EFFECTS OF AGROCLIMATIC CONDITIONS AT TRIAL LOCATIONS AND FERTILIZATION ON GRAIN YIELD OF TRITICALE

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Abstract: *Triticale is a plant species which is characterized by high genetic potential for grain yield, as well as good nutritive properties of its grain, while it is not so demanding as wheat in regard to agrotechnic measures and ecological conditions, so it is regarded as a very promising crop. In order to reach high and stable grain yield, few demands ought to be fulfilled, such as favorable agroclimatic conditions of the production area, growing superior cultivars, and good production technology, especially sufficient and well-balanced mineral nutrition. In Serbia, acid soils represent a serious problem for field crop production. These are soils with bad air-water and physico-mechanical properties, so plant production carried out on them is highly unstable. For that reason, correction of those soils acidity is necessary to improve their productive properties, which has a long-term effect on increasing yield of the grown crops. This paper deals with the effect of agroclimatic conditions at trial locations and fertilization on grain yield of triticale. The experiment was established at two locations (Zaječar and Kraljevo), during two years (2009 and 2010), and included control variant without fertilization and three variants fertilized by mineral fertilizers, lime and manure (1. NP_1K, 2. NP_2K, and 3. $NP_1K + CaCO_3$ + manure). The individual trials were set in random complete block design with three replications. The subject of the study was triticale cultivar KG-20. Results were processed by analysis of variance. Results of the study showed significant effect of location and fertilization on triticale grain yield. The average grain yield, for the all fertilization variants, was high-significantly greater in Zaječar (5.65 t ha^{-1}) than in Kraljevo (4.93 t ha^{-1}). Fertilization showed a highly significant effect on grain yield increase in regard to the control variant. The highest grain yield (7.04 kg ha^{-1} at Zaječar; 6.62 kg ha^{-1} at Kraljevo) was observed in the variant where combination of NPK, lime and manure was applied, and it was significantly higher regarding the other fertilization variants. There were no statistically significant differences (in both locations) between the first and second fertilization variants. Adequate application of lime fertilizers, in combination with manure and mineral fertilizers is the most efficient way for correction of undesired production properties of acid soils, which can cause huge increase of triticale grain yield, with the simultaneous improvement of its quality.*

Key words**:** *triticale, fertilization, location, agroclimatic conditions, grain yield*

INTRODUCTION

According to the opinion of the most researchers, triticale is a plant species characterized by a high genetic potential for grain yield, as well as good nutritive properties of its grain, so it is regarded as a very promising crop (BOROJEVIĆ, 1981; CVETKOV, 1982; ĐOKIĆ, 1988). In order to reach high and stable grain yield, few demands ought to be fulfilled, such as favorable agroclimatic conditions of the production area, growing superior cultivars, and good production technology, especially sufficient and well-balanced mineral nutrition. In Serbia, acid soils represent a serious problem for field crop production. These are soils with bad air-water and physico-mechanical properties, so plant production carried out on them is highly unstable. According to ANIOL and MADEJ (1996), the highest tolerance to soil acidity is expressed by rye, than triticale and wheat, and the most sensitive crop is barley. IMPIGLIA (1987) reported that triticale was less demanding than wheat and showed a greater adaptability to soil acidity, as well as higher resistance to common diseases. Data reported by MILOVANOVIĆ et al. (1994) showed that grain yield of triticale was affected by annual ecological conditions, even more than the one of wheat.

Before application of fertilizers, one ought to do chemical soil analysis, in order to determine type and amount of fertilizer which can significantly affect grain yield. Numerous studies previously published showed that adequate application of lime fertilizers, in combination with manure and mineral fertilizers, is the most efficient way for correction of undesired production properties of acid soils, which can cause huge increase of triticale grain yield (JOVANOVIĆ et al., 2006; KOVAČEVIĆ et al., 2006; JELIĆ et al., 2006).

Our study was aimed to determine grain yield of triticale as affected by agroclimatic conditions at production locations, as well as by doses and types of the applied fertilizers.

MATERIAL AND METHODS

The investigation was carried out through field trials set in the Center for Agricultural and Technological Research at Zaječar and Agricultural School at Kraljevo, during the production seasons 2008/09 and 2009/10. The trials were set in random complete block design with three replications. The trials included control variant and three variants fertilized by mineral fertilizers, lime and manure (1. NP_1K, 2. NP_2K, and 3. $NP_1K + CaCO_3$ + manure). The subject of the study was triticale cultivar KG-20. The applied agrotechnic measures and fertilization were the same at both locations. Amounts of pure nutrients used in the experiment are given in table 1.

Table 1

Amounts of pure nutrients used in the experiment

Fertilization variants	Amount of nutrients (kg ha^{-1})				
	N	P_2O_5	K_2O	$CaCO_3$	Manure
Control	0	0	0	0	0
NP_1K	80	80	60	0	0
NP_2K	80	100	60	0	0
NP_1K + lime + manure	80	80	60	4,000	20,000

Area of each elementary experimental plot was 50 m^2. The total amount of phosphorus and potassium fertilizers together with one third of nitrogen was dispersed manually, before fine cultivation of soil. At the liming variant, lime fertilizer "Njival Ca" was dispersed together with manure and mineral fertilizers. The rest of nitrogen was applied in one side dressing, in early spring, during the stage of full tillering. Mineral fertilizers used were complex NPK fertilizer (8:24:16) and superphosphate (17% P_2O_5), while for additional nutrition (side dressing) ammonium nitrate (AN) with 34.4% N was used.

Plowing and fine cultivation of soil were done in classic way (down to 25 cm of depth) immediately after maize harvest and removal of corn straw. Triticale was sown in October. The rest of the applied production technology in the trials was standard.

Harvest of triticale was carried out during full ripeness. Grain yield was recalculated to 14% of moisture and processed by analysis of variance.

Soil and climatic conditions

Chemical properties of the soils at two trial location are presented in table 2. Soil at Zaječar location belongs to the type carbonate-free vertisol and is characterized by high soil acidity (pH in nKCl 4.84-5.15). Humus content in the layer down to 20 cm was 0.12% and decreasing by depth. Available phosphorus content of the layer to 20 cm was 16.68 mg/100g of soil, and 12.34 mg/100g in deeper layers. This soil is well-supplied by available potassium

(29.53 mg/100g of soil in cultivated layer). Such soils are prone to volume change, to imbibition and contraction, so they are very hard to cultivate. They belong to the category of soils characterized by a short optimal term for cultivation. Remediation of these soils is necessary in order to reach satisfactory grain yields on them.

Table 2

Chemical properties of the soil

Depth (cm)	pH		Humus	Available (mg/100g of soil)	
	H_2O	nKCl		P_2O_5	K_2O
Zaječar – vertisol					
0-20	5.23	4.84	0.12	16.68	29.53
20-40	5.54	5.15	0.11	12.34	27.22
Kraljevo – pseudogley					
0-20	5.24	4.34	0.12	6.70	7.80
20-40	5.55	4.48	0.05	6.90	9.80

Soil at Kraljevo location belongs to the pseudogley soil type. This soil has very bad physical properties (compacted, having high content of silt and clay particles, with slow water percolation) and extremely acid pH value (pH<4.5). Its total humus content is relatively fair, but microbiological activity is low, because of its poor physical properties. That causes low mineralization of organic nitrogen, and so nitrogen fertilizers show a great effect on such soils. It is characterized by low content of available phosphorus (6.70-6.90 mg/100g of soil) and potassium (7.80-9.80 mg/100g of soil).

Although triticale belongs to the group of grain crops fairly tolerant to soil acidity, extreme pH values of pseudogley significantly decreased grain yield. Despite remediation measures, more remarkable grain yield increase could be expected in next few years.

Table 3

Meteorological conditions during the trial

Months	Zaječar				Kraljevo			
	Mean monthly air temperature (ºC)		Monthly sum of precipitation (mm)		Mean monthly air temperature (ºC)		Monthly sum of precipitation (mm)	
	2009	2010	2009	2010	2009	2010	2009	2010
I	-1.3	-2.2	67.3	54.1	0.4	1.1	47.0	34.4
II	1.3	0.4	91.1	108.0	2.3	2.7	55.5	81.6
III	6.0	6.0	58.3	64.3	6.6	7.2	72.0	38.6
IV	12.1	11.9	15.4	73.5	13.4	12.1	22.8	100.2
V	17.8	16.6	18.0	58.9	18.1	16.6	36.2	84.0
VI	20.6	20.8	76.4	95.1	20.1	20.2	194.0	136.4
VII	22.7	23.2	63.0	89.2	22.3	22.6	58.1	38.2
Average or sum	**11.3**	**10.9**	**389.5**	**543.1**	**11.8**	**11.7**	**485.6**	**513.4**

The average monthly temperature, at both locations and in both years of investigation, was similar, especially during spring and summer part of vegetation. In January and February, of both years, the average monthly air temperature was a bit higher in Kraljevo (tab. 3). However, air temperature had not an effect on difference in grain yield between the locations.

In both locations, higher amount of precipitation was observed in 2010, which influenced increased grain yield in regard to the previous year. At the location of Kraljevo, during both years, there was slightly higher precipitation amount in June, which decreased grain yield, for triticale was in ripening stage when abundant rainfall did not suit it. At the location of Zaječar, precipitation pattern during vegetation was much more regular, and that increased grain yield.

RESULTS AND DISCUSSIONS

The aim of every agricultural production is to achieve high and stable product yield. This can only be fulfilled by full production technology applied, proper choice of grown genotypes, and with favorable agroclimatic conditions of production area. Table 4 gives triticale grain yield as affected by agroclimatic conditions of trial locations and fertilizers type and amount.

Table 4

Grain yield of triticale as affected by location conditions and fertilization (kg ha^{-1})

Fertilization variants (A)	Location (B)					
	Zaječar			Kraljevo		
	2009	2010	**Average**	2009	2010	**Average**
Control	2.50	2.97	**2.73**	2.25	3.00	**2.62**
NP_1K	4.64	5.69	**5.16**	5.95	6.85	**6.40**
NP_2K	4.94	5.50	**5.22**	6.10	7.05	**6.57**
NP_1K + lime + manure	6.05	7.19	**6.62**	6.68	7.41	**7.04**
Average	--	--	**4.93**	--	--	**5.65**

LSD values	A	B	AxB
0.05 (5%)	0.46	0.33	0.65
0.01 (1%)	0.63	0.45	0.90

Agroclimatic conditions of trial locations showed a significant effect on triticale grain yield. Hence, at Zaječar, in the all fertilization variants, triticale grain yield was significantly higher than in Kraljevo. These differences are mainly caused by better characteristics of vertisol at Zaječar, compared with pseudogley at Kraljevo. Bad air-water properties and high soil acidity of pseudogley at Kraljevo caused lower grain yield of triticale.

Fertilization showed significant effect on triticale grain yield in both locations. The highest grain yield (7.04 kg ha^{-1} at Zaječar; 6.62 kg ha^{-1} at Kraljevo) was given by triticale at the variant with combination of NPK, lime and manure, and it was high-significantly greater in regard to the all other fertilization variants. There was not any statistically significant difference in grain yield (in both locations) between the first and second fertilization variants. In contrast, numerous previous reports pointed to a positive influence of increased phosphorus doses on grain yield of small grain crops (JELIĆ et al., 1998; JOVANOVIĆ et al., 2006; KOVAČEVIĆ et al., 2006).

The annual weather conditions showed a significant effect on triticale grain yield. When precipitation amount during vegetation is considered, one can see there was more precipitation in 2010 than in 2009, which caused a grain yield increase. Many reports showed the effect of weather conditions on nutrients utilization (JELIĆ, 1995; ŽIVANOVIĆ-KATIĆ et al., 2000; JELIĆ et al., 2006; JELIĆ et al., 2007).

Numerous previous reports showed that triticale is a crop moderately sensitive to low soil pH values, so on acid soils full application of NPK, lime and manure gave a high effect on its grain yield (OGNJANOVIĆ et al., 1994; JELIĆ et al., 1995; JELIĆ et al., 2004).

Thanks to its positive effect on improving fertility level, physical and biological properties of soil, which results in grain yield increase on acid soils, application of lime together with manure and mineral fertilizers is the most important measure, which ought to be regularly conducted in future for remediation of these degraded soils.

CONCLUSIONS

On the basis of the study, dealing with influence of agroclimatic conditions at trial locations and fertilization on grain yield of triticale, we can conclude the following:

- Agroclimatic conditions at trial locations had a significant effect on triticale grain yield;
- Soil type showed a great effect, so grain yield was significantly higher on vertisol than on pseudogley;
- Application of fertilizers had a positive effect on triticale grain yield increase;
- Grain yield at fertilized variants was significantly higher comparing with the control variant;
- The highest grain yield achieved at the variant fertilized by the combination of mineral fertilizers, lime and manure;
- Increased phosphorus dose did not show any significant effect on triticale grain yield;
- In order to reach high grain yield values on acid soils, application of lime together with manure and mineral fertilizers is the most important measure, which ought to be regularly conducted in future for remediation of these degraded soils.

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