 3 t/ha before planting and liquid vermicompost applied at foliar level in a dose of 5 l/ha at 14 days) are the best for growing tomatoes.

In the case of production, measured in tonnes/ha, if we take into account the untreated control (V1) we notice that all productions are good, with some being better, as following: variants V4 and V5 have significant distinct results and V3, V6, V7 have greater statistically assured results.

If we compare the production with the control variant fertilized with Cropmax (V2), the results are significant in V4 and V6, distinctly better in V3 and the best in V7.

Therefore, it can be said that vermicompost fertilization was superior to Cropmax fertilization.

CONCLUSIONS

Based on the research carried out with solid and liquid vermicompost, applied in different doses and methods of application to tomato crops, the following conclusions were drawn:

From the results obtained in tomatoes - for Repetition 1 it can be concluded that V7 was the best option, obtaining 27.2 fruits/plant and 3.944 kilograms/plant. In second place was V3, with 25.3 fruits/plant and 3.757 kilograms/plant.

From the results obtained in tomatoes - for Repetition 2 it can be concluded that V7 was the best option, obtaining 26.8 fruits/plant and 3.898 kilograms/plant. In second place was V3, with 25 fruits/plant and 3.75 kilograms/plant.

From the results obtained in tomatoes - for Repetition 3 it can be concluded that V7 was the best option, obtaining 28.2 fruits/plant and 4.1 kilograms/plant. In second place was also V3, with 25.4 fruits/plant and 3.787 kilograms/plant.

From the estimated results at a density of 30,000 plants/hectare, it is shown that the highest quantity of tomatoes per hectare was obtained in variant V7 (118.33 t/ha; 116.94 t/ha; 123 t/ha), followed in second place by variant V3 (112.71 t/ha; 112.5 t/ha; 113.61 t/ha).

The statistical interpretation of the number of fruits, as well as of the production showed that variants V3 (solid vermicompost applied in 2 t/ha before planting), V4 (solid vermicompost applied in 3 t/ha before planting) and V7 (solid vermicompost applied in 3 t/ha before planting and liquid vermicompost applied at foliar level in a dose of 5 l/ha at 14 days) are the best for growing tomatoes.

In conclusion, in order to obtain the highest possible production, of the best quality, the vermicompost should be applied both at root and foliar level.

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DETERMINING THE SEEDS SOWN PER REVOLUTION OF THE SOWING APPARATUS

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Abstract

Increasingly, work is being done to replace the mechanical gearbox for driving the shaft of seed drills with electric ones. To achieve this, it is necessary to determine the transfer function of the drive system. A stage in its definition is to determine the quantity and volume of seeds sown per revolution of the sowing apparatus. In the present study, a tooth (pin) sowing apparatus was used for sowing wheat with a Saxonia A200 seeder. The seed density is 825 kg.m^{-3}. It was found that for 1 revolution of the sowing apparatus 29.77 g of seed were sown, and their volume was 0.0000360646 m^{3}.

***Key words**: sowing apparatus, seeds sown.*

INTRODUCTION

The sowing apparatus is one of the most important working bodies in the construction of the drill. It plays a major role in the dosing, distribution and supply of seed material (Firsov & Golubev, 2013). It is used to separate from the total mass of a certain number of seeds and their formation in the initial flow with certain parameters.
Sowing apparatus are different both in purpose and in their design (Klishin, 2003; Krasovskikh & Klishin, 2007). Conditionally can be divided into several groups: mechanical, hydraulic, electromechanical, pneumatic and electropneumatic. Currently, the most widely used are pneumatic and mechanical. Mechanical sowing apparatus do not withstand competition from modern pneumatic ones, as the latter have a number of advantages. Due to the lower mechanical impact, pneumatic sowing apparatus ensure minimal seed trauma.
Drum apparatus are universal and are used for sowing different crops. They have a relatively simple construction and are easy to adjust to different sowing rates. Their significant disadvantage, laid down in their principle of operation, is the uneven supply of seeds.
The uneven arrangement of the seeds on the field is also influenced by the working speed (Maga & Krištof, 2017). It has been established that the best uniformity and respectively the highest biological yield when sowing winter wheat is achieved at a speed of 12 km.h^{-1}.
Pin sowing apparatus are characterized by good uniformity of the sown seeds and are less affected by the influence of external factors (Syrkin et al., 2014). The feeding of the seeds in the devices of this type is carried out under the action of the friction forces in the surface of the pins and indirectly depends on the physical and mechanical properties of the seeds. The main disadvantages are: the pulsations of the seed flow, formed by the entrainment of the seeds by the moving pins and the use of large reducers to regulate the sowing rate.
When sowing cereals with a "merged" surface, an important parameter for adjusting the sowing rate is the bulk mass (Lovric, 2003).
According to (Malinovic et al., 1998) the volumetric dosing of seeds by seed drills satisfies the criteria for accuracy of the general norm and stability of seed flow as a function of speed. Central sowing machines with pneumatic transport and separation to the depositories achieve a high coefficient of variation in the transverse distribution.
When growing cereals, sowing is one of the most responsible operations, as the correctly chosen technology, the exact adjustment of the sowing rate depending on the specific soil and climatic conditions, determine future yields

(Kuvaytsev et al., 2014). Currently, one of the most common ways to change the speed of rotation of sowing apparatus is the use of replaceable gears and gearboxes (Antonov & Laryushin, 2011). Unfortunately, this method has a number of disadvantages that affect sowing and ultimately the harvest. Thus, one of the main disadvantages is the difficulty in regulating the sowing rate due to the abrupt change in gear ratio of the gearbox.

This shortcoming is eliminated by installing a variator (Antonov & Laryushin, 2011), with which the gear changes smoothly, steplessly throughout the control range. This allows you to more accurately select the mode in which optimal sowing is achieved.

Increasingly, work is being done to replace the mechanical gearbox for driving the shaft of sowing apparatus with electric drive (Gorobey & Tarimov, 2009). In this case (developed stand) the shaft is driven by a stepper motor and a motor driver (with modulations up to 200 step pulses in s).

The basis of the electric drive of the sowing machines and regulation of the sowing norm are the mechatronic systems. Existing control systems of sowing machines are intricate and not reliable enough (Aulin et al., 2019). In these systems, devices are connected by a variety of signal and power wires. This leads to a "problem of interfaces" and a decrease in the efficiency of the control process. The solution to this problem is based on the mechatronic approach or combining elements and control units into mechatronic modules. They are characterized by reliability, compact design and lower cost.

It is necessary to improve the functional and structural integration of the components of the control system by integrating them into the mechatronic module. The module for regulating the sowing rate based on the Arduino software and hardware platform has been developed. The work of the proposed management system in case of change of the sowing rate in the sowing system is studied.

When sowing oilseeds, the use (Brichagina et al., 2017) of sowing apparatus controlled by a mechatronic system is promising. It was found that for sowing rapeseed and other small-seeded crops, a seeder equipped with a mechatronic seed metering device satisfies all agro-technical requirements and works much better than those equipped with a mechanical transmission system. Practically does not damage the seeds, allows very precise adjustment of the required sowing rate, ensures sustainable sowing and even distribution of seeds in rows and between them.

To adjust the sowing rate, the gear ratio in the drive system must be precisely determined. An interesting methodology for this is offered (Lysy, 2015). According to this methodology, the volume of seeds sown per 1 revolution of the sowing wheel is:

$$V_0 = \pi . l . R^2 . sin^2\alpha \quad (1)$$

where l, R - width and radius of the drum, cm; α - angle of lifting the seeds from the drum relative to the vertical diameter of the apparatus.

This formula was developed assuming that the volume of seeds sown per 1 revolution of the drum depends on the height of their layer at the outlet of its exposed part. This should not be taken for granted, as the seed volume depends on the cross-section of the outlet in the seed drill box. This area is:

$$f = h_0 . l \quad (2)$$

where h_0 is the height of the hole.

As it is difficult to determine the speed of movement of the seeds in the layer passing through the outlet, it is assumed that its average speed is Vc = 0.5Vk (Vk - peripheral speed of the working surface of the drum). Then the volume of seeds sown by the sowing apparatus per unit time is:

$$V_0 = 0{,}5 . \beta . h_0 . l . V_k \quad (3)$$

where β is the correction coefficient.

The volume of seeds sown per 1 revolution of the drum is:

$$V_0 = \beta . h_0 . l . \pi . R \quad (4)$$

Knowing the volume V_0, the gear ratio required to realize a certain sowing rate can be calculated:

$$V_0 = \frac{2.\pi.b.Q.R_{CT}}{10^3.\gamma.i.(1-\varepsilon)} \quad (5)$$

where Q - sowing rate, kg/ha; b - row spacing, cm; Rct - static radius of the drive wheel, m; γ - seed density, kg.m^{-3}; ε - coefficient of wheel slip,%; i-gear ratio of the drive from the wheels to the shaft of the sowing apparatus.

The aim of the present study is to determine experimentally the amount of wheat seeds that are sown per 1 revolution of the sowing apparatus.

MATERIALS AND METHODS

The experiments are performed in laboratory conditions, in the Department of Mechanization of Agriculture at the Agricultural University, Plovdiv, with a Saxonia 200A seeder. The damper of the observed sowing apparatus is set to position 1, the movable bottom - also to position 1.
The drive of the sowing apparatus is provided by a transmission system consisting of 3 chain gears and a gear reducer, allowing 72 gear ratios. The movement from the right running wheel through the transmission system is fed to the sowing apparatus.
6 of the possible gears in the gear reducer are randomly selected. The movement from the right running wheel through the transmission system is fed to the sowing apparatus.
The crank is mounted on the drive wheel of the second chain gear. For each of the selected gears in the gear reducer, the gear ratio in the transmission system is determined by taking into account the number of revolutions of the crank, at which the shaft of the sowing apparatus performs 1 complete rotation. 42 revolutions are performed for each gear with the crank. The seeds sown from the observed sowing apparatus are collected and weighed on the scales.
The number of repetitions is determined at a level of significance α = 0.05 and relative error δ = 5% according to the authors' recommendations (Mitkov & Minkov, 1989; Bojanov & Vuchkov, 1983).
The quantity of seed sown per 1 revolution of the sowing apparatus **y** is determined by dividing the product by the quantity of seed sown per 42 revolutions of the crank **x** and the revolutions of the crank required for 1 revolution of the sowing apparatus n_{1ca} by 42:

$$q_{об} = \frac{x.n_{1ca}}{42} \quad (6)$$

The volume sown per 1 revolution of the sowing apparatus is obtained by dividing the amount of sown seeds by the density of the sown material:

$$v_{об} = \frac{q_{об}}{\gamma} \quad (7)$$

RESULTS AND DISCUSSIONS

The experiments were performed with wheat seeds with a density of 825 $kg.m^{-3}$.
Gears 111, 211, 231, 322, 431, 634 of the seed gear unit are selected at random. For each of them a different number of turns of the crank is made for one complete rotation of the sowing apparatus. The results of these preliminary experiments are presented in Table 1.

Table 1. Pre-determination of the number of turns of the crank for 1 turn of the sowing machine

Gear Number	Repetitions			Average value	Standard deviation	Coefficient of variation
	1	2	3			
111	141	140	141	**141.67**	0.577	0.410
211	70	71	70	**70.33**	0.577	0.821
231	44	44.5	44	**44.17**	0.288	0.654
322	22.5	22.5	22.5	**2.5**	0.00	0.000
431	11	11	11	**11.00**	0.00	0.000
634	2.5	2.5	2.5	**2.5**	0.00	0.000

It is noteworthy that for all gears the coefficient of variation is small. This speaks to a good grouping of data, without much distraction. The highest value of the coefficient of variation is in the gear number 211. Normally, the largest number of repetitions is needed here. For this reason, the number of repetitions for this gear is determined first. According to the methodology at significance level α = 0.05, relative error δ = 5% and coefficient of variation 0.821 the number of repetitions is 3. For each of the selected gears in the gear reducer, the number of repetitions when determining this indicator is assumed to be 5. After performing the final measurements, the results were obtained, reflected in Table 2.

Table 2. Number of turns of the crank for 1 turn of the sowing apparatus

Gear Number	Number of revolutions
111	**141.0**
211	**70.0**
231	**44.0**
322	**22.5**
431	**11.0**
634	**2.5**

The data in the second column in Table 2 represent the gear ratio in the transmission system of the drill from the second shaft (on which the crank is located) to the shaft of the sowing apparatus.
For each gear, 42 turns of the crank were made. The amount of wheat seeds sown was collected and weighed. The results of the experiments are reflected in Table 3.

Table 3. Quantity of seeds sown for 42 turns of the crank, g

Gear Number	Repetition					Mean
	1	2	3	4	5	
111	17	18	18	17	18	**17.6**
211	28	30	27	28	28	**28.6**
231	56	54	57	55	56	**55.4**
322	119	110	112	108	116	**113.0**
431	240	238	242	238	242	**240.0**
634	505	503	501	503	501	**502.4**

With a decrease in the gear ratio, an increase in the amount of sown seeds is observed (Table 2). This is logical, because reducing the gear ratio increases the speed of rotation of the sowing apparatus and, accordingly, more seeds are exported.
What has been said so far is visualized and confirmed in the Figure 1.

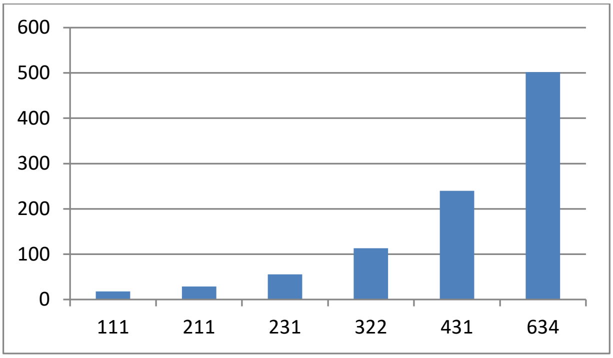

Figure 1. Variation of the sown quantity depending on the gear unit

Using formula 6, a certain amount of seeds is sown per 1 revolution of the seed drill. The following results are obtained for the individual gear ratio in the gear unit (Table 4):

Table 4. Quantities of seeds sown per 1 revolution of the sowing apparatus, g

Gear Number	Quantity of seeds
111	**30.17**
211	**29.38**
231	**29.61**
322	**29.68**
431	**29.86**
634	**29.90**

The average value of the amount of wheat seeds sown per 1 revolution of the seed drill is 29.77 g.
Variation analysis was performed with the data from Table 3 and the variance was determined (σ=0.074), the standard deviation (0.272) and the coefficient of variation (υ=0.915). From the performed measurements and statistical analysis it is established that the data are well grouped around the average value, with insignificant scattering.
For greater certainty in the obtained results, a check was made for gross errors in the measurements, according to the methodology

proposed by the authors (Mitkov A. and Minkov D., 1989). At the significance level α=0.05 and the number of measurements n=6, the limit value of the criterion for gross errors in the measurements is V_T=1.996. The calculated values of this criterion for the minimum (29.38) and maximum (30.17) quantities of seeds sown for 1 revolution of the sowing machine are respectively $V_{29,38}$=1.434 and $V_{30,17}$=1.618, which gives grounds to claim that there are no gross errors in the measurements made.

The density of wheat seed used is 825 kg.m^{-3}. According to formula 7, the volume of seeds sown per 1 revolution of the sowing apparatus is 0.0000360646 m^3.

CONCLUSIONS

Based on the conducted experiments and analyzes, it can be concluded that the sown amount of wheat seeds with a density of 825 kg.m^{-3} for 1 revolution of the sowing apparatus is 27.99 g with a volume of 0.0000360646 m^3.

The same should be done when determining the quantity and volume of seeds from other crops.

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"OPEN INNOVATION ECOSYSTEM 2.0" DIGITAL PLATFORM FOR AGRICULTURE, FORESTRY AND FOOD INDUSTRY

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Abstract

The paper presents an "OPEN INNOVATION 2.0" digital platform that allows multilateral interaction between independent parties. The platform is based on a web portal and offers information, collaboration and communication resources and services for organizations and users who can work together and create value based on innovation. It facilitates transactions between customers and companies. The business environment, research institutions, civil society and public administration - Quadruple Helix model can work together in dynamic and diverse innovation ecosystems online through this platform. The digital platform contains specific instruments: innovative instrument for trading the demand and supply of RDI in the field of agriculture, forestry, food industry and related fields (databases with research results, patents and section dedicated to communication and discussions on topics specific to the trading of supply and demand of RDI; databases with entities involved in open innovation and technology transfer: Universities, Clusters, Stakeholders; open discussion forum to address new topics specific to innovation and technology transfer; e-learning section in the field of open innovation, agriculture, forestry and food industry, as well as related fields; events section, newsletter etc.

Key words*: Open innovation ecosystem, digital platform, innovative instruments.*

INTRODUCTION

The "Open Innovation Ecosystem" is an important component of the European innovation system, in which all stakeholders must interact in promoting the ideas and results of innovative research in the development of new systems (Traitler et al., 2011). The European Commission has shown that innovation policy needs to be designed in a complex framework that promotes innovation and research capabilities in an integrative way that bridges research, industry and entrepreneurship. (EU Open Innovation Strategy and Policy Group, 2013). The platform addresses all actors in the innovation process and facilitates collaboration between research and development institutes, universities, clusters and stakeholders in the field of agriculture, forestry and food industry and related fields (https://ec.europa.eu/eip/agriculture/).

The platform was designed with the clear intention of helping researchers, agriculture, forestry and the food industry and related fields to find each other in a simple way, without intermediaries, restrictions or hidden costs (https://bigdata.cgiar.org/).

The platform facilitates the opportunity for collaboration between companies, thus increasing the chances that certain technologies will benefit from technology transfer.

MATERIALS AND METHODS

The digital platform "Open Innovation Ecosystem 2.0" can be accessed at https://inma-ita.ro/op20 from the most important browsers: Google Chrome, Microsoft Edge, Opera and Firefox.

Platform menu

The "Open Innovation 2.0" platform has a tree structure, consisting of the main menu containing the main buttons and the secondary menu containing buttons adjacent to the main buttons. The main buttons are: About the Platform, Quadruple Helix Entities, Internationalization, Database, E-learning, Events, Legal Support, Forum, Newsletter.

Figure 1 shows a screenshot of the "Open Innovation Ecosystem 2.0" platform. Below is the description of the main buttons.

About O.I. 2.0
When accessing the "ABOUT O.I. 2.0" button (Figure 2), the "Open Innovation 2.0" section opens with the following adjacent buttons (submenus): "Prospective study - Open innovation", "Prospective study - Ecosystem", "Prospective study - Open Innovation 2.0" , Prospective study - Structure and architecture of digital tools for "Open Innovation Ecosystem", "Technological study - digital instruments implementation ", which in turn by access it opens the prospective or technological studies mentioned.

Quadruple Helix Entities
When accessing the "QUADRUPLE HELIX ENTITIES" button, the section in Figure 3. It contains the following adjacent buttons: "About Quadruple Helix", "Universities", "Research Entities", "INMA-ITA" and "Stakeholders".

Internationalization
When accessing the “INTERNATIONALIZATION” button (Figure 4) the user is directed to the following adjacent buttons: “Enterprise Europe Network - EEN” (https://een.ec.europa.eu/), “HORIZONT 2020”, “European Cluster Collaboration Platform EECP” (https://clustercollaboration.eu).

Database
By accessing the "DATABASE" button (Figure 5) the user has access to the following databases: "Universities", "Specialists", "Research Entities", "Clusters", "Patents", "Stakeholders", "Research Results" , “Innovation and Technology Transfer”, “Digital Innovation Hub” and “Technology Information Centers”. Digital tools such as the database of research results, patents and the section dedicated to communication and discussions on topics specific to the trading of supply and demand of RDI: ("Ideas and patents", "Open Innovation", "Partnerships / Project proposals") are an innovative tool for the trading of supply and demand of RDI in the field of agriculture, forestry and food industry and related fields.
Another digital tool is databases with entities involved in open innovation and technology transfer: Universities, Specialists, Research Entities, Clusters, Stakeholders. When accessing the adjacent button "Research results" the user is directed to a web page where the results of the research obtained by the CD institutes in the country are presented. When accessing the adjacent button "Research results" opens "Published articles" where you can find scientific articles in the field of RDI published in prestigious scientific journals indexed ISI or BDI.

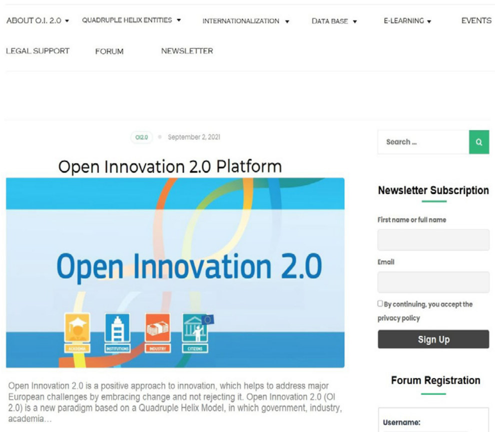

Figure 1. Screenshot “Open Innovation Ecosistem 2.0” platform

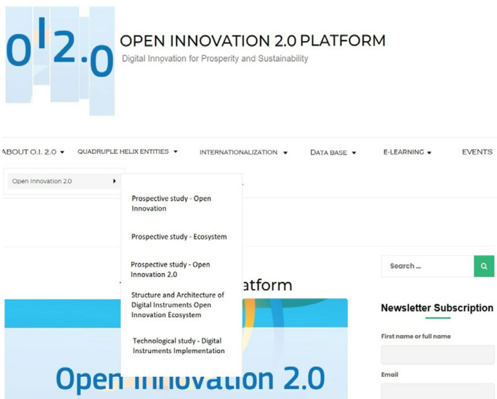

Figure 2. Screenshot “About O.I. 2.0” main button

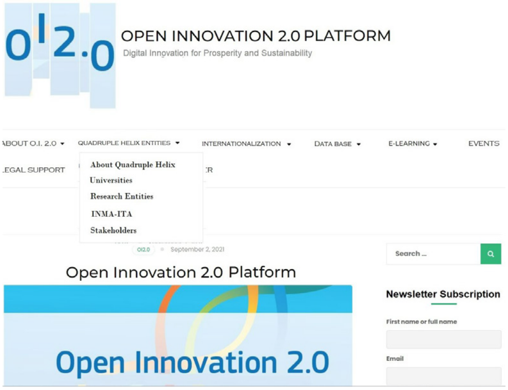

Figure 3. Screenshot "QUADRUPLE HELIX ENTITIES" main button

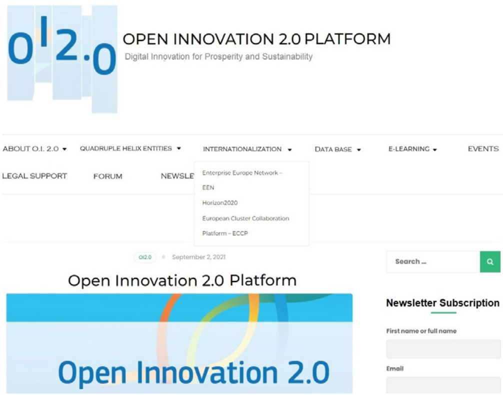

Figure 4. Screenshot "INTERNATIONALIZATION" main button

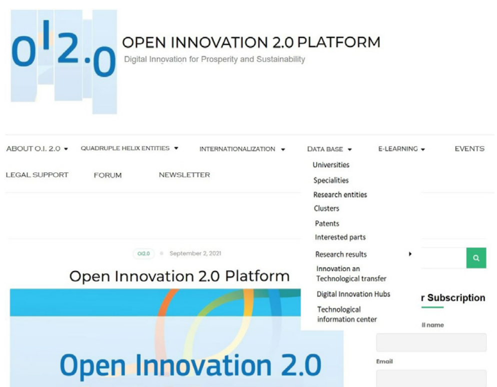

Figure 5. Screenshot "DATABASE" main button

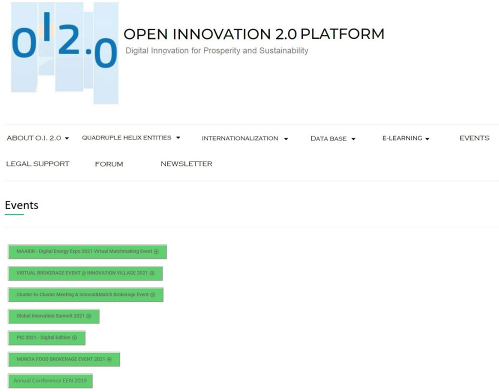

Figure 6. Screenshot "EVENTS" main button

E-learning

When accessing the "E-LEARNING" button, the web page opens with the section dedicated to e-learning trainings in the field of open innovation, agriculture, forestry and food industry, as well as related fields, it is a digital tool.

Events

When accessing the "EVENTS" button (Figure 6) the user is directed to the Facebook pages of some organized events. By simply connecting to Facebook, the user finds out details about those events. The "EVENTS" section will be completed with other events depending on their development.

Legal Support

By accessing the "LEGAL SUPPORT" button, the user has access to the legislation that regulates the field of research, development and innovation, contained in laws, decrees, Government Decisions, Orders, etc.

Forum

When accessing the "FORUM" button, the platform offers the user a series of topics for discussion, for example: "Ideas and patents", "Open Innovation", "Partnerships / Project proposals" (Figure 7).

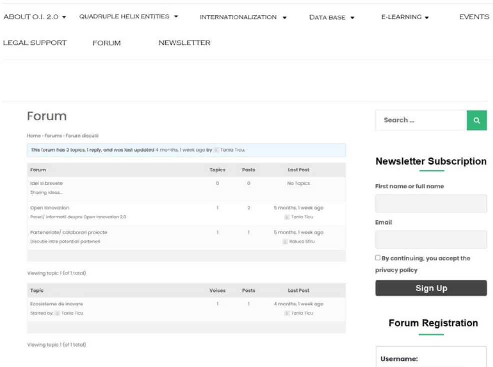

Figure 7. Screenshot “FORUM” main button

To participate in discussions or initiate a discussion proposal, the user must create a username and introduce a valid e-mail address, then access the "Register" button. The open discussion forum for addressing new topics specific to innovation and technology transfer is a digital tool. The user will receive an e-mail address with which he registered on the platform. By accessing the link, the user is directed to a page containing two fields: username and new password. Once the new password is entered, the user can use it to log in to the discussion forum. Each discussion forum participant must be registered with a single email address (username). The discussion forum contains Topics, Posts, and Last Posts. For each discussion topic posted on the platform, user comments are counted by displaying the user's name and the date they made the comment, as shown in the example in Figure 8.

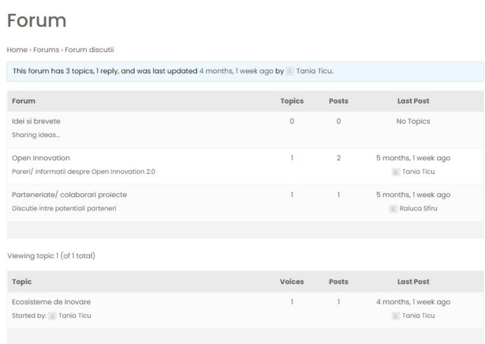

Figure 8. Screenshot of topics, posts, and recent posts on the "FORUM" page - digital tool

Newsletter

The "NEWSLETTER" button allows the user to subscribe to the newsletter generated by the platform administrators by filling in the platform "First name or full name" and "E-mail", and by checking the box from "By continuing, you accept the privacy policy ”the user accepts the privacy policy. After completing the required fields, the user will receive an e-mail confirming that he has subscribed to the newsletter of the digital platform "Open Innovation 2.0" at the e-mail address he entered in the form in which he requested the subscription,

By accessing the "Newsletter" button, the user is informed about the events related to the field of agriculture, forestry and food industry and related fields that will take place in the next period.

The user has at his disposal the "Read more" button where by accessing he can find out more details about the event and can post a comment in the "Leave a Reply" section (Figure 9).

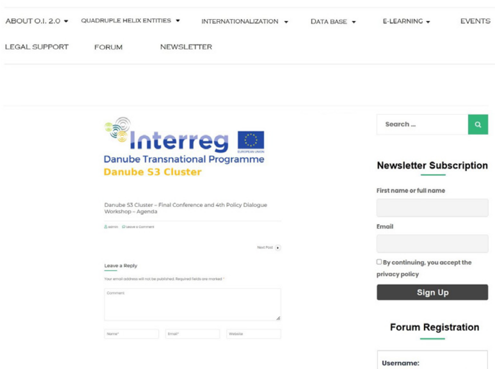

Figure 9. Screenshot - posting a comment in “Newsletter” section

RESULTS AND DISCUSSIONS

The digital platform "Open Innovation Ecosystem 2.0" together with the digital tools contained, have been tested in terms of functionality and performance.

Platform performance testing was performed using open source web.dev software (https://web.dev/measure/).

The test resulted in a test report (RUN AUDIT), which details the results of measure-ments related to: Performance, Accessibility, Best Practices and SEO (Search Engine Optimization) (Figures 10-14).

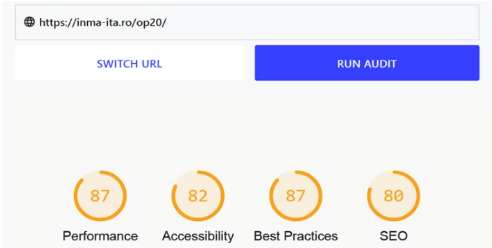

Figure 10. Screenshot - "RUN AUDIT" report generated by web.dev software

The following shows the results of the component testing.

• Performance = 87 points

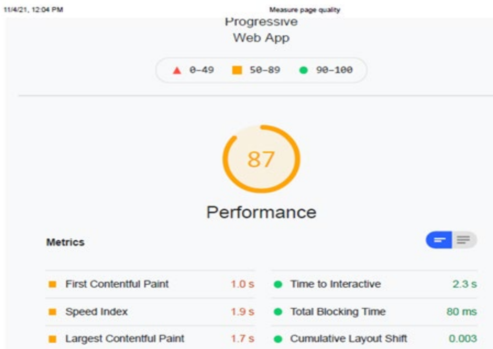

Figure 11. Screenshot "Performance"

- Accessibility = 82 points

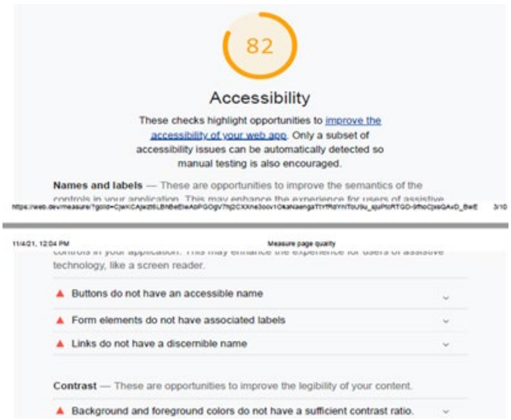

Figure 12. Screenshot "Accessibility"

- Best Practices = 87 points

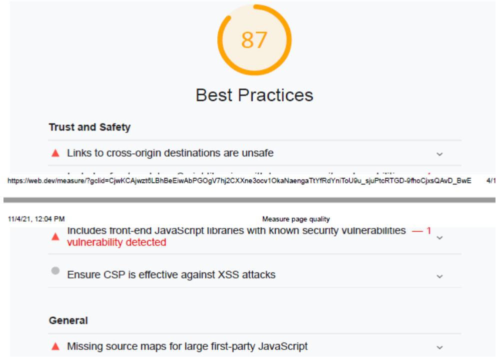

Figure 13. Screenshot "Best practices"

- SEO (Search Engine Optimization) = 80 points

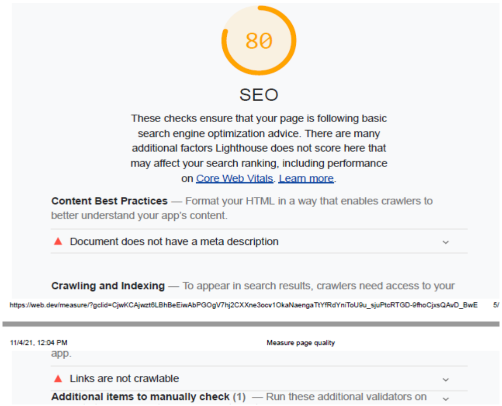

Figure 14. Screenshot "SEO (Search Engine Optimization)"

CONCLUSIONS

The digital platform contains innovative tools to which users have free access, as follows:

- Innovative tool for trading the supply and demand of RDI in the field of agriculture, forestry and food industry and related fields (databases with research results, patents and section dedicated to communication and discussion on topics specific to the trading of supply and demand of RDI: "Ideas and patents" ,"Open Innovation","Partnerships/Project Proposals", etc.);
- Databases with entities involved in open innovation and technology transfer: Universities, Specialists, Research Entities, Clusters, Stakeholders in agriculture, forestry and food industry and related fields.

- Open discussion forum to address new topics specific to innovation and technology transfer;
- Section dedicated to e-learning training in the field of open innovation, in the field of agriculture, forestry and food industry, as well as related fields.

The digital platform "Open Innovation Ecosystem 2.0" together with the digital tools contained have been tested in terms of functionality and performance, using several types of internet connection from various providers (RCS-RDS - guaranteed bandwidth 300 Mb/sec., TELEKOM - guaranteed bandwidth 150 Mb/sec., RCS-RDS - no guaranteed “home” bandwidth, ORANGE - mobile telephony, ORANGE - internet stick). The performance tests of the platform were very good (between 85 and 100 points): Performance (87) and Best practices (87) and good (over 80 points): Accessibility (82) and SEO (80). All deficiencies found after functionality tests have been fixed. The platform has been tested for speed when accessed simultaneously by multiple users, and the results have been good. If any deficiencies occur, they will be remedied in a timely manner.

The content of the “Open Innovation Ecosystem 2.0” platform will be enriched with interesting discussion topics depending on the feedback received from users.

The “Open Innovation Ecosystem 2.0” platform will be updated according to the development of events in the field of research-development and innovation and the elaboration of e-learning courses.

ACKNOWLEDGMENTS

This project is financed by Ministry of Research, Innovation and Digitalization through Program 1 - Development of the national research-development system, Subprogram 1.2 - Institutional performance - Projects for financing excellence in RDI, Contract no. 1PFE/30.12.2021 and was done by “NUCLEU” Programme, developed with the support of the RRIM, project PN 19 10 01 02

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***Enterprise Europe Network, https://een.ec.europa.eu/.

***European Cluster Collaboration Platform: Homepage, https://clustercollaboration.eu/.

***Platform for big data in agriculture, https://bigdata.cgiar.org/.

***The agricultural European Innovation Partnership (EIP-AGRI), https://ec.europa.eu/eip/agriculture/.

***web.dev, Measure page quality. https://web.dev/measure.

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DEVICE WITH CHISEL-TYPE WORKING PARTS FOR MEASURING THE TENSION STRENGTH INDEPENDENTLY ON EACH WORKING PART OR VARIOUS GROUPS OF WORKING PARTS

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Abstract

The paper presents a device with chisel-type working parts for measuring the tensile strength independently on each working parts or on various groups of working parts, equipped with devices designed for separate measurement, intended for complex research of agricultural machinery in interaction with the soil. The proposed solution is new and is based on flexibility and allows the mounting of various working parts in various positions. The functional model developed with elements of novelty and innovation led to the elaboration of a patent application, which refers to a load-bearing structure modulated with multiple applications for tillage machines, on which active parts are mounted in different working variants, in order to extension of the period of use, depending on the size of the agricultural exploitations and the power of the tractor. The modular design of the device will allow the development of a range of flexible cultivators that can be configured to in order to use power sources (tractors) from 30 hp to 90 hp, allowing the manufacturer to expand its market.

***Key words**: device, working parts, chisel, load-bearing structure, tensile strength measurement.*

INTRODUCTION

The paper presents an experimental model of device with chisel-type working parts for measuring the tensile strength independently on each working part, equipped with devices designed for separate measurement, which is intended for complex research of agricultural machinery in interaction with the soil, shown in Figure 1. Also, the experimental model can be transformed into an homologated prototype that will offer to agricultural technical equipment manufacturers a product destined to carry out agricultural works for the preparation of the soil and the germination bed with a series of advantages mentioned below.

Figure 1. Device with working parts - left view

MATERIALS AND METHODS

Components description of the device with working parts

The proposed solution is new and is based on flexibility and allows the mounting of various working parts in various positions (Figures 3, 5, 6 and 7).

Central frame

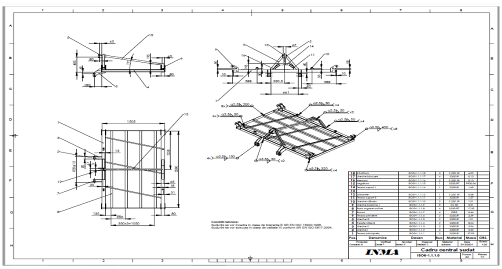

Figure 2. Welded central frame

Welded central frame, Figure 2 has the shape of a rectangle made of welded pipes, square of

80 x 5, 50 x 5 mm, three square profiles of 25, welded obliquely to strengthen the frame, eight ears for coupling the left - right side frames and two pairs of ears for coupling the hydraulic cylinders folding the side frames. It is provided at the front with a coupling triangle which ensures correct three-point fastening to the tractor's hydraulic lift.

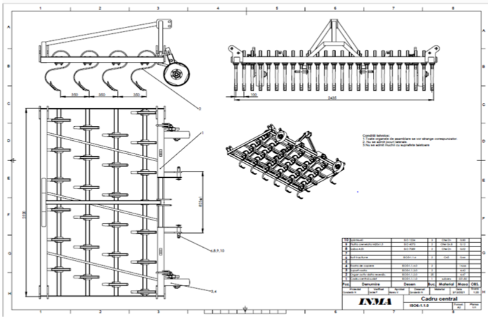

Figure 3. central frame

The central frame is presented in Figure 3. Also, at the front are provided two pairs of lugs for fixing the copying wheels left-right. On the central frame can be mounted a number of 24 active parts of various types, arranged in four rows with a distance of 400 mm, row and 100 mm between them in the direction of advance.

Left side frame

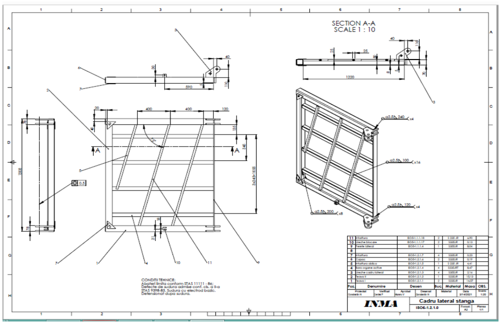

Figure 4. Left welded side frame

Left welded side frame, Figure 4 has the shape of a rectangle made of welded pipes, 80 x 5 square, 50 x 5 mm, three 25 square profiles, welded obliquely to strengthen the frame, four coupling ears with the central welded frame. The coupling ears with the welded central frame must be concentric with each other for easy coupling.

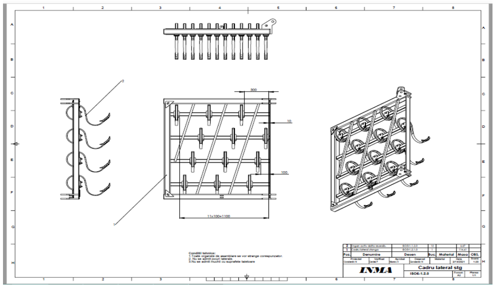

Figure 5. Left side frame

Left side frame, Figure 5 has the shape of a rectangle made of welded pipes, 80 x 5 square, 50 x 5 mm, three 25 square profiles, welded obliquely to strengthen the frame, four coupling ears with the welded central frame. On the left side frame are mounted a number of 12 active parts, arranged in four rows with a distance of 400 mm per row and 100 mm between them in the direction of advance. The coupling ears with the welded central frame must be concentric with each other for easy coupling.

Right side frame

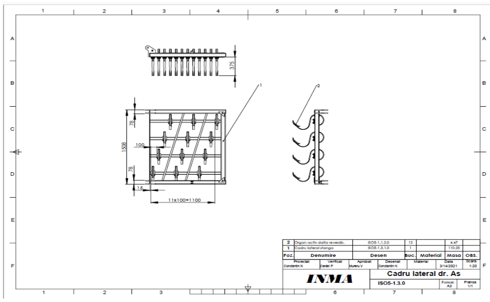

Figure 6. Right side frame

Right side frame, Figure 6 has the shape of a rectangle made of welded pipes, 80 x 5 square, 50 x 5 mm, three 25 square profiles, welded obliquely to strengthen the frame, four coupling ears with the central welded frame. On the right side frame are mounted a number of 12 active parts, arranged in four rows with a distance of 400 mm per row and 100 mm between them in the direction of advance.

Description of the device equipped with working parts

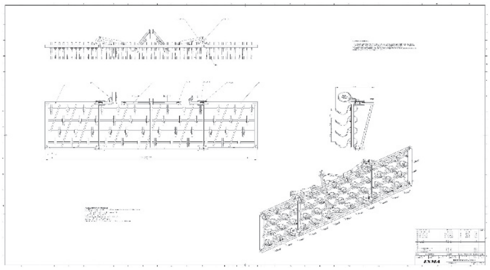

Figure 7. Working variant equipped with working parts

The device with working parts equipped with working parts, presented in Figure 7 consists of three frame modules on which are mounted active chisel-type parts with elastic supports. The active parts, in number of 48 pieces, are arranged in four rows, mounted at equal distances in a row, according to a verified scheme, namely the "cocor" scheme that eliminates clogging with processed soil.
On the central frame are mounted a number of 24 active parts, arranged in four rows with a distance of 400 mm, row and 100 mm between them in the direction of advance. On the left side frame are mounted a number of 12 active parts, arranged in four rows with a distance of 400 mm per row and 100 mm between them in the direction of advance. On the right side frame are mounted a number of 12 active parts, arranged in four rows with a distance of 400 mm per row and 100 mm between them in the direction of advance.
Figures 8a, 8b, 9 and 10 show images of the experimental model performed.

Figure 8a. Device with workig parts - right view

Figure 8b. Device with working parts - right view

Figure 9. Device with working parts – front view

Figure 10. Device with working parts – left view

RESULTS AND DISCUSSIONS

The experimental model was subjected to several series of analyses and simulations that used structural models with finite elements (Bathe, 2006; Seshu, 2012; Zienkiewicz & Taylor, 2014; Maksay & Bistrian, 2008).
The stages of structural analysis and simulation on structural models were classical one.
If the device meets the requirements of good functioning following the structural modeling and simulation, it can be executed. Otherwise, the dimensions materials, conditions, etc. used will be adjusted until the requirements are met (Blumenfeld, 1995; Cardei et al., 2012; Vladut et al., 2018).
Designed of the CAD/CAM model of the structure is done with the help of a 3D design program, for example Solid Works. (Lee, 1999; Rao, 2002; Zeid, 2009; Coticchia et al., 1993).

The main feature is the multiple modulation of the working widths, being able to operate in structures with different size and can be used by traction sources of small and large powers and can ensure a better protection of the soil to compacting.
Regarding the research, the device allows the evaluation of the effect of increasing the number of parts on the tensile strength in the same environmental conditions, can determine the effect of increasing the density of working parts in the structure and can compare the tensile strengths produced by different working parts. The device is designed for complex research of the interaction of agricultural machinery designed for soil work, is new and is based on flexibility and allows the mounting of various working parts in various positions (Figures 11, 12).

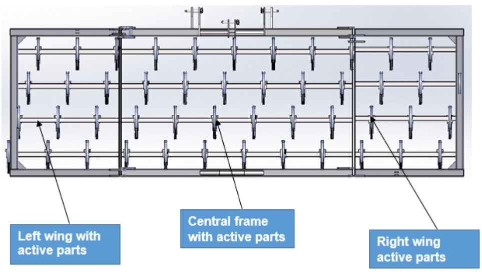

Figure 11. Device with active parts, working position

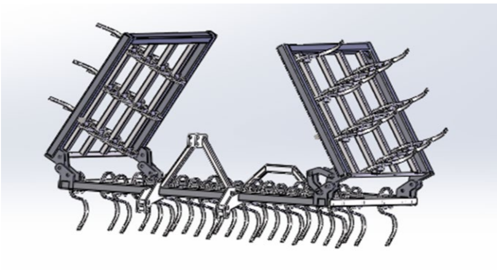

Figure 12. Device with active parts, transport position

Eliminating spacers or gaps and interferences.

The transformation of the CAD/CAM model into a CAD/CAE model is achieved by checking, detecting and eliminating the interferences between the component parts of a subassembly or the assembly from the product composition. To do this, select the subassembly or assembly to be checked, activate "Interference Detection" and command "Calculate", according to Figures 13 and 14.

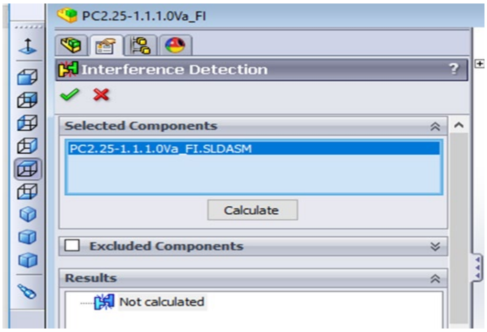

Figure 13. Interference detection

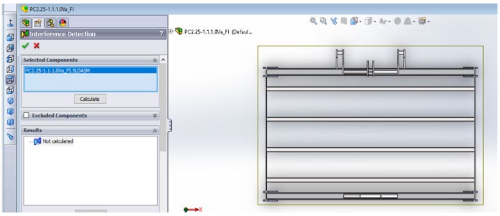

Figure 14. Central frame - verification, detection and elimination of the interferences

After accsessing the "Calculate" command, the interference detection is obtained and the interference areas are specified, and if they are not, one specifies: "No Interfereces", according to Figures 15-19.

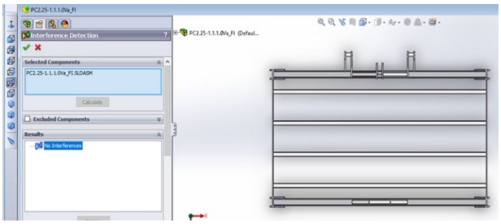

Figure 15. Central frame - interferences calculation

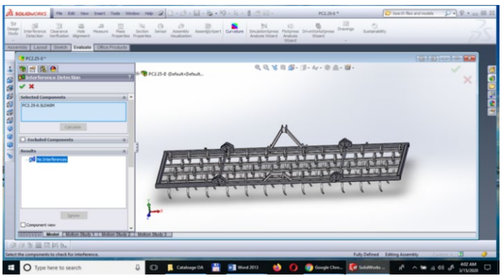

Figure 16. Device interference calculation

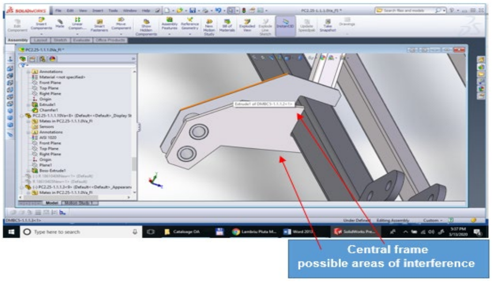

Figure 17. Detail of interference calculation

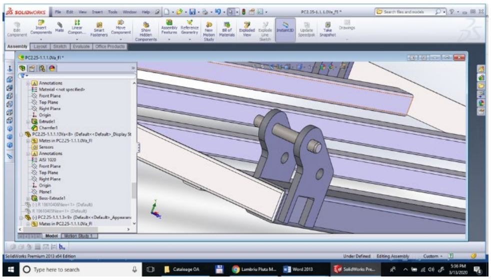

Figure 18. Gaps elimination

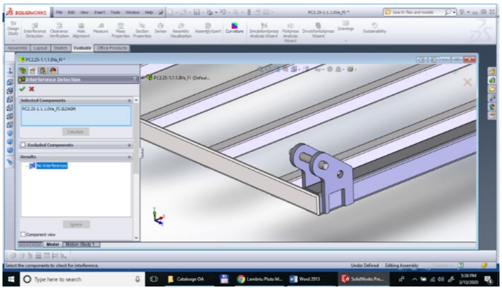

Figure 19. Device, interferences calculation (eliminated gaps)

Figure 20 shows the Assembly - Active parts + Support Bar which are assembled with tangent "mats" to eliminate interferences.

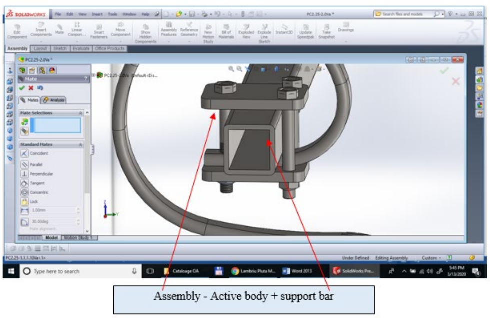

Figure 20. Interferences calculation by tangent "mats"

Figure 21 shows the "Assembly - Bolt bushing + baching plate" which are assemblies by removing the gaps between the outer diameter of the bushing and the coupling hole of the backing plate in order to eliminate the interferences.

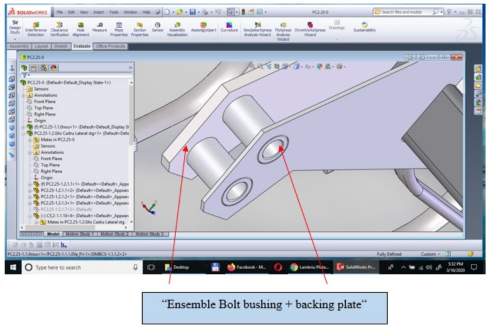

Figure 21. Gaps elimination

The experimental model of device with chisel-type working parts for measuring the tension strength independently on each working part or various groups of working parts it is realized with elements of novelty and innovation.

The experimental model contributes to the research of modern soil cultivation technologies.

The experimental researches that will be carried out with these devices can facilitate technologies with a minimum of innovative works and the effect of new working parts on some agricultural crops can be studied, as well as their economic efficiency.

The main novelty is a load-bearing structure modulated with multiple applications for tillage machines on which active parts are mounted in different working variants, in order to extend the period of use depending on the size of agricultural exploitation and the power of the tractor.

The structure is composed of a central frame supported by wheels for limiting the working depth and equipped with the central triangle for coupling, to which two side frames and can optionally be coupled on which the working parts are mounted.

The three frames are of modular construction, with the hinge system through which their coupling/decoupling can be easily modified, obtaining four variants of working widths, respectively a maximum one consisting of all three frames: central, left side and right side and using the center triangle, two intermediates using the center frame or the two left and right side frames and the additional triangle, and the minimum width using only one of the side frames or the additional triangle.

From the researches carried out in the specialized literature on some similar elements, prospectuses, etc. it follows that there are agricultural equipments that have load-bearing structures on which active working parts with different working widths are mounted (eg SANDOKAN or GRATOR model by Maschio Gaspardo; KOMPACTOR or ZIRKON model by Lemken.

The disadvantages of this equipment are that the load-bearing structures are not modulated and do not allow obtaining other working widths (lower than the basic one).

Another disadvantage is the limitation of the working period being related to the size of the power of the tractors and of the agricultural exploitations on which it is used.

The technical problem solved is the realization of a modulated load-bearing structure for the variation of the working width of the basic structure in order to increase the utility of the equipment and to extend the period of use depending on the size of agricultural exploitations and the tractor power.

The central frame of the structure is supported by working depth limiting wheels, equipped with a central coupling triangle, to which they can be attached, through a system of hinges and hydraulic folding cylinders coupled in the hydraulic system of the tractor, two other left - right side frames also provided with an additional coupling triangle, frames on which the active parts are mounted in different working schemes.

During work depending on the working variant, either all three frames: central and two lateral for the maximum width can be easily mounted through the hinge system, using the central triangle, or the central frame for the intermediate width, or only the left or right side frames using the additional triangle for the minimum width, or both lateral frames, using the additional triangle for another intermediate working width.

Several structural mathematical models have been developed, such as:

MS1 - Structural model with finite elements BEAM3D type of the central structure (Figure 22);
MS2 - Structural model with finite elements SOLID type of the right wing;
MS3 - Structural model with finite elements SOLID type of the left wing (Figure 23);
MS4 - Structural model with finite elements SOLID type for the central body;
MS5 - Structural model with finite elements SOLID type for the entire experimental model structure;
MS6 - Structural model of the spiral spring work support with SOLID type finite elements (Figure 24);

The first model is one with 1D finite elements, developed entirely in the COSMOS/M structural analysis program. The structural mathematical models are CAD/CAE 3D models for the two wings of the structure, right and left, respectively.

Those two wings are neither symmetrical nor anti-symmetrical, due to the special distribution of the supports of the working parts.

This distribution (given by the series of the distances between two consecutive supports) is generated by the experience in operation of such equipment, which shows that the drainage of plant debris is much more fluent through this arrangement of the supports and, implicitly, working parts.

The MS1 model is the structural model of the central body. The most complex model is the MS5 model, the structural model of the entire load-bearing structure of the experimental model. The MS6 is a much simpler model, a structural model of a type of working support.

Further some mathematical models structurally designed are presented.

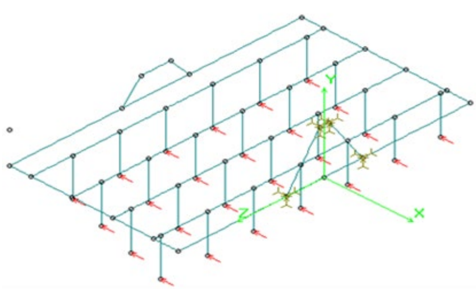

Figure 22. MS1 model -central body, 1D finite element model (BEAM3D)

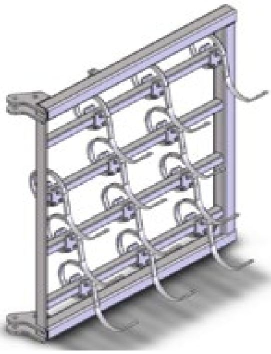

Figure 23. MS3 model - Left side frame

Figure 24. MS6 model - Structural model
of the working parts supports

CADCAM models were created according to the design of the structure using classic CAD/CAM techniques with the SolidWorks program,

By design, these drawings have certain imperfections given by the tolerances allowed in the execution drawings or by the games imposed by the standard for the purpose of the good operation of the machine or its mounting.

Some of these deficiencies (structurally) are interferences (intersecting bodies or components), others are spacers or gaps (which are given by non-contact bodies).

Despite the fact that they are generally not natural, they are the simplest cases to solve, any additional links introduced to model the contacts being risky, which can have unpredictable consequences.

The transformation of CAD/CAM models into CAD/CAE models was done by eliminating interference and gaps. CAD/CAE models were analyzed (discretized, loaded and supported, then calculated).

All models were tested by static stresses in the elastic linear domain. This is the normal operating mode of the load-bearing structures of the tillage machines.

Simulations of other phenomena are possible on the same models: vibrations (calculation of eigenfrequencies), dynamic analysis, stability analysis, vibrations in transport, nonlinear analysis (which includes elasto-plastic calculation, irreversible plastic deformations, etc.).

All these models can be used to simulate various experimental conditions and to obtain information on the required traction source.

The left side frame, center frame and right side frame substructures were tested both separately and together.

Static analysis provides useful results in the decision of strength testing, but also additional information on certain areas that need to be revised in the technical drawing, respectively in the CAD/CAM model or even in resizing the structure or choosing other materials for certain components.

The reaction calculation also gives an idea of the tractor capacity required for each of the working variants.

Some of the main results of the structural analysis (modelling and simulation) are given in Figures 25-28.

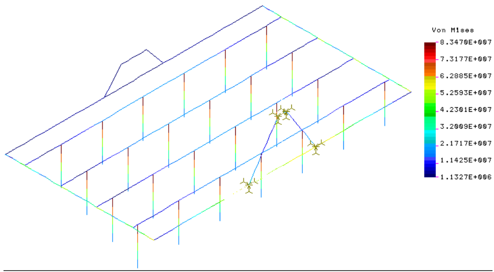

Figure 25. MS1 Model - Equivalent stress distribution in the structure (Pa)

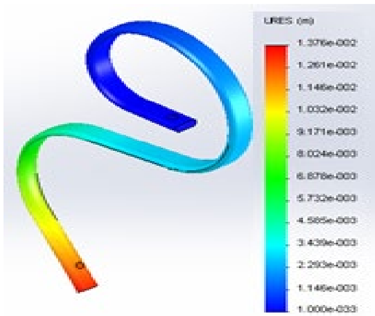

Figure 26. MS6 Model - The resulting relative displacement field in the structure (m)

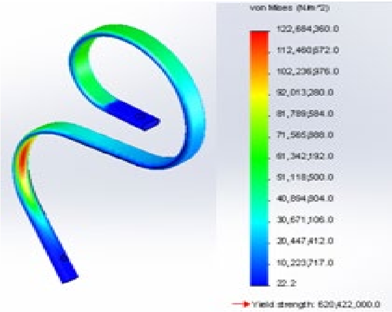

Figure 27. MS6 Model - Equivalent stress distribution in the structure (Pa)

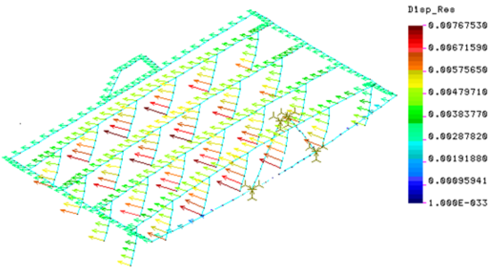

Figure 28. MS1 Model - The resulting relative displacement field in the structure (m)

After the virtual testing, the device behaves satisfactorily under the normal working conditions provided: work with organs specific to depths of up to 10 cm in plowed and discussed soil, in order to prepare the germination layer.
Under these conditions, the stresses calculated in the load-bearing structure ensure, using ordinary materials (with a plasticity limit around 220 MPa), a safety factor (coefficient) with a value of approximately 3, approximately 66% higher than the standardized one.
The structure was examined on a structural model in the integral version, but also on components, which are given by structural mathematical models on which the operation was simulated in different modulated working variants (left wing, right wing central frame, left wing coupled with wing right). A structural model of one of the work supports intended to be used in the experimental works was also tested. All these structural mathematical models led to the conclusion of a behavior characterized by a safety factor with a minimum value 3.

CONCLUSIONS

The experimental model of the device with chisel type working parts for measuring the tensile strength independently on each working part, equipped with devices designed for separate measurement was developed within the execution department of INMA, in accordance with the execution documentation ;
-All the technical prescriptions from the execution documentation were respected;
The execution model is operational and is prepared for conducting experimental research..
The novelty elements are the following:
- Modulation characteristic in various formations, which require different traction powers, formations equipped with different traction source fastening systems; (three working modules: independent central module, independent side wing, two independent side wings);
- Ability to mount various working elements, in various geometries on any variant;
- The possibility of working with maximum width having in composition the three frames;
- The possibility of working with intermediate width having in composition the central frame;
- The possibility of working with minimum width having in composition the lateral frame;
- The possibility of working with intermediate width having in composition two lateral frames joined by the hinges of the basic structure and towed with the additional triangle.
In the virtual testing, the experimental model working with specific organs behaved satisfactorily under the normal working conditions provided.

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THE VEGETATION CHARACTERISTICS OF A POLLUTED SMALL RIVER (GLAVACIOC RIVER) FROM ROMANIAN PLAIN

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Abstract

Glavacioc River crosses many rural areas in southern Romania. The soil and groundwater in the neighboring area of the Glavacioc River are mainly polluted by nitrates from agriculture (excessive fertilization with mineral nitrogen fertilizers), husbandry (mismanagement of manure) and/or human waste. Based on previous research regarding soil and water chemical content, our aim was to identify the plant species that could survive in the vicinity of Glavacioc River. Knowing the concentration of chemical content in some localities, we inventoried the plant species from the water and from the river banks. We can argue that the vegetation changes from up to down river, most nitrophilous and ruderal species (diversity and abundance) growing down river. The highest impact on plant species distribution and abundance is given by clear cutting the woody vegetation growing natural on the river banks (riparian). Any management practices should include re-vegetation of river banks with the natural woody vegetation that have a very important role in diminishing the entrance of pollutants in the water and maintaining most of the herbaceous natural vegetation.

Key words: *Glavacioc River, Romanian Plain, vegetation characteristics.*

INTRODUCTION

The most complex and intensively used ecosystems in the world are considered rivers and their catchments. Peoples understanding of the complex connections between river ecosystems and the landscapes through which they flow increased during recent decades (Calow & Petts, 1994; Naiman & Decamps, 1997; Campos et al, 2002; Burt et al., 2002; Anbumozhi et al., 2005; Shearer & Xiang, 2007; Shabaga & Hill, 2010; Kuglerová et al., 2014; Luke et al., 2019; Fonseca et al., 2021).
In time, European floodplains from temperate zone display patches of vegetation/plant communities (ranging from softwood to hardwood communities) corresponding to natural dynamic stages influenced by abiotic factors (flood, wind, temperature fluctuation): in early successional dynamics, the influence of abiotic factors is strong, the riparian areas are barely structured and comprise short-lived species, and they are very dynamic; the long-lived established hardwood forest stage, may have long time persistence (if no accident occurs), the ecosystem reaches a higher level of organization and becomes stable, the relationships among plants and animals communities increase and diversify (Sanchez-Perez et al., 1993; Huggenberger et al., 1998; Tremolieres et al., 1998). The nutrient status of the riparian zones is determined by regular floods supply of water, nutrients and sediments, the floods being the main driver of the strong dynamics, high productivity, the structure complexity and the species richness (Tornqvist, 1997; Bell et al., 2000). The distribution of organic matter is a controlling factor affecting water quality, habitat, and food webs (Giese et al., 2000). Riparian plant communities are biological processors of terrestrial-aquatic interfaces and they develop a proper response to hydrological disturbance, hydric stress and nutrient or sediment inputs from the floodplain (Tabacchi et al., 2000).
The variety and magnitude of human impacts on rivers and their catchments (very important natural systems) have rapidly accelerated

(Naiman & Decamps, 1997; Martin et al., 1999).

Riparian vegetation can effectively intercept agricultural point and/or diffuse source pollution into the rivers water body and reduce the risk of water pollution (Tang et al., 2021) and have a very important role in reduction, regulation and control of the environmental impacts of agriculture (Birnie et al, 2002; Riis et al., 2020).

In recent decades, water pollution became a major problem of the countries around the world causing water quality degradation (Tabacchi et al., 2000).

N_2O emissions are caused by nitrogen (N) loading and riparian zones might act like buffers for the nitrogen input from agricultural landscapes (Sanchez-Perez et al., 1993; Mayer et al., 2007; Rriis et al., 2020). Even recently, a knowledge gap still exists on how different types of riparian vegetation influence N_2O emissions (Baskerville et al., 2021).

In Romania, a few studies had been performed on some rivers from the Romanian Plain, regarding: the biodiversity of alluvial shrubland characteristic for the Câlniştea River (Paucă-Comănescu et al., 2005), ecosystem characterization of some flooding ash forest from the Neajlov Holm (Giurgiu District) (Falcă et al., 2004), the diversity of alluvial shrubland flora and fauna in the Neajlov Floodplain (Paucă-Comănescu et al., 2004), phenology of the main plant populations from the *Tamarix* shrubland located on the lower floodplain of the Prahova and Teleajen rivers (Paucă-Comănescu et al., 2000; 2002),

The objective of our paper is to highlight the diversity and characteristics of vegetation along a small river valley where nitrogen inputs are already known.

MATERIALS AND METHODS

The Glavacioc River is a permanent small river, tributary of the river Câlniștea, which in turn flows into the Neajlov river and thence via the Argeş river into the Danube river. It rises near the settlement of Ștefan cel Mare, Argeș County (44°31′34″N 25°06′19″E) and discharges into the Câlniștea near Ghimpați (44°09′37″N 25°48′07″E) passing through four counties (Argeș, Dâmbovița, Giurgiu and Teleorman) (Figure 1).

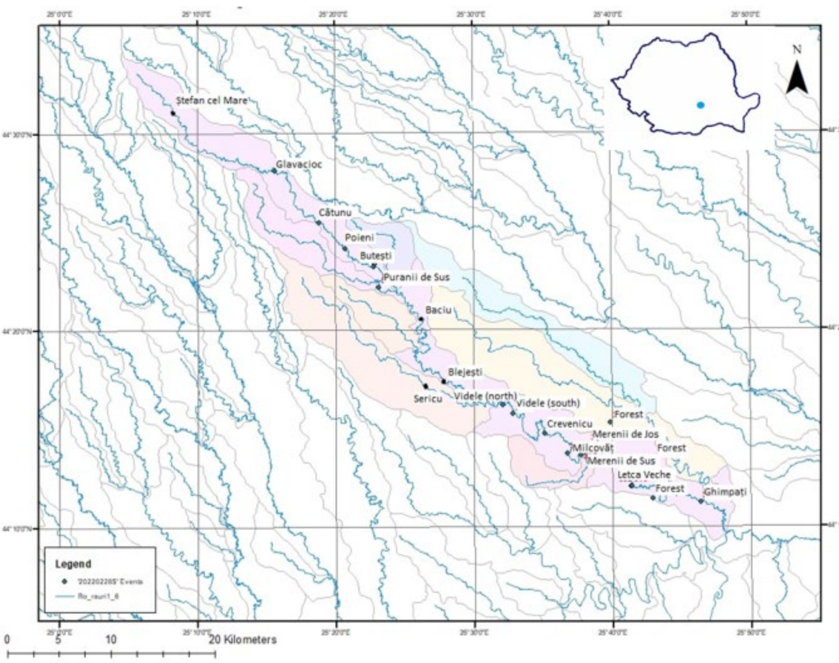

Figure 1. Location of Glavacioc River watershed (EUNIS level 3 map)
and localities where plant species were investigated

The total length of the river is *ca* 120 km and it descends from 181 m altitude at its source to 56 m at its confluence with the Câlniștea.

The total area of the Glavacioc basin is 682 km^2, including the following tributary semi-permanent rivulets: Căldăraru, Fătăceni, Glavaciocul Mare, Milcovăț, Sericu, Valea de Margine and Vii (MSM, 2022).

The topography of the basin is gently undulating. Apart from settlements and associated industry, most of the basin is under agriculture (almost entirely arable, with some orchards) but with occasional blocks of woodland, many of which are clearly of planted origin.

The land in Glavacioc watershed is used mainly for agriculture (79% arable land), pastures (4.5%), vineyards and orchards (0.5%), towns and villages (5.3%) and forests (10%) (Figure 2).

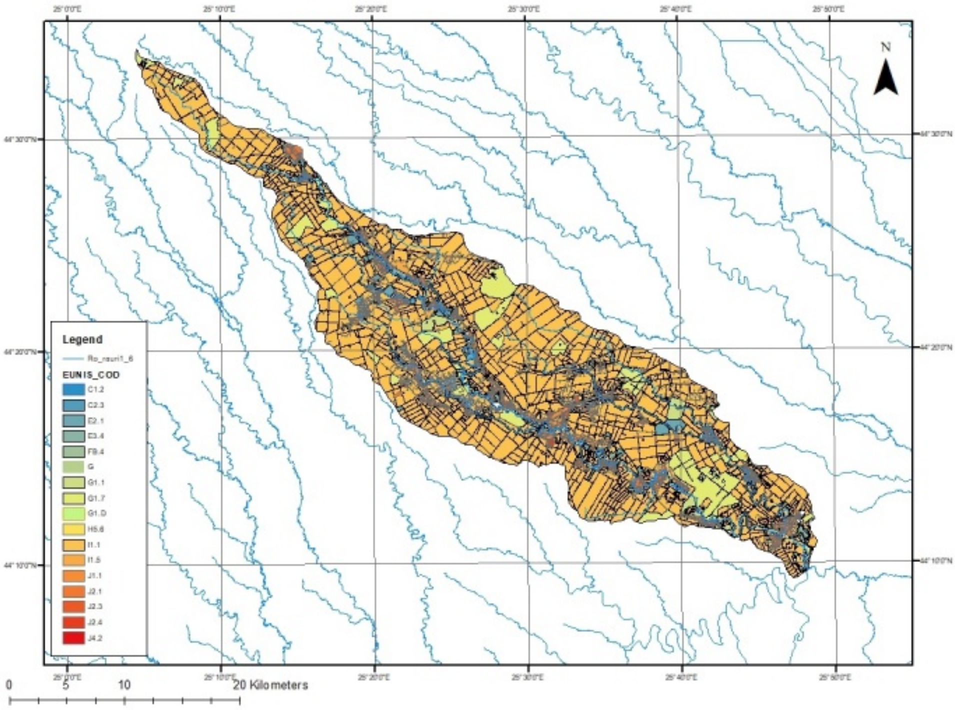

Figure 2. Glavacioc watershed land usage (EUNIS level 3 map)

We conducted our vegetation survey from the place of river discharging (confluence with Câlniștea River) toward its spring (Ștefan cel Mare locality), in towns and villages where the concentration of surface and ground-water nitrate pollution was already investigated by Lăcătușu et al. (2019 a & b) (Table 1).

Our field investigations inventoried plant species (herbaceous, shrubs and trees) from the river margins (dry and wet riparian areas) and inside the water (hygrophytous vegetation) (Table 2) and from a few adjacent forests, characterise the vegetation and habitat type within the riparian zone; note plant species that were important ecologically or in terms of biodiversity; make an appraisal of the impact of human activity on the riparian zone and the river itself.

At each survey-site, the following were recorded: dominant and characteristic species; species of interest including any of higher biodiversity value and any invasive species that constituted a threat to the habitats; management and/or disturbance of the surveyed reach of the river by human beings.

Table 1. The geographic data of the localities where the inventory of plant species had been performed

Location	Coordinates	Altitude (m)
Ghimpați	N44 11.213 E25 46.384	61
Forest between Letca Veche and Ghimpați	N44 11.410 E25 42.954	90
Letca Veche	N44 12.062 E25 41.406	75
Forest near Letca Veche	N44 12.055 E25 41.392	76
Merenii de Jos	N44 14.186 E25 38.328	78
Forest near Merenii de Sus	N44 15.281 E25 39.897	88
Merenii de Sus	N44 13.642 E25 37.730	74
Milcovăț river	N44 13.724 E25 36.769	80
Crevenicu	N44 14.728 E25 35.158	82
Videle (Sowth)	N44 15.777 E25 32.848	90
Videle (Centre)	N44 16.207 E25 32.072	89
Forest near Blejești	N44 13.236 E25 43.056	92
Blejesti	N44 28.563 E25 47.889	100
Baciu	N44 28.429 E25 44.228	100
Puranii de Sus	N44 22.183 E25 23.138	114
Butești	N44 23.385 E25 22.837	119
Poieni	N44 23.223 E25 22.804	117
Poieni	N44 24.176 E25 20.689	125
Catunu	N44 25.501 E25 18.828	123
Glavacioc	N44 28.129 E25 15.601	138
Ștefan cel Mare	N44 48.344 E25 25.136	154

The created database is not a complete inventory of plant species observed during the field assessment but does indicate the main dominant species and those of ecological importance.

The taxonomic order of plant species followed Sârbu et al. (2013). For ecological characterization of each inventoried plant species, ecological indexes from Sârbu et al. (2013) were used.

For statistical multivariate analyses we used the PAST program (Hammer et al., 2001). In table 2 we present the investigated localities and the abbreviations used for statistical analysis.

Table 2. Investigated localities and abbreviation (Abr.)

Locality	Abr.	Locality	Abr.
Toward Letca Veche_forest	TLVF	Crevenicu_water	CW
Letca Veche_water	LVW	Crevenicu_riparian	CVR
Letca Veche_riparian	LVR	Videle_water	VW
Toward Ghimpați_Forest	TGF	Videle_riparian	VR
Ghimpați_water	GW	Baciu_water	BW
Ghimpați_riparian	GR	Baciu_riparian	BR
Toward Merenii de Sus_forest	TMSF	Blejești_water	BLW
Merenii de Sus_water	MSW	Blejești_riparian	BLR
Merenii de Sus_riparian	MSR	Sericu_water	SW
Glavacioc_water	GLW	Puranii de Sus_water	PSW
Glavacioc_riparian	GLR	Puranii de Sus_riparian	PSR
Câlniștea_water	CLW	Butești_water	BTW
Câlniștea_riparian	CR	Butești_riparian	BTR
Cătunu_water	CTW	Ștefan cel Mare_water	SMW
Cătunu_riparian	CTR	Ștefan cel Mare_riparian	SMR
Poieni_riparian	PR		

RESULTS AND DISCUSSIONS

Lăcătușu et al. (2019a) stipulated that in the Glavacioc River basin, shallow groundwater is polluted with nitrates, exceeding the maximum permissible limit (50 mg/L): 7 times the average values and 12 times maximum value. The surface water is slightly alkaline (pH = 8). The input of pollutants in Glavacioc river came from agricultural activities, fertilizers being applied on arable land, pastures, vineyards, orchards; domestic contribution (animal stables, unlined toilets close to the water table and penetrating the soil and clay deposits with low permeability, solutes and polluted waters from human households leaching directly in the water table, etc.

Dunea et al (2021) specified that there is a reduction of nitrates due to the buffering capacity of riparian areas and wetlands, suggesting that the wetland vegetation intercepts and consumes nutrients, diminishing their concentration in the water table. For instance, in Poieni wetland area the lowest pH and nitrates concentration was recorded, especially in the months (March-April) when the development of plants is high and maintaining a steady trend during year.

Statistical analyses of data base highlights the similarities among localities placed downstream and those from upstream, concerning plant species from riparian areas and those located in the water (Figure 3). The riparian zones within the Glavacioc catchment have different extents, mostly small to very small or even absent (the agricultural fields became riparian). Some riparian areas comprise extensive water bodies (wetland) containing hydro- and hygrophilous herbaceous species: i.e. in riparian areas of Letca veche and Cîlniștea (LVR and CR) with similar abundance and dominance (Figure 3).

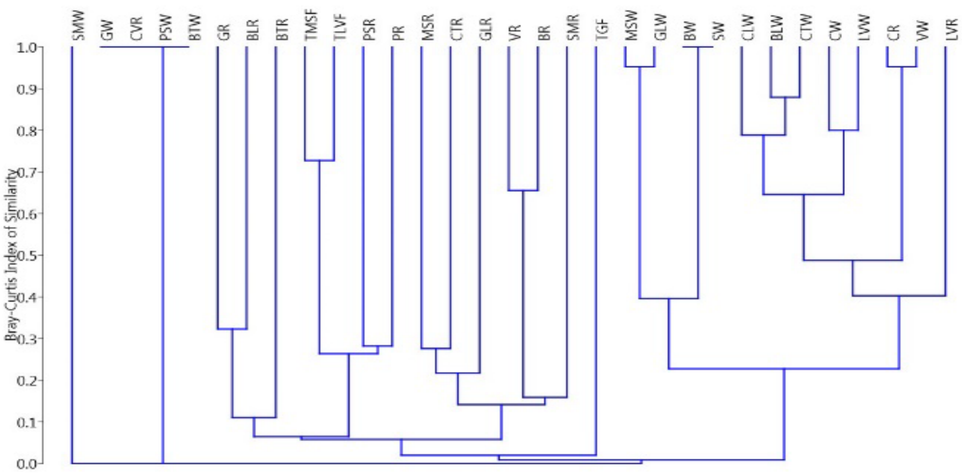

Figure 3. Bray-Curtis similarity of the localities based on inventoried plant species

Principal Components Analysis (Figure 4) shows that the wet areas (river margins and water) comprise similar vegetation, with common plant species in most localities (*Typha latifolia* L., *Sparganium erectum* L. em. Rchb., *Phragmites australis* (Cav.) Steud., *Lemna* sp. cf *minor* L., *Ceratophyllum demersum* L., *Carex riparia* Curtis) but also, some localities had a more distinctive species assemblage. The riparian areas comprise a high variety of species. Most riparian areas are highly anthropized and degraded, with a few remnant trees. The main problem is that the riparian forests shrank or disappeared over large areas Thus, the forests in the Glavacioc basin are patchy and mainly planted (Table 3).

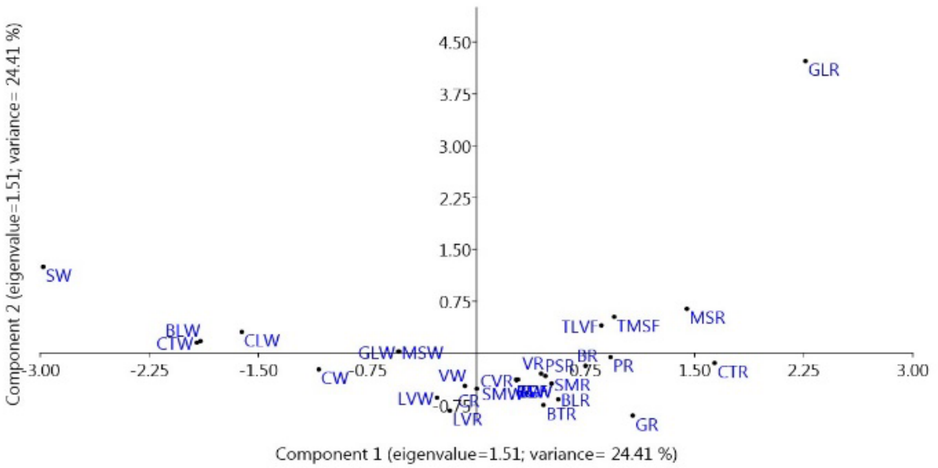

Figure 4. Principal Components Analysis of the localities based on inventoried plant species

Table 3. The trees and shrubs recorded on riparian and neighbouring areas

Plant species	**Distribution in Glavacioc basin**
Salix alba	Common dominant of riverside woodlands and scrub.
Salix purpurea	In most riparian scrub only confirmed rarely.
Salix fragilis	In many places with *S. alba.*
Populus alba	Scattered in most sites within the Glavacioc area but was hardly dominant.
Populus nigra	The morphology of the Glavacioc trees was varied, and we suspect several hybrids and cultivars are present.
Tilia platyphyllos	In small woodland blocks mainly comprised of native trees on drier ground and at the upper edge of the floodplain TLVF and TMSF.
Morus nigra	Planted near habitation but also quite frequent sub-spontaneous in disturbed riparian scrub and woodland along the river in LVR and MSR.
Quercus cerris	Frequent on disturbed banks in woodland near the Glavacioc river; much commoner in small woodlands above the flood-line in TMSF.
Quercus pubescens	Only present in small woodlands above the flood-line in TLVF.
Quercus rubra	A major component of small, planted woodlands, both on higher ground and at the edges of the floodplain in TLVF and TMSF.
Juglans regia	Occasional trees near habitation and rare in BLR.
Gleditsia triacanthos	Quite common on roadsides, at edge of woodland blocks and in disturbed riparian scrub in MSR and GLR.
Amorpha fruticosa	Occasional to frequent on banks of rivers and in woody riparian habitats.
Robinia pseudoacacia	Frequent in planted woodland blocks, by roads and in riparian woodland, and riverbanks in LVR, TMSF and SMR.
Acer negundo	Widespread on verges, woodland edges and scrub including riparian scrub only in MSR.
Acer tataricum	Only in woodland blocks with a native flora on drier, unflooded sites in TLVF, TMSF and GLR
Acer platanoides	On dry and moist soils but is rare where the site is flooded frequently; though native in some woodland sites here, it appeared to be planted in some blocks in TLVF and TMSF.
Euonymus europaeus	In drier woodlands with native flora in TMSF and MSR.
Cornus sanguinea	Mostly in drier woodland blocks with a native flora but also on moist riverbanks TLVF, BTR and CTR.
Tamarix ramosissima	Rarely and confined to the dry verges of roads but not seen on riverbanks.

The preferences of the plants for Light (L), temperature (T), soil humidity (U), soil reaction (pH) (R) and mineral nitrogen soil content (N) (Figure 5) show that in the Glavacioc basin, some plant species prefer shadow (L 4) and semi shadow (L 5), some prefer full light (L 9) and are indifferent (L x) but most species prefer light and weak shading (L 7 and 8).

Regarding temperature preferences, many of the plant species whose distribution is typically in the plain and hilly areas, require warm temperate climate (T 6) but numerous other species are indifferent (eurythermic) (Tx).

The preferences for soil moisture are very varied, showing the diversity of the vegetation areas from the Glavacioc basin and also that dry land is widely distributed into the basin. The number and abundance of species preferring dry soils is higher than of the species preferring wet soil (hydrophytous) or submergent (hygrophytous).

Most of the plant species tolerate neutal soils (with pH low acid to low alkaline) (R 7) and also many species are indifferent (R x).

The preference for nitrogen is highly variable, from N 3 (soils poor in mineral nitrogen) to N 9 (soils with excessive loading of nitrogen, deposits and pollution) dominating plant species growing on soils rich N content (N 7) and soils with higher N content toward excessive (N 8). The plant species preferring (N 9) (*Alliaria petiolata*, *Arctium lappa, Arctium tomentosum*, *Epilobium hirsutum*, *Rubus caesius*, *Rumex patientia*, *Sambucus nigra*) are present in riparian areas.

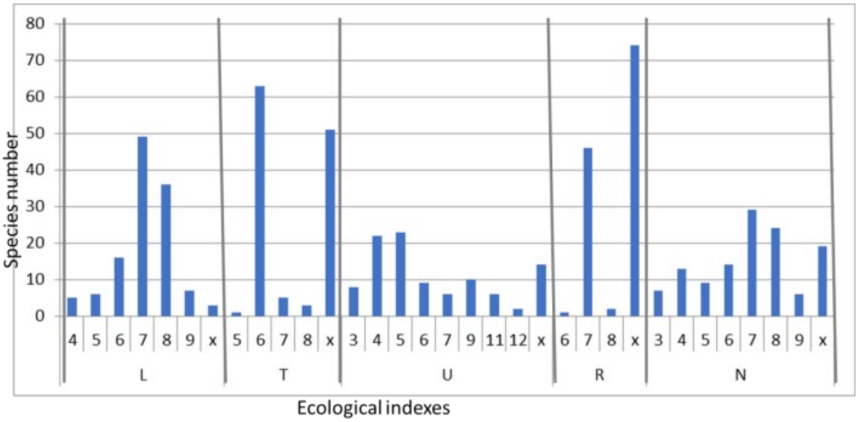

Figure 5. Ecological indexes of inventoried plant species

In Glavacioc basin, plant species dominating riparian areas are as follows: *Bidens vulgatus* (annual invasive species growing in the drawdown zone by the rivers), *Cynodon dactylon* (in many kinds of disturbed, trampled and even steppic grasslands often on paths along the flood-banks of the rivers, and on road verges, but seldom if ever where flooded), *Lythrum salicaria* (most common in marshes, fens and swamps, scattered in taller vegetation on river-banks), *Xanthium italicum* (non-native species from the Americas, it has become typical of nutrient-rich sites, locally dominant near the river especially on broader gently sloping banks, marshes and the edges of paths and tracks).

A common vegetation type in dry land, wetland and water is dominated by *Phragmites australis* which is abundant in many parts of the Glavacioc basin, usually in fringing swamps in shallow water but also in still water of backwaters and adjacent pools and marshes.

The aquatic vegetation is dominated by *Lemna* sp. cf *minor* L. common in still water vegetation of the *Lemnetalia*. In most lengths of the rivers examined in the Glavacioc basin, *Lemna* dominated most of the width (the flow was seldom sufficient to break up the floating carpets). Although only *Lemna minor* was recorded, the related *L. gibba* is likely to have been present and can be difficult to distinguish in forms without the inflated cells under the frond.

Ceratophyllum demersum, typical of the *Potamion* and *Potametalia*, in the Glavacioc basin, is often dominant in still water, especially in backwaters of the rivers.

Carex acutiformis and *C. riparia*: these two *Carex* species occur in similar habitats and often grow together in shallow still water at the edge of rivers and pools, or in marshes (sometimes where shaded). In the Glavacioc basin, they were especially common at the margins of the rivers but also grew in adjacent marshes, especially where these were liable to flooding from the rivers.

Sagittaria sagittifolia is morphologically variable and able to grow in flowing or standing water over a range of depths in communities of *Sagittario-Sparganietum, Phragmition, Oenanthion aquaticae* and *Potamion*. Frequent at the edge of rivers in the Glavacioc basin, usually in still water but occasionally as submerged leaves in the flowing portions.

Upstream (near the source), some plant species were recorded that cannot be found in the rest of the basin: *Alisma plantago-aquatica (*found in shallow and still (or slow-moving) water and on the muddy banks of the drawdown zone in vegetation of the *Phragmititi-Magnocaricetea* and *Bidention*, near the Glavacioc river and its tributaries, it grew in shallows, on gently-sloping wet banks and in seasonally-flooded depressions in riparian scrub or woodland), *Berula erecta* (in swamps and marshes of the *Phragmition, Magnocaricion* and *Glycerio-Sparganion*, in Glavacioc, most common at the upstream end of the river nearing its source, where it formed patches in shallow water at the edge of the flowing river), *Veronica anagallis-*

aquatica (often in shallow water in communities of the *Glycerio-Sparganion*, *Bidention* and *Phragmiti-Magnocaricetea*, in Glavacioc, mainly nearing the source of the river, where there were patches in shallow water at the edge of the flowing river).

Although *Berula erecta* and *Veronica anagallis-aquatica* were rare at the Glavacioc basin level and only grew upstream, near the source, these species prefer high concentration of mineral nitrogen, suggesting that not even the waters near the source are unpolluted.

CONCLUSIONS

Crossing many rural areas in southern Romania, the Glavacioc River itself and the soil and groundwater of its neighbouring area are mainly polluted by nitrates from agriculture (excessive fertilization with mineral nitrogen fertilizers), husbandry (mismanagement of manure) and/or human waste.

The vegetation changes from up to down river, most nitrophilous and ruderal species having diversity and abundance growing down river.

The riparian zone of the Glavacioc and its tributaries represents the only significant area of non-cultivated, semi-natural land in the basin but even here the impact of human activity is clearly discernible. The main problem is that the extent of riparian forests had shrunk or disappeared in large areas, the trees were clear cut, and the remnant herbaceous vegetation is dominated by ruderal species (weeds) or has even been replaced by agricultural fields.

The investigation of the presence, abundance and dominance of plant species in different areas and their ecological characterization, may bring new knowledge about the ecological status of an area. Most of all, inventorying the plant species and characterizing the vegetation may be done by specialists without the need for expensive equipment.

Any management practices should include both re-vegetation of riverbanks with the natural woody vegetation that have a very important role in diminishing the entrance of pollutants in the water (retaining or filtering them) and maintaining most of the herbaceous natural vegetation.

Because of the existence of knowledge gap regarding how different types of riparian vegetation influence N_2O emissions, inter-disciplinary research on Glavacioc River might be valuable.

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METHODS USED FOR ECOTOXICITY ASSESSMENT OF POLYMERIC PACKAGING MATERIALS

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Abstract

In recent years, the growing demand and use of polymeric materials resulted in a great waste disposal problem at a global level. Furthermore, polymeric materials can cause serious damage to the environment due to the fact that they are not biodegradable and persist in the environment for hundreds of years. In order to minimize the environmental impact, researchers developed various formulations of polymeric materials that can be obtained from natural resources and present properties such as biodegradability and biocompatibility, as substitutes to the traditional polymers. In addition to biodegradation tests, in order to determine their effect on the environment, ecotoxicity tests have been used. The aim of this study is to present various methods for polymeric materials ecotoxicity determination.

Key words: *aquatic ecotoxicity, soil/compost ecotoxicity, polymeric materials.*

INTRODUCTION

In the conditions of the modern economy, characterized by the expansion and modernization of markets, by the more pronounced orientation of producers towards consumers, the packaging industry is booming, thus many companies are investing in designing sustainable food packaging materials (Hermabessiere et al., 2017). Packaging manufacturers are focusing on technologies that reduce the consumption of raw materials, increase labour productivity in both packaging and product packaging, increase the shelf life and shelf life of the product, combine various types of materials to increase packaging performance, reduce environmental impact (Sforzini et al., 2016).
Traditionally, the vast majority of the food packaging materials on the market are made from petroleum-based polymers (Gutierrez & Alvarez, 2018), thus creating an environmental problem. The lack of compostability and biodegradability capabilities of petroleum-based packaging materials have made? possible the development of newly bio-based and eco-friendly packaging materials (Kuai et al., 2020).
Biodegradable biopolymers are a current field of scientific research of great ecological, scientific and economic importance. In the context of concerns related to the preservation of the environment, the recovery and recycling of plastic waste, the replacement of traditional synthetic polymers with polymers obtained from renewable and ecological resources and the development of biodegradable polymer blends, with applications in agriculture, medicine, food industry etc. are topics of great interest and research currently. High molecular weight macromolecules, containing covalent bonds, are not easily decomposed naturally under the conditions provided by waste management infrastructures (Mitrus et al., 2009). With a growing consumption market, sustainability becomes a very important factor which depends on the attitudes adopted by the production sector in order to achieve cleaner manufacturing processes. Consuming consciously is a practice which has grown nowadays at a global level and producers should adopt a proactive approach for pollution monitoring and the impact that their products have over the environment (Marzullo et al., 2018). Therefore, the sustainability of packaging materials from an environmental point of view should be evaluated with tools/ methods that allows the estimation of environmental impacts that could be produced by packaging during all its life stages (Feo et al., 2022).

Ecotoxicity tests are nowadays required for the risk-assessment of existing and newly developed chemical-based products and pesticides in order to test their impact on the environment. Usually, the standards of which the ecotoxicity tests are made differ slightly from one country to another. There is a two-way classification of ecotoxicity testing methods, the first one being lower-tier testing in laboratory scale after standardised conditions, which consists of single cohorts of test species from different environmental categories. The second category is known as higher-tier testing which is more intricate, thus the ecotoxicity test are made on a larger scale population or more species (Ratte et al., 2003). In order for the ecotoxicity testing to be justiciable, attributes like reproducibility and repeatability are a must, thus all testing is performed under accepted standards, guidelines and Good Laboratory Practice (OCED, 1998b). Another important part of the validation of ecotoxicity testing is the statistical analysis of the obtained results (Sparks, 2000). When selecting the appropriate statistical analysis method a few key factors must be taken into consideration: measurement variables, ranked variables, attributes and derived variables (Ratte et al., 2003).

MATERIALS AND METHODS

To determine the impact that polymeric materials have over the environment, ecotoxicity tests can be performed under laboratory conditions. Choosing the method and test species depends on the investigated specific ecosystem. For example, for terrestrial environments could be used as test species various soil organisms like microorganisms or terrestrial plants and for aquatic ecosystems algae, crustaceans or fish could be used as test organisms (Haider et al., 2018).

RESULTS AND DISCUSSIONS

Soil/compost ecotoxicity

There is an increased interest in the effects over the environment of composting and soil degradation at a global level. This is why all the testing protocols that have been developed for the characterization of biodegradable plastics and packaging include the assessment of ecotoxicity potentially originated after biodegradation or composting (Sforzini et al., 2016; Vaverková et al., 2018). From an environmentally protection point of view, compost should not contain substances that could be harmful in any way. Therefore, several methods can be used in order to determine soil/compost ecotoxicity, by exposure of different organisms to the tested material. Some research are based on studies regarding bioaccumulation - results from direct exposure (the accumulation of a contaminant in a tested organism), bioconcentration - results from direct contact like respiration or skin contact (the accumulation of a contaminant in an specific organism only from its environment in which it lives) or biomagnification (the accumulation of the contaminant in one organism is higher than the concentration in an organism that is on a lower trophic level) (Bour et al., 2015).

Mitelut & Popa (2011) evaluated the ecotoxicity of compost obtained after composting of six types of biodegradable materials for 90 days, using seed germination bioassay. Compost extracts of 25%, 50%, 75% and 100% were obtained as the test solution for *Raphanus sativus* seeds, and their germination capacity and root growth were monitored. No direct correlations with the composition of the tested materials could be found; however, it was observed a direct correlation between the phytotoxicity and the concentration of the compost extract, all tested extract being more toxic than the control. In another study, Mitelut et al. (2019) determined the ecotoxicity of the soil resulted after the biodegradation process of some polymeric packaging materials using seed germination bioassay on radish (*Raphanus sativus*) and cucumber (*Cucumis sativus*) seeds. The results of the study showed that the tested soils had no toxic effect over the tested seeds development, obtaining a germination index over 80%, being higher for the samples compared to the control soil.

Gutiérrez et al., 2012, studied the biodegradability and ecotoxicity proprieties of some newly developed packaging materials derived from thermoplastic gluten (TPG) developed under reactive extrusion and thermo-molding. The films consisted of TPG, TPG/poly (ε-caprolactone) (PCL) and TPG/PCL + chrome octanoate (Cat) as food grade catalyst. Thermal, physicochemical, thermal, mechanical and environmental tests were made on all the developed films. The ecotoxicity method used in the analysis was performed by comparing the growth of primary roots of lettuce treated with the powder of developed film system (0.1 and 1 mg/mL) compared to samples that grew in water. The results showed that all samples were biodegradable under vegetal compost storage after a period of 90 days. None of the analysed materials showed any ecotoxicity during testing. Martin-Closas et al., 2014, carried out a study in which an in vitro system for ecotoxicity analysis of different plastic constituents was developed. Seeds of tomato, *Lycopersicon esculentum*, and lettuce, *Lactuca sativa* were subjected to the plastic particles during mulch biodegradation, and different parameters (seed germination period, changes in culture media and plant growth) were monitored over time. The results of the in vitro bioassay showed that the under exposure to 50 and 500 mg l^{-1} of adipic acid in the culture medium, tomato growth was severely restricted. Opposite to this, the samples exposed to butanediol and lactic acid presented a better growth rhythm that the control samples. It was shown that the roots are more prone to be affected by exposure chemicals than the shoots and leaves.

The ecotoxicity of four iron-based nanomaterials, loaded with iron oxide and nanoscale zero valent iron (nZVI), provided directly by the manufacturer was assessed by Hjorth et al. (2017). Eight ecotoxicity tests were performed over radish (*R. sativus*), ryegrass (*L. multiflorum*), algae (*P. subcapitata*, *Chlamydomonas* sp.), bacteria (*V. fisheri*, *E. coli*), earthworms (*E. fetida*, *L. variegatus*) and crustaceans (*D. magna*). The results showed that the materials did not show any ecotoxicity at concentrations up to 100 mg/L. Only one Fe nanomaterial, namely FerMEG12 particles, presented toxicity effects to aquatic organisms, thus being classified as potentially toxic.

In a study performed by Jiang et al. (2019) higher plant *Vicia faba* root tips were exposed to different amounts of polystyrene fluorescent microplastics. The results of the study indicate that polystyrene microplastics can be toxic to *V. faba*, especially at the highest concentration used (100 mg/L).

Abe et al., 2022, carried out a research study in which newly developed bioplastics from xylan/starch combining α-cellulose and holocellulose were developed and tested for ecotoxicity and biodegradation proprieties. The disintegration of the bioplastic was assessed in soil and compost, thus the method consisted in burying the bioplastic samples (cut into 3.5 x 3.5 cm squares) and quantifying the resulting mass loss after 13 days of incubation. The ecotoxicity study was made with the soil resulted from the biodegradation process and cucumber seeds. One gram of each soil sample was washed with 5 mL of deionized water and the filtered solution was transferred on filtered paper disks in a Petri dish. Eight cucumber seeds were placed on the filtered paper and the percentage of germination and inhibition was calculated. The results showed that the tested bioplastics presented no ecotoxicity over the growth of the cucumber seeds.

The ecotoxicity of compost containing biodegradable polymeric materials were determined by Kopec et al. (2013) using five test organisms. The study shows germination and root growth inhibition, *Heterocypris incongruens* growth inhibition *Vibrio fischeri* luminescence inhibition in composts containing biopolymers.

Due to limited information regarding soil ecotoxicity of microfibres, Kwak & An (2022) compared the effect of short lyocell microfibers, short polypropylene microfibers, and long polypropylene microfibers on the earthworm *Eisenia andrei*. After 21 days of exposure, the study showed that the earthworm was negatively affected at high exposure concentration (1 g/kg dry soil). All tested microfibres reduced earthworm survival, more toxic being the short polypropylene microfibres.

Aquatic ecotoxicity

Aquatic ecotoxicity is performed in to obtain information on toxicity for in order to determine the risks to both aquatic and terrestrial environments unless the information regarding physical and chemical properties of a specific substance suggest that it might divide onto aquatic sediments or soils. Aquatic biological indicators that are usually used in these tests are represented by algae or fish (Crane et al., 2008).

A study on the ecotoxicity of micro-debris derived from the aging process of polyvinylchloride and Mater-Bi® plastic materials on freshwater organisms was carried out by Magni et al., 2020. The sub-lethal effect of the above plastic micro-debris was assessed on *Dreissena polymorpha*, which can be found in freshwater systems. 1 mg/L of polyvinylchloride (PVC) and Mater-Bi® powders were introduced in semi-static conditions to *D. polymorpha* and a suite of biomarkers analysis (oxidative damage, genotoxicity and cellular stress) were performed over a period between 6 and 14 days. The results showed that there were no relevant sub-lethal effects after exposure to micro-debris plastics.

Vijayakumar et al., 2016 studied the ecotoxicity of samples made from sodium alginate stabilized silver nanoparticles using *Ceriodaphnia cornuta*, which is a crustacean found in fresh waters. For the ecotoxicity testing, *C. cornuta* was cultured in synthetic freshwater at temperatures around 23°C, pH of 7.9 and with a density of maximum of 50 animals per litre. The toxic effect of the sodium alginate stabilized silver nanoparticles was performed by exposing the *C. cornuta* to different concentrations of the tested nanoparticles. To highlight the potential toxic effect, the number of dead organisms after 24h of exposure to the nanoparticles. The results showed that lethal effect of the nanoparticles was at 40 $\mu g\ L^{-1}$.

The cytotoxicity of nanomaterials from zinc oxide on murine macrophages was studied by Vijayakumar & Vaseeharan (2018). Three different quantities of (20, 50 and 75 µg/ml) of the analysed nanomaterials were subjected to RAW264.7 murine macrophages cell lines and the cytotoxic effect was studied under phase contact microscopy over the apoptotic cell morphology. The control samples consisted of collagen and bare zinc acetate. The results were gathered after 48 hours of exposure and showed that both the control samples and the test samples did not exhibit any cytotoxic effect on the morphology and cell viability of the murine macrophage cells.

Graphene (like graphene oxide) based materials can be used in various applications which can lead to potential release and occurrence into aquatic environments. Therefore, ecotoxicity tests were performed by Evariste et al. (2020) using a consortium of algae and bacteria as primary producers, then as primary consumers and decomposers - chironomid larvae and as secondary consumers larvae of the amphibian *Pleurodeles waltii* were used. In this study, changes in bacterial communities were observed, while in chironomids no toxic effects were determined.

Tiede et al. (2009) studied the environmental effect and ecotoxicity of nanoparticles through analytical techniques such as dynamic light scattering, microscopy and size separation technologies. The test conditions must be selected carefully as the medium will greatly influence the ecotoxicity of the nanoparticles. When conducting the ecotoxicity experiments several parameters must be monitored, such as characteristics and concentrations of the nanoparticles as well as the conditions of the environment. The main factors that can greatly influence the results of the aggregation, stabilization and ecotoxicity of nanoparticles are: type of aquatic system, the presence of humic substances, pH alterations, light conditions, sediments, type of test vessels. The conclusions of the study revealed that it is not entirely known in the present what impact do the nanoparticles have on the environment and further testing must be done.

Capolupo et al. (2020) determined the toxicity of plastic/rubber leachates on *Raphidocelis subcapitata* (freshwater), *Skeletonema costatum* (marine) and the Mediterranean mussel *Mytilus galloprovincialis*. The results showed that with increasing, the leachates ranged from slightly to highly toxic to algae and mussels, therefore additional tests are necessary for a better comprehension of the total impact of chemical associated with plastic on aquatic ecosystems.

The effects of glyphosate-based herbicides, glufosinate ammonium-based herbicides and polyethylene microplastic particles on *Scinax squalirostris* tadpoles were determined by Lajmanovich et al. (2022). The study concluded that the increased ecotoxicity and the changes in the biochemical parameters of *S. squalirostris* tadpoles exposed to both herbicides mixed with the microplastics and their occurrence in water bodies represents in fact an ecotoxicological risk for amphibian tadpoles.

Choi et al. (2014) determined the ecotoxicity of water-solubilized aminoclay nanoparticles on the bioluminescent marine bacteria *Vibrio fisheri*, the crustacean *Daphnia magna* and on eukaryotic microalga *Pseudokirchneriella subcapitata*. The results showed that aminoclay nanoparticles could be used as algae inhibition with concentrations lower than 100 mg/L with mild affection or no effect on other organisms' inclusive zooplanktons.

Villa et al. (2020) aimed to perform a study in order to determine the ecotoxicological effect of CeO_2NPs with different surface modifications characteristic to nanoparticles bio-interactions with naturally occurring molecules in the water environment. Further, ad hoc synthesis of CeO_2NPs with different coating agents (alginate and chitosan) was performed. The ecotoxicity was assessed using *Aliivibrio fischeri* and *Daphnia magna*. The different coatings significantly influenced the toxic effects of CeO_2NPs. For example, the alginate coated CeO_2NPs activated oxidative stress in *D. magna*, while the ones coated with chitosan induced hyperactivity. Our findings emphasize the role of environmental modification in determining the NP effects on aquatic organisms.

Four (one in liquid phase and three in solid phase) water soluble polymers based on polyacrylic acid were tested in terms of ecotoxicity by Rozman & Kalčíková (2021) using aquatic plant *Lemna minor*, crustacean *Daphnia magna*, microalga *Pseudokirchneriella subcapitata*, bacterium *Allivibrio fischeri*, and a mixed bacterial culture of activated sludge. The effect on the tested organisms was low or moderate, the liquid water soluble polymer having a specific toxic effect on the bioluminescence of *Allivibrio fischeri* and on the oxygen consumption of the nitrifying microorganisms (inhibition) from the activated sludge.

CONCLUSIONS

This paper aimed to present the ecotoxicity methods used for the determination of environmental impact of polymeric packaging. Two major directions were identified within this study, namely ecotoxicity performed in aquatic environments (marine, fresh water) and ecotoxicity of soil/compost resulted after biodegradation/composting of polymeric materials. These tests are performed based on the necessity and further use of the teste materials. However, scientific data in this area is scarce, more research is needed in order to clearly establish methods for ecotoxicity determination.

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IN VITRO PROPAGATION OF SWEET POTATO VARIETIES USING AXIAL SHOOTS AS A SOURSCE OF EXPALNTS AND THEIR ANALYSIS BY COMPARING SOME GROWTH PARAMETERS

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Abstract

In order to obtain the shoots in laboratory conditions, it was necessary to prepare the sweet potato tubers and plant them, ensuring favorable conditions of temperature, light and humidity. Axial shoots from sweet potato varieties: KSP1, DK 19/1, DK 19/2, DCh 19/3, DK 19/4 and DK 19/5 were used as a source of explants for the initiation of in vitro culture. Through a single factor experiment in three repetitions, the analyzed factor was the sweet potato variety, with 6 graduations, and as a control the average values for the studied elements were established. Determinations were made on the following parameters: the formation of shoots, the number of leaves, the height of the plantlets and the weight of the fresh root. The results presented in this study highlight the possibility of obtaining sweet potato shoots and in laboratory conditions, throughout the year, with minimal costs. allowing in vitro cultivation technique to obtain in a short time a stock of healthy starting material, which can be used as planting material.

***Key words**: sweet potato shoots, in vitro, plantles.*

INTRODUCTION

Sweet potato crops play an important role in agriculture and facilitate food security in many underdeveloped countries. From recent statistical studies, worldwide, in 2017, 494.6 million tons of sweet potatoes were obtained (FAOSTAT, 2019). The consumption of sweet potatoes for the majority of the global population is on average per capita of 19.4 kg / year (2013-2015) and an increase of 21.0 kg / year is expected in the future, until 2025 (OECD-FAO, 2016).

This crop is widespread in the world, being used fresh, cooked, or as a raw material for industrial processing: starch, alcohol, coloring agent, liqueur, juices, rich in beta-carotene and alpha-tocopherol (vit E) (Benisheikh et al., 2013).

It contains almost all macro- and micro-nutrients, substantial amounts of vitamin C, moderate amounts of vitamin B complex (vitamins B1, B2, B5 and B6) and folic acid, as well as satisfactory amounts of vitamin E. This species is appreciated due to nutritional value of thickened roots (tubers), rich in starch, mineral salts of calcium, potassium, phosphorus, magnesium, various organic acids and beta-carotene. Beta-carotene is converted by the human body into vitamin A, with beneficial effects on increasing immunity, health of the skin and membranes covering the nose, lungs and intestines. The high beta-carotene content also helps to alleviate joint pain, having an anti-inflammatory effect. It tends to become a staple food in many parts of the world. This crop is vital for small farmers with limited land, low labor and small capital. One of its major advantages is the ability to be harvested gradually for family consumption, or income generation (Tumwegamire et al., 2004). Because the sweet potato has a high degree of heterozygotes, the seeds are used only for propagation and creation of new varieties and lines (Gaba and Singer, 2009), used in breeding programs. There are a number of advantages to using in vitro micropropagation methods over conventional vegetative propagation. The micropropagation process has been used on a commercial scale, for the production of qualitative planting material, of several horticultural species. Meristems and nodal explants have become popular in sweet potato micropropagation. The effectiveness of micropropagation techniques depends on a variety of factors, including: genotype, stock plant physiology, season, culture medium composition, growth regulators, light source (type and intensity), photoperiod, gelling agents and carbon sources (George et al., 2008).

MATERIALS AND METHODS

For this purpose, the biological material (sweet potato tubers) was provided by the Research and Development Station for Agricultural Plants on Sands Dăbuleni (SCDCPN), Dolj County. Six Korean sweet potato varieties were studied and used to obtain the donor (mother) plant., respectively: KSP 1 (control), DK 19/1, DK 19/2, DCh 19/3, DK 19/4 and DK 19/5. The tubers were planted in plastic boxes measuring 57.5 x 29 x 6 cm. This type of perforated box is used for direct sowing, using as substrates fine peat, perlite, or others and provides easy mobility, and can optionally be used together with a tray from which the plants can absorb water or nutrient solution.

Watering and fertilizing were carried out as needed throughout the emergence and growth period. Optimal conditions of temperature (20-24°C) and light were ensured. Until the buds appeared, the boxes were kept in the dark, and after the appearance of the first buds, they were provided with optimal lighting conditions (photoperiod of sixteen hours of light and eight hours of darkness). Under these conditions, after about a month, the tubers began to sprout.

Healthy donor plants, grown for two weeks, were treated preventively to prevent insect infestation and the development of microorganisms (fungi and bacteria). The young explants, with vigorous shoots, had all the chances to develop successfully in laboratory conditions.

One week before the process of obtaining the explants, the plants were sprayed with Ridomil Gold MZ, which has a systemic and contact action. Metalaxyl-M (mefenoxam) is systemic and is rapidly absorbed by the green parts of plants, distributed upwards (acropetally) throughout the plant and in new growths after treatment. Mancozeb has a contact action, forming a protective barrier on the surface of the plants, preventing the germination of spores of any kind.

After the laboratory production of sweet potato shoots, they were used as a source of explants to initiate the in vitro culture of the six sweet potato varieties. When the shoots were about 20-25 cm long, they were detached from the mother plant and fragmented into stem cuttings. Both axillary buds and buds can be used apical (terminal). Cut knots from the same stem, leaving 5-10 mm of stem above and below the buds. The explants are rinsed several times with running water to remove impurities. Immersion in 1% sodium hypochlorite solution and 2-3 drops of Twen 20 (R) for 15 minutes, 70% alcohol immersion, 3 minutes, rinsing. with double-distilled water several times. Remove the explants on a sterilized paper towel to remove the water. Using the instrument from the hood, periodically sterilized in the oven, then each time it is manipulated by the flame, the explant is placed on the propagation medium; 18 x 150 mm sterilized test tubes are used, at a temperature of 1800°C, for 3 hours, in the oven; the test tubes contain the culture medium (5 ml/test tube). Nutrient Murashige-Skoog is used in the cultivation of many plant species commonly used for new species (Table 1). The Murashige-Skoog environment is characterized by a higher nitrogen concentration than that used in previous studies, namely: 5 times higher than that established by Miller (1956), quoted by Badr, 2011, 15 times higher than the one developed by Hildebrandt (1946) and 19 times larger than the one issued by White (1943) (George and Sherrington, 1993/1996, cited by Badr, 2011). MS salts 4.4 g/l, sucrose 30 g/l are used, as gelling agent agar 9 g/l is used, the pH being corrected to 5.8, before autoclaving. Two-distilled water is used, ie distilled water subjected to an autoclave sterilization process. The test tubes containing culture medium are sterilized in an autoclave (20 minutes, 1200°C and a pressure of 1.1-1.2 atmospheres). Chemicals added to the Murashige - Skoog culture medium for the introduction and in vitro multiplication of sweet potatoes (Table 2).

Table 1. Chemical composition of Murashige-Skoog culture medium (mg/l and molar concentrations) (after Robert N. Trigiano, Dennis J. Gray, 2005)

Compounds	Culture medium: Murashige-Skoog	
	mg/l	Molar concentrations
Macronutrients (mg/l or mM)		
NH_4NO_3	1650	20.6
$CaCl_2$	440	3.0
$MgSO_4 \cdot 7H_2O$	370	1.5
KNO_3	1900	18.8
KH_2PO_4	170	1.3
Micronutrients (mg/l or µM)		
H_3BO_3	6.2	100
$CoCl_2 \cdot 6H_2O$	0.025	0.1
$CuSO_4 \cdot 5H_2O$	0.025	0.1
Na_2EDTA	37.3	100
$FeSO_4 \cdot 7H_2O$	27.8	100
$MnSO_4 \cdot H_2O$	16.9	100
KI	0.83	5
$Na_2MoO_4 \cdot 2H_2O$	0.25	1
$ZnSO_4 \cdot 7H_2O$	8.6	30
Organic compounds (mg/l or µM)		
Inositol	100	550
Glycine	2	26.6
Nicotinic acid	0.5	4.1
Pyridoxine HCl	0.5	2.4
Thiamine HCl	0.1	0.3

Table 2. Hormone supplement added to the Murashige-Skoog culture medium

Chemicals	Quantity (g/l)
Ascorbic acid	0.1
Gibberellic acid	0.02
Calcium pantothenate	0.002
Calcium nitrate	0.1
L-arginine	0.1
Putrescine (HCl)	0.02

At the end, each stand is labeled with the name of the variety, the date of initiation and the name of the laboratory that performed the work; after 4-5 weeks of in vitro culture, the plants are visually evaluated to see their growth and development; plants with abnormal or contaminated growth are removed; plants with normal development are used in another in vitro propagation cycle.

Figure 1. Sweet potato shoots

Figure 2. Sterilization of sweet potato shoots

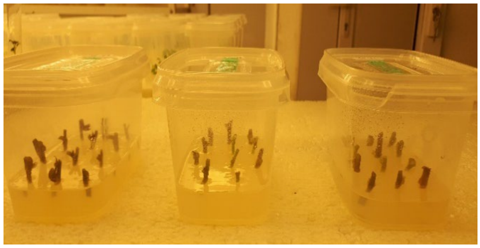

Figure 3. Inoculation of sweet potato cuttings

Figure 4. Incubation of cultures in the growth chamber

RESULTS AND DISCUSSIONS

A photoperiod of 11.5 hours of light/day, or less, stimulates flowering, while 13.5 hours of light/day stops flowering, but does not affect tuber production. In short day conditions and low light intensity, root development is stimulated. The multiplication ratio for the use of stem shoots is estimated at 1:15 to 1:20 (Fuentes and Mwanga, 2011).

During 2020 in the Laboratory of Vegetable Tissue Cultures, NIRDPSB Braşov was initiated a single factor experiment in three repetitions, the analyzed factor being the sweet potato variety, with 6 graduations: KSP 1, DK 19/1, DK 19/2, DCh 19/3, DK 19/4 and DK19/5. Determinations were made on the following parameters: the formation of shoots, the number of leaves, the height of the plantlets and the weight of the fresh root.

Comparing the determinations made weekly (over 6 weeks) for the 6 sweet potato varieties (Figure 5), in terms of shoot formation, it can be said that the DK 19/1 variety performed better than the other varieties during the 5 weeks (from the second week until the end of the study).

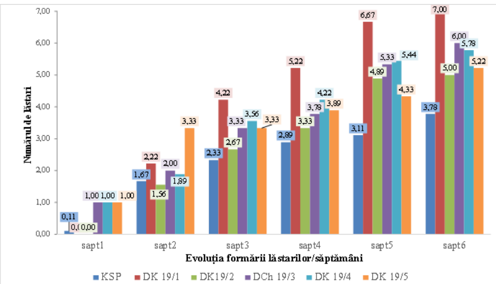

Figure 5. Formation of shoots in the studied varieties / 6 weeks

Regarding the formation of leaves, the same variety of sweet potato DK 19/1 (Figure 6) is highlighted with a high number of leaves from the third week until the end of the determinations (from 4.56 leaves in the third week to 8.00 leaves in the sixth week).

Determinations performed for two other parameters: average plantlet height (cm) and root weight/variety (g) (six weeks after in vitro inoculation show for DCh variety/3 a good development both regarding the average height of the plantlet 5.47 cm and for the weight of the root (0.0826 g) (Figure 7).

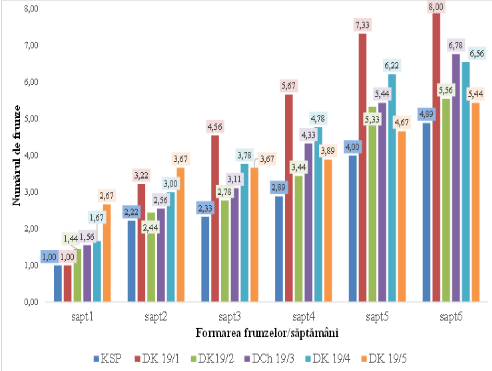

Figure 6. Leaf formation in the studied varieties/6 weeks

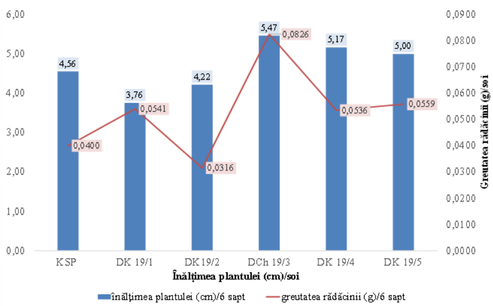

Figure 7. Average plantlet height and root / variety weight, 6 weeks after inoculation

By comparing the differences of the studied variants with the control variant (average values) with LSD of 5, 1 and 0.1%, it appears that the KSP 1 variety registered inferiority in the formation of shoots (at 6 weeks after inoculation), with a significant negative difference of -1.76 shoots. The DK 19/1 variety, although showing a high value of the number of shoots (7.00), does not register a significant difference (Table 3).

Table 3. The influence of sweet potato varieties on the formation of shoots, 6 weeks after inoculation

Variety	The weight of the fresh root (g)	Diff. (g)	Significance
KSP 1	0.040	-0.013	ns
DK 19/1	0.053	0.001	ns
DK19/2	0.033	-0.019	ns
DCh 19/3	0.083	0.031	*
DK 19/4	0.053	0.001	ns
DK 19/5	0.053	0.001	ns
Average (Ct)	0.053	-	-

LSD 5% = 1.67 shoots; 1%= 2.37 shoots; 0.1% = 3.43 shoots.

Regarding the average number of leaves/ plantlet (Table 4), at which the average of the values of the number of leaves / plantlet (6.24 leaves) was chosen as a control, a positive result was obtained for the sweet potato variety DK 19/1 (at 6 weeks from inoculation), with a significant difference (1.76 leaves).

Table 4. The influence of sweet potato varieties on leaf formation, 6 weeks after inoculation

Variety	Number of leaves	Diff. (no. leaves)	Significance
KSP 1	4.89	-1.35	ns
DK 19/1	8.00	1.76	*
DK19/2	5.55	-0.68	ns
DCh 19/3	6.78	0.55	ns
DK 19/4	6.56	0.32	ns
DK 19/5	5.63	-0.60	ns
Average (Ct)	6.24	-	-

LSD 5% = 1.67 leaves; 1%= 2.37 leaves; 0.5% = 3.43 leaves.

The analysis of plantlet height (Table 5) belonging to the 6 genotypes studied, compared to their average (4.70 cm), shows the DK 19/1 variety with a lower behavior, registering a significant negative difference (-0.94 cm). The Dch 19/3 variety obtained the highest plantlet height (5.47 cm), but with an insignificant difference.
The analysis of the weight (Table 6) of the sweet potato root, freshly sampled, shows the variety DCh 19/3, with a significant positive difference (0.083 g).

Table 5. Influence of sweet potato varieties on plantlet height (cm), 6 weeks after inoculation

Variety	Number of shoots	Diff. (no. Shoots)	Significance
KSP 1	3.78	-1.76	o
DK 19/1	7.00	1.46	ns
DK19/2	5.00	-0.54	ns
DCh 19/3	6.00	0.46	ns
DK 19/4	5.78	0.24	ns
DK 19/5	5.67	0.13	ns
Average (Ct)	5.54	-	-

LSD 5% = 0.028 g; 1%= 0.039 g; 0.1%= 0.057 g.

Table 6. Influence of sweet potato varieties on fresh plantlet root weight (g), 6 weeks after inoculation

Variety	Plantlets height (cm)	Diff. (cm)	Significance
KSP 1	4.56	-0.14	ns
DK 19/1	3.76	-0.94	o
DK19/2	4.22	-0.47	ns
DCh 19/3	5.47	0.77	ns
DK 19/4	5.17	0.47	ns
DK 19/5	5.00	0.31	ns
Average (Ct)	4.70	-	-

LSD 5% = 0.93 cm; 1%= 1.32 cm; 0.1%= 1.90 cm.

CONCLUSIONS

The results presented in this study highlight the possibility of obtaining sweet potato shoots and in laboratory conditions, throughout the year, with minimal costs. By the conventional method from a shoot of 30-35 cm a single rooted plant is obtained, by the micropropagation method 7-8 plantlets can be obtained.
The *in vitro* cultivation technique can be successfully applied in the case of sweet potatoes, using shoots as a source of explants, allowing to obtain in a short time a stock of initially healthy material, which can be used as planting material.

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Asclepias syriaca A NEW SEGETAL SPECIES IN ROMANIA

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Abstract

The purpose of this study was to report the presence of Asclepias syriaca in agroecosystems in Romania. The species Asclepias syriaca L. is part of the Apocynaceae or Asclepiadaceae family, since 2018, it has been observed in corn culture, in western part of Romania. The study was conducted in 2019-2021, in eight counties (Alba, Arad, Caraş-Severin, Mureş, Sibiu, Satu-Mare, Sibiu, Timiş) in May-August. The species Asclepias syriaca was present in seven counties (Alba, Arad, Mureş, Sibiu, Satu - Mare, Sibiu, Timiş), both in the plain areas (77 m altitude) and in the hills area (412 m altitude). The study carried out in Romania showed that the species is present in the agroecosystems of: corn, alfalfa, sunflower, wheat, soybean. Up to date, there are no studies in Europe that indicate the presence of Asclepias syriaca in the sunflower agroecosystem. We consider that this species, which is classified by EPPO as an invasive species for Europe, will become a weed problem for Romanian crops, due to its strong competitive capacity, due to the rhizomatic root system and the plant's property to produce allelopathic substances.

Key words*: Asclepias syriaca, reporting, crop, area.*

INTRODUCTION

Beeswax (*Asclepias syriaca* L.) is an invasive species in Romania (Sîrbu et al., 2021, Urziceanu et al., 2021), this being in the last 10 years in continuous expansion. The species is native to North America (Bakacsy, 2019). Taxonomically the species *Asclepias syriaca* is classified in: Dicotyledons, Order: *Gentianales*, Family: *Apocynaceae*. The genus *Asclepias* comprises about 140 species. The species is currently found on the continents: America and Europe (EPPO, 2022). According to the CABI database, it is also present on the Asian continent (https://www.cabi.org/isc/datasheet/7 2 49# toDistri butionMaps).

In Europe, *Asclepias syriaca* was introduced as an ornamental plant in the 17th century (Bagi 2008; Rothmaler 2008; Follak et al., 2021). With its introduction in Europe, the species became subspontaneous, being found in various habitats and in larger areas.

Currently the species has been reported in 27 European countries: Belgium, the Netherlands (Verloove, 2020), France (EPPO, 2022), Switzerland (EPPO, 2022), Italy (Brundu et al. 2020), Germany (Nehring and Skowronek, 2017), Poland (Tokarska-Guzik et al., 2018; Zając, 2019), Austria (Follak et al., 2018), Czech Republic (Kaplan et al., 2017), Slovakia (Mártonfi et al., 2014), Hungary, (Bartha et al., 2015), Bulgaria (Vladimirov and Georgiev 2019), Ukraine (Dvirna, 2018), Romania (Zimmermann et al. 2015, Sîrbu and Oprea, 2011), Slovenia (EPPO, 2022), Croatia (Boršić et al., 2018), Serbia (Vrbničanin et al., 2008), Bosnia and Herzegovina (Maslo, 2016), Montenegro (EPPO, 2022), Lithuania (Gudžinskas et al., 2018), Latvia (Nāburga and Evarts-Bunders, 2019), Sweden (EPPO, 2022), Russia (Smekalova, 2008), Belarus (EPPO, 2022), Denmark (Miljøstyrelsen, 2018), Moldova (EPPO, 2022), Spain (EP PO, 2022).

The distribution of *Asclepias syriaca* in European countries is favoured by its ability to adapt to different climatic and edaphic conditions, it can infest soils of any texture, but most often occurs on well-drained, light-textured soils (Bhowmik and Bandeen, 1976).

Currently the species is found in the List of Invasive Alien Species of Union Concern in 2017 (European Commissions, 2017).

The main characteristics of the plant are milky sap (latex), papule seeds, rhizome propagation

(Bhowmik, 1994; Dvirna, 2018; Follak et al., 2021) and allelopathic substances (asclepiadin, sitoserol, quercetin and nicotine) (Kazinczi et al., 1998). These characteristics were decisive in approaching the studies related to this species, so that in the scientifical papers we will find studies on the positive and negative economic impact.

Studies by Gaertner (1979) and Small (2015) provide information on the industrial and pharmaceutical potential of *Asclepias syriaca*. The latex present in the stem can be used for the rubber tires industry, the flowers are harvested by bees for honey, the fibers in the stem suitable for making paper, the seed doll, being light and waterproof, can be used for protective clothing, the flowers are a source of sugar, which together with lemon can be used for making wine. The species can also be seen as a source of biofuel (Follak et al., 2021).

In Europe, the species has been cultivated for ornamental purposes as well as for beekeeping, *Asclepias syriaca* flowers being an important source of nectar for bees (Bagi, 2008).

In respect of the negative economic impact produced by *Asclepias syriaca*, 3 directions are approached:

Negative impact on biodiversity and ecosystem functionality. *Asclepias* syriaca due to its morphological characteristics and allelopathic potential has managed to spread widely in semi-natural habitats, and for valuable natural ones (protected areas) represent a threat of invasion (Bakacsy, 2019). In semi-natural meadows, *Asclepias syriaca* has slowed down and mitigates their regeneration processes. At the level of native species, this may lead to a reduction in the size of height, Bakacsy (2019). The presence of the species in ecosystems can lead to a decrease in the diversity of some spider species and soil nematodes (Jurová et al., 2019).

Negative impact on health

Asclepias syriaca contains cardioactive steroids, especially asclepiadin, gomfoside, and afrozide (Simpson et al., 2013). The whole plant is toxic, but fruits and seeds contain the most toxic substances. Poisoning in humans is rare, but has been reported (Simpson et al., 2013).

An intoxication report in cattle has been issued in Hungary following the ingestion of large amounts of *Asclepias syriaca* (Sályi and Petri 1987, cited by Follak, 2021).

Negative impact on agriculture

In its native area, *Asclepias syriaca* is found in many crops, it is commonly found in crops like corn, soybeans, wheat, alfalfa (Follak et al., 2021).

In Europe, *Asclepias syriaca* has emerged locally as a weed in field crops (corn, soybeans, cereals, legumes), orchards and vineyards (abandoned) (Follak, 2018a), Slovakia (Pauková et al. 2013, 2014), Czech Republic (Kaplan et al., 2017) and Serbia (Vrbničanin et al., 2008).

In Europe, there are no studies on crop losses caused by *Asclepias syriaca*. Research into production losses is only being conducted in America. For example, at a density of 12 *Asclepias syriaca* plants per m² in spring wheat, caused a loss of 47% of the crop. In sorghum crop, can reduce the yield by 18-30%, in soybean crop by 12-19%, and in corn by 2-10% (Cramer and Burnside, 1982).

Asclepias syriaca is an intermediate host plant for various crop viral diseases and harmful insects (Bhowmik, 1994; Bagi, 2008; Ștef, 2021; Fericean, 2017).

Worldwide, agricultural systems are under the pressure of climate change (Lazu et al., 2019) affecting directly corp production and indirectly the relationship of weeds, payhogens and pests with plants, bringing new challenges for both breeders and farmers în order to face yeld losses and avoid alteration of natural landscape vegetation (Paraschivu et al., 2021; Durău et al., 2021).

Asclepias syriaca, being a new species for agroecosystems in Romania, we intend to identify the crops in which it settled and to know some morphological characteristics in order to establish control methods.

MATERIALS AND METHODS

Establishing agroecosystems

Studies on the presence of *Asclepias syriaca* in the agroecosystem took place between 2019-2021. To signal the species *Asclepias syriaca*, trips were made to the counties: Alba, Arad, Caras-Severin, Hunedoara, Mehedinți, Mureș, Sibiu, Satu Mare, Timiș (Figure 1). The route used to observe the species *Asclepias syriaca* was between 77 m (Uivar - Timiș) and 412 m (Botorca - Mureș) altitude.

Figure 1. Study area

The climate of the sites where the observations were performed is temperate continental, both in terms of temperature (7.5-11.2°C) and rainfall (459-900 mm). The multiannual average temperatures and the amount of precipitation recorded at the study sites are as follows: 8.6°C and 600 mm Jidvei - Alba; 8.0°C and 542-570 mm Pănade - Cetatea de Baltă - Alba; 9.3°C and 550 mm Lunca Târnavei - Alba (https://judetul-alba.ro); 10.0°C and 565-600 mm Șeitin - Arad (Ștef and al., 2021); 10.6°C and 770.6 mm Iaz - Obreja - Glimboca - Jupa - Caras-Severin (https://www.Meteoromania.ro); 9.8°C and 688 mm Adămuș - Botorca - Cornești - Căpâlna de Jos - Mureș (Ștef și colab., 2021); 7.5°C și 707 mm Agârbiciu - Sibiu; 8.7°C and 627.8 mm Axente Sever - Sibiu (https://www.axentesever .ro); 8.6°C and 900 mm Copșa Mică - Copșa Sat - Sibiu; 8.6°C and 600-700 mm Mediaș - Târnava - Sibiu (Ștef and al., 2021); 10.0°C and 500-700 mm Resighea - Satu Mare; 10.95°C and 580 mm Cărpiniș - Timiș; 9-10°C and 623 mm Pădureni - Jebel - V. V. Delamarina - Timiș (http://primaria-padureni. ro); 10.9°C and 631 mm Ghiroda - Timiș (https://primariaghiroda.ro); 10.9°C and 631 mm Săcălaz - Timiș (https://pcdn.ro); 11.2°C and 459 mm Uivar - Timiș ; - 2°C-10°C and 625-750 mm Hunedoara (http://apmhd.anpm.ro/).
Altitude and angular coordinates were determined using GPS. The reported aspects were photographically illustrated.

Determining morphological characters

The plants that were subjected to morphological analysis were sampled from the corn agroecosystem from the Cărpiniș site, Timiș County. Morphological study consisted of investigating a sample of 30 plants. The following biological characteristics were determined: plant height; number of leaves/plants; petiole length; leaf length; the width of the leaf; number of inflorescences; the number of fruits.

The measurements were performed in August 2021. For the measurements, roulette (Figure 2) and graduated ruler were used.

The leaf area was determined by the formula:

SF = L x l x correction coefficient

Where:

SF - leaf surface; L - leaf length; l - the maximum width of the leaf; correction coefficient - 0.654

The data obtained were interpreted statistically through statistical indicators: mean, standard deviation, coefficient of variation.

Figure 2. Materials used in the study

RESULTS AND DISCUSSIONS

The results of the observations performed during the years (2019-2021) are shown in Table 1, it includes: counties, sites, altitude and agricultural crops in which the weed *Asclepias syriaca* was reported.

Of the eight counties studied, the species was reported in seven counties, it was not identified in the crop areas of Hunedoara county.

In the sites (AB-CeB, AB-Ji, AB-LuT, AB-Pa, CS-Gl, CS-Ob, CS-Ia, CS-Ju, MS-CaJ, MS-Co, MS-Ad, MS-Bo) from Alba, Caras-Severin, Mureș and Satu Mare counties, the species was found only in the corn agroecosystem (Figure 3).

Asclepias syriaca was identified, in Sibiu County, in corn (in the sites SB-Me, SB-CoM, SB-CoS, SB-Tâ, SB-Ag, SB-AxS), alfalfa (SB-Tâ) (Figure 4) and (wheat) stubble (SB-Tâ) (Figure 5).

In Timiș County, the greatest diversity of agroecosystems was identified (soybean (TM-

Ui), sunflower (TM-Ui) (Figure 6), corn (TM-Că, TM-Pă, TM-Gh, TM-Să,), stubble - wheat (TM – Je), stubble - barley (TM – VVDe)], where the invasive species *Asclepias syriaca* was present.

Table 1. Agroecosystems (crops) and sites where the species *Asclepias syriaca* has been reported

Country*	Sit**	Latitude	Longitude	Alt. (m)	Crops
AB	AB-CeB	46.234276°	24.200416°	316	*Zea mays* (maize)
	AB-Ji	46.229195°	24.080848°	267	*Zea mays* (maize)
	AB-LuT	46.218352°	23.971997°	254	*Zea mays* (maize)
	AB-Pa	46.222274°	23.964980°	247	*Zea mays (maize)*
AR	AR-Șe	6.118481°	20.856870°	96	*Medicago sativa* (Alfalfa)
CS	CS-Gl	45.489764°	22.308550°	231	*Zea mays* (maize)
	CS-Ob	45.484833°	22.286159°	217	*Zea mays* (maize)
	CS-Ia	45.476862°	22.241506°	198	*Zea mays* (maize)
	CS-Ju	45.464012°	22.184886°	181	*Zea mays* (maize)
MS	MS -CaJ	46.243007°	24.128583°	271	*Zea mays* (maize)
	MS- Co	46.277958°	24.203265°	314	*Zea mays* (maize)
	MS-Ad	46.312865°	24.280179°	286	*Zea mays* (maize)
	MS-Bo	46.262223°	24.302623°	412	*Zea mays* (maize)
SM	SM-Re	47.597443°	22.278754°	134	Zea mays (maize)
SB	SB-Me	46.140083°	24.312508°	330	*Zea mays* (maize)
	SB-CoM	46.119319°	24.273427°	308	*Zea mays* (maize)
	SB-CoS	46.121097°	24.258509°	284	*Zea mays* (maize)
	SB-Tâ	46.121578°	24.282171°	299	*Medicago sativa* (Alfalfa)
		46.120037°	24.277772°		*Triticum aestivum*
		46.120037°	24.277772°		*Zea mays* (maize)
	SB-Ag	46.065563°	24.188131°	305	*Zea mays* (maize)
	SB-AxS	46.077733°	24.203062°	300	*Zea mays* (maize)
TM	TM-Că	45.782127°	20.962170°	81	*Zea mays* (maize)
	TM-Pă	45.599624°	21.170175°	82	*Zea mays* (maize)
	TM-Je	45.594959°	21.171979°	82	*Triticum aestivum* (wheat)
	TM-Gh	45.793134°	21.326614°	96	*Zea mays* (maize)
	TM-Să	45.768427°	21.131055°	82	*Zea mays* (maize)
	TM – VVDe	45.635295°	21.876437°	151	*Hordeum vulgare* (barley)
	TM-Ui	45.599630°	21.170330°	77	*Helianthus annuus* (sunflower)
		45.657244°	20.872785°	76	*Glycine max* (soybean)

Abbreviations: *AB – Alba; AR-Arad; CS – Caras-Severin; MS - Mureș; SM – Satu Mare; SB – Sibiu; TM - Timiș; ** CeB - Cetatea de Baltă; Ji – Jidvei; LuT - Lunca Târnavei; Pa – Pănade; ȘE - Șeitin; Gl – Glimboca; Ob – Obreja; Ia – Iaz; Ju – Jupa; CaJ – Căpâlna de Jos; Co - Cornești; Ad - Adămuș; Bo – Botorca; Re – Resighea; Me - Mediaș; CoM - Copșa Mică; CoS - Copșa Sat; Tâ – Târnava; Ag – Agârbiciu; AxS - Axente Sever; Că - Cărpiniș; Pă – Pădureni; Je – Jebel; Gh – Ghiroda; Să – Săcălaz; VVDe - V. V. Delamarina; Ui – Uivar.

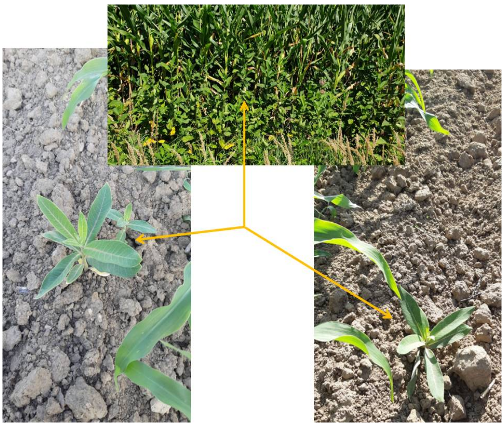

Figure 3. *Asclepias syriaca* in the corn agroecosystem

Figure 4. Asclepias syriaca in the alfalfa agroecosystem

Figure 5. Asclepias syriaca in stubble

Figure 6. Asclepias syriaca in the sunflower agroecosystem

Investigations have shown that the species is present in patches in agricultural crops. *Asclepias syriaca*, in most sites, is present in the crop, at the edge, dough there are areas where appear in the middle of the agroecosystem (Figure 7).

Figure 7. *Asclepias syriaca* installed inside crops (TM-Gh, TM-Ui)

It should be mentioned that the species *Asclepias syriaca* is present in Romania, since 1836 (first report), being introduced as an ornamental species (Urziceanu et al., 2020). In 1939, the species has been found spontaneously in some areas (Țopa, 1947 quoted by Sirbu and Oprea, 2011, Sîrbu et al., 2021).

Figure 8. Habitats invaded by *Asclepias syriaca* in România: (a) roadside, (b) and (c) agricultural crops (maize and alfalfa), (d) forest edge, (e) lake shore (f) irrigation canal edge, (g) meadows (Photos: Arsene G.G. (d, e, f, g,) and Ștef R (a, b, c)

Asclepias syriaca being adapted to a wide range of climatic and edaphic conditions can persist in many habitats (Bhowmik, 1994). In North America, *Asclepias syriaca* colonizes prairies and alluvial areas, meadows, fields, roadsides, and railroads (Woodson 1954; Cramer and Burnside, 1982 cited by Follak et al., 2021). In Europe, the habitats occupied by *Asclepias syriaca* are abandoned agricultural and viticultural lands, wet and dry meadows, the edge of dams, forests, poplar and pine plantations (Csiszár and Korda, 2017; Gudžinskas et al., 2018; Jarić et al., 2011; Follak et al., 2018; Szatmári et al., 2016). In Romania, the species occupies natural, semi-natural and artificial habitats (Figure 8).

Up to date, the species has been reported to be present in natural and semi-natural habitats in 14 counties (Table 2). Observations performed in the frame of this study (2019-2021) revealed that the species is present in artificial habitats (agricultural crops) in seven counties, six of which are found in the reports in Table 2. In the literature data on the reporting of *Asclepias syriaca*, Alba County lacks natural and semi-natural habitats. Another difference between the two reports refers to the presence of *Asclepias syriaca* in Hunedoara County, although the species is mentioned as being present in natural habitat (Kovács and Pálfalvi, 2012) it seems that it has not yet settled in agroecosystems.

Table 2. Reporting of the species *Aclepias syriaca* in Romania (2000-2022)

Country	Site	Reporting years	Reference
AR	Păuliș	2012	Turcuș and Daraban, 2013
	Vladimirescu	2012	
	Felnac	2012	
	Pecica	2017-2019	Sărăţeanu et al. 2020
BC	Ghimeș	2002-2005	Kovács and Pálfalvi, 2012
BH	Sânmartin	2002-2005	Kovács and Pálfalvi, 2012
BV	Piatra Craiului Natural Park	2005-2010	Pop et al., 2011
DJ	Rastu Vechi	2012	Răduţoiu and Stan, 2013
	Calafat	2000 -2004	Ilie et all., 2018
HD	Geoagiu	2002-2005	Kovács and Pálfalvi, 2012
HR	Tudeni	2002-2005	Kovács and Pálfalvi, 2012
	Rugănești	2002-2005	Kovács and Pálfalvi, 2012
	Dejuțiu	2002-2005	Kovács and Pálfalvi, 2012
	Porumbenii Mari	2002-2005	Kovács and Pálfalvi, 2012
	Ulcani	2002-2005	Kovács and Pálfalvi, 2012
	Atid	2002-2005	Kovács and Pálfalvi, 2012
	Firtănuș	2002-2005	Kovács and Pálfalvi, 2012
	Medișoru Mic	2002-2005	Kovács and Pálfalvi, 2012
MH	Cireşu	2010	Negrean and Ciortan, 2014
MS	Sighişoara	2012	Öllerer (cited by Sîrbu et al, 2021)
		2000-2005	Zimmermann et al., 2015
		2000-2004	Sămărghiţan et al., 2018
	Roteni	2004	Negrean et al. 2017
	Gălățeni	2004	Negrean et al. 2017
SB	Târnava Mare	2017	Sămărghiţan et al., 2018
	Copșa Mică	2010	Bolea et all., 2010
	Dumbrăveni	2002-2005	Kovács J.A., Pálfalvi P., 2012
	Mediaș	2002-2005	Kovács and Pálfalvi, 2012
SJ	Căpâlna	2015	Negrean et al. 2017
	Cristolț	2016	Negrean et al. 2017
	Văleni	2016	Negrean et al. 2017
	Marin NE	2016	Negrean et al. 2017
	Crișeni	2002-2005	Kovács J.A., Pálfalvi P., 2012
	Sărmășag	2016	Negrean et al. 2017
	Cehei	2013	Karácsonyi and Negrean, 2013
SM	Carei Plain protected area	2010-2011	Szatmari, 2012
TL	Danube Delta – Sulina	2011	Anastasiu (cited by Sîrbu,2021)
TM	Satchinez	2005-2011	Otves et al., 2014
	Sânandrei	2017-2018	Cucu et al., 2019
	Surduc	2004-2017	Neacșu et al.,2017
	Pișchia	2005-2006	Neacșu et al.,2007
	Cenad	2013	Turcuş et al., 2014
	Igriș	2012	Turcuș and Draban, 2013

Although in Europe, the species is present in 27 countries, so far there are few studies that indicate *Asclepias syriaca* at weed level. Data published so far show that the species has settled in field crops, vineyards and orchards in Austria, Slovakia, Czech Republic, Serbia, Bulgaria, Poland (Follak, 2018a; Pauková et al., 2013, 2014; Kaplan et al., 2017; Vrbničanin et al., 2008; Dolmagić, 2010).

Results on morphology characters

The analysis of *Asclepias syriaca* plants, harvested from the TM-Că site, showed that the leaves are opposite, elliptical, 16.6-26.5 cm long and 6.9-13 cm wide (Figure 9), population are homogeneous (cv - 10.42%), in terms of length and heterogenity in terms of width (cv - 41.44%) and leaf area (cv - 53.66%). These morphological features differ from the studies of Ujvárosi (1973), Bagi (2008), Gudžinskas et al. (2019). The determined length, in the present study proved to be higher than the values obtained by those mentioned above (7-20 cm; 10-20 cm), and the width proved to be less (5-15 cm, 5-11 cm).

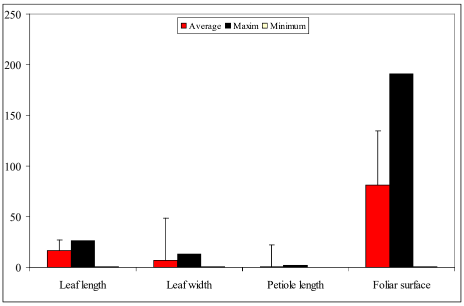

Figure 9. Biometrics of foliar characteristics within the population of *Asclepias syriaca*

The basal leaves of the plant are lighter green, and those on the upper canopy are darker green. The leaves have densely hairy on the underside (Figure 10).

Figure 10. *Asclepias syriaca* leaves

The leaves are inserted on the stem through a short petiole of 0.1 mm - 1.8 mm, with cv – 21,13%. The length of the petiole differs from those mentioned by Gudžinskas et al. (2019). The number of leaves per plant varied between 18-42, the variability low (21.75%).

The stem of *Asclepias syriaca* is erect, robust, hairy, green to purple, generally unbranched, according to the literature, but in the present study we also found specimens that showed branches, from 20-40 cm above the ground. *Asclepias syriaca*, from the corn agroecosystem, grew up to 150 cm. In terms of size, the population of *Asclepias syriaca* is homogeneous, the variation coefficient being 18.95% (Figure 11).

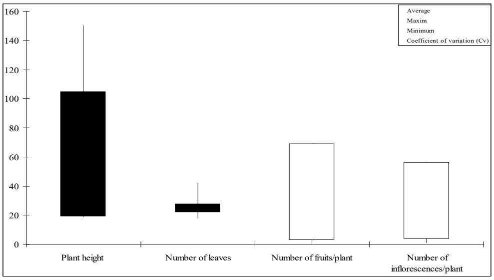

Figure 11. Results on the biometrics of the morphological characters within the population of *Asclepias syriaca*

The population of *Asclepias syriaca*, from Lithuania, analyzed by Gudžinskas et al. (2019), exerted a lower average waist (95.7 cm) compared to Romania. Results like those in Romania, in terms of the size of beeswax plants, were recorded in Hungary (Bagi, 2008).

The fruit produced by *Asclepias syriaca* is a capsule (Figure 12), the plants from the analyzed population presented 0-8 capsules/ plant, the dimensions reached were 6-11.5 cm, the number of seeds was 131-280.

They have a long white papus (Figure 13), which appears in large follicles (Bagi, 2008; Petrova et al., 2013; Tokarska-Guzik et al., 2015) which propagates species along with rhizomatic roots. The number of inflorescences and fruits showed a high coefficient of variation of 56.4% and 68.99%, respectively, which indicates that the population has a high heterogeneity (Figure 11).

On a beeswax plant, between 1 and 8 umbels were found (Figure 11), but not all of them end up bearing fruit. The flowers are fragrant, nectariferous grouped in umbellate tops, pink - reddish (Figure 14).

Figure 12. Fruit of *Asclepias syriaca*

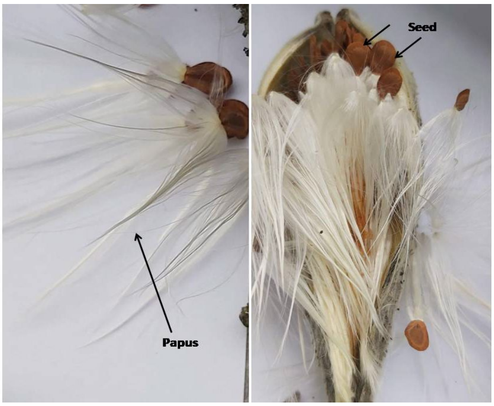

Figure 13. Seed and papus of *Asclepias syriaca*

The *Asclepias syriaca* plants, harvested from the TM-Că site, produced an average of 3.67 inflorescences/plant (Figure 11).

Figure 14. Inflorescences (umbellate tops) and individual flowers of *Asclepias syriaca*

In its native habitat in Washington state (USA), *Asclepias* sprouts produced 2-7 inflorescences (average 5) (Finer and Morgan 2003). In Lithuania the population studied by Gudžinskas et al. (2019) presented an average number of inflorescences of 3.4/plant (with minimums and maximums between 2-5). The average number of inflorescences in the population of *Asclepias syriaca* in Europe is lower than in the USA, the country of origin. These differences could be influenced by the climatic and ecological conditions of the habitats, as well as by the different angular coordinates (Romania - 45.78.21'N, Lithuania 54°28.51'N, Washington USA - 47°25.43'N).

CONCLUSIONS

The species *Asclepias syriaca* is expanding on the Romanian territory, settling in more and more agroecosystems. The observations made highlighted the presence of the species *Asclepias syriaca* in 7 counties out of the 8 studied. The species is present both in the plain area (77 m altitude) and in the hilly area (412 m altitude). We believe that studies should continue because this species will become a weed problem for Romanian crops, due to its strong competitive capacity, rhizomatic root system and the property of the plant to produce allelopathic substances.

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INFLUENCE OF OPERATING TEMPERATURE AND FUEL CONSUMPTION ON ADBLUE® CONSUMPTION DURING SOWING OF SILAGE CORN

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Abstract

The study is based on a Polish experiment (2021) in the territory of the Plovdiv region in the central part of the Republic of Bulgaria. The study was conducted with a nine-meter precision seed drill, aggregated to a 302 kW tractor when sowing silage corn. Using the service diagnostic program, graphic dependences describing the consumption of AdBlue® in relation to the operating temperature and the consumed diesel fuel have been extracted. Factors influencing AdBlue® consumption were monitored: operating temperature, diesel quality, and tractor engine load. It has been found that any drop in temperature, whether influenced by external factors or by the tractor engine, appears to be a determining factor for AdBlue® dosing. The consumption of AdBlue® for 8 hours of working change of the machine-tractor unit was monitored and it was found that the consumed amount of liquid reagent is 37.5% of the entire tank and the consumption of diesel fuel is 68.75%.

Key words: *sowing unit, silage corn sowing, service diagnostic program, fuel consumption, AdBlue® consumption*

INTRODUCTION

The impact of car traffic on local air quality is a global problem. This requires the industry to focus on improving key technologies in vehicles (cars, tractors, trucks, etc.) and fuels, reducing emissions through traffic management, and seeking improvements through the application of advanced systems and modified emission control software. (Jääskeläinen, 2007; Auld et al., 2017; Laurikko et al., 2020; Komitov, 2020). In recent decades, tighter regulations on exhaust emissions have dominated the automotive industry and encouraged manufacturers to innovate (Giakoumis et al., 2012). They are developing the Selective Catalytic Reduction (SCR) system, which has different names according to the manufacturers: BlueTEC, *AdBlue*, DeNOxtronic, and others. These systems consist of the following main components: a particulate filter, a *NOx* catalytic converter, an engine control unit, and an *AdBlue* fluid reservoir (Frandsen, 2018; Demir et al., 2022). They remove up to 98% of the NOx produced. Fleedguard, 2016 defines SCR as a technology that uses urea-based diesel exhaust fluid (known as *AdBlue* or DEF) and a catalytic converter to significantly reduce nitrogen oxide (*NOx*) emissions. *AdBlue* is the reagent needed for the SCR system to function. *AdBlue* is an aqueous solution of urea with 32.5%, synthetic urea, and 67.5% deionized water. *AdBlue* consumption needs to be about 5% of the consumed diesel fuel (4-6% range depending on the application conditions). With 5% of the diesel consumed, the fuel to *AdBlue* ratio is 20 to 1. With 100 liters of diesel consumed, approximately 5 liters is the expected consumption of *AdBlue*. If the average fuel consumption of the vehicle is known, then *AdBlue* consumption can be easily calculated. A number of authors are looking for solutions to reduce NOx emissions (Str¨om et al., 2009; Liao et al., 2015; Arnaudova et al. 2020; Fontanarosa et al., 2021; Demir et al., 2022). Lambert et al., 2001 performed tests to monitor diesel fuel economy and investigate the efficiency of the (SCR) system at higher exhaust temperatures. In a study by Demir et al., 2022, they examined the effects of commercial *AdBlue*, urea-pure water, and urea-pure water-citric acid mixtures as additives to diesel fuel on exhaust emissions and diesel single-cylinder performance.

MATERIALS AND METHODS

The study was conducted in the spring of 2021 in the Plovdiv region, central Bulgaria. The soil type is leached chernozem resin. The experiments were performed on a field with an area of 108,2 ha shown in Figure 1. The slope of the terrain is 2%.

Figure 1. The experimental field, Plovdiv region, Central Bulgaria

The study was conducted with seed drill for precision sowing *Amazone EDX 9000-TC*, mounted on a *Claas Axion 950* tractor shown in Figure 2. The crop sown in the experimental field is silage corn of Balasco variety with a sowing rate of 6600 *pcs/da*.

Figure 2. Machine-tractor unit consisting of Claas Axion 950 and Amazone EDX 9000-TC

During the operation of the machine-tractor unit, data on the consumption of *AdBlue*® in relation to the operating temperature and fuel consumption were extracted from the service diagnostic program of the tractor. The change of the reagent consumption during sowing at the most optimal speeds of the tractor engine was monitored. Of course, the consumption cannot be indicative of this field, as a number of other factors are affected: outdoor temperature, the movement of the sowing unit in the field, sowing quality, fuel consumption, and many other factors.
To accurately determine the consumption of urea, an individual study was performed for the studied parameter, excluding the influence of other factors during sowing.
In Figura 3 presents the system for reduction of the exhaust gases of the tractor participating in the study with European standard *Tier 4F* (Claas Axion, 2020).

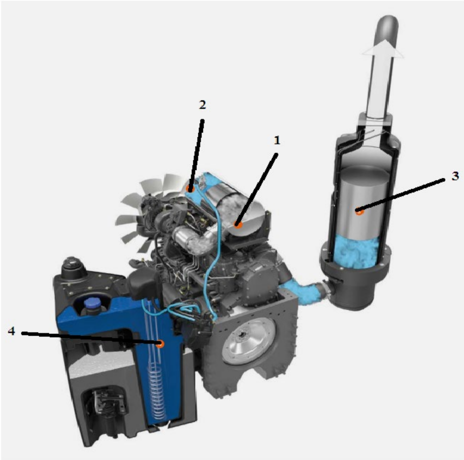

Figure 3. Tractor exhaust reduction system Claas Axion 900 with European standard Tier 4F: 1 - diesel oxidation catalyst (DOC); 2 - injection nozzle for urea; 3 - catalyst (CSR); 4 - heated urea tank

Despite the fact that the exhaust gas reduction systems of tractors work with a very small percentage of defects, farmers accept it with distrust. They define this system as inefficient, and as an additional cost. In the Republic of Bulgaria, the consumption of *AdBlue*® for tractors is more focused on protected machines in Western European countries. This is influenced by some external factors:
The sulfur content of diesel fuel according to European standards is accepted to be S < 15 mg/kg. In Bulgaria, this standard cannot be achieved, as fuels of dubious origin are often used at a lower price.

A sticker showing the sulfur content of diesel fuel is affixed to each new energy machine manufactured in Europe, Figure 4.

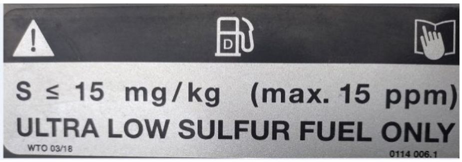

Figure 4. Information on the sulfur content in diesel fuel according to European standard

The content of urea in the aqueous solution for the preparation of the reagent is 32.5%. It is not in vain that it is reflected on all packages that the shelf life after opening is six months, but this is not always observed and is used after this period and the percentage of urea decreases. This in turn leads to less cleaning efficiency.
Another no less important factor is the maintenance and servicing of the system for reduction of exhaust gases from the engine after reaching the service interval.

RESULTS AND DISCUSSIONS

In Figure 5 presents the basic scheme of connecting the diagnostic program to the agricultural machine used in our study. The sequence of signal transmission from the tractor to the diagnostics, which is installed on a laptop, is indicated.

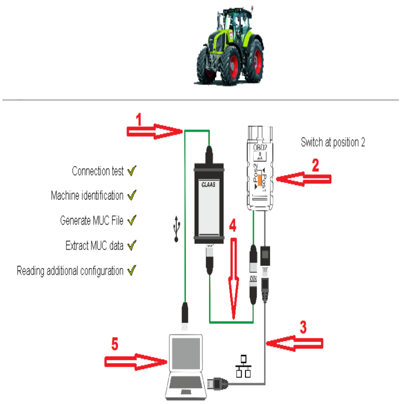

Figure 5. Schematic diagram of connecting the diagnostic program to the drill:
1 - CAN decoder; 2 - OBD socket for connection to the diagnostic terminal of the tractor; 3 - LAN transition; 4 - connecting bridge OBD → CAN; 5 - computer with diagnostic program

The figure shows the sequence of signal transmission from the tractor to the diagnostics, which is installed on the laptop. It recognizes the CAN decoder 1. Once it is recognized, it connects to the agricultural machine via the OBD socket for connection to the diagnostic terminal of the tractor 2 and starts the process of recognizing the ECU from the diagnostic program.
Electronic Calculator Unit/ECU/ as a general concept is an electronic controller, whose function is to monitor changes in the set parameters in its memory.
The information about the monitored parameters from the ECU comes from the sensors and sensors mounted on the components that are set to be monitored and after the corresponding processing information is received about the real-time operation in the form of graphs or numbers.
Any modern agricultural or harvesting machine that is equipped with an ECU can be connected to the service program and be diagnosed, programmed, replace damaged controllers or update the programs in the ECU with newer versions in order to quickly process information or implementation of new parameters.

1. Consumption of *AdBlue*® in relation to the operating temperature

Figure 6 shows graphically the consumption of *AdBlue*® in relation to the operating temperature in real production conditions of the sowing unit. From the data taken from the service diagnostic program, we find that the correctly selected engine speed of the tractor during the technological operation "sowing" affects the uniform consumption of *AdBlue*®.
The abscissa of the graph in Figure 6 shows the time, with each unit of the graph corresponding to a time in seconds. The ordinate of the graph shows the parameters: engine speed and temperature, data for *NOx* nitrogen oxides from the sensors at the input and output of the SCR, ie. before and after treatment with urea, and the amount of urea injected. Each parameter is reflected in the figure with colored lines. A red line shows the set engine speed of the tractor. They are set in the *Cebis* control terminal together with the actual operating speed that we need to maintain. The purple line shows the

temperature of the exhaust gases coming from the tractor engine into the SCR, ie. the flue gas treatment area. The orange line shows the data from *NOx* nitrogen oxides and the SCR inlet and outlet sensor before urea treatment, and the green line shows the data after urea treatment. The blue line shows the cost of *AdBlue*® during the operation of the sowing unit.

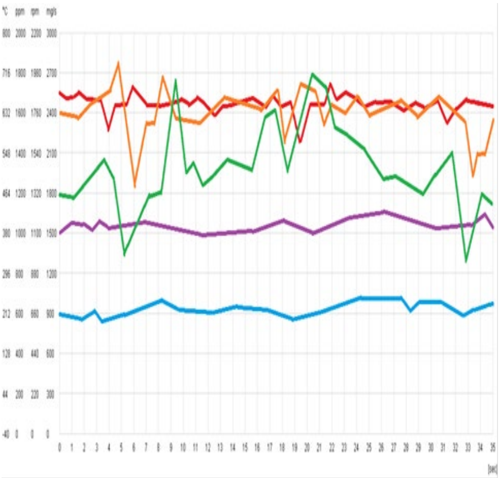

Figure 6. Influence of *AdBlue*® consumption on operating temperature

Figure 6 shows that the smooth operation of the sowing unit maintains a constant consumption of *AdBlue*®. The peak torques of the tractor engine are kept to a minimum.

The values of nitrogen oxides *NOx* at the input and output of *SCR* are a determining factor for the dosing of *AdBlue*® in the system. Although peak periods are observed on the chart, *AdBlue*® dosing remains unchanged. This is due to the period during which the data were collected. It does not affect the overall determination of the reagent dose, but it is determined by an individual algorithm, taking data for a longer cycle of time.

Another parameter shown in Figure 3 is the exhaust gas temperature in the *SCR*. It appears to be the determining factor. The process of flue gas treatment with *AdBlue*® becomes feasible at an optimum temperature of about 3600°*C*. In conclusion, it can be noted that any drop in temperature, regardless of whether it is influenced by external factors or engine performance is the determining factor for dosing.

2. *AdBlue*® fuel consumption versus fuel consumption

Figure 7 graphically presents the consumption of *AdBlue*® compared to the consumption of diesel fuel in real production conditions of the sowing unit.

The abscissa of the graph also shows the time, with each unit of the graph corresponding to a time in seconds. According to the ordinate of the graph, three parameters are presented: tractor engine speed (min^{-1}), diesel fuel consumption (l/h), and *AdBlue*® consumption (mg/s). The red line shows the engine speed of the sowing unit. The green line shows the consumption of diesel fuel, and the blue line shows the consumption of *AdBlue*®.

Diesel fuel consumption is an extremely important indicator of the urea consumption rate. Higher fuel consumption leads to higher temperatures in SCR and more concentrated gases in nitrogen oxides *NOx*. In SCR, nitrogen oxides are converted to water and pure nitrogen by means of the synthetic aqueous urea solution (*AdBlue*®), which is added to the tractor's auxiliary tank.

Despite slight fluctuations in fuel consumption, we note that urea consumption remains almost unchanged. This is due to the correctly selected engine speed of the tractor, the maintenance of a constant actual working speed of the sowing unit, the constant temperature in the SCR, and last but not least the amount of diesel fuel consumed.

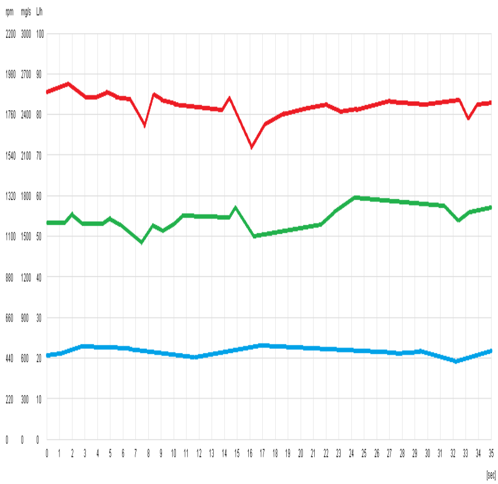

Figure 7. Effect of *AdBlue*® consumption on fuel consumption

From the data in Figure 7, we can summarize that theoretically the consumption of urea is considered satisfactory if the ratio is one to two (1:2). Virtually, it is considered that one *AdBlue*® tank is necessary to supply two tanks of diesel fuel to the tractor. In case of incorrect dosing of the reagent in the system and obtaining large differences, we find that there is a problem that must be resolved. From the obtained values reflected in the graph for the consumed amount of diesel fuel and *AdBlue*® at the time of the study during sowing, we determine the ratio in the following sequence:
After converting the average values for *AdBlue*® injection shown in Figure 4, we obtain 2.59 l/h x 8 h = 21 liters of *AdBlue*® for one working change of the unit. From the manufacturer of the tractor, we have data on the capacity of the reagent tank, which is 56 l. From there we determine its percentage ratio to the amount of reagent consumed for 8 hours of operation of the machine-tractor unit and we get:

$$21\ l / 56\ l = 37.5\% \quad (1)$$

From the technical data for the tractor, the fuel tank is 640 liters. According to data from Figure 4, we calculate the consumption of diesel for 8 *h* of operation of the machine-tractor unit, obtaining an average of 55 l/h x 8 h = 440 liters. Therefore, we also determine the percentage of diesel fuel in the tank in relation to the amount of fuel consumed:

$$440\ l / 640\ l = 68.75\% \quad (2)$$

After calculating the percentage of *AdBlue*® consumed and the amount of diesel consumed, we divide the two ratios and get:

$$37.5\% / 68.75\% = 1.83 \quad (3)$$

From (3) we find that the ratio of the amount of reagent consumed to the consumed diesel fuel is obtained (1:2), i.e. one *AdBlue*® tank will supply two diesel tanks to the tractor.

CONCLUSIONS

As a result of the study, the following conclusions can be drawn: (i) using the data from the service diagnostic program, the consumption of *AdBlue*® in relation to the operating temperature, and the consumed diesel fuel has been determined; (ii) the factors influencing the *AdBlue*® consumption have been found to be: operating temperature, diesel quality and tractor engine load; (iii) *AdBlue*® consumption calculations show that one reagent tank can supply two tanks of the diesel tractor. These data fully meet the parameters set by the manufacturer.

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FIRST RESULTS REGARDING RELATION BETWEEN GIBBERELLINS AND OTHER GROWTH HORMONES IN MICROPOPAGATION PROTOCOLS OF TWO ECONOMICALLY IMPORTANT SPECIES: *Solanum tuberosum* and *Ipomoea batatas*

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Abstract

Potato is the world's most important non-cereal food crop, one of the major sources for humankind food. Conventional propagation asexual by tubers, can disseminate pathogens to new cultivation areas which can threatens the maintenance of genotypes of these specie. Ipomoea batatas as well, is a hard climate conditions plant, with a major role in food worldwide battle and have similar response to viruses or diseases In this work we analyzed varieties of Ipomoea batatas, 'Ro-Ch-M', 'KSH' and 'KSP1', two varieties of Solanum tuberosum L. with purple flesh, 'Violet Queen' and 'Purple Majesty'. The stydy compare the influences of gibberellic acid GA3, along with another two hormones, cytokinins (6-benzylaminopurine BAP), and α-naphthaleneacetic acid (NAA), the culture duration and response to tuberization of those varieties. Optimal proliferation was observed when shoots were cultured on MS medium that was supplemented with 1.5 mg/L GA3 and a variation of another two hormones. In this medium, the greatest number of shoots (4.1) and total number of nodes (12.2) per explant were observed.

***Key words**: auxins, cytokinins, gibberellins, Ipomoea batatas, micropropagation, Solanum tuberosum.*

INTRODUCTION

Roots and tubers are an important source of food, nutrition and income for a large part of the worlds (Diaconu et al., 2018). Potato (*Solanum tuberosum* L.) is a crop of high biological value for its amount of vitamins, minerals trace elements and valuable protein (Fiergert et al., 2000). It is the fourth most cultivated food crop exceeded only by wheat, rice, and maize (Zaheer et al., 2016). The edible part of potato is the tuber, which is used as cheap food, industrial raw material, animal feed, and seed tuber for crop production.

Sweet potato is considered the seventh most important food crop in the world and is ranked fourth in developing countries (FAO, 1997). It is cultivated in more than 100 countries (Gastelo et al., 2014) as a valuable source of food for humans, animals and industrial raw material (Devaux et al., 2021). However, pests and viral diseases prevent the crop from reaching its maximum agricultural potential.

Viruses and shortage of good quality seeds limiting potato and sweet potato production, and that why tissue culture techniques are an alternative of vegetative plant propagation for those two species (Zine et al., 2008). Potato micropropagation methods are used on large scale now due to plant capacity of multi-plication on culture medium supplemented with hormones. That allows multiplication on large scale of asexual virus free plants. The potato plants are multiplied with a range of different techniques, such as nodal segments apex culture or meristem culture and hormonal and nutritional composition of media promotes rapid development of new plantlets (Murphy, 2003)

Diseases like bacterial wilt, scab, anthracnose, stem and root rot are the common challenges in sweet potato multiplication, and that why micropropagation is the most potential technique to achieve the goals of quality virus free planting material (Dewir et al., 2020).

Gibberellins commonly known as gibberellic acids first appear in 1950s, but they had been discovered much earlier in Japanese rice culture (Jones et al., 1994). In 1950s scientists of Tokyo University identify and stabilized 3 different gibberellins, gibberellin A1, gibberellin A2 and gibberellin A3 and nowadays we use in plant micropropagation especially GA3 (Lang, 1970). Gibberellic acid has been reported to inhibit meristematic grows in tobacco or enhanced the grows if the cassava (*Manihot esculenta*) callus culture derived from medium contain GA in addition to N6-benzylamionopurine (BAP) (Jansson et al., 2009). Gibberellins are involved in a wide range of plant responses, include promotion of elongation in stems and grass leaves, induction of hydrolytic enzymes such as α-amylase and protease facilitating endosperm mobilisation in grass and cereals, or promote seed germination, sex determination, fruit development and juvenility control (Salem and Hassanein, 2017). Addition of growth regulators to the culture media has been reported to improve the growth and development of shoots (Rabbani et al., 2001), though they are genotype dependant. Using higher concentrations of GA3 supplemented with 1-naphthaleneacetic acid (NAA) and vitamins has increase number of nodes (Zaman et al., 2007). Rabbani (2001) recommended the use of higher concentrations of GA3, supplemented with other phytohormones like NAA/BAP and vitamins in order to increase the multiplication capacity of potato. For a rapid multiplication addition of GA3 to MS media is shown improving explants growth and shoots development (Muller & Lipschutz, 1984). Since each hormone has it's unique signal on regeneration (Vreugdenhil et al., 2007), it's important to determine the combined effects of these on *in vitro* regenerative processes. Even GA is essential in adventitious shoots starting with various *in vitro* culture types like potato discs, meristem culture or shoots (Vinterhalter et al., 1997), the exact role of this hormone in shoot formation process is not fully determined yet (Ehsanpour & Jones, 2000).

MATERIALS AND METHODS

1. **Plant material and study area**

Two *Solanum tuberosum* purple cultivars, 'Violet queen' and 'Purple majesty' and three *Ipomoea batatas* cultivars, 'RO-CH-M', 'KSP-1' and 'KSH' were analysed.

Solanum tuberosum 'Violet queen' (previous 'Hot Purple') - a potato with deep purple skin and high concentration of anthocyanins and flesh descended from ancient Peruvian varieties. Originated from a cross made in 2000 between the selection designated 'VG3CAE 5' as the female parent and 'Charmante' as the male parent at the HZPC 'Research & Development Centre' in Metslawier, The Netherlands.

Solanum tuberosum 'Purple majesty'- Peruvian cultivar, probably the most intensely from all purple potatoes. The origin of 'Purple Majesty' (experimental designation CO94165-3P/P) is the result of the cross made in 1994 between 'All Blue'

Figure 1. *Solanum tuberosum* 'Violet queen'

and ND2008-2 at the San Luis Valley Research Centre, Colorado State University; it is a beautiful purple colour potato with exceptional flavour and texture. Is an early-maturing potato variety that is typically ready to harvest in 85-90 days after planting.

Ipomoea batatas - 'KSP-1', matures in 3.5-4 month, well grow in sandy soil of 'Research and Development Station for Plant Culture on Sands Dabuleni', Romania, being drought-resistant with vigorous growth and high productivity (Draghici, 2018).

2. **Micropropagation**

For *Solanum tuberosum* 'Violet Queen', explants were initial cultivated from flesh biological material, on MS medium without hormones for 3 months with 3 sub cultivations in order to obtain diseases free explants (Figure 1).

Figure 2. *Solanum tuberosum* 'Purple Majesty'

After primary sterilization (fungal decontamination with Aliette 80WG, 0.4% for 20 minutes), the explants were treated with 70% ethanol for 35 seconds, rinsed with sterile distilled water, dipped in 0.2 mg/l $HgCl_2$ (mercuric chloride) for 4.5 minute and washed for 4 times with sterilised distilled water.

For *Solanum tuberosum* 'Purple majesty', explants were generated from *in vitro* stabile culture, multiplicated and conserved on MS medium without hormones for over 6 months (Figure 2).

For *Ipomoea batatas* 'KSP-1' cultivar, tests were started with sterile unimodal segments obtain form rooted shoots in vitro cultivated on MS medium without hormones (Figure 3).

Figure 3. *Ipomoea batatas* 'KSP-1'

KSP-1 culture were stared with nodal segments, immersed in 0.4% Aliette 80WG for 10 minutes, rinsed with distilled water, treated for 20 seconds with 70% ethanol and rinsed again. Decontamination was made with 0.2 mg/l $HgCl_2$ (mercuric chloride) for 3 minutes and washed for 3 times with sterilised distilled water.

3. **Culture initiation**

Cultures for both species were initiated with 0.5-0.8 cm uninodal segments for all tested varieties from aseptic *in vitro* pre-culture on MS medium with different concentration of BAP (V variant), GA_3 (X variant) (Table 1) and ANA (Y variant). Each treatment had five repetitions and five replications. The culture media was pH 5.75, 30 g/l agar and 7 g of sucrose in 30 ml container for each repetion. Media was autoclaved for 21 minutes at 121°C. Cultures were inoculated in the laminar flow bench and incubated at 24±1 °C under 14 h of light. All measurement was done at 7-12-19-26 and 33 days from inoculation.

Table 1. Media combination in different treatments on variant X

Variant	BAP mg/l	GA_3 mg/l	ANA mg/l
X0	0	0	0
X1	0.25	0	0.03
X2	0.25	0.5	0.03
X3	0.25	1.0	0.03
X4	0.25	1.5	0.03
X5	0.25	2.0	0.03

The GA_3 impact on growing, number of leaves, height of the plants, number of *in vitro* roots and callus proliferation were analysed. This paper is part of a complex study on both species regarding interaction between three important hormones (BAP, GA_3, NAA) and here we test the method that we applied on *Solanum tuberosum* and discuss only two parameters – height and roots.

The obtained experimental data were statistically processed using the software Jasp 0.16.1. ONE WAY ANOVA tests were used to study the influence of different variants during the time. Also, we used POST-HOC Test to identifying the significant differences between samples (p value less 0.05).

RESULTS AND DISCUSSIONS

Results were obtained after 33 days of culturing and metric observations.

1. *In vitro* shoot induction and viability of explants. Purple potato cultures were established from uninodal segments of *Solanum tuberosum* L. 'Purple majesty' (PM) and 'Violet queen'(VQ) varieties. All cultures remain sterile after 10 days after inoculation and allow metric observation. One explant from X5_PM were exhausted starting with day 12.

2. *Shoot length*

2.a. PM_X variant. Variation of GA_3 plus NAA and BAP affected shoot length variability on both varieties among them. The longest shoots were observed on PM variant starting with day 26, where we found a significant differences between Control_PM and X5_PM (p=0.016). The trend is confirmed at 33 days with a 4.18 cm average (Figure 4) for Control_PM height. The Post Hoc Test comparisons show a significant differences only between control_PM and X5_PM (2 mg/l GA_3), where *p* value is slightly below 0.05)

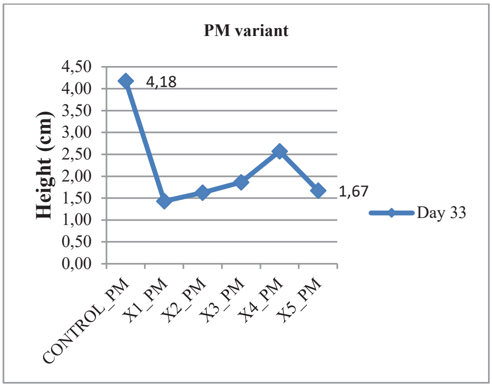


Figure 4. Height distribution on PM variety on day 33

2.b. VQ_X variant. For VQ variety, ANOVA shoes that are significant differences between the height for variant on day 12 from inoculation. Post Hoc test shoes that variant X1_VQ, X2_VQ, X5_VQ doesn't have significant differences between them, but they have significant difference form the control, and variant X3_VQ (1.5mg/l GA_3) show significant higher results then variants X1_VQ, X2_VQ, X5_VQ

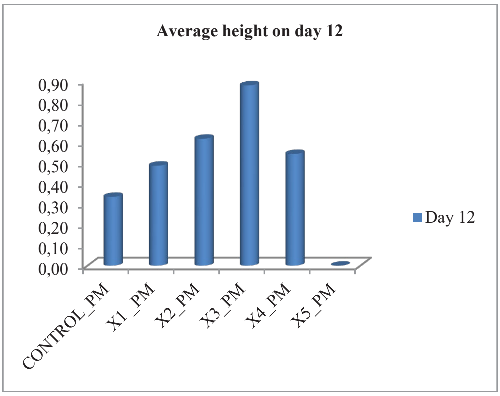
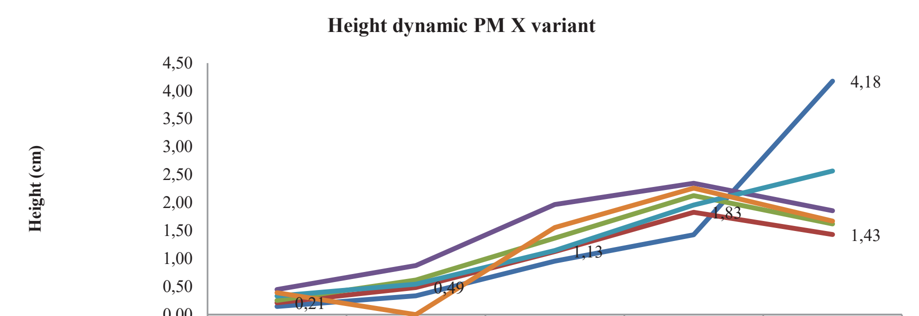


Figure 5. Height distribution on PM variety on day 12

2.c. *Dynamics of shoot height.* Regarding dynamic of height growing on PM variant, there are no significant differences between X1, X2,..X5_PM. Between day 1 and day 26, height parameter had a similar evolution both on control and variants. Starting with day 26, the Control_PM (without hormones) show a rapid growth rate, with an 4.18 cm average.

The lowest height rate with 1.43 cm we observe on X1_PM variant (with 0.25 mg/l BAP, 0.03 mg/l NAA and no GA_3) (Figure 5).

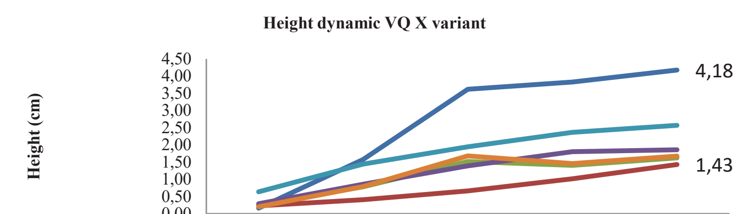
Regarding dynamic of height of VQ variant, the significant rise is shown on Control_VQ (without hormones), starting with day 12, continuing ascension until day 33, at an 4.18 cm average (Figure 6). The other variants X2_VQ, X3_VQ, X4_VQ and X5_VQ don't had any important dynamic, instead of X1_VQ (with 0.25 mg/l BAP, 0.03 mg/l NAA and no GA_3). Even it had a continuous ascending height curb, the value at day 33 is the lowest from all range.



	Day 7	Day 12	Day 19	Day 26	Day 33
CONTROL_PM	0,15	0,34	0,96	1,43	4,18
X1 _PM	0,21	0,49	1,13	1,83	1,43
X2_PM	0,25	0,62	1,37	2,13	1,62
X3_PM	0,45	0,88	1,97	2,35	1,86
X4_PM	0,33	0,54	1,15	1,96	2,57
X5_PM	0,39	0,00	1,56	2,26	1,67

Figure 6. Height dynamic for PM_X variant

The dynamic of both variant (PM and VQ) show that the minimum and maximum ranges are similar on PM and VQ (1.43 cm; 4.18 cm), but the growth dynamics on each variant are different as shown in (Figure7).

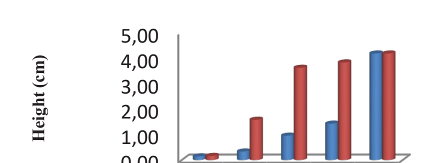


	Day 7	Day 12	Day 19	Day 26	Day 33
CONTROL_VQ	0,16	1,58	3,62	3,83	4,18
X1 _VQ	0,23	0,41	0,66	1,02	1,43
X2_VQ	0,26	0,79	1,52	1,41	1,62
X3_VQ	0,29	0,86	1,39	1,81	1,86
X4_VQ	0,64	1,44	1,95	2,37	2,57
X5_VQ	0,20	0,79	1,68	1,46	1,67

Figure 7. Height dynamic for VQ_X variant

As we see in Figure 8, we have the following significant differences on Control_PM vs. Control_VQ: day 12- very significant diference ($t = 4.458$; $df=54$; $p < 0{,}001$); day 19 - very significant diference ($t = 6.262$; $df=54$; $p < 0{,}001$; day 26 - very significant diference ($t = 4.948$; $df=58$; $p < 0{,}001$).

Also, we observed on day 26 that we have significant difference between X2_PM and X2_VQ, both with 0.5 mg/l GA_3 ($t = 2.878$; $df=58$; $p = 0.005$) (Figure 8).



	Day 7	Day 12	Day 19	Day 26	Day 33
CONTROL_PM	0,15	0,34	0,96	1,43	4,18
CONTROL_VQ	0,16	1,58	3,62	3,83	4,18

Figure 8. Relation between height from Control_PM and Control_VQ

3. Root number.

3.a. PM_X variant. ONE WAY ANOVA show significant difference between variants ($p = 0.016 < 0.050$) and Post Hoc Test show us there are significant difference between X1_PM (no GA_3) and X4_PM (1.5 mg/l GA_3) (Figure 9)

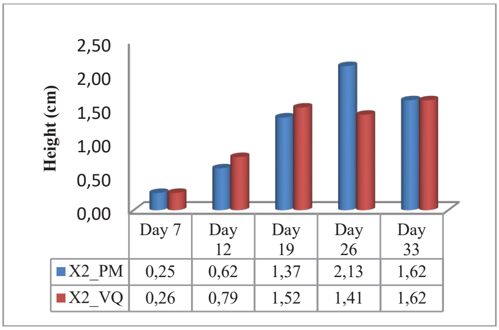


Figure 9. Root number distribution on PM variety on day 19

In day 26 we obtain the similar results as in day 19 (Figure 10), ONE WAY ANOVA show significant difference ($F=3.874$, $p= 0.003$) between variants and Post Hoc Test show us difference between X1-X2, X1-X4, X3-X4.

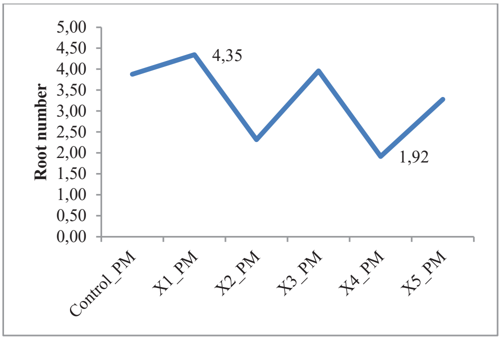


Figure 10. Number of roots PM_X on day 19

For day 33, ONE WAY ANOVA show significant difference ($F=7.033$, $p< 0.001$) and from Post Hoc Test we obtain a significant diference ($p=0.008$) between Control_PM (no hormones) and X3_PM (1.0 mg/l GA_3) (Figure 11)

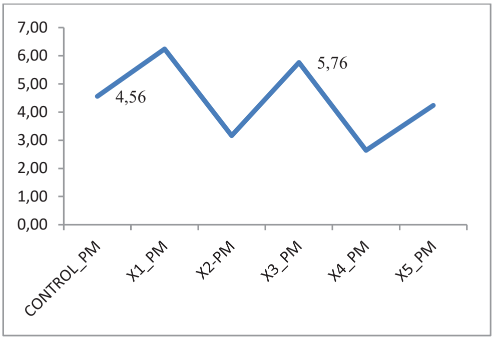


Figure 11. Number of roots PM_X on day 26

3.b. VQ_X variant. In day 7, the p value for ONE WAY ANOVA show very significant difference ($p<0.001$) but the Post Hoc Test show significant difference only between Control_VQ and X1_VQ (0.25 mg/l BAP, 0.03 mg/l NAA but no GA_3) ($p=0.029$).

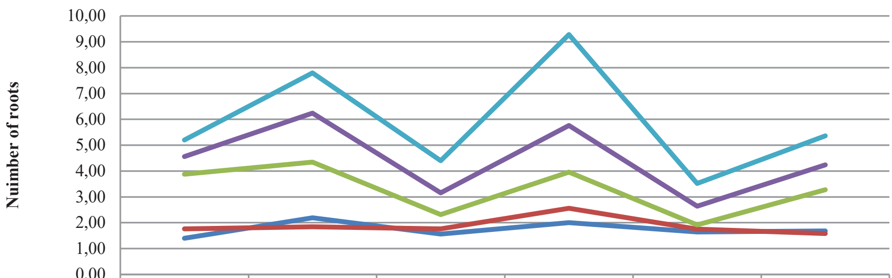
For VQ variant with day 12 to day 33 we have significant difference between variants and Post Hoc Test sow us significant difference between Control and the rest of variants (Table 2).

3.c. *Dynamics of root number*

Regarding dynamic of the roots number on PM_X variant, we observe that we have a sinusoidal evolution of roots number (Figure 12). Regarding dynamic of the number of the roots for VQ_X variant, for the Control we have a logarithmic grows and for the rest we observe a three stage of dynamics (Figure 13).

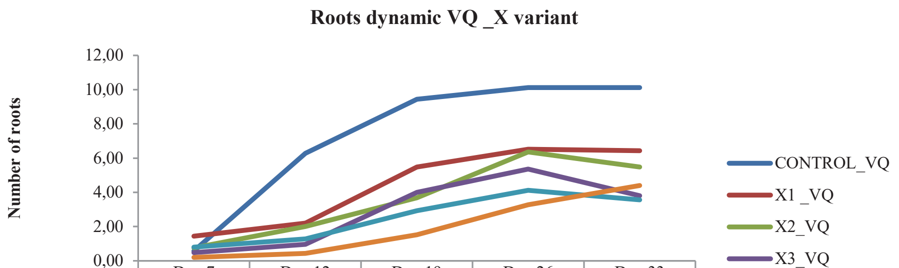
Table 2. Root number distribution for VQ_X

		Day 7	Day 12	Day 19	Day 26	Day 33
	ANOVA	<0.001	<0.001	<0.001	<0.001	<0.001
Post Hoc Test	C-X1	0.029	<0.001	<0.001	0.03	0.02
	C-X2	0.987	<0.001	<0.001	0.02	0.003
	C-X3	0.999	<0.001	<0.001	0.001	<0.001
	C-X4	0.968	<0.001	<0.001	<0.001	<0.001
	C-X5	0.76	<0.001	<0.001	<0.001	<0.001



	M_PM	X1 _PM	X2_PM	X3_PM	X4_PM	X5_PM
Day 7	1,40	2,19	1,56	2,00	1,64	1,68
Day 12	1,76	1,85	1,76	2,56	1,75	1,58
Day 19	3,88	4,35	2,32	3,96	1,92	3,28
Day 26	4,56	6,24	3,16	5,76	2,64	4,24
Day 33	5,20	7,80	4,40	9,28	3,52	5,36

Figure 12. Roots dynamic PM_X variant

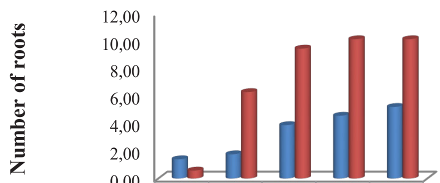


	Day 7	Day 12	Day 19	Day 26	Day 33
CONTROL_VQ	0,58	6,28	9,44	10,12	10,12
X1 _VQ	1,44	2,20	5,48	6,52	6,44
X2_VQ	0,76	2,00	3,68	6,36	5,47
X3_VQ	0,48	0,96	4,00	5,36	3,80
X4_VQ	0,80	1,28	2,92	4,12	3,57
X5_VQ	0,20	0,44	1,52	3,28	4,40

Figure 13. Roots dynamic PM_X variant

Regarding number of roots compared on both cultivars PM and VQ, ONE WAY ANOVA show us two distinctive type of differences:

a) between Controls: day 12 – Control_PM vs Control_VQ ($t = 4.462$; $df=48$; $p < 0.001$ /very significant differences; day 19 – Control_PM vs Control_VQ ($t = 4.813$; $df=48$; $p < 0.001$/very significant differences; day 26 – Control_PM vs Control_VQ ($t = 4.623$; $df=48$; $p < 0.001$/very significant differences; day 33 – Control_PM vs Control_VQ ($t = 3.989$; $df=48$; $p < 0.001$/very significant differences (Figure 14)



	Day 7	Day 12	Day 19	Day 26	Day 33
CONTROL_PM	1,40	1,76	3,88	4,56	5,20
CONTROL_VQ	0,58	6,28	9,44	10,12	10,12

Figure 14. Roots number for Control_PM and Control_VQ

b) between variants: day 19 - X5_PM vs. X5_VQ ($t = 2.952$; df=48; $p = 0.005$/distinct significant differences); day 26 - X2_PM vs. X2_VQ ($t = 2.894$; df=49; $p = 0.005$/distinct significant differences); day 33 - X3_PM vs. X3_VQ ($t = 5,269$; df=48; $p < 0.001$/very significant difference (Figure 15)

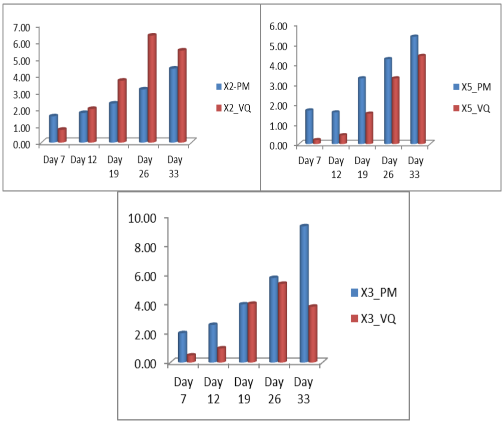


Figure 15. Differences between PM and VQ variants on day 19, day 26 and day 33

CONCLUSIONS

All parameters analysed show us a synergic relation between GA_3, NAA (with 0.03 mg/l) and BAP (0.25 mg/l) and even Control on both varies show better metric values, X3 medium, with 1 mg/l GA_3 had a good average for height for PM cultivar and X4 medium, with 1.5 mg/l GA_3 had a good impact on height average for VQ cultivar. All results will be correlate with other parameters that we follow in out thesis: leaf, callus and secondary shoots (data not shown at this moment).

On the roots experience, X3 variant (0.25 mg/l BAP, 1 mg/l GA_3, 0.03 mg/l NAA) on PM cultivar reached an 9.28 cm average at day 33. For VQ, no variants of GA_3 made significant rates against Control. Regarding roots, comparing dynamics reveal two different type of root evolution, one sinusoidal for PM_X and one logarithmic, for VQ_X, information that will be compared with other two linked experience: V (variation of BAP) and Y (variation of NAA) - data not shown at that moment.

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INTERCROPPING - AN OPPORTUNITY FOR SUSTAINABLE FARMING SYSTEMS. A REVIEW

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Abstract

As population expansion, urbanization, environmental pollution, and climate change, the global food crisis is currently aggravated in the world. One strategy for coping with the effects of climate change in arid regions is intercropping. The purpose of this paper is to review the main types of intercropping- Row intercropping, Mixed intercropping, Strip intercropping, Relay intercropping and present their advantages. Intercropping is as a multiple cropping system, in which two or more crops species planted simultaneously in a field during a growing season. An example of sustainable farming systems is intercropping, which creates balance with the environment, contributes to better use of resources, and reduces damage from diseases and pests. Potential advantages of this practice include higher crop yields- due to extra sunlight that taller crops receive on their borders. Intercropping enables plants to efficiently utilize plant growth resources like water, nutrients, sun light; to improve soil erosion control. Intercropping patterns are more effective than monocropping in suppression of weeds, but their effectiveness varies greatly. Intercropping is ways to increase diversity in an agricultural ecosystem.

Key words: *agroecosystem; intercropping; sustainable agriculture.*

INTRODUCTION

Intercropping has a vast potential for sustainable agriculture, as it provides 15-20% of the world's food supply (Lithourgidis et al., 2011) and contributes to reducing the contradiction between population growth and the reduction of arable land (Fowler et al., 2015). By increasing the yields of some cereals, the Green Revolution has so far permitted humans to cope with population growth (Pingali, 2012), and its new technologies are still central to ongoing reduction in the total number of undernourished people (Martin-Guay et al., 2018). Lithourgidis et al., (2011) point out that according to Altieri, (1999) self-sustaining, low-input and energy-efficient agricultural systems in the context of sustainable agriculture are the focus of many farmers. From an environmental point of view, intercropping looks promising, aiming to have a limited impact on the environment, which is achieved through the sustainable intensification of agriculture, i.e. without any harmful trade-offs between productivity and other ecosystem services (Tilman et al., 2011).

The purpose of this paper is to review the main types of intercropping - Row intercropping, Mixed intercropping, Strip intercropping, Relay intercropping, and to present their advantages. An attempt is made to present the advantages of intercropping, which creates a balance with the environment and contributes to the better use of resources.

MATERIALS AND METHODS

This review article summarizes the results from researchers conducting intercropping experiments. The studies are multi-layered and highlight the role of intercropping in maintaining environmental balance.

A number of authors emphasize the role of intercropping in the direction of diversification and suggest various ways to arrange crops in the agroecosystem to make it more sustainable.

A comparison is made between crop monoculture with intercropping and the advantages it brings, namely increased crop yield, efficient utilization of agricultural resources and competition for resources between species.

Intercrops improve soil fertility and make the intercropping-based agri-horti system ecologically sustainable and economically feasible to farmers.

RESULTS AND DISCUSSIONS

Intercropping is an old cropping system, which dates back to ancient civilization (Nasar et al., 2019) and has a long history (Ghaffarzadeh, 1999; Bybee-Finley & Ryan, 2018; Feng et al., 2021), being practiced to achieve higher yields and to satisfy the world's demand for food (Vandermeer, 1990; Connolly et al., 2001; Dakora & Phillips, 2002; Zhang & Li, 2003; Zhang et al., 2003; Zhang, 2004; Nasar et al., 2019). An example of sustainable farming systems is intercropping, which creates a balance with the environment and contributes to the better use of resources (Mousavi & Eskandari, 2011). Improving crop diversity on a piece of land through intercropping is one of the adaptation strategies to climate change in drylands (Jaya & Rosmilawati, 2017) and is an opportunity to cope with the effects of climate change (Liu et al., 2016). Intercropping is one form of crop diversification that is meant to spread the risk of crop failure on a single piece of land (Jaya & Rosmilawati, 2017), and intercropping as a practice has survived the evolution of agriculture in the semi-arid areas of the tropics (Tignegre et al., 2018; Jun-bo et al., 2018; Godfray et al., 2010; Foley et al., 2011), according to whom as population expansion, urbanization, environmental pollution, and climate change, the global food crisis is currently aggravated in the world. One of the main reasons for the worldwide use of intercropping is the production of more than pure cropping from the same amount of land (Caballero & Goicoechea, 1995; Mousavi & Eskandari, 2011; Šeremešić et al., 2020), with component crops being selected in such a way that they can complement each other in order to achieve better overall resource utilization as compared to when the crops are grown separately (Anon, 2015; Nishanthi et al., 2015). Intercropping combines the temporal and spatial dimensions of crop diversification and offers a variety of ways to shape agroecosystem ecology and productivity (Himanen et al., 2017) and intercropping as a multiple cropping system, in which there are two or more crops species planted simultaneously in a field during a growing season (Vandermeer, 1989; Ariel et al., 2013). The above, however, does not mean that they are planted together at the same time, but that the aim is for two or more crops to be together in one place during their growing season, or at least for a certain period of time (Mousavi & Eskandari, 2011). Intercropping systems help farmers to exploit the principle of diversity (Ghosh, 2004), as they are helpful to avoid reliance on a single crop and result in a variety of products of a different nature, such as forages, oil and pulses (Iqbal et al. 2018b). In 1989 an interdisciplinary research team was set up to develop a more environmentally sustainable cropping system that was also economically favorable (Cruse et al., 1995). Qian et al., (2018) cites Lithourgidis et al., (2011), according to whom intercropping was initially practiced to provide a yield advantage and stability. It also provides possible options for the sustainable intensification of agriculture.

Organic production represents one of the most important sustainable agriculture systems, wherein higher nutritional values of food could be achieved alongside the preservation of biodiversity and agroecosystems (Šeremešić et al., 2017). In organic vegetable cultivation, the proper selection of varieties/hybrids, crop rotation, and intercropping cultivation also play a very important role (Ugrinović et al., 2014) because complementary relationships are created with neighbouring ecosystems and environmental resources are used more fully (Šeremešić et al., 2018). Jones & Sieving, (2006) points out in order for agriculture to evolve towards environmentally sustainable systems (Atkinson & McKinlay, 1997), the cultivation of intercrops (strips within the field), cover crops, field margins, hedgerows, windbreaks that serve ecological functions on farms (i.e. predator refugia) (Nentwig, 1998). Intercropping has always been the most widespread form of cropping system in (sub-) tropical and developing countries (Schulz et al., 2020). Yildirim & Ekinci, (2017) cites authors (Francis, 1989; Legwaila et al., 2012) who point out that intercropping systems are widely used in Latin America, Asia and Africa where capital investment is restricted thus minimizing the risk of total crop failure. Brooker et al., (2015) cites Francis, (1986) who has indicated that smallholder farmers in Latin America grow 70-90% of beans with maize, potatoes and other crops, while maize is intercropped on

60% of the maize-growing areas of the region; according to Vandermeer, (1989) 98% of cowpeas in Africa are grown as intercrops, 90% of beans - in Colombia. The total percentage of cropped land in the tropics used for intercropping varies from 17% in India to 94% in Malawi. In Europe intercropping persists in agroforestry systems, such as the Swiss pâturages boisés (wooded grassland systems) and Mediterranean coltura promiscua (cereals and vegetables grown under trees, often olive and fruit trees or vines) (Dupraz & Liagre, 2011; Brooker et al., 2015). Intercropping has been used in numerous parts of the world (Głowacka, 2013; Chang et al., 2020). Jun-bo et al., (2018) points out authors (Feike et al., 2012; Liu et al., 2013; Zhang et al., 2013), according to whom the limited farmland in China impels people to increase crop yields by using chemical fertilizers, thus degrading the environment and severely polluting the water and air, acidifying the soil and eroding it. Tignegre et al., (2018) cited authors Tsubo et al., (2005) who point out that in many developing countries intercropping is an important practice in subsistence and food production farming systems, as in the Guinea savanna zone of Northern Region of Ghana, a maize is one the most widely grown food staples for intercropping during the humid season. Nishanthi et al., (2015) presents the results from an intercropping system of black gram and *Amaranthus tricolor* L., where black gram is one of the important grain legumes in the rainfed farming system in the dry and intermediate zones of Sri Lanka. Singh et al, (2018) cites Sarkar et al., (2008) who has reported that vegetables, such as chili, brinjal, *Colocasia*, *Amorphophallus* and pumpkin, are the most acceptable intercrops in papaya under West Bengal condition. Singh et al. (1994) suggest that cowpea, peas, turmeric, radish and pawpaws are suitable intercrops for mango orchard.

Intercropping is a way to increase diversity in an agricultural ecosystem (Mousavi & Eskandari, 2011) and traditionally intercropping has been used to increase crop production and land efficiency, as it is also a strategy to mitigate risks (Bybee-Finley & Ryan, 2018). Ariel et al., (2013) reports authors (Liebman & Dyck, 1993; Ren et al., 2008; Gao et al., 2010; Coll et al., 2012) who point out that intercropping systems can provide many benefits through the increased efficiency of land use and by increasing the length of production cycles. Intercropping enables plants to efficiently utilize plant growth resources such as water (Wang et al., 2015; Raza et al., 2021), nutrients (Zhang et al., 2003), sunlight (Nasar et al., 2019) for their growth, which is associated with the better utilization of resources, and the numerous positive effects of growing certain varieties in intercropping systems (Eskandari, 2012; Šeremešić et al., 2018), thus having an impact on plant growth, increasing the biomass production and yield (Zhang et al., 2011). Intercropping is practiced with the aim of maximizing plant cooperation rather than plant competition for maximum crop yields (Sullivan, 2001; Ofosu-Anim & Limbani, 2007). Other advantages of intercropping is the decreased number of pests and weeds (Dolijanović et al., 2008; Mousavi & Eskandari, 2011) and the reduced disease infestation (Ren et al., 2008). The potential advantages of this practice include higher crop yields due to extra sunlight received by taller crops on their borders (Cruse et al., 1995). Qian et al., (2018) reports that nutrient (e.g. nitrogen and phosphorus) transportation is of interest in intercropping systems (Mei et al., 2012; Gao et al., 2014), as the organic matter added by the intercrops improves soil fertility and makes the system more environmentally sustainable (Upadhaya et al., 1994; Singh et al., 2018). Agricultural sustainability encourages intercropping practices, thus reducing wind speed, providing shade and increasing infiltration, which result in retaining water in the soil and improving its structure, fertility and ensuring its conservation (Guvenc & Yildirim, 2006). Yildirim & Ekinci, 2017, cites Mobesser, (2014), according to whom the different root architects of intercrops influence water uptake and the capability of plants to reach for water resources. Maize-cowpea intercropping systems have enhanced light interception, decreased water evaporation and conserved the soil water when compared to sole maize cropping, and therefore have been having consistently greater water use efficiencies. Legumes adapt well to various cropping systems owing to their ability to fix atmospheric nitrogen in symbiosis with the soil bacteria of Rhizobium spp. (Nishanthi et al., 2015) and forage legumes can provide other, less known benefits besides biological nitrogen fixation, such as buffering from weeds, pests and abiotic stresses, support for beneficial biota and higher yields per area (Himanen et al., 2017). There may be a symbiotic cohabitation between the two crops, where intercropping reduces soil erosion due to the optimum soil coverage (Cruse et al., 1995; Zougmoré et al., 2001; Tignegre et al., 2018). Qian et al., (2018) reports that intercropping systems have been proven to have positive effects on the control of wind erosion, weed control (Gronle et al., 2015; Liang et al., 2016) and can simultaneously suppress soil-borne diseases (Boudreau, 2013; Chang et al., 2020). Tignegre, et al. (2018) quotes authors Nampala et al., (2002) stating that insect populations (aphid and thrips) are significantly reduced in cowpea-sorghum intercrops, and that when chili-maize (Gutierrez, 1999) and tomato-maize (Pino et al., 1993) are grown, pests and disease pressure are moderate. Ariel et al., (2013) cites authors Hummel et al., (2009) who indicate that intercropping may be the improved quality of the seed, an improvement of the crop canopy structure susceptible to lodging. The author also points out another advantage reported by Crew & Peoples, (2004), namely that the legumes used contribute to minimizing the inorganic nitrogen fertilizers used and this improves water quality. Tignegre et al., (2018) cites Akunda, (2001) indicating that positive physiological interactions can be accounted for intercropping with sorghum-soybean intercrops density resulting in increases of the soybean seed protein. According to Mousavi & Eskandari, (2011) intercropping can be included for: annual plants with annual plants intercrop; annual plants with perennial plants intercrop; and perennial plants with perennial plants intercrop (Eskandari et al., 2009a). Singh et al., (2018) presents an in-depth literature review on vegetable crops as the most effective and economical intercrops that improve orchard health, food security and prevent soil erosion through orchard floor covers. The author cites Singh et al., (2016), which suggested that shade-loving tuber crops (Colocassia, Elephant Foot Yam, Turmeric and Ginger), which have a great potential to withstand and grow under the canopy of fruit plants, are well-suited in the intercropping system because they have a higher biological efficiency for food production and the highest rate of dry matter production through efficient solar energy transfer. Tignegre et al., (2018) cites authors stating that the practice of vegetable-maize intercropping ensures sustainable production with a minimal risk to satisfy the subsistence and commercial needs (Baker & Norman, 1975; Beets, 1990; Wu et al., 2017), as if one crop fails to be harvested, the farmer has another one that can provide food (Lawson et al., 2013). There is a wide diversity of maize intercropping components, which include soybean (Muoneke et al., 2007; Hugar & Palled, 2008) vegetables (tomatoes, hot pepper, okra), fruit crops (Seran & Brintha, 2010; Ijoyah et al., 2012) in Ghana in the humid season (Tignegre et al., 2018). Planting vegetables by using the intercropping method has many advantages, such as a high economic value, easier cultivation techniques, a lower risk of failure, and more suitable cultivation on marginal land. In terms of competitiveness, this means that components of intercrops are not competitors that occupy the same niche (ecological nest) due to morphological and physiological differences, as the competition between species is less than the competition within species (Vandermeer, 1992). In monocropping systems, all available natural sources, such as light, moisture and nutrients, are rarely used by plants, consequently released nich are captured by the weeds (Mousavi & Eskandari, 2011), that are competitors of the main crop. Preserving weed diversity on farmland provides important ecosystem services and must be carefully managed to limit the negative impact of weeds on crop yields through competition for essential resources (e.g. water, light and nutrients) or even maintaining pests (Gaba et al., 2016; MacLaren et al., 2020). Weeds provide a shelter and food for various taxa of the agroecosystems, either beneficial species for pollination services or crop pests. Therefore, the wise agroecological management of weeds should keep weed species of functional interest for regulation, e.g. biocontrol or trophic resources and cultural services (Gaba et al., 2014). As compared to crop monoculture (sole cropping), intercropping has advantages when it comes to the increase of crop productivity and the efficient use of agricultural resources (Chang et al., 2020; Bourke et al., 2021), as the competition for resources between species is less than the one existing within the same species (Ghaffarzadeh, 1999). Intercropping patterns are more effective than monocropping in suppression of weeds, but their effectiveness varies greatly (Girjesh & Patil, 1991). Mousavi & Eskandari, (2011) points out many authors (Gliessman, 1997; Mazaheri et al., 2006), according to whom success of intercrops in comparison with a pure cropping can be determined by a series of agronomic operations, as interactions between the species will be affected by them. These operations include ultimate density, planting date, resources availability and intercropping models. Jun-bo et al., (2018) adds that as compared to continuous monoculture systems, intercropping systems increase soil biodiversity and soil quality, as they also enhance the nutrient-use efficiency (Wang et al., 2014; Cong et al., 2015). In an article Mousavi & Eskandari, (2011) reports the results of studies by several research teams, which indicate that as compared to pure cropping, intercropping of beans and barley results in higher grain and dry matter yields (Martin & Snaydon, 1982), as well as that the higher dry matter production in wheat and beans intercrops has been more than their pure cropping (Ghanbari & Lee, 2002). A number of authors point out that mixed cropping has implications for the higher yields realized (Jensen, 1996). The yield of sweet corn increases when planted with pea as intercrops due to the better use of environmental resources (Francis & Decoteau, 1993). The advantages of smaller yield were associated with intercrops, where the species had the same growing period and where legumes were combined with small grain cereals, such as wheat or barley, in full mixtures to obtain sustainable yields with reduced nutrient inputs (Werf et al., 2020). The interspecific interactions, both facilitative and competitive, contribute to high yielding, however, the roots are strongly responsible for yield improvement (Ghaffarzadeh, 1999; Ghanbari & Lee, 2003). According to Nasar et al., (2019) and (Dakora & Phillips, 2002; Dakora, 2003; Zhang, 2004) cereal-legume intercropping is a common cropping system, in which cereals get growth and yield advantages from legumes by sharing nutrients and some other unknown resources. The interactions between legumes/cereal mixture interactions (facilitating and competing) are complicated to examine (Maurya & Lal, 1981; De Ridder & Van Keulen, 1990; Jensen, 2003) in the utilization and modification of natural resources. Further research is required to address the interactions (above & below ground) in traditional cropping mixture (Ghaffarzadeh, 1999). Intercrops with maize and beans in different ratios prove that production has increased due to the reduced competition between species as compared to the competition within species (Odhiambo & Ariga, 2001). Mousavi & Eskandari, (2011) cites authors (Eskandari et al., 2009b; Eskandari, 2012) who indicate that the production obtained in intercropping is higher, which is probably due to the higher growth rate, reduction in pests, diseases and weeds and more efficient use of resources due to differences in crop preferences for environmental resources. According to Altieri, (1995) if the plants used in intercropping are complementary in the use of environmental resources, the intercropping system will be more efficient. The study by Soria et al., (1975) shows that intercropping (corn- cassava and beans- cassava) is effective in weed control (Mousavi & Eskandari, 2011). A large number of papers (Ofori and Stern, 1987; Vandermeer, 1992) report that intercropping is divided into the following four groups: Row intercropping, Mixed intercropping, Strip intercropping, and Relay intercropping.

In row intercropping, distinct rows of component crops are clearly identifiable (Crusciol et al., 2012), where there is simultaneous cultivation of two or more crops. Row intercropping is carried out either in additive series (no sacrifice of main crop lines) or replacement series (main crop row is reduced for each intercrop row) (Iqbal et al., 2017; Iqbal et al., 2019). Growing two or more crops simultaneously where one or more crops are planted in regular rows, as the crop or other crops may be grown simultaneously in row or randomly with the first crop (Iqbal et al., 2018a). Another key advantage associated with intercropping is its potential to increase the land productivity per unit area and the efficient utilization of farm resources (Mucheru-Muna et al., 2010). Cereals intercropping with legumes result in the increased resource capture by component crops and improve the soil microbial activity along with a better efficiency of resource conversion, which triggers higher biomass production (Alvey et al*.,* 2003). Wide spacing and slow growing nature during the initial growth period of fennel and ajwain make it possible to raise short duration intercrops in between the rows (Mehta et al., 2017). Singh & Kumar, (2002) points out that the inclusion of radish and fenugreek as intercrop increases the productivity and profitability per unit area in winter maize as compared to growing it as a sole crop. According to Rao & Singh, (1990), an intercropping system improves crop yield and contributes to the eimproved returns in the system (Mehta et al., 2017). Cucumber and okra are among the most important vegetables that farmers grow in Ghana, which are commonly interplanted (Ofosu-Anim & Limbani, 2007).

Mixed intercropping entails the intercropping system, in which seeds of different crops are mixed and sown in a blended form in the same row or broadcasted (Iqbal et al., 2019; Khatiwada, 2000), with no distinct row arrangement. This type can be suitable for grass-legume intercropping in pastures (Mousavi & Eskandari, 2011). A mix cropping system not only enhances crop production and returns but can also help safe the plants from complete failure as compared to mono-cropping (Zhang & Li, 2003; Nasar et al., 2019). Ultimately, there is no row distinction of component crops in mixed intercropping systems (Agegnehu et al., 2006). Plants interact with each other in a mixed cropping system, thus efficiently utilizing facilitative (positive interactions) resources and curtailing competition both in the above and underground plant compartments in order to improve growth and yield (Jose et al., 2000; Rao & Mathuva, 2000; Silwana & Lucas, 2002; Wu, 2012; Nasar et al., 2019). In mixed cropping system, crops will be in direct competitions while capturing the same resources (Ghaffarzadeh, 1999).

Strip intercropping adds a spatial diversity to species across the landscape (Ghaffarzadeh, 1999). In strip intercropping, two or more crops are sown in strips (Iqbal et al., 2019) and grown simultaneously in strips wide enough to accommodate many rows (Li et al., 2001; Jaya & Rosmilawati, 2017) and to allow independent cultivation, but strips narrow enough to allow the crops to be close enough to facilitate interaction between them (Mousavi & Eskandari, 2011). Strip-row intercropping distributes labor requirements more evenly over the growing season, allowing complementary interactions that increase yields (Ghaffarzadeh, 1999). Głowacka (2013) cites many authors (Andrade et al., 2012, Hauggaard-Nielsen et al., 2012; Coll et al. 2012) who state that strip cropping is a form of intercropping used in many regions of the world. Strip cropping is practiced with success by several American farmers (Francis et al, 1986). One model of intercropping is strip intercropping, which has many advantages (Li et al., 2001), as Jaya et al, (2017) points out that the potential of strip intercropping on a dryland has been explored and the productivity advantage of the strip intercropping over monoculture has been calculated. This system protects the soil from water and wind erosion and reduces nutrient and pesticides leaching (Zhang & Li, 2003; Głowacka, 2013). Intercropping, especially in relation to maize and pulse crops, is an old cultivation practice, but has recently been re-practiced in relation to the phenomenon of climate change. The use of intercropping has been found to be an approach in sustainable agriculture (Fung et al., 2019). The shift to strip cropping aims to achieve more sustainable crop production and to preserve the natural nutrient richness of the soil. The relevance of strip cropping is based on the potential for this agronomic practice to help stabilize the agroecosystem due to the less soil erosion, lower levels of residual concentrations of excess nutrients in the soil environment (Gitz et al., 2015), successful weed management, and the development of fewer diseases and pests in strip crops (Hijbeek, 2017). Strip cropping and intercropping are agricultural systems where the diversity of cultures simultaneously cultivated on the field contribute to and encourage agricultural biodiversity (Zhang & Li, 2003). Strip cropping can also limit the occurrence of pests, diseases, and weeds, so that the use of pesticides can be reduced (Ma et al., 2007). In strip intercropping, three or more crops (typically corn, soybeans, and a small grain such as oats or wheat interseeded with a legume such as alfalfa or berseem clover) are grown in contiguous narrow strips of four to six rows each within the same field (Cruse et al., 1995). Strips must be equal in width to accommodate this rotation scheme, and farmers must use a strip width compatible with their equipment (Cruse et al., 1995), and the machinery must be modern (Nowatzki, 2017). The strip intercropping system has a greater production potential than do traditional systems (Ghaffarzadeh, 1999; Nowatzki, et al., 2017). The strip cropping system has clearly been a success and is thought to bring additional ecosystem services, such as nitrogen fixation by legumes and the ability of perennial grass-clover to act as a carbon sink (Juventia, et al., 2021), which warrants consideration when considering climate change mitigation tools within the principles of organic agriculture (Lüscher et al., 2014). Strip cropping is a strategy for dividing individual fields into strips of different crops in order to achieve the same positive effects that are known from standard crop rotation (Rodriguez et al., 2021). If compared to monocropping, strip cropping modifies the soil microbial C/N/P ratios, favors fungidominated communities and promotes plant mycorrhizal symbiosis, thus guaranteeing a higher or comparable crop yield. Examples of strip crops are annuals - winter rye + vetch and corn combined with perennial perennial grass-clover in a strip system with sizes of 6x6 m; alternating rows of Emmer wheat and Celtic beans.

Climate change and the ever-increasing production costs result in challenges for farmers and thus requiring the implementation of better farming practices. Farmers are moving towards applying ecological approaches to sustainable agrocenosis management, such as the less extreme strip-till system of tillage, where the soil surface is tilled in strips of different widths and the area in between is left covered with crop residues. The strip-till technology has the advantages of protecting the soil from erosion, reducing fertilizer rates by up to 30% as a result of targeted fertilizer application, and the more efficient uptake of applied fertilizer; tillage, fertilizer application and sowing are all carried out in one pass, thus reducing fuel costs and the need for labour. Plant residues are left on the soil, between the strips, which leads to an improved soil structure, retaining more moisture for a longer period and at the same time the presence of a well-treated seedbed that warms up faster in spring. The variety of crops that are suitable for cultivation under the strip-till technology is large (Pretty & Bharucha, 2014) and this technology has been applied to almost all row crops - maize, sorghum, soybean, sunflower, canola, sugar beet, etc. (Nowatzki et al., 2017).

Relay-intercropping: Growing two or more crops simultaneously during a part of the life cycle of each. A second crop is planted after the first crop has reached its reproductive stage but before it is ready for harvest. In relay intercropping systems, a second crop is sown in a standing crop that has nearly reached the end of its production cycle, prior to harvest (Reda et al., 2005).

CONCLUSIONS

Intercropping creates a very good opportunity to make better use of available resources - light, water and nutrients, thus increasing the yield of the combined crops. The great advantages of intercropping include protecting the soil against water and wind erosion, reducing nutrient and pesticide leaching, and limiting pests, diseases and weeds. A very important aspect is the improvement of crop diversity on a given piece of land, which benefits the agroecosystem and creates resilience under the conditions of a changing climate.

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GEOINFORMATION ANALYSIS OF THE CURRENT STATE OF THE PROTECTIVE FOREST BELT ON THE TERRITORY OF THE VOLGA UPLAND

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Abstract

The state protective forest belt Penza-Kamensk is an important component of the ecological framework of the territory, where it is included in the system of protective forest plantations and contributes to the transformation of the steppe agricultural landscape into an agroforest landscape. The purpose of the research was an inventory and assessment of the state of forest protective plantations in order to preserve and restore the agroforest reclamation fund. In office conditions, up-to-date cartographic material was created on the basis of satellite images of high and ultra-high resolution, visual interpretation was carried out with the compilation of a vector polygonal layer of the current location of protective forest plantations, the number of decoded objects was determined. Visual interpretation of space images made it possible to identify disturbed areas of forest belts, in which the sparseness (fragmentation) of the forest stand is noted. At present, forest stands of pedunculate oak (62.0% of the forested area) dominate in the plantations of the forest belt in terms of species composition, the second place is occupied by birch (22%), pine, larch and spruce by 12%, willow - 2%, aspen and ash - by 1 %. Artificial plantations in most of the area have an average density of 0.7-0.8, which indicates a qualitative selection of the main forest-forming species in relation to soil conditions, on the one hand, on the other hand, the correct choice of the type of crops and the required planting density, taking into account the survival rate and preservation of plants at all stages of forest growing. Preservation of plantings is high, fluctuating within 75-85%. In general, the state of plantings is satisfactory.

Key words: *inventory, protective forest plantations, planting safety.*

INTRODUCTION

State forest protection belts play an important role in maintaining the natural potential of the region, in maintaining soil fertility and increasing the biological diversity of ecosystems. Protective forest plantations increase the bioclimatic potential of the area, improve the hydrothermal regime of the lands adjacent to the protective forest belts, protect them from droughts and dry winds. In addition to performing the main water protection and protective functions, they play a large social and aesthetic role: together with other types of protective plantations, they form a forest-agricultural landscape new for the region, and are a significant regulator of carbon balance in the surface layer of the atmosphere (Mikhina et al., 2019; Mikhin et al., 2020; Larionov et al., 2021; Lavrov et al., 2021).

The most western of the watershed forest belts laid across the Penza, Saratov, Voronezh, Volgograd and Rostov regions is the Penza-Kamensk state protective forest belt with a total length of more than 700 km. She is aboutone of eight water protection and watershed wide state protective forest belts established by the Decree of the Council of Ministers of the USSR and the Central Committee of the All-Union Communist Party of Bolsheviks of October 20, 1948 (Brain, 2010; Kulik, 2018).

In accordance with the geographical zoning of the Penza region, located on the East European (Russian) plain and occupying the middle and western part of the Volga Upland, the forest belt runs between the Sursky site of the Volga region of the European forest province, located in the east of the region, and the Khopersky site of the Volga-Don region of the Steppe province, located in the west of the region. It is located in the forest-steppe at the junction of the Vorono-Khopersky low-elevated steppe and Kadada-Uzinsky ridge-hilly forest-steppe regions. The forest cover of the area where the forest belt is located is 8.6%, represented by broad-leaved forests. Within the borders of the Penza region, it runs from the central part to the southern border along the most elevated parts of the relief through the steppe spaces of the Penza, Kolyshleysky and Maloserdobinsky regions. The total area of forest plantations is 1477 hectares, the length of the territory of the region is 80.1 km. It consists of 3 parallel forest belts about 60 meters wide at a distance of 300 meters from each other. Each strip consists of 20 rows of plants. The total width of the route is 780 m, and the area, including inter-lane spaces, is more than 6 thousand hectares.

MATERIALS AND METHODS

The research was carried out in three stages. The first, preparatory stage, was implemented in office conditions. The study and analysis of forest management documentation (taxation descriptions, flatbed materials), forestry regulations of the forestry was carried out. The material for the analysis was an electronic database containing the taxation characteristics of forest stands in the Penza region. Second phase, inventory of protective forest belts using satellite imagery materials using the SAS Planet interactive application (spatial resolution of about 0.5 m), Sentinel Hub satellite sensing materials (spatial resolution of 10 m) and web services that provide access to high-resolution satellite imagery (Bing Maps, Yandex Maps, Google Maps). At the third stage, a vector polygonal layer of the site was created. The raster was transformed according to the absolute coordinates of control points presented in the MSK-58 system, the creation of a vector map was carried out in the GIS Panorama program. The data on the state of the forest belt were updated by the method of visual interpretation of satellite images. When assessing the functional state of protective forest plantations based on satellite imagery visually, based on the criteria of continuity, the horizontal degree of density of the forest stand and the integrity of the forest belt, a rank scale of the state was used: good (forest belts do not require restoration measures), satisfactory (partially lost functionality, require restoration) and oppressed (mostly or completely lost functionality) state. When conducting research, methods of analysis and synthesis, statistical methods for calculating absolute, relative, average values, methods for constructing and studying time series, tabular, photogrammetric, graphic, monographic and method of statistical groupings.

RESULTS AND DISCUSSIONS

Research has established that forest belt plantations created on chernozem soils are characterized by rich forest growing conditions, under the influence of which forest plant communities were formed, which belong to four types of forest. The largest areas belong to the forest type oak forest - mixed herbs - 886.4 ha (61% of the total area) and oak forest - 549.7 ha (38%) in the type of habitat conditions D2 - fresh oak forest. Oak plantations consisting of 3 to 10 oak units occupy 62.0% of the forested area, birch accounts for 22%, pine, larch and spruce - 12%, willow - 2%, aspen and ash - 1% each. In the undergrowth there are hazel, euonymus, honeysuckle.

Plantings of the forest belt differ from each other in the composition of forest stands, the share of participation of the main species, the type of mixing of rows and trees in a row. The stands with the most diverse composition of tree species were formed in oak, ash and larch plantations, which indicates a positive mutual influence of tree species that form these stands. The poorest in terms of biological biodiversity are pine plantations, which prevent the development of trees of other species. In the forest belt, 6 groups of plantations pure in composition, as well as 6 groups of mixed plantations according to the prevailing main tree species, were formed, which in turn are divided into many varieties depending on the composition and proportion of species in it. Pure stands have the following taxation indicators:

- birch plantations in the type of forest oak forest, in the conditions of fresh oak forest, have an average height of 20 m, a diameter of 21.0 cm, a density of 0.7, quality class I, with an average reserve of 162 m^3/ha.
- oak plantations in the type of forest oak forest of snotty-forb in the conditions of fresh oak forest growth have an average height of 14.2 m,

a diameter of 17.8 cm, a density of 0.7, quality class III, with an average reserve of 122 m^3/ha.
- pine plantations in the oak forest type, in the conditions of the fresh oak forest habitat, have an average height of 20.5 m, a diameter of 22.5 cm, a density of 0.8, a grade of 1A, an average stock of 310 m^3/ha.
- spruce plantations of units in the type of forest oak forest-forb in the conditions of fresh oak forest growth have an average height of 8.0 m, a diameter of 10.0 cm, a density of 0.8, quality II, an average stock of 80 m^3/ha.
- plantations of aspen in the type of forest oak forest snotty-forb in the conditions of fresh oak forest habitat have an average height of 19.0 m, a diameter of 26.0 cm, a density of 0.7, quality II, an average stock of 180 m^3/ha.
- willow plantations in the type of forest oak forest snotty-forb in the conditions of fresh oak forest growth have an average height of 11.0 m, a diameter of 14.0 cm, a density of 0.6, a quality class of 3, an average stock per 1 ha is 70 m^3/ha.

Pure plantations of oak, birch, pine, willow, aspen and spruce grow on 40 forest plots with an area of 156 hectares, which is 10.7% of the forested area of the forest belt and are mainly single-story plantations with undergrowth.

Plantations mixed in terms of species composition are mainly single-tier plantations with undergrowth and a second layer.

Oak mixed plantations with a predominance of pedunculate oak from 6 to 9 units in the composition grow in the type of forest oak forest and oak forest - forb in the conditions of growth - fresh oak forest. Oak grows mixed with maple, willow, linden, birch, ash and larch. Average height 15.2 m, diameter 17.2 cm, weight 0.7, quality II, average stock 144 m^3/ha. Oak is most often found in the first tier as a dominant in 15% of cases, as a co-dominant in 12%.

Mixed birch stands with a predominance of warty birch from 5 to 9 units grow in the forest type oak forest in the conditions of fresh oak forest. Birch grows mixed with maple, ash, aspen and oak. Average stand height 20.6 m, diameter 23.0 cm, density 0.73, quality class I, average stock 179 m^3/ha. Mixed pine plantations with a predominance of Scotch pine in the forest type snotty oak forest in the conditions of fresh oak grove. Pine grows mixed with maple, linden, birch, ash, spruce and larch. Average stand height 18.3 m, diameter 20.4 cm, density 0.8, quality class IA, average stock 264 m^3/ha.

Mixed stands of larch with a predominance of larch 8-9 units in the type of forest oak forest in the conditions of fresh oak forest growth. Larch grows mixed with maple, willow, linden, birch, ash and oak. Average stand height 21.0 m, diameter 23.0 cm, density 0.8, class I, average stock 240 m^3/ha.

Mixed plantations of spruce with a predominance of larch 8-9 units in the type of forest oak forest in the conditions of fresh oak grove. Spruce grows mixed with maple, pine and aspen. The average height of stands is 16.0 m, diameter is 18.0 cm, density is 0.9, class II, average stock is 218 m^3/ha.

Ash mixed plantations with a predominance of ash 6-9 units in the type of forest oak forest in the conditions of fresh oak grove. Ash grows mixed with maple, willow, linden, birch and oak. Average stand height 14.2 m, diameter 17.0 cm, density 0.67, quality II, average stock 130 m^3/ha.

Forest stands with the participation of common ash in the forest belt grow in the type of habitat conditions fresh oak forest (D_2) on an area of 640.3 ha (43.3% of the total plantation area). The largest areas of plantations with the participation of ash belong to the type of forest oak forest snytevo - forb in the type of habitat conditions D_2 - fresh oak forest on an area of 365.0 ha, which is 24.7% of the total area of the forest belt and in the forest type oak forest snytevo in the type of habitat conditions D_2 fresh oak forest on the area of 275.3 ha or 18.6%.

Five types of mixed forest stands with the participation of ash were identified, differing among themselves, first of all, in the share of tree and shrub species in the composition of the plantation and the nature of their mixing:
- oak mixed plantations with a predominance of English oak 3 to 9 units in the composition. Oak grows mixed with maple, willow, linden, birch, ash and larch. The average height of stands is 13.8 m, diameter is 16.3 cm, density is 0.7, quality class is III, average stock is 130.0 m^3/ha. Oak is found in the first tier as a dominant in 67% of cases.
- ash mixed stands with a predominance of ash from 2 to 6 units. Ash grows mixed with

maple, willow, linden, birch and oak, pine and larch. The average height of stands is 14.2 m, diameter is 17.0 cm, density is 0.7, quality class is III, average stock is 130.0 m^3/ha.

- birch plantations with a predominance of warty birch from 4 to 9 units. Birch grows mixed with maple, ash, and oak. The average height of stands is 20.5 m, diameter is 22.6 cm, density is 0.7, quality class is I, average stock is 166.0 m3/ha.
- mixed pine stands with a predominance of Scotch pine from 4 to 8 units. Pine grows mixed with maple, birch, ash and larch. The average height of plantations is 20.0 m, diameter is 22.0 cm, density is 0.75, quality index is IA, average stock is 280 m^3/ha.
- mixed stands of larch with a predominance of larch from 3 to 8 units. Larch grows mixed with maple, willow, linden, birch, ash and oak. The average plantation height is 20.8 m, diameter is 21.8 cm, density is 0.8, quality index is IA, average stock is 246 m^3/ha.

In terms of composition, forest stands with the participation of ash have a complex structure, consist of 4-5 tree species, of which oak (35.0%), linden (22%), birch (15%), Norway maple (12%), larch (8%), willow (8%). The share of ash in them varies from 1 to 6 units, most often 1-3 units. The predominance of ash was noted only on an area of 15 hectares out of 640.3 hectares with its participation, which is 2.2%. Ash grows in forest stands from IA to III class of bonitet (on average II), density from 0.7-0.8, age 60 years. A high occurrence of ash (more than 40%) is observed in larch and birch plantations.

Thus, the creation of mixed plantations of the state protective belt helps to increase their resistance to adverse environmental factors and increases the degree of their positive impact on the microclimate of adjacent territories. As an example, the protective forest plantations play important role in the biota and the food chains management within agrocenoses.

It is identified

that the forest belts have smoothing influence on the change in the abundance of insects belonging to the different trophic groups on the developed fields. The peaks in the number of harmful and useful insects coincide in these fields, whereas in treeless agrocenoses the rise in useful components density takes place only after a year of the mass reproduction of pests (Belitskaya, 2015).

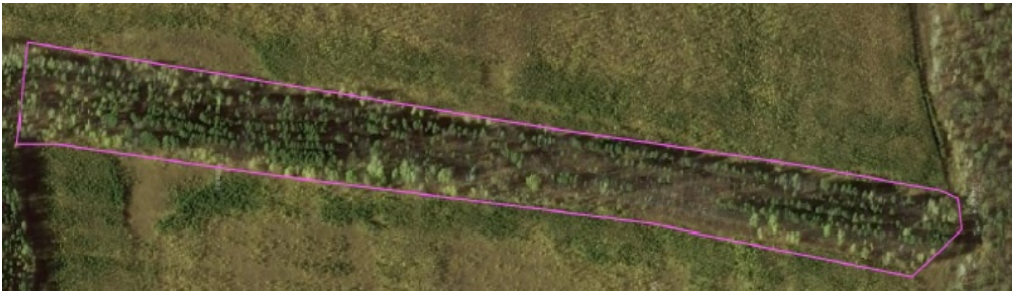
In the areas of the forest belt, environmental conditions were formed that are characteristic of forest ecosystems, with the so-called "edge effect". Trees in the outer rows have a maximum diameter and more powerful crowns. As the distance from both edges goes deeper into the forest belt, the diameter of the trees decreases rapidly and decreases to a minimum in the middle of the belt. In the central rows, there is an increase in the average height compared to the edge trees and a decrease in the average diameter, which is associated with the illumination of the crowns and the growth of tree species. The maximum height - 24.5 m, they reach not in the extreme rows, but fifteen meters from the edge. The least intensive growth in height and thickness is observed in the middle part of the belt.

One of the most advanced, efficient and reliable sources of information for forest inventory in order to determine qualitative and quantitative characteristics is Earth remote sensing data. The main advantages of the remote monitoring system are the speed of obtaining information, objectivity, simultaneity and periodicity, uniformity, visibility and a comprehensive solution to a wide range of applied agricultural problems (Franklin, 2001; Xue et al., 2017).

A visual interpretation of the current satellite images (2019-2020 surveys) was carried out with the compilation of a vector polygonal layer of the current location of the forest belt. From these results, it was found that: good (forest belts do not require restoration measures) condition have 726.7 ha of forest belts; satisfactory (partially lost functionality, require restoration) - 654.3 ha; oppressed (mostly or completely lost functionality) conditions - 96 ha forest belts (Figure 1). In plantations of the forest belt, seed and vegetative renewal of trees and shrubs is observed. The physical properties of soils, in order of decreasing importance for ecosystem services such as crop production, are texture, structure, bulk density, porosity, consistency, temperature, color and resistivity.

With natural overgrowth, the water-physical properties of the soil favorable for the development of woody plants are preserved in the territory of the forest belt.

Good condition



Satisfactory condition

Unsatisfactory condition

Figure 1. Examples of assessing the condition of forest belts according to criteria their continuity, integrity and degree of density of the forest stand

In this regard, the formation of natural plantations of seed and vegetative origin is a very important process for increasing biodiversity and sustainability of the biocenosis as a whole. To ensure the natural regeneration of tree species under the canopy of plantations, it is necessary to create conditions for the mass appearance of self-seeding of woody plants under the canopy of the parent stand by thinning it to fullness up to 0.5-0.6, and arranging gaps and windows. To improve the condition of plantations in the forest belt, it is recommended to carry out selective sanitary felling of moderate intensity,

CONCLUSIONS

The experience of creating a protective forest belt by planting seedlings of trees and shrubs has shown the possibility of forming mixed forest stands with a complex structure of forest stands that are resistant to adverse biotic, abiotic and anthropogenic factors in sparsely forested areas.

Forest belt plantations are unique objects for studying the methods of steppe afforestation in specific soil and climatic conditions, the features of the existence of artificially created forest biogeocenoses, and their spatial influence. A wealth of experience has been accumulated in the technology of growing broad-band protective forest plantations, the selection and reclamation mixing of species, soil preparation and care for plantings of different ages in the forest-steppe zone of the Middle Volga region. Biogeocenoses have formed in them, consisting of more than three dozen species of trees and shrubs, which regulate the carbon balance in the surface layer of the atmosphere, have a positive effect on soil structure, increase humus content, and improve other water-physical properties of the soil.

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