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WHEAT YIELD AND QUALITY UNDER THE INFLUENCE OF SOWING DATE, PLANT DENSITY AND VARIETY IN SOUTH OF ROMANIA

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Abstract

The efficiency of the autumn wheat crop requires the application of some general technologies, but improved with innovative and specific technological sequences, depending on the evolution of the vegetation cycle and the expected production components. The researches were performed during the 2020-2022, in the experimental field of NARDI Fundulea and aimed to study the influence of agrotechnical practices on the yields and quality of wheat. The paper presents the results obtained in experiences with sowing dates and plant density, under non-irrigation condition, in the south of the country. Recording a stable and high production of autumn wheat is possible if a good sowing quality is ensured and the optimal sowing interval and plant density per m2 are observed. The variability of individual productivity of wheat plants can increase with the delay of the sowing date by up to 10-20% for the number of grains/plant and between 10-25% for the weight of grains/plant, and these lead to a decrease for production per hectare with 1000-3000 kg/ha. The variation of climatic conditions influenced negatively wheat yield and quality.

***Key words**: wheat, sowing dates, plant density, variety, yield and quality, climatic conditions.*

INTRODUCTION

Wheat (*Triticum aestivum*) is one of the most important crops and ranks first in the world, cultivated on 220 million ha and producing about 781 million tons of grain (www.fao.org). In Romania, wheat is cultivated on 2.2 million ha (www.madr.ro).

The rapid and uniform emergence of wheat seeds and the evolution of all growth phases under good conditions are closely related to the availability of soil moisture, climatic conditions and applied technological links. To see the production potential of varieties, it is necessary to take into account the relationship between rainfall and yield when determining the time of sowing (Iagaru, 1998; Lupu, 2001; Popa, 2003). Previous research on the influence of sowing time and climatic conditions on the yield capacity of winter wheat has shown that other technological conditions are also important (Epplin, 1998; Tack et al., 2015).

Previous research shows the influence and importance of sowing time and plant density on the growth and evolution of the wheat crop in different climatic conditions from the point of view of precipitation and temperature (Raza et al., 2019). Sowing time is a very important technological link to maximize wheat crop yield and quality and therefore research is focused on wheat crop response to sowing at different times and other technological factors (Paraschivu et al., 2017; Abendroth et al., 2017).

For the sowing of wheat crops in good conditions, the optimal time can be different from one agricultural area to another depending on the type of soil and climatic evolution, especially soil moisture (Donatelli et al., 2012; Paraschivu et al., 2015; Partal & Paraschivu, 2020). Wheat seeds need optimal moisture and positive soil temperatures to germinate and develop in the early stages of growth (Abendroth et al., 2017), and early sowing is now widely applied by farmers to take advantage of positive temperatures (Partal, 2020). Sowing in the optimal period leads to increased yields and avoids the unjustified delay of seed germination and the growth of premises for their low quality. In the conditions of a late sowing and low temperatures in the soil, the seeds have the gestational capacity to absorb water, but they will delay the uniform germination and the growth of the roots, which leads to a defective germination and evolution of the crop (Donatelli et al., 2012; Abendroth et al., 2017). The amount and availability of water in the soil and the appropriate temperatures for the sowing period are the limiting factors that affect the optimal plant density and finally, the yield and quality of the wheat crop. The amount and distribution of precipitation, soil water and plant density interact and directly influence the period of active crop growth both in autumn and spring (Lobell and Burke, 2008; Raza et al., 2019). Production and quality register variations between varieties that are determined by the genetic characteristics of the variety, the supply of soil with nutrients, environmental conditions, especially soil moisture and temperatures, and the technological links applied to the culture (Theago et al., 2014; Partal, 2020).

Thus, in this paper we present the results recorded in the last three years on the influence of sowing time, plant density, variety and climatic conditions on wheat yield and quality.

MATERIALS AND METHODS

The field tests were established in the period 2020-2021-2022, on a specific soil for southern Romania (cambic chernozem). Regarding the physical characteristics 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 1.41 g/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 material included two wheat variety (Izvor and Pitar), developed at the National Institute for Agricultural Research and Development in Fundulea. Variety were sown at five different dates (SD I - September 20, SD II - October 01, SD III - October 10, SD IV - October 25 and SD V - November 10) and at three plant density (500 and 600 seeds/m^2). The main plots are 240 m^2 (30 m x 8 m) and the sub-plots 48 m^2 (6 m x 8 m). The cultivation of wheat followed the maize, in the rotation of 4 years.

In terms of quality, samples were taken from each repetition and variant and determined:

- the weight of one thousand grains - WTG was weight with the Kern precision electronic scale.
- the hectolitre weight - HW- was determined with the special cylinder, followed by weighing on the Kern scale.

Using the electronic device INFRATEC 1241 Grain Analyzer, the elements of seed analysis were determined: Protein %.

The analyzes and data obtained were processed and statistically interpreted according to the analysis of variance method.

RESULTS AND DISCUSSIONS

Climatic aspects

The climatic aspects recorded during the research period showed significant differences from one year to another due to the variation in temperature and distribution of precipitation.

The agricultural year 2019/2020 was a dry one, with a high water shortage and high temperatures, compared to the multiannual average. The months with the lowest precipitation were September 2019 by 6.2 mm, compared to the multiannual average of 50.9 mm, April by 14 mm compared to 45.1 mm on average, august by 5.4 mm compared to 49.7 mm on average and July by 34.2 mm compared to 71.1 mm on average. In May and June there were almost normal rainfall amounts, 57.8 mm and 68.4 mm, respectively. The rainfall deficit affected the installation and development of crop plants in the early phases after sowing, which had a negative impact on the final production. Temperatures higher than the annual average have exacerbated drought.

The average temperatures recorded in the 2019/2020 agricultural year were 13.5ºC, compared to the multi-annual average of 10.8ºC, with an increase of 2.7ºC.

In 2020/2021, a normal year in terms of water quantities recorded, but with an uneven distribution, especially in March, May and June (135 mm against 74.9 mm multi-year average). The temperatures registered a difference of 1.2ºC compared to the multiannual average.

In 2021/2022, the months with the lowest rainfall were September with 4.0 mm against the multi-year average of 48.5 mm, January with 4.8 mm against the multi-year average of 34.1 mm and August with 14.4 mm against the multi-year average of 49.7 mm. The highest amount of precipitation was in April with 47.6 mm, 2.5 mm above the multi-year average.

Regarding the thermal regime, in the period from October 2021 to July 2022, the values show that the monthly averages were higher than multiannual average. The temperatures registered a difference of 1.8ºC compared to the multiannual average.

In order to establish the influence of the climatic elements, on the evolution of the wheat culture, the values obtained in different phenological phases of the plants with the final production were analyzed and corroborated, in terms of quantity and quality (Table 1).

The annual climate data were compared with the multiannual average over the last 50 years, which recorded precipitation values of 584.3 mm and temperature of 10.8°C.

Table 1. The meteorological parameters in the experimental period (NARDI Fundulea, 2019-2022)

Years/Months		Sept	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	July	Aug	Total/ Average
Precipitations (mm)	’19/’20	6.2	38.2	33.2	16.2	2.0	16.6	29.8	14.0	57.8	68.4	34.2	5.4	322.0
	’20/’21	68.6	24.0	20.0	77.6	77.0	16.2	59.0	31.0	57.6	135	21.2	24.2	611.4
	’21/’22	4.0	56.4	33.8	37.6	4.8	5.4	12.3	47.6	30.1	59.6	29.2	14.4	335.2
50 years average		**48.5**	**42.3**	**42.0**	**43.7**	**35.1**	**32.0**	**37.4**	**45.1**	**62.5**	**74.9**	**71.1**	**49.7**	**584.3**
Temperatures (ºC)	’19/’20	19.3	12.0	11.0	4.0	0.9	5.2	8.3	12.4	16.8	21.8	25.1	25.5	13.5
	’20/’21	20.8	12.8	6.2	4.0	1.6	3.2	5.1	9.7	17.2	21.1	25.3	24.2	12.6
	’21/’22	17.3	10.2	7.7	2.6	2.1	4.7	4.4	12.1	17.9	22.6	25.0	25.6	12.6
50 years average		**17.3**	**11.3**	**5.4**	**0.1**	**-2.4**	**-0.4**	**4.9**	**11.3**	**17.0**	**20.8**	**22.7**	**22.3**	**10.8**

Production and quality

Production registered differences under the influence of applied technological links. In 2020, the control variant with the sowing date of September 20 achieved a production of 3500 kg, thus becoming the lowest production in the series of factor ratings. The variant with the sowing date of October 10 recorded a production of 4500 kg/ha with 1000 kg (or 28.6%) above the values of the control variant, thus becoming the highest production in the series of factor graduations. The variant with the sowing date of October 25 had a production of 4450 kg/ha, 27.1% above the value of control variant with 3500 kg/ha.

The density at sowing showed a significant variation, so the control variant with 500 g.s./m^2 recorded a production of 4000 kg/ha.

The application of a density of 600 g.s./m^2 (g.s. - germinating seeds) led to a production of 4350 kg/ha, 8.8% more than the control, becoming the best variant in the series of graduates.

The production data after the gradations of factor C - the variety, show us that in the control version, with the Izvor variety, 4020 kg/ha were obtained, and in the version with Pitar 4120 kg/ha., 2.5% more (Table 2).

The hectoliter weight (HW) registered different values depending on the graduations of the studied factors. The highest values were recorded for the variants with sowing dates of October 25 and October 10, with 79.5 and 79.1 kg/hl, respectively.

The density at sowing led to obtaining a maximum value of 79.4 kg/hl for the variant with the density of 600 g.s./m^2, and the variant with 500 g.s./m^2 which registered 78.0 kg/hl.

The Pitar variety obtained the highest HW value, namely 79.4 kg/hl.

Weight of one thousand grains (WTG) recorded values between 44.0-45.7 g depending on the factors. The density at sowing influenced WTG in a small percentage, so that at the density of 500 g.s./m^2, 45.0 g was recorded, and at the density of 600 g.s./m^2, 45.2 g was recorded. The Pitar variety had the highest WTG value of 45.7 g, followed by the Izvor variety with an average recorded value of 45.2 g (Table 2).

Table 2. Production results obtained for wheat crop in 2020

Specification variant	Production/Diference			HW		WTG	
	(kg/ha)	(%)	Semnific.	kg/hl	%	g	%
A. Sowing time							
A1 - Mt	3500	100.0	0	77.0	100.0	44.0	100.0
A2	4050	115.7	550*	78.1	101.4**	45.1	102.5**
A3	4500	128.6	1000*	79.1	102.7**	45.7	103.8***
A4	4450	127.1	950*	79.5	103.2**	45.5	103.4***
A5	4000	114.3	500	78.4	101.8**	45.1	102.5**
DL (kg/ha/kg/hl/g)	DL = (P 5% = 550/P 1% = 1005/P 0.1% = 1910)			DL = (0.74/1.24/2.30)		DL = (1.11/1.73/3.31)	
B. Density							
B1 - Mt	4000	100.0	0	78.0	100.0	45.0	100.0
B3	4350	108.8	350	79.4	101.8*	45.2	100.4
DL (kg/ha)	DL = (P 5% = 620 /P 1% = 1075 /P 0.1% = 1980)			DL = (0.70/1.11/2.23)		DL = (1.04/ 2.11/3.35)	
C. Variety							
C1 - Mt	4020	100.0	0	78.0	100.0	45.2	100.0
C2	4120	102.5	100	79.4	101.8**	45.7	101.1*
DL (kg/ha)	P 5% = (605/P 1% = 1011 /P 0.1% = 1820)			DL = (0.73/1.19/2.31)		DL = (1.09/2.15/3.28)	

In 2021, the control variant with the sowing date of September 20 achieved a production of 3100 kg, thus becoming the lowest production in the series of factor gradations. The variant with the sowing date of October 10 recorded a production of 4660 kg/ha with 1560 kg (or 50.3%) above the values of the control variant, thus becoming the highest production in the series of factor gradations. The variant with the October 25 sowing date had a production of 4550 kg/ha, 46.8% above the control value. The density at sowing recorded significant variations, so the control variant with 500 g.s./m^2 recorded a production of 4060 kg/ha. The application of a density of 600 g.s./m^2 led to a production of 4344 kg/ha, 6.9% more than the control, becoming the best variant in the series of graduates.

The production data depending on the gradations of factor C - the variety, show us that in the control version, with the Izvor variety, 3550 kg/ha were obtained, and in the version with Pitar 3900 kg/ha., with 9.9% more (Table 3).

The hectoliter weight recorded the highest for the variants with sowing dates on October 25 and October 10, both with 78.2 kg/hl.

The density at sowing led to obtaining a maximum value of 78.6 kg/hl for the variant with the density of 600 g.s./m^2, compared to the variant with 500 g.s./m^2 which recorded 77.0 kg/hl.

Pitar variety obtained the highest weight value in hectoliter, namely 78.3 kg/hl.

The weight of one thousand grains (WTG) recorded values between 43.0-44.6 g depending on the factors.

The density at sowing influenced WTG in a small percentage, so that at the density of 500 g.s./m^2, 44.0 g was recorded and for the density of 600 g.s./m^2, 44.3 g was recorded.

The Pitar variety had the highest WTG value of 44.6 g and the Izvor variety recorded 44.1 g. (Table 3).

Table 3. Production results obtained for wheat crop in 2021

Specification variant	Production /Diference			HW		WTG	
	(kg/ha)	(%)	Semnific.	kg/hl	%	g	%
A. Sowing time							
A1 - Mt	3100	100.0	0	77.0	100.0	43.0	100.0
A2	4088	131.8	988*	78.0	101.3**	44.5	103.5***
A3	4660	150.3	1560**	78.2	101.5**	44.6	103.7***
A4	4550	146.8	1450**	78.2	101.5**	44.5	103.5***
A5	4000	129.0	900*	78.0	101.3**	44.5	103.5***
DL (kg/ha/kg/hl/g)	DL = (P 5% = 600/P 1% = 1080/P 0.1% = 1872)			DL = (0.70/1.16/2.10)		DL = (1.03/1.66/3.12)	
B. Density							
B1 - Mt	4060	100.0	0	77.0	100.0	44.0	100.0
B2	4344	106.9	284	78.6	102.1	44.3	100.7
DL (kg/ha)	DL = (P 5% = 614/P 1% = 1022/P 0.1% = 1912)			DL = (0.68/1.09/2.20)		DL = (1.03/2.08/3.31)	
C. Variety							
C1 - Mt	3550	100.0	0	77.0	100.0	44.1	100.0
C2	3900	109.9	350	78.3	101.7**	44.6	101.1*
DL (kg/ha)	P 5% = (591 /P 1% = 1081,1 /P 0,1% = 1799,0)			DL = (0.72 / 1.13 / 2,28)		DL = (1.09/2.11/3.22)	

In 2022, the control variant with the sowing date of September 20 achieved a production of 3100 kg, thus becoming the lowest production in the series of factor gradations (Table 4).
The variant with the sowing date of October 10 recorded a production of 3980 kg/ha with 880 kg (or 28.4%) above the values of the control variant, thus becoming the highest production in the series of factor gradations. The variant with the October 25 sowing date had a production of 3900 kg/ha, 25.8% above the control value.

The density at sowing recorded significant variations, so the control variant with 500 g.s./m^2 recorded a production of 2600 kg/ha. The application of a density of 600 g.s./m^2 led to a production of 3410 kg/ha, 33.4% more than the control, becoming the best variant in the series of graduates.
The production data after the gradations of factor C - the variety, show us that in the control version, with the Izvor variety, 3500 kg/ha were obtained, and in the version with Pitar 3750 kg/ha, with 7.1% more (Table 4).

Table 4. Production results obtained for wheat crop in 2022

Specification variant	Production /Diference			HW		WTG	
	(kg/ha)	(%)	Semnific.	kg/hl	%	g	%
A. Sowing time							
A1 - Mt	3100	100.0	0	75.1	100.0	42.0	100.0
A2	3700	119.4	600*	76.0	101.2*	43.4	103.3***
A3	3980	128.4	880*	76.7	102.1***	43.2	102.8**
A4	3900	125.8	800*	76.7	102.1***	43.4	103.3***
A5	3800	122.6	700*	76.5	101.9**	43.2	102.8**
DL (kg/ha/kg/hl/g)	DL = (P 5%= 480/P 1% = 890/P 0.1% = 1560)			DL = (0.53/1.06/2.00)		DL = (1.03/1.51/3.06)	
B. Density							
B1 - Mt	2600	100.0	0	75.1	100.0	43.1	100.0
B2	3410	133.4	810**	76.5	101.9**	43.6	101.2*
DL (kg/ha)	DL = (P 5% = 440 /P 1% = 802 /P 0.1% = 1590)			DL = (0.61/1.02/2.13)		DL = (1.00/2.12/3.19)	
C. Variety							
C1 - Mt	3500	100.0	0	75.2	100.0	43.2	100.0
C2	3750	107.1	250	76.4	101.6**	43.6	100.9
DL (kg/ha)	P 5% = (480/P 1% = 960/P 0.1% = 1711)			DL = (0.70/1.12/2.25)		DL = (1.01/2.10/3.05)	

The hectoliter weight recorded the highest for the variants with sowing dates on October 25 and October 10, both with 76.7 kg/hl.

The density at sowing led to obtaining a maximum value of 76.5 kg/hl for the variant with the density of 600 g.s./m^2, compared to the variant with 500 g.s./m^2 which recorded 75.1 kg/hl.

The Pitar variety obtained the highest value of hectoliter weight, namely 76.4 kg/hl.

The weight of one thousand grains (WTG) recorded values between 42.0-43.4 g depending on the factors. The Pitar variety had the highest WTG value of 43.6 g.

The protein content recorded the highest values in 2021, these being the associated variant sown on October 25 with a density of 500 g.s./m^2 for the Pitar variety (with 13.8%) followed by the associated variant sown on October 1 with a density of 600 g.s./m^2 for the Izvor variety (with 13.5%) (Figure 1).

Among the existing functions in the Windows program - linear, logarithmic, polynomial, power and exponential - the polynomial function has the highest regression coefficient for the connection between agrotechnical measures (sowing date/seeds density/variety) and protein content in wheat (Figure 1).

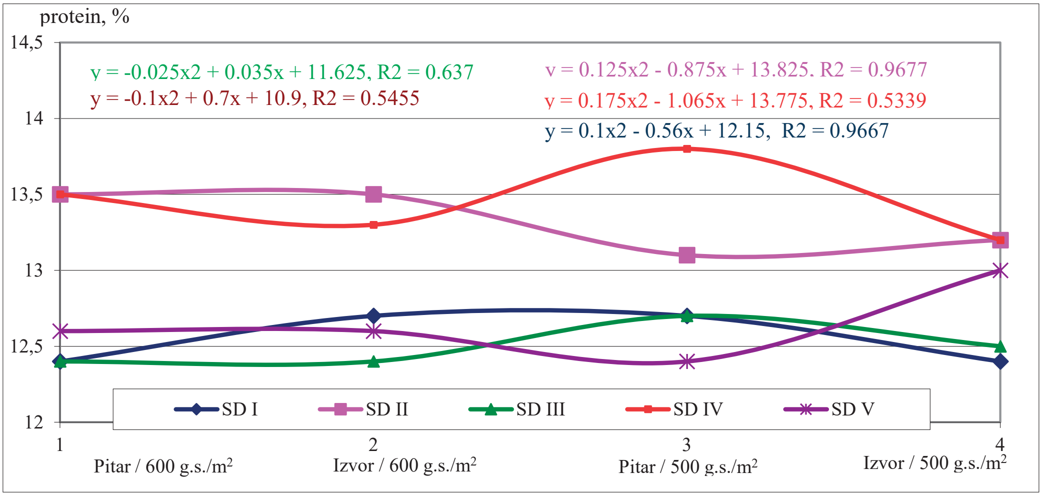

Figure 1. Correlation between agronomic measures and wheat protein content

Increasing the possibilities of choosing the sowing date and establishing the sowing density and especially the association of these factors ensure the correlations as very positive, with regression coefficients between 0.54 and 0.96. Early sowing, associated with a high sowing density, resulted in a reduced amount of protein, and the regression coefficient is 0.54.

CONCLUSIONS

The results of the study and the analyzes presented in this paper showed that sowing date, plant density and variety interact with water supply and affect the quantity and quality of wheat production. The technological links applied to the wheat crop have contributed sustainably to the growth and stability of crops and their quality.

Taking into account the technology applied to wheat, the following technological links were noted: the sowing time should be between October 10 and October 25, even delayed compared to the optimal time recommended until now; density at sowing of 600 g.s./m^2; the Pitar variety which ensures a stable and high quality production followed by the Izvor variety.

Temperatures and non-uniform distribution of precipitation affect wheat plants in any phase of the vegetation, with a negative impact on the final production and its quality.

The phenomenon of drought influences by intensity and duration, sometimes to the point of compromising the culture and in this case the drought resistance of the variety has a decisive role.

The protein content of wheat groups the variants as follows: very good quality (protein > 13%), good (12-13%) and satisfactory (8-12%). Thus, sowing in the optimal period or later and densities of 600 g.s./m^2, resulted in an increase in the protein content to values between 12-13.8%, compared to the control variant.

In the years 2020 and 2022, the drought affected the final productions regardless of the technological links applied.

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