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AGRONOMIC PERFORMANCE OF TRITICALE VARIETIES (× *Triticosecale* Wittm.) GROWN UNDER FERTILIZATION WITH ORGANIC MANURE FROM RED CALIFORNIAN WORMS (*Lumbricus rubellus*)

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Abstract

The aim of the study was to evaluate a grain yields of triticale varieties and some parameters of productivity - plant height and structural elements of spike, as well as possible relations between the studied traits under biological cultivation. In the period 2014–2017 three–factor field experiment was set up with block design method with 4 replicates, plot size of 18 m^2 with 550 germinated seeds per m^2. Three varieties of triticale, three fertilizing rates with organic fertilizer and two predecessors (sunflower and durum wheat) were tested on Vertisols soils. The most productive was Respect variety - 1,293 kg/ha. The greatest increase on yields was observed at a rate of 1,750 kg/ha Lumbrical - 1,416.4 kg/ha. After a predecessor of sunflower higher yield was established - 1,350.9 kg/ha. A positive correlation between grain yields and plant height for Colorit and Boomerang varieties were observed. A positive interdependence between length of spike, number of grains per spike and weight of grains per spike was founded in all the investigated varieties.

Key words*: organic farming, organic fertilization, predecessors, triticale.*

INTRODUCTION

In 1888 the german scientist Rimpau (Rimpau, 1891) created the first triticale plants. Since triticale sustained an evolutionary progress and is diffused in the world, due to the high productivity of grain and biomass. In 1967 the first Bulgarian 42-chromosomal triticale T–AD is created by Prof. Stoyan Tsvetkov. Bulgaria became the seventh country in the world selecting the culture. According to Tsvetkov (1982), this plant species is promising because exhibits high genetic potential for yields and favorable nutritional values. Bulgaria is located in the zone of the suitable area for the sowing of winter triticale forms. According to Salmon et al. (2004), sowing of triticale in Eastern and Western Europe, where the climate is cool, completely responds with the culture's requirement to pass its vernalization stages. According to FAOSTAT data over the last 20 years, triticale areas in the world are grown. Since the middle of 90's to the beginning of the 21st century, the triticale area ranged from two million to nearly two million and half hectares. Since the beginning of the century there has been a increase of area, with over 3.8 million hectares in 2005. It followed a slight decrease in 2006 and a further increase to reach the absolute maximum of triticale areas in the world in 2009 - more than 4.3 million hectares. On average for 20 years, the area of triticale in the world is 3.4 million hectares (FAO, 2018).

In Bulgaria, the area cultivated with triticale in 2017 compared to 2015 is increased with 45.4%, the average yields marked an increase with 5.0%, the production is increased with 54.0% (MAF, 2019). The main use of the grain and green mass of triticale is as a source of fodder. According to Grain Advisory Council, the area planted in 2018 is increased with 15.34% compared to 2017 (MAF, 2018).

Organic farming is an important priority in agricultural development policy and one of the focus of the Common Agricultural Policy for the period 2014-2020. According to a strategy for development of this direction in Bulgaria to 2020, one of the goals is to conduct a oriented to the practiceresearch based on organic farming (Atanasov, 2019). The grain

production without a negative impact on environmental with a long-term trend of sustainability is identified as crucial for the development of agriculture (Foresight, 2011).

The selection of modern varieties is related to cultivation of varieties growing under conventional system. They are not suitable for organic farming, because are created in order to combine high productivity and standard quality, growing under high agrophone (Bozhanova and Dechev, 2009). The different requirements of the biological system limit their use, because the plants have difficulty adapting. Döring et al. (2012) and Butler et al. (2007) have confirmed that a few varieties are created specifically for organic farming. It is possible, triticale as a new culture to be adapted better to the requirements of organic farming. The tolerance against disease does not require the use of pesticides, which results in ecological production (Golovkov, 1969). In areas characterizing by unfavorable abiotic conditions such as drought and extreme temperatures, the triticale proves to be a competitive crop compared to other cereals (Salmon et al., 2004; Martinek et al., 2008). Compared to other cereals, especially common wheat, it is an interesting alternative in environment, where the conditions of farming are associated with low inputs (Erekul and Köln, 2006).

Because of the high grain quality, triticale has great potential for use as a food for humans and a source of fodder (Green et al., 2002). Its advantages are the higher values of a lysine content in protein. According to Georgieva et al. (2016), the triticale is characterized by a higher digestibility of dry and organic matter of straw and grain (55.23, 46.65) compared to rye (44.68, 38.25). Under organic farming conditions Bozhanova et al. (2014) have received the highest yields of dry biomass from triticale. Pogonets (2015) has developed a science-based recipe for production of bakery products with triticale flour, defining a rational ratio of wheat flour and triticale of 40: 60.

In Bulgaria, triticale studies have been conducted by many scientists (Kirchev et al., 2007; Kolev et al., 2011; Atanasova et al., 2014; Gerdjikova, 2015; Dobreva et al., 2018a; Dobreva et al., 2018b; Kirchev et al., 2018; Stoyanov, 2018; Stoyanov and Baychev, 2018), but few experiments have been carried out to determine productivity of varieties under biological system, especially against the background of various predecessors and levels of organic fertilization. This creates necessary to conduct field trials to provide information on the most appropriate variety. Because organic management practices continue to be tested (Doltra and Olesen, 2013), the purpose of the study was to evaluate grain yields of triticale varieties and some parameters of productivity-plant height and structural elements of spike following different predecessors and fertilization rates, as well as possible relations between the specified parameters under biological cultivation.

MATERIALS AND METHODS

In the period 2014-2017 three-factor field experiment was set up with block design method with perpendicular arrangement of the degrees of the tested factors with 4 replicates, plot size of 18 m^2 with 550 germinated seeds per m^2. Three varieties of triticale (Colorit, Boomerang and Respect), three fertilizing rates with organic fertilizer (0, 1,400 and 1,750 kg/ha) and two predecessors (sunflower and durum wheat) were tested. The soil treatment before sowing included a double processing with heavy disc harrows at a depth of 8-12 and 6-8 cm followed by manual fertilization and cultivation. The plant samples were taken and processed according to the accepted methodology (Topalov et al., 1994).

The organic fertilizer Lumbrical is product from processing of manure and other organic waste from Red Californian worms (*Lumbricus rubellus* and *Eisenia foetida*), was used. The commercial product contains: organic substance 45-60%; humic-acids up to 14%; fulvic-acids 7%; ammonium nitrogen (NH_4-N) - 33.0 ppm; nitric nitrogen (NO_3-N) - 30.5 ppm; P_2O_5 - 1410 ppm; K_2O - 1910 ppm; useful microflora of 2 x 1012 pg/g and a large number of biologically active substances. pH = 6.5-7.0. In accordance with EU Regulation 889/2008 for organic farming was applied. The Colorit variety exceeds an yields of all varieties created from Dobrudja Agricultural Institute

and since 2015 was selected for a standard in Bulgaria for productivity in Executive Agency on Aproabation and seed control (IASAS). The cold resistance of Boomerang variety is close to wheat № 301 or slightly above it. The Respect variety demonstrates a cold resistance as the most cold-resistant standard-common wheat Mironovska 808.

The soil (PellicVertisols) is low to medium provided with mineral nitrogen, with low content of mobile phosphates and good supply of digestible potassium.

Field Crops Institute (42°11'58"N, 25°19'27"E) is located in temperate-
continental subarea zone (Sabev and Stanev, 1963). The Chirpan area is characterized by strong variability of temperature conditions during the growing season. During the winter is possible the temperatures to decrease to -20°C...-30°C). The main precipitation maximum is observed in summer, as average over a multi-year period is 160.7 mm. The amount of annual rainfall more than 750 mm is observed average once every 10-12 years. The vegetation of triticale for the first and the second year occurred under conditions of temperature amounts above average for 86 years (2,009.7°C), respectively 2,264.1°C and 2,530.4°C, and during the last year of the study the temperature sum was lower than a multi-year period - 1,843.5°C (Figure 1).

The fallen rainfall during 2014/15 period were 183.2 mm higher than multi-year period (395 mm), and during the next two years the rainfall were 71.6 mm and 19.8 mm less.

In order to establish statistically significant influences of the studied factors and differences between the tested variants BIOSTAT was applied on date for a period 2015-2017 (Penchev et al., 1989-1991). The software Statistica 13 was used to establish correlation dependencies.

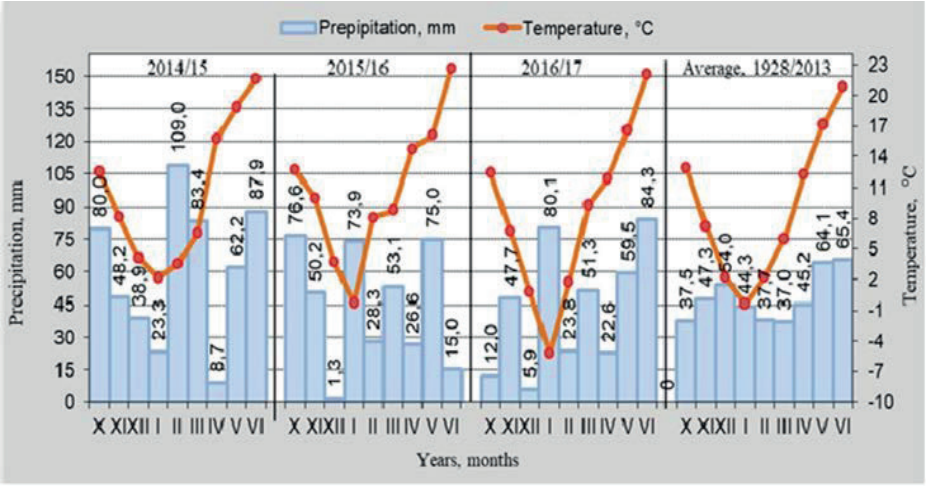

Figure 1. Temperatures and precipitation condition during vegetation of triticale

RESULTS AND DISCUSSIONS

The grain yields from triticale is result of a number of complex morphological and physiological processes that influence each other and occur in different stages of growth during vegetation (Janušauskaite, 2014). During the three years of the study, the triticale realized its productive potential through the amount of grain yields in varying degrees under the influence of the studied factors. The data, both in productivity and studied parameters showed that the varieties are differed in vary degrees.

According to results on Table 1, the test of increasing fertilizer rates of 1,400 kg/ha and 1,750 kg/ha increased a grain yields and spike

Table 1. Results of ANOVA analysis of grain yields, structural elements of spike and plant height. Interaction of the factors A × B × C

Factors and levels		GY (kg/ha)	LS (cm)	NGS	WGS (g)	PH (cm)
after predecessor of sunflower						
Colorit	0	929.0	8.4	46.0	1.84	77.3
	1,400 kg/ha	1,203.0^{ns}	9.3^{ns}	50.7^{ns}	2.14^{ns}	81.5^{ns}
	1,750 kg/ha	1,427.0**	9.9**	59.3**	2.62**	92.7*
Boomerang	0	1,116.0^{ns}	8.3^{ns}	42.2^{ns}	1.65^{ns}	81.6^{ns}
	1,400 kg/ha	1,431.0**	8.6^{ns}	46.3^{ns}	1.87^{ns}	87.5^{ns}
	1,750 kg/ha	1,597.0***	9.4^{ns}	52.0^{ns}	2.17^{ns}	94.2*
Respect	0	1,117.0^{ns}	7.9^{ns}	43.0^{ns}	1.75^{ns}	77.9^{ns}
	1,400 kg/ha	1,499.0***	8.7^{ns}	49.8^{ns}	1.97^{ns}	82.8^{ns}
	1,750 kg/ha	1,780.0***	9.7*	58.7**	2.63**	94.6*
after predecessor of durum wheat						
Colorit	0	949.0^{ns}	8.9^{ns}	42.8^{ns}	1.56^{ns}	76.2^{ns}
	1,400 kg/ha	1,115.0^{ns}	8.6^{ns}	45.6^{ns}	1.82^{ns}	87.9^{ns}
	1,750 kg/ha	1,294.0^{ns}	9.3^{ns}	51.9^{ns}	2.07^{ns}	92.6*
Boomerang	0	883.0^{ns}	8.7^{ns}	43.3^{ns}	1.78^{ns}	76.0^{ns}
	1,400 kg/ha	1,066.0^{ns}	9.0^{ns}	47.8^{ns}	2.08^{ns}	85.2^{ns}
	1,750 kg/ha	1,228.0^{ns}	9.5*	52.5^{ns}	2.27*	92.3*
Respect	0	1,006.0^{ns}	8.2^{ns}	42.7^{ns}	1.86^{ns}	71.0^{ns}
	1,400 kg/ha	1,130.0^{ns}	9.0^{ns}	48.7^{ns}	1.88^{ns}	74.7^{ns}
	1,750 kg/ha	,1172.0^{ns}	9.2^{ns}	53.2^{ns}	2.20^{ns}	80.3^{ns}
LSD	5.0%	298.0	1.1	8.5	0.4	13.6
	1.0%	400.0	1.4	11.4	0.6	18.3
	0.1%	527.0	1.8	15.0	0.8	24.2

A - variety; B - fertilizing; C - predecessor; ns - no significant; *, **, ***significant at P = 5%, P = 1% and P = 0.1%, respectively; GY - Grain yields; PH - Plant height; SL - Spike length; NGS - Number of grain per spike; WGS - Weight of grains per spike.

Table 2. Results of ANOVA analysis of triticale grain yields

Source	LSD			Levels of factors (kg/ha)		
	5.0 %	1.0 %	0.1 %	Control	2	3
A	121.5	163.1	215.2	1,152.7	1,220.2^{ns}	1,293.9*
B	121.5	163.1	215.2	1,009.9	1,240.6***	1,416.4***
C	99.2	133.2	175.7	1,350.9	1,093.7^{ns}	-

A - variety; B - fertilizing; C - predecessor; ns - no significant; *, **, ***significant at P = 5%, P = 1% and P = 0.1%, respectively.

elements values for all triticale varieties after of two predecessors. The highest values was observed at maximum fertilizer rate - 1,750 kg/ha. The greatest increase of grain yields compared to a control option was received after a predecessor of sunflower (29.5-91.6%) with high significance for Boomerang and Respect varieties when was applayed 1,750 kg/ha Lumbrical, and for Respect variety was in range of 61.4-91.6%. After a predecessor of durum wheat the increase was between 14.7% and 39.3%, but the differences were not statistically significant. In the study LS, NGS, WGS and HP modifed under influence of the test factors for all varieties. According to date on Table 1, after predecessor of sunflower the LS values was from 7.9 to 9.9 cm, NGS varied from 42.2 to 59.3, the WGS was between 1.65 to 2.63 g and the PH was in the range of 77.3 and 94.6 cm. After durum wheat the increase of the values changed as follows: LS (8.2-9.5 cm); NGS (42.7-53.2); WGS (1.56-2.27 g); PH (76.0-92.6 cm). According to Alheit et al. (2014) has no observed large variation in LS for triticale. Gerdgikova et al. (2008) have obtained under biological system for triticale after two predecessors - soybeans and winter peas -, higher average values for PH and LS, but lower results for NGS and WGS. Stoyanov and Baychev (2018) have received higher results under conditions of Northeastern Bulgaria in regard to PH for Colorit, Boomerang and Respect varieties - 122, 131 and 123 cm, respectively.

Maximum average yields was achieved for Respect variety (1,293.9 kg/ha), which completely characterized productive capacity of a variety compared to other two Colorit and Boomerang - 1,152.7 kg/ha and 1,220.2 kg/ha, respectively (Table 2). It can to be suppose, that the Respect variety exhibits better adaptability to environmental conditions, realizes higher productivity under low supply of soil nitrogen and manifest high responsiveness to the applied biological fertilizer. In detail study of Respect variety (Bajchev and Petrova, 2011) has pointed the better ecological plasticity which has evidenced by the higher relative yields during unfavorable years, higher productivity (8,330 kg/ha), compared to average standard from all varieties included in the study.

The average grain yields after a sunflower was 1,350.9 kg/ha and after a durum wheat was lower - 1,093.7 kg/ha or 257.2 kg/ha less than a control option (Table 2). Obviously, the varieties showed same reaction to the two predecessors. This is confirmed by the results presented on Table 4 where is shown, that 11.89% from the total yield dispersion is due to the influence of a factor predecessor. In contrast to our results, higher yields values under organic farming (2.60-4.84 t ha^{-1}) have obtained by testing triticale varieties in Lithuania (Kronberga et al., 2013). In another study, the authors has obtained 4.76 t/ha average yields from triticale lines growing on the same technological system (Kronberga, 2008).

From Table 2 is obviously, that the fertilizing significantly increased the grain yields in rate of 1,400 and 1,750 kg/ha Lumbrical, respectively 1,240.6 and 1,416.4 kg/ha or 230.7 and 406.5 kg/ha, respectively over the control option.

According to the data on Table 3, 19.92% from the total dispersion is due to a fertilizing and significantly influence of a factor fertilizing was observed in all the yields parameters.

Table 3. Results of ANOVA analysis of investigating parameters

Source	df	GY		LS		NGS		WGS		PH	
		η_i	MS	η_i	MS	η_i	MS	η_i	MS	η_i	MS
A	2	2.3	898.0 ^{ns}	0.3	0.3^{ns}	0.6	24.2 ^{ns}	0.8	2.78^{ns}	3.8	171.4^{ns}
B	2	19.9	7,482.9***	16.4	15.2***	14.2***	574.6***	45.9	1.5***	20.9	942.0***
C	1	11.9	8,929.4***	7.6	0.1^{ns}	0.8	62.6^{ns}	2.9	0.28^{ns}	2.1	191.4^{ns}
A × B	4	0.1	11.0^{ns}	0.1	3.9^{ns}	0.3	6.8^{ns}	1.5	2.58^{ns}	0.3	7.0^{ns}
A × C	2	3.4	1,267.2*	1.5	1.3^{ns}	1.1	43.8^{ns}	8.6	0.3*	3.4	151.0^{ns}
B × C	2	1.8	668.0^{ns}	0.3	0.3^{ns}	0.3	13.5^{ns}	3.4	0.18^{ns}	0.5	21.3^{ns}
A × B × C	4	0.6	116.2^{ns}	0.9	0.4^{ns}	0.1	2.5^{ns}	1.6	2.68^{ns}	0.8	17.0^{ns}

A - variety; B - fertilizing; C - predecessor; ns - no significant; *, **, ***significant at P = 5%, P = 1% and P = 0.1%, respectively; GY - Grain yields; PH - Plant height; SL - Spike length; NGS - Number of grain per spike; WGS - Weight of grains per spike.

Ugarte et al. (2007) have established that WGS of triticale is influenced by environmental conditions. In terms of the present study WGS was most affected by fertilization - 45.91% of the total dispersion. In regard to a predecessor, it should be noted that its biological role in crop rotation is undisputed, from a point of view of the amount of plant residues which subsequently are mineralized. On the other hand, the quantity of the exported nitrogen from the predecessors is different. Durum wheat assimilates less nitrogen to realize 100.0 kg grain (3.2-4.9 kg N), unlike sunflower–about 6.0 kg N (Terziev et al., 2007). Such conclusions about the role of predecessor, fertilizing and meteorological conditions have expressed other authors. Delibaltova and Kirchev (2016) have founded that the predecessor and the nitrogen fertilization in combination with meteorological conditions are crucial factors for formation of the productivity of winter wheat. A low significant interaction between the factors variety and predecessor on GY and WGS was observed, 3.73% and 8.58%, respectively from the total dispersion.

Each variety exhibits a specific response to the environmental conditions. This determines differences in a character of the correlation relations between the individual components of

yield in the various studies. Additional correlation analysis was applied to estimate all possible relations of yields with studied agronomic characterists, which results are presented on Table 4. It is known that the yields is integral value, this value has a complex character and is related with other parameters. Rachovska and Ur. (2010) have observed a relation between yields and spike parameters, Nikolova and Panayotov (2008) have found a relation of yields with number of productive tillers and Stoyanov (2013) with photosynthetic activity of crops. The established positive correlations not necessarily to give explanation for causality dependence between the studied indicators and yields, as there are additional, uncontrolled factors in the study. It is known
that triticale is characterized with many features of its phenology, which depend mostly of the the environment conditions (Giunta et al., 1993).

Different values of the coefficients as well as the different character of the relations between the considered components of spike, YG and PH were observed. For Colorit variety, a positive and significant correlation was founded between GY ($r = 0.586^{*}$) and LS ($r = 0.513^{*}$) with fertilization. A low dependence of PH with fertilization was established ($r = 0.487^{*}$). The same tendency was also observed for Boomerang variety - the PH correlated with fertilization ($r = 0.535^{*}$). The common in both varieties is that the LS showed equal coefficient between GY and PH ($r = 0.540^{*}$). This finding is in agreement with results in triticale study which have indicated that in reference to correlation, one of the main components associated with increasing the grain yield of triticale is the plant height (Gulmezoglu et al., 2010).

Table 4. Correlation coefficients between investigating parameters

	Fertilizing	GY	LS	NGS	WGS	PH
Colorit						
Fertilizing	1					
GY	0.586*	1				
LS	0.513*	-0.096	1			
NGS	0.314	-0.172	0.827**	1		
WGS	0.308	-0.140	0.775**	0.971**	1	
PH	0.487*	0.540*	-0.158	-0.511*	-0.548*	1
Boomerang						
Fertilizing	1					
GY	0.438	1				
LS	0.402	-0.210	1			
NGS	0.304	-0.315	0.894**	1		
WGS	0.286	-0.368	0.891**	0.984**	1	
PH	0.535*	0.540*	-0.283	-0.454	-0.504*	1
Respect						
Fertilizing	1					
GY	0.361	1				
LS	0.404	-0.356	1			
NGS	0.425	-0.198	0.957**	1		
WGS	0.321	-0.174	0.904**	0.939**	1	
PH	0.326	0.271	0.164	0.171	0.182	1

*, **significant at P = 5% and P = 1%, respectively; GY - Grain yields; PH - Plant height; SL - Spike length; NGS - Number of grain per spike; WGS - Weight of grains per spike.

Agronomic performance of seven lines and two spring triticale varieties presented by Dogan et al. (2009), have confirmed the results obtained regarding to expressed correlation between grain yields and plant height. The same dependence have obtained with other cereal crops. Ivanova and Tsenov (2009) and Dragov et al. (2019) have reported a good defined positive correlation between yields and plant height for durum wheat. Base on the significant of the phenotypic correlation between plant height and grain yields it can be assumed that the better leafiness, respectively the vegetative

mass, corresponds to grain yield. No correlation was established between YG and considered spike components. In previous triticale studies have suggesed that WGS is of the least importance in determining grain yields (Singh and Sethi, 1974; Kamboj and Mani, 1983). However, there are authors who have established a high correlation between grain yields with number of grain per spike and weight of grains per spike (Dogan et al., 2009). Concerning Colorit and Boomerang varieties was observed a significant, negative relations ($r = -0.548^{*}$ and $r = -0.504^{*}$, respectively).

A high and significant positive correlation was established between SL with NGS and WGS for the three tested varieties. The NGS was in strongly expressed, positive correlation with WGS, $r = 0.971^{**}$, $r = 0.984^{**}$, $r = 0.939^{**}$, respectively for Colorit, Boomerang and Respect varieties. These data showed that, the spike productivity of studied triticale varieties directly depends on the length of spike. Based on similar correlation coefficients, it can be assumed that the spike productivity is determined of the same biometric and physical characteristics for the three tested varieties.

In respect to Respect variety, established interdependencies between spike length, number of grain per spike and weight of grains per spike, have confirmed in report by Stoyanov and Baychev (2015). The correlation coefficients in their research for Respect variety as follows: $r = 0.761^{**}$ between SL and NGS; $r = 0.792^{**}$ between SL and WGS; $r = 0.933^{**}$ between WGS and NGS. No significant negative correlation between GY with NGS ($r = -0.315$) and WGS ($r = -0.368$) for Boomerang variety was observed. These results are in contradiction with Shimelis data (2006), who has established that the number of grain per spike and the weight of grains per spike are positively correlated with grain yields in durum wheat.

A negative relation was observed betwen NGS and PH for Colorit variety ($r = -0.511^{*}$). It should be noted, that as opposed to Respect variety PH correlated negatively with WGS, $r= -0.548^{*}$ and $r= -0.504^{*}$, respectively for Colorit and Boomerang varieties.

The results received give rise to grounds for further work with triticale, to analyze of more agronomic characteristics and additional yields estimation with a view to increase of the areas and their participation in the structure of the arable land.

CONCLUSIONS

The results on the influence of the three triticale varieties, the fertilization rates and the predecessors on grain yields allow the following conclusions to be formulated: the greatest significant effect on yields, the structural components of spike and the plant height had the fertilization; the highest yields was obtained after a fertilization in rate of 1,750 kg/ha Lumbrical - 1,416.4 kg/ha; after a predecessor of durum wheat the yields was lower with 257.2 kg/ha compared to a predecessor sunflower; the Respect variety realized highest productivity - 1,293.9 kg/ha; the complex influence of the factors variety and predecessor on yields and weight of grains per spike was low; a positive, significant correlation between grain yields and the plant height for the Colorit and Boomerang varieties and a negative between the weight of grains per spike and plant height was established; for Colorit variety the relation between number of grain per spike and plant height was significantly negative, and the fertilization correlated positively with grain yields and spike length; a high, positive and significant interdependence of length of spike, number of grains per spike and weight ofgrainsperspikewasfoundedinalltheinvestigatedvarieties. The results of the present one and future researchs can be used for formation of a triticale cultivation technology under organic farming.

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