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INFLUENCE OF FERTILIZATION ON SOME PARAMETERS OF GROWTH AND DEVELOPMENT OF *Triticum monococcum* L. IN THE CONDITIONS OF ORGANIC FARMING IN BULGARIA

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Abstract

The purpose of the study is to determine the influence of fertilization on the growth and development of Triticum monococcum L. A three-year field experiment was conducted at the Agricultural University - Plovdiv. A block method was used in four replications, with a plot area of 15 m^2. The main factors of the study are: year (2018-2019; 2019-2020 and 2020-2021), and fertilization (Control - no fertilization; Italpolina - soil fertilizer, Naturamin WSP - foliar fertilizer). The phenological development of the crop was analyzed, as well as interphase periods. The growing season was 231 days in which they accumulated 1512.2°C effective temperature sums. Growth in height is highly dependent on the year. Plants reach sizes of 81.19 to 113.18 cm. The year has a strong influence on tillering - the most number of tillers per plant (4.4-4.6) develop in the second and third years. Italpolina - soil fertilizer has a better effect on this indicator. The influence of soil fertilizer is stronger compared to foliar fertilizer both on the number of productive tillers/plant and on the number of productive stems/m^2.

Key words: *Triticum monococcum L., growth, phenophases, fertilization, organic farming.*

INTRODUCTION

A number of authors consider *Triticum monococcum* L. to be the most ancient cereal crop, which is believed to have been used for human food as early as 10.000 years ago (Salamini et al., 2002). According to Arnaudov (1936a; 1936b) and Lipshits (1945), this species was cultivated in the Thracian lands more than 3500 years ago. According to Demosten (384-322 BC), grains of *Triticum monococcum* L. were found in Thracian underground storages (Katzarov, 1912; Ikonom, 1936). It was called "the bread of the Thracians", "the wheat of the pharaohs", "the last food of Christ". In German and English it is known as "einkorn", in French "engrain", in Hungarian "alakor", and in Russian as "odnosrianka" (Stamatov et al., 2017). In Bulgaria, Stranski (1929) studied einkorn and described 4 wild and 11 domesticated varieties of the species, including some endemic ones (var. *bulgaricum,* var. *sofianum*).

Until 40 years ago, einkorn production was limited to small isolated regions in France, India, Italy, Turkey and the former Yugoslavia (Harlan, 1981; Perrino and Hammer, 1984).

Currently, there is a renewed interest in this crop due to the nutritional qualities of the grain, its adaptation to economic cultivation and high resistance to diseases and enemies, which are an advantage for organic farming (Stamatov et al., 2012). Cultivated einkorn is also a valuable source of genes for the breeding improvement of modern wheats (Zaharieva and Monneveux, 2014).

Today, einkorn can be found all over Bulgaria, but more often as a weed. It is grown in small areas in the area of the cities of Haskovo, Stara Zagora, Yambol, Pernik, Sofia and Kyustendil.

According to the Bulgarian scientist Stranski (1929, 1934), the einkorn was brought by the ancient Bulgarians to the lands of the former Volga-Kam Bulgaria from the Balkan Peninsula, and the German researcher Schiemann (1954) determined the distribution directory of einkorn, which started from the Bulgarian lands and went in the Volgo-Kama-Ural direction. According to Arnaudov (1936a), this plant was found during archaeological excavations near the village of Veselinovo (Yambol region), in the form of charred mature classes.

The large number of wild and cultivated varieties of this species in these lands is an indication that Bulgaria is a secondary formative center.

Current trends towards sustainable and economical agriculture, as well as the use of "biological" and "functional" foods, suggest that this cereal can play a significant role in the dietary and healthy nutrition of humans. Additional research is needed to specify some components of the technology for organic farming in Bulgaria.

The aim of the present study is to determine the influence of fertilization with products for biological production on phenological development, tillering dynamics, growth in height and the formation of the productive stem.

MATERIALS AND METHODS

To achieve the aim of the study, a field experience was undertaken at the Agroecological Center - Demonstration Center for Organic Agriculture at the Agricultural University - Plovdiv, Bulgaria, in the period 2018 - 2021. The Agroecological Center has been a member of the International Federation of Organic Agriculture (IFOAM) since 1993. A block method was used in four replications, with a harvest plot area of 15 m^2. A common vetch (*Vicia sativa* L. ssp. *sativa*), sown in spring, was used as a preceding crop for the experiment.

The following variants have been tested: Control - without fertilization; Fertilization with soil fertilizer - Italpolina, in a dose of 0.7 t/ha; Fertilization with foliar fertilizer - Naturamin WSP - an amino acid product applied in three treatments - in the tillering, stem elongation and heading phases with 30 g/da. The year was also considered as a factor in the statistical processing for the three-year period.

The seeds are from local forms of einkorn, produced in an organic farm and provided by the Institute of Plant Genetic Resources "K. Malkov" town of Sadovo. They are certified with the relevant necessary documents of origin.

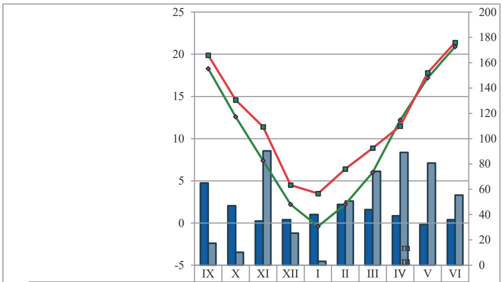
Statistical processing of the experimental data was performed using the SPSS V. 9.0 for Microsoft Windows program, using Duncan's method, Anova.

The soils in the Agroecological Center are alluvial - meadow (Mollic Fulvisols) (FAO-UNESCO, 1988). They have low N availability, low to medium P availability, and good K availability. The soil analyzes (Table 1) made immediately before sowing confirm the previously made characterization of the soil (Popova and Sevov, 2010). The soil conditions in the three years are relatively the same.

Table 1. Agrochemical indicators of the soils in the experimental areas

Year	pH (H_2O)	NH_4^+	NO_3^{2-}	NH_4^+ NO_3^{2-}	P_2O_5	K_2O
		mg/kg	mg/kg	mg/kg	mg/ 100 g	mg/ 100 g
2018	7.3	12.0	19.0	31.0	7.8	32.0
2019	7.5	23.4	16.5	39.9	13.6	29.2
2020	7.8	19.3	8.3	27.6	12.5	33.1

Agrometeorological conditions in the experimental period are presented in Figures 1, 2 and 3.



	IX	X	XI	XII	I	II	III	IV	V	VI
mm/m2 average 1965-1995	65	47	35	36	40	48	44	39	32	36
precipitations (mm/m2) 2019-20	17,4	10,2	90,4	25,3	3	50,7	74,1	89,1	80,7	55,4
t C° average 1965-1995	18,3	12,6	7,4	2,2	-0,4	2,2	6	12,2	17,2	20,9
t C° 2019-20	19,9	14,6	11,4	4,5	3,5	6,4	8,9	11,5	17,8	21,4

Figure 1. Agrometeorological conditions for the development of *Triticum monococcum* L. in the region of Plovdiv (2018/2019)

The einkorn growing season in 2018/2019 is defined as warm and wet (Figure 1). Temperatures in autumn - September, October and November are higher than the monthly averages for the long-term period. At that time, however, rainfall is limited, which delays the preparation of the soil and the timely entry into the third leaf and tillering phases at an optimal time. The amount of precipitation in the September-June period is about 50 l/m^2 more than the norm, but it is disproportionately distributed. The months of November, April and June are distinguished by the maximum rainfall. Rainfall in the autumn months of 2019 (Figure 2) was more favorable for treatments, the plants passed normally through the third leaf phases and entered tillering on time. Crops are provided with sufficient amounts of moisture.

Until ripening, the plants develop in optimal agrometeorological conditions.

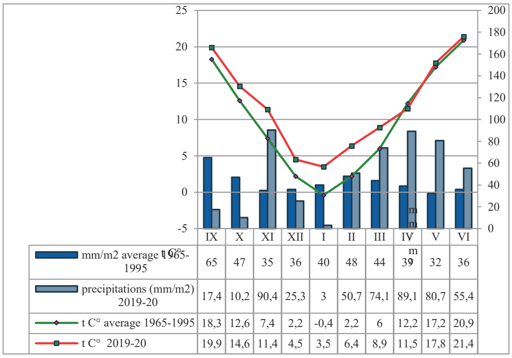


Figure 2. Agrometeorological conditions for the development of *Triticum monococcum* L. in the region of Plovdiv (2019/2020)

The third experimental year (Figure 3) started with temperatures above normal and very little moisture, especially in the month of November, but by the end of the growing season the conditions were favorable for normal plant development.

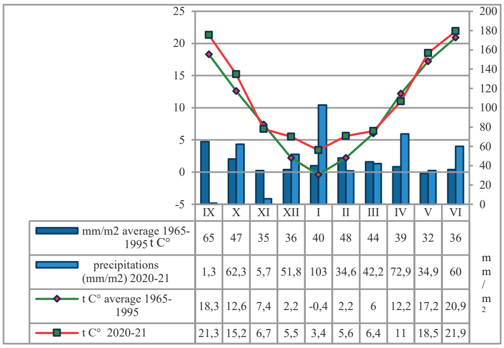


Figure 3. Agrometeorological conditions for the development of *Triticum monococcum* L. in the region of Plovdiv (2020/2021)

The three years of the study appear to be significantly warmer than normal, which is in line with global trends. For a 6-month growing season, the average monthly temperature is 1.7°C higher than the norm for 2018-2019 (X to VI), 3.2°C higher for the same period in 2019-2020 and by 1.7°C - in the last year of study.

Precipitation in the growing seasons is in larger amounts, but not always evenly distributed, which reflects the duration of the interphase periods and the optimal course of life processes.

RESULTS AND DISCUSSIONS

Phenological development. The vegetation period of einkorn under the experimental conditions was found to be 230 to 233 days (Table 2). It begins with germination between November 5 and 10 and ends with harvesting in the period June 26-27.

Our data on duration of the growing season are similar to those obtained and described by Stamatov et al. (2017a) results in the period 2015-2016 in the experimental field of IRGR - Sadovo. When einkorn is sown in October, the genotypes included in the study have a growing season of 236 to 238 days.

Despite the relatively equal duration of the vegetation period, in the three experimental years differences were reported regarding the duration of the interphase periods. In the first interphase period - from germination to the third leaf phase, plants enter the fastest in 2019 (in 27 days), and the slowest (40 days) in 2020. The differences in the three years reach up to 13 days and are due to the different temperature conditions from the second ten days of November to the second ten days of December in the three experimental years. In this interphase period, plants accumulate the most active temperature sum (240.5°C) in the second experimental year (2019-2020), which explains the faster entry into the third leaf phase (Table 3).

Seven to nine days is the difference in the three years and in relation to the next interphase period - third leaf - tillering. However, crops enter the tillering phase in one calendar term, regardless of how the previous phases went. The required number of days from germination to tillering is a relatively constant value - from 43 to 47 days, and for this purpose a temperature sum of about 187°C, as accumulated in the cooler autumn of 2018 is sufficient.

In the following phases, the plants enter at the same time in the three years with a difference of a maximum of 4 calendar days until the beginning of stem elongation and with a difference of one day each in heading, milky, waxy and full maturity.

Table 2. Duration of interphase periods in *Triticum monococcum* L., number of days, 2018-2021

Interphase period	Duration of vegetation period, number of days			
	2018-2019	2019-2020	2020-2021	Average
Germination - Third leaf	36	27	40	34
Third leaf - Tillering	9	16	7	11
Tillering - Stem elongation	123	120	120	121
Stem elongation - Heading	21	24	24	21
Heading - Milk maturity	23	24	23	23
Milk maturity - Wax maturity	11	9	11	10
Wax maturity - Full maturity	7	10	8	8
Vegetation period	230	230	233	231

The average accumulated temperature during the three years is 1512°C, with the minimum sufficient effective temperature amount recorded in 2020/2021 - 1431.1°C. In combination with the largest amounts of precipitation in the March-June period, the agro-meteorological conditions in the second experimental year (2020/2021) are the main prerequisite for the highest yield.

Table 3. Sum of active temperatures by interphase periods, for *Triticum monococcum* L., °C, 2018-2021

Interphase period	Duration of vegetation period, number of days			
	2018-2019	2019-2020	2020-2021	Average
Germination - Third leaf	160.6	240.5	227.5	209.5
Third leaf - Tillering	26.2	88.7	34.4	49.8
Tillering - Stem elongation	389.4	354	260.1	334.5
Stem elongation - Heading	242.2	270.1	264.9	259.1
Heading - Milk maturity	347.1	319.4	316.1	327.5
Milk maturity - Wax maturity	216.4	138.6	165	173.3
Wax maturity - Full maturity	137.8	174.5	163.1	158.5
Vegetation period	1519.7	1585.8	1431.1	1512.2

No differences were found in the phenological phases as a result of the different fertilization variants.

Productive tillering. In the first year, 2.9 to 3.9 productive tillers develop per plant, on average from the repetitions for the different fertilization variants. In the second and third year, their number is significantly higher - from 4.3 to 4.5, and from 4.4 to 4.9 pieces, respectively.

Fertilization has different effects in different years. In the first year, the variants without fertilization and those fertilized with the soil fertilizer Italpolina have the same average values. In the second year, the control variants (without fertilization) have a higher productive tillering than those fertilized with soil fertilizer and leaf fertilizer, and in the third year, fertilization with soil fertilizer has been proven to increase the productive tillering. In all three years, Naturamin WSP did not lead to an increase in productive tillering (Table 4).

Table 4. Influence of fertilization on number of productive tillerss/plant, at the end of the growing season in *Triticum monococcum* L., by years

Variant (Fertilization)	2018/2019	2019/2020	2020/2021
Without fertilization (control)	2.9 a*	4.5 a	4.6 ab
Italpolina	2.9 a	4.4 a	4.9 a
Naturamin WSP	3.9 a	4.3 a	4.4 b

*Means followed by the same letter are not statistically different (P < 0.05) by Duncan's multiple range test

The summary statistical analysis for the three-year experimental period shows proven differences in the influence of year on productive tillering (Table 5).

Table 5. Influence of the year and fertilization on the number of productive tillers at the end of the growing season in *Triticum monococcum* L., 2018-2021

Influence of factor Year			Influence of factor Ferilization		
Variant	Number of tillers/ plant	%	Variant	Number of tillers/ plant	%
2018-2019	2.9 b*	100.0	Without fertilization (control)	4.0 a	100.0
2019-2020	4.4 a	151.7	Italpolina	4.1 a	102.5
2020-2021	4.6 a	158.6	Naturamin WSP	3.9 a	97.5

*Means followed by the same letter are not statistically different (P < 0.05) by Duncan's multiple range test

The second and third experimental years provide proven better conditions for tillering than the first year. In the third year, the plants reached a maximum of 4.6 productive tillers per plant, which is 58.6% more than the first year. Productive tillering increases as a result of soil fertilization with Italpolina, while the foliar Naturamin WSP does not affect this indicator.

Dynamics of growth in height. Plant height is an important parameter monitored by specialists and farmers, given the fact that excessive growth can lead to lodging, which negatively affects both harvesting and final yield. On the other hand, it is an indicator of active growth processes and biomass accumulation, which correlate with yield. The dynamics of growth in height was followed by measuring in three phases - tillering, stem elongation end heading (Figure 4).

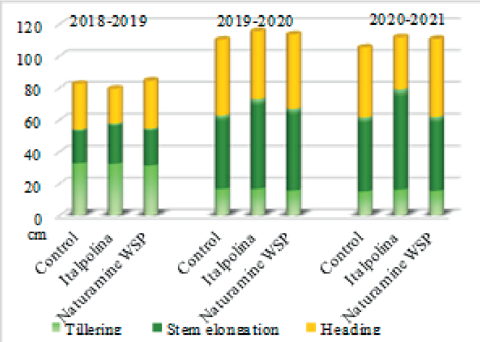


Figure 4. Dynamics of growth in height of *Tr. monococcum* L. depending on fertilization, by phenological phases and years, cm

It is clear from Figure 4 that the second and third growing years provide more favorable conditions for reaching maximum plant heights. Vegetative growth is directly dependent on rainfall, which in these two years is better distributed.

When studying the influence of the tested fertilizers on the height (Table 6), the stronger influence of the soil fertilizer is established, which is mainly manifested in the second and third year. Already during the stem elongation phase, differences of 9.7 cm in the second and 17.6 cm in the third year are reported, which, until heading, decrease to 5.3 cm and 6.4 cm, respectively.

The influence of the foliar fertilizer Naturamin is weaker, only in the stem elongation phase and only in the second year. By the heading phase, some influence was reported in all three years. The differences with the control reached 2.0 cm in the first year, 4.2 cm in the second and 5.3 cm in the third year. It can be summarized that the influence of fertilization is more significant in the more moisture-provided years 2019/2020 and 2020/2021. The summary statistical treatment for the three-year period shows the strong proven influence of the year. Italpolina leads to an increase in height by 2.9 cm, and Naturamin WSP - by 3.5 cm.

Table 6. Influence of the year and fertilization on plant height at the end of the growing season for *Triticum monococcum* L., cm, 2018-2021

Influence of factor Year			Influence of factor Ferilization		
Variant	Height, cm	%	Variant	Height, cm	%
2018-2019	82.2 b	100.0	Without fertilization (control)	99.5 a	100.0
2019-2020	113.2 a	137.7	Italpolina	102.4 a	102.9
2020-2021	109.4 a	133.1	Naturamin WSP	103.0 a	103.5

*Means followed by the same letter are not statistically different ($P < 0.05$) by Duncan's multiple range test

Zorovski et al. (2018) also conducted similar studies in Bulgaria, comparing *T. monococcum* L. with other ancient cereal species. In the period 2014-2018, on average, einkorn plants reached heights of 79.90 to 97.38 cm, which corresponds with our results.

Einkorn was also included in studies by Kirchev and Semkova (2016). They establish the influence of nitrogen fertilization on this indicator. At a nitrogen fertilizer rate of 40 kg/ha, the plants reach a height of 103.4 cm, and at 80 kg/ha - 106.2 cm.

With our results, we also confirm the influence of fertilization as a factor that can influence the growth and development of *Triticum monococcum* L.

Productive stems/m². The dynamics of stem formation gives us information about what productivity can be expected from a crop that started its vegetation with a certain number of plants and developed a certain number of tillers of each plant - non-productive and productive. The reduction of the number of plants, as well as the reduction of the tillers of each individual plant, is a natural biological process, also known as self-regulation in the crop.

Einkorn reacts in a specific way (Table 7). Even in the less favorable 2018/2019 year, it formed a relatively stable number of productive stems - from 799 pieces to 861 pieces per m^2, most likely due to the highly adaptive reactions of the species. Fertilization with soil fertilizer has a positive effect on this indicator, while foliar fertilizer is of lesser importance, and only in the second and third year.

Table 7. Influence of fertilization on the productive stem in *Triticum monococcum* L., by years, number per m^2

Variant Fertilization	2018/2019	2019/2020	2020/2021
Without fertilization (control)	799 a	496 a	963 a
Italpolina	861 a	1050 a	1020 a
Naturamin WSP	796 a	1030 a	1004 a

*Means followed by the same letter are not statistically different ($P < 0.05$) by Duncan's multiple range test

The summary data for the three-year period (Table 8) confirms the strong influence of the year. Both types of fertilization have a positive effect, but it is stronger with soil fertilizer.

Table 8. Influence of the year and fertilization on the productive stems of *Triticum monococcum* L., average for the period 2018-2021, number per m^2

Influence of factor Year			Influence of factor Ferilization		
Variant	Produc-tive stems, number/m^2	%	Variant	Produc-tive stems, number/m^2	%
2018-2019	819 b*	100.0	Without fertilization (control)	903 a	100.0
2019-2020	1009 a	123.2	Italpolina	977 a	108.2
2020-2021	996 a	121.6	Naturamin WSP	943 a	104.4

*Means followed by the same letter are not statistically different ($P < 0.05$) by Duncan's multiple range test

The correlation coefficients presented in Table 9 support our conclusions about the significance of the studied indicators. The productive tillering of the individual plants, as well as the total number of formed productive stems per m^2, is in a proven positive correlation with the yield.

Table 9. Correlation dependencies between the yield and some productivity parameters of *Tritium monococcum* L. (Correlation coefficient - R; Determination coefficient - D)

Productivity parameters	Yield kg/da	Productive tillering, number of tillers/plant		Productive stems, number/m^2	
		R	D	R	D
Yield kg/da	1.000	0.422**	18	0.371**	14
Productive tillering, Number of tillers /plant		1.000		0.419**	18
Productive stems, Number/ m^2				1.000	

**The correlation is significant at the level of $P \leq 0.01$;

CONCLUSIONS

The vegetation period of *Triticum monococcum* L. is available in 230 to 233 days (in case of autumn sowing) under the conditions of Bulgaria. The duration of the first interphase periods (from emergence to third leaf and from third leaf to tillering) strongly depends on agrometeorological conditions. In the course of their vegetation, plants accumulate an average of 1512.2°C. Productive tillering strongly depends on the conditions of the year, and less on fertilization. The influence of the soil fertilizer Italpolina is more significant. Growth in height is more intense in the more favorable second and third experimental years. Fertilization with Italpolina and Naturamin affects plant height, increasing it by 2.9 to 3.5%. Both fertilizers have a positive effect on the formed productive stem/m^2 at the end of the year. Productive tillering/plant and productive stems/m^2 have been shown to be positively correlated with yield.

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MISCELLANEOUS