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GRAIN YIELDS OF TRITICALE VARIETIES GROWN UNDER BIOLOGICAL AND CONVENTIONAL AGRICULTURE

Angelina MUHOVA, Stefka STEFANOVA-DOBREVA

Field Crops Institute, 2 Georgi Dimitrov Blvd, 6200 Chirpan, Bulgaria

Corresponding author email: muhova.angelina@gmail.com

Abstract

Triticale is mainly used as a source of feed and the tendency is to include in people's diet. Information concerning comparison of yields under biological and conventional agriculture is needed. The aim of the research is to evaluate the productivity of triticale varieties depending on the fertilization, under biological and conventional agriculture. Two by two-factorial trials were conducted during the period 2014-2017. The experiments were performed after predecessor sunflower on Pelic Vertisols. Three varieties of triticale were tested, certified organic fertilizer from red Californian worm on biological field and mineral fertilizers containing nitrogen and phosphorus on conventional field were applied. The results showed an increase between 31.3%-52.4% after organic fertilization and between 28.6%-55.4% after mineral fertilization. Concerning variety an increase between 15.8%-23.0% under biological system was established. Under conventional system, 83.0% lower compared to control and 6.9% more was established. A specific reaction of the varieties to the agricultural system was found. The Respect variety achieved the highest productivity under biological system and the Boomerang variety under conventional system. The average grain yield under biological system was 32.6% lower. The effects of year, farming system, variety and fertilization on grain yields were confirmed.

Key words*: biological farming, conventional farming, fertilization, grain yield, triticale.*

INTRODUCTION

After its artificial creation, triticale is confirmed as an important cereal crop. According to FAOSTAT data (2018), in Europe the largest production was reported in Poland, Germany and France, and the registered areas in the world were 3.81million ha, which is 1.5 more than in 2000-around 2.49 million ha.

The main agro-technical approach in the conventional agriculture is the application of nitrogen mineral fertilization. Nitrogen fertilizers have a rapid effect and guarantee high yields. The discovery of the Haber-Bosch process in the early 19th century led to production of comparative cheap nitrogen fertilizer (Erisman et al., 2008; Follett et al., 2010) and the use of mineral fertilizers has become a regular worldwide strategy to eliminate nitrogen deficiency and increase yields (Piepho et al., 2017). Nitrogen fertilization leads to an increase in soil nutrients and improved crop growth conditions (Hu et al., 2020), but on the other hand over time the stock of soil organic matter may be exhausted (Šimon et al., 2018). The increase of the intensity of agricultural practices in recent decades caused environmental problems such as water pollution, soil degradation and biodiversity loss (Kalnina et al., 2013). In response to these negative trends alternative agricultural practices have developed, whose beginning was placed before the beginning of the new century. Professor King - the author of the book "Farmers of the 40th Century", called for a "global movement" in agricultural reform, and the detailed report presented for previous organic farming of China, Korea and Japan, was adopted as a validation of the principles of organic farming (Paull, 2011). The organic farming is an alternative farming system based mainly on crop rotations, the use of legumes, intensive soil treatments and the application of licensed organic preparations. In this regard, the use of vermicompost is widely used. In agricultural practice the vermicompost gives remarkable benefits regarding soil aggregation, plant nutrition and the development of beneficial microorganisms against phytopathogens (Pereira et al., 2014). One of the first researchers of the relationship between soil fertility and earthworms, subsequently having a direct connection with biological

farming was Charles Darwin (Darwin, 1881). Earthworms consume different soil substrates and release nutrients (Whalen and Janzen, 2002). The resulting product "is one of the richest nutrient organic fertilizer and shows a positive effect on plant growth and development" (Bhat et al., 2018).

Currently the biological farming has become one of the most dynamic agricultural sectors in European Union (Mikulioniene and Balezentiene, 2009). From 2010 to 2017, the certified area under biological farming, occupied by field crops in Bulgaria has increased by 59.1% and in Europe by 81.5% (FAOSTAT, 2018). Demand for high quality agricultural products has grown worldwide, especially for those produced under biological farming conditions (Oleynikova et al., 2020). Farmers, who practice intensive production, perceive the transformation into biological as difficult, risky and uncertain in terms of production results (Orlando et al., 2020). Many studies have confirmed that yields from biologically grown crops are lower. According to De Ponti et al. (2012) biological yield from individual crops are on average 80% from conventional, and the difference in yield has increased with an increase in conventional yield. Study by Brückler et al. (2018) has showed that the difference in yields between biological and conventional system varies between different types of crops, regions and in some locations crop yields are close to conventional. The cited data shows that the topic of yield comparison between biological and conventional system is not exhausted and is current. In Bulgaria no field research was conducted to compare triticale yield grown under biological and conventional system, given the use of triticale mainly as a source of feed, and the data is important for future production decisions in livestock farms.

The aim of the research is to evaluate the productivity of triticale varieties depending on the fertilization, under biological and conventional agriculture.

MATERIALS AND METHODS

Two by two-factorial trials were conducted during the period 2014-2017 at the Institute of Field Crops, Bulgaria on certified biological and conventional field. The experiments were performed after predecessor sunflower in four replications on Pelic Vertisols. Three Bulgarian triticale varieties, i.e. - Colorit (Standard for Bulgaria), Boomerang and Respect, were tested in both agricultural systems. The grain yield (GY) was evaluated. The sowing on both fields was carried out on 13 November 2014, 3 November 2015 and 20 October 2016 with a density of 550 seeds per m^2.

Certified organic fertilizer Lumbrical from red Californian worm (0, 1,400.0 and 1,750.0 kg/ha) was applied on the biological field. The commercial product contains: organic substances 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. The fertilizer was applied in autumn, at the same time with the main tillage. No disease and pest control was applied. Mechanical treatments were applied to reduce weeds. The experimental plot was 18 m^2.

Different rates of nitrogen fertilizer (ammonium nitrate)-0, 60, 120 and 180 kg/ha were tested. Phosphorus fertilizer (ternary superphosphate) at a rate of 60 kg/ha was applied to options N_{60}, N_{120} and N_{180} and was incorporated in autumn with the main tillage before sowing. Nitrogen fertilizer was applied in early spring in the tillering phase. Herbicide combination of pinoxaden and iodosulfuron-methyl - sodium with amidosulfuron was applied to control the weeds. The experimental plot was 12 m^2.

A two-factor date analyze was performed using ANOVA. Significant differences in the mean values were determined using the LSD test at significance level 5.0, 1.0 and 0.1%.

RESULTS AND DISCUSSIONS

The data presented in Figure 1 shows that the sum of temperature during the growing seasons 2014-2015 and 2015-2016 were higher by 248.3°C and 515.5°C, respectively over the average for the period 1928-2013. In the first vegetation period the precipitations were 285.0 mm more compared to climatic average. During October (135.4 mm), December (142.3 mm) and March (134.9 mm) the amount of precipitation was higher than multi-annual average-37.5 mm, 54.0 mm and 37.0 mm,

respectively. The amount of precipitation in 2015-2016 period (400.0 mm) was about climatic average (428.5 mm). In the third year the registered precipitations were 51.6 mm less.

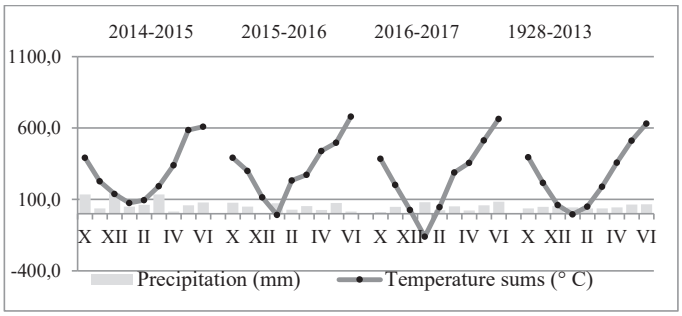

Figure 1. Monthly temperature sum and rainfall for 2014-2017 in the 1928-2013 reference periods

The results of the average triticale grain yields data presented in Table 1, illustrate considerable differences in individual years within systems of agriculture. Compared to the grain yield obtained under biological field in 2015 harvest year, for all three years under conventional agriculture and under biological field in 2016 the values were significant. This data shows that even if the weather conditions were the same, the variation in the average yield of both systems could be due of biotic and abiotic factors within the two agroecosystems. Under conventional system in 2017 highest average number of spikes (385.5 per m^2) was obtained compared to 2015 (369.9 per m^2) and 2016 (312.1 per m^2) (Stefanova-Dobreva, 2019). Similarly, the yield obtained in 2016 under biological system can be explained by the highest average number of spikes (509.6 per m^2), compared to 2015 (481.2 per m^2) and 2017 (496.3 per m^2) (Muhova, 2018).

Table 1. Influence of year and system of agriculture on triticale grain yield for the period 2015-2017

Agriculture system	GY (kg/ha)	% Control
2015		
Biological	1,168.1	100.0
Conventional	3,883.5***	332.5
2016		
Biological	1,784.6***	152.8
Conventional	3,645.7***	312.1
2017		
Biological	1,080.3ns	92.5
Conventional	4,828.3***	413.3
LSD		
5.0%	335.7	28.7
1.0%	446.0	38.2
0.1%	579.1	49.6

*** significance at p=0.1%; ns no significance.

According to Table 2, the average yield under conventional farming was 206.4% higher compared to biological farming and statistically significant. This data corresponds to threefold increase. The data obtained by Kronberga et al. (2013) for triticale showed a yield under conventional farming two time higher compared to biological farming and Oljača et al. (2010) reported 7.8% higher average yield for rye. The data from the present study showed that the average yield under biological system is 32.6% lower compared to conventional. This data confirms the results obtained by Torikov et al. (2020). The authors reported 33.7% and 32.9% lower grain yield under biological system compared to conventional for two

triticale cultivars. An analyses made by Brückler et al. (2018) showed a 68.4% lower triticale yield under biological system compared to the conventional one. The difference in average yield between the agricultural systems, can be explained by the applied agricultural techniques and the incoming nitrogen levels. The analyses for evaluation of cereal varieties under conventional and biological management strategies showed that there are differences in entry levels under conventional and biological systems (Le Campion et al., 2020).

Table 2. Influence of agricultural system on triticale grain yield for the period 2015-2017

Agricultural system	GY (kg/ha)	% Control
Agricultural system		
Biological	1,344.3	100.0
Conventional	4,119.2***	306.4
LSD		
5.0 %	193.8	14.4
1.0 %	257.5	19.2
0.1 %	334.4	24.9

***significance at p=0.1%.

Table 3. Effect of the year and agricultural system on triticale grain yield for the period 2014-2017

Source of variation	df	SS	η (%)	MS	F	P value
Options	5	1.515223E+08	93.11	3.030446E+07***	178.62	0.00000
A	2	2213824	1.36	1106912**	6.52	0.00296
B	1	1.385957E+08	85.17	1.385957E+08***	816.9	0.00000
A×B	2	1.071283E+07	6.58	53565416***	31.57	0.00000
Error	66	1.119693E+07	6.88	16964950.4		

A - year; B - agricultural system; **, ***significance at p = 1.0% and p = 0.1%, respectively.

The results presented in Table 3 show the significance of the year, the agricultural system and their complex influence, which is obvious from Table 1 and Table 2. The greatest effect on triticale grain yields had the agricultural system - 85.17% of the total variation, followed by the interaction of factors (6.58%) and the year conditions (1.36%).

The results of the analysis on yield of the varieties showed a different increase in yield compared to Colorit variety (Table 4). On a three year average, the yield varied between 15.8% and 23.0% within the varieties compared to the control under the biological system. On average, the highest average productivity (1,464.4 kg/ha) was observed at the Respect variety. Under conventional system the yield varied from 83.6% lower to the control option and 6.9% more to the control. The highest productivity was registered at the Boomerang variety (4,586.5 kg/ha). It is obvious that the studied varieties show different productivity under the two systems of agriculture.

This can be established from the results presented on Table 5, where is visibly that in both systems of agriculture the influence of the variety is significant - under biological system is 6.74% of the total variation and under conventional - 17.59%. Torikov et al. (2018) have reported similar results. In their study two varieties of triticale showed different productivity under conventional and biological farming system. The study made by Kronberga et al. (2013) for the evaluation of triticale productivity under biological and conventional systems showed that some genotypes are more productive under biological system, but their yield under conventional is below average yields. In the present study, the Respect variety showed the highest average productivity under biological system (1,464.4 kg/ha), but the yield under conventional system (3,560.4 kg/ha) was lower compared to the average for the period 2014-2017 (4,145.3 kg/ha) (Table 4).

Table 4. Influence of variety on triticale grain yield under biological and conventional system for the period 2014-2017

Variety	Biological system (kg/ha)	% Control	Conventional system (kg/ha)	% Control
Colorit	1,190.6	100.0	4,289.0	100.0
Boomerang	1,379.0*	115.8	4,586.5*	106.9
Respect	1,464.4**	123.0	3,560.4 ns	83.0
Average	1,344.6		4,145.3	
LSD				
5.0%	175.0	14.7	277.8	6.5
1.0%	231.6	19.5	367.1	8.6
0.1%	299.0	25.1	472.7	11.0

*, **significance at p = 5.0% and p = 1.0%, respectively; ns no significance.

Table 5. Effect of variety and fertilization on triticale grain yield for the period 2015-2017

Source of variation	df	SS	η (%)	MS	F	P value
Biological system						
Options	8	7116096	33.93	889512***	6.36	0.00001
C	2	1413568	6.74	706784**	5.05	0.00830
D	2	5537136	26.40	2768568***	19.78	0.00000
C×D	4	165392	0.79	41348 ns	0.30	0.88020
Error	99	1.385462E+07	66.07	139945.7		
Conventional system						
Options	11	8.962329+07	58.92	8147573***	17.21	0.00000
C	2	2.675943E+07	17.59	1.337971E+07***	28.27	0.00000
D	3	5.942963E+07	39.07	1.980988E+07***	41.85	0.00000
C×D	6	3434240	2.26	572373.3 ns	1.21	0.30489
Error	132	6.248423E+07	41.08	473365.4		

C - variety; D - fertilization; **, ***significance at p = 1.0% and p = 0.1%, respectively; nsno significance.

Table 6 presents the results for the influence of organic and mineral fertilization on triticale grain yield. The average results showed a 31.3% and 52.4% higher yields, respectively when 1,400.0 and 1,750.0 kg/ha organic fertilizers were applied. The highest grain yield obtained when Lumbrical 1,750.0 kg/ha was applied can be explained by larger amount of imported macronutrients. A similar trend was observed under the influence of nitrogen fertilization on triticale yield under conventional system. The yield obtained when fertilizing with N_{60}, N_{120} and N_{180} was 28.6%, 40.5% and 55.4% higher than the non-fertilizing option. Under both systems of agriculture, the maximum increase in yield was similar-52.4% under biological system and 55.4% under conventional system more than control option, but the difference in kg/ha was an advantage for the conventional system. This data suggests that in both agricultural systems, fertilization plays a crucial role for yield formation.

The results in Table 7 show the influence of organic fertilization with rate of 1,400.0 and 1,700.0 kg/ha Lumbrical on grain yield among all triticale varieties. Thus, at Colorit variety the grain yields were 27.5% and 51.3% higher than the control, at Boomerang, 51.4% and 69.7% higher and at Respect variety, 60.4% and 88.8% respectively. The largest increase in yields compared to the control was observed at Respect variety. A similar trend concerning fertilization was observed in the conventional system. Boomerang variety registered the highest productivity when applying N_{60}, N_{120} and N_{180}, the increase in yields varying from 41.3% to 72.2% compared to the control. At Colorit variety, the increase in grain yields varied from 30.3% to 60.7% and at Respect, from 8.2% to 26.1%.

Table 6. Influence of fertilization on triticale grain yield under biological and conventional system for the period 2015-2017

Fertilization	GY (kg/ha)	% Control	LSD		
			%		% Control
Organic fertilization					
0	1,051.1	100.0	5.0	175.0	16.6
1,400.0	1,380.6***	131.3	1.0	231.6	22.0
1,750.0	1,602.3***	152.4	0.1	299.0	28.4
Mineral fertilization					
N_0	3,161.6	100.0	5.0	320.8	10.2
N_{60} P_{60}	4,064.8***	128.6	1.0	423.8	13.4
N_{120} P_{60}	4,442.6***	140.5	0.1	545.8	17.3
N_{180} P_{60}	4,912.3***	155.4			

*** significance at $p = 0.1\%$.

Table 7. Influence of fertilization and variety on triticale grain yield under biological and conventional system for the period 2015-2017

Variety	Biological system			Conventional system		
	Organic fertilization (kg/ha)	GY (kg/ha)	% Control	Mineral fertilization (kg/ha)	GY (kg/ha)	% Control
Colorit	0	942.8	100.0	N_0	3,211.0	100.0
	1,400.0	1,202.0 ns	127.5	N_{60} P_{60}	4,184.8***	130.3
	1,750.0	1,426.9**	151.3	N_{120} P_{60}	4,599.5***	143.2
				N_{180} P_{60}	5,160.8***	160.7
Boomerang	0	1,109.9 ns	117.7	N_0	3,376.5	105.2
	1,400.0	1,427.5***	151.4	N_{60} P_{60}	4,536.5***	141.3
	1,750.0	1,599.5***	169.7	N_{120} P_{60}	4,904.5***	152.7
				N_{180} P_{60}	5,528.6***	172.2
Respect	0	1,100.6 ns	116.7	N_0	2,897.3 ns	90.2
	1,400.0	1,512.3***	160.4	N_{60} P_{60}	3,473.0 ns	108.2
	1,750.0	1,780.4***	188.8	N_{120} P_{60}	3,823.8*	119.1
				N_{180} P_{60}	4,047.4**	126.1
LSD						
5.0%	303.0		32.1	555.6		17.3
1.0%	401.1		42.9	734.1		22.9
0.1%	518.0		54.9	945.4		29.4

*, **, *** significance at $p = 5.0\%$, $p = 1.0\%$ and $p = 0.1\%$, respectively; ns no significance.

Based on the data presented it can be summarized that under both systems of agriculture triticale varieties show a specific reaction according to the tested doses of organic and mineral fertilizer and subsequently had different productivity. The Respect and Boomerang varieties show high responsiveness to the applied fertilization, respectively under biological and conventional system. The Respect variety manifests high ecological plasticity according to the conditions of the biological system. The results showed that the effect of the fertilization under biological and conventional systems was respectively 26.40% and 39.07% of the total variation and statistically significant (Table 5). The complex influence of factors was found to be low and with no significant effect under both tested systems (0.79% and 2.26% of the total variation).

CONCLUSIONS

Triticale grain yield was influenced by the characteristic conditions of the years and the agricultural system. So the conditions of the years had low effect, and the agricultural system had a significant, large impact on triticale grain yields. The average grain yield under biological system was 32.6% lower compared to conventional. For both systems of agriculture a crucial role for the yield formation had fertilization and less degree the variety. The Respect variety showed the highest productivity under condition of biological system when applying Lumbrical organic

fertilizer at rate of 1,750.0 kg/ha and under conventional system the Boomerang variety when fertilized with N_{180}.

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