BIOLOGICA NYSSANA

9 (1) • September 2018: 45-53

DOI: 10.5281/zenodo.1470850

Original Article

Received: 29 January 2018
Revised: 29 Mart 2018
Accepted: 27 June 2018

The interaction of genotype and environment on yield and quality components in triticale

***Vera Đekić*[1]*, Jelena Milivojević*[1]*, Snežana Branković*[2]**

[1]*Small Grains Research Centre, Save Kovačevića 31, 34000 Kragujevac, Serbia*

[2]*University of Kragujevac, Faculty of Science, Institute of Biology and Ecology, Radoje Domanović 12, Kragujevac, Serbia*

** E-mail: verarajicic@yahoo.com*

***Abstract*:**

Đekić, V., Milivojević, J., Branković, S.: *The interaction of genotype and environment on yield and quality components in triticale. Biologica Nyssana, 9 (1). September, 2018: 45-53.*

The experiment was established at the Small Grains Research Centre in Kragujevac, where two varieties of triticale were investigated. The highest three-year average of grain yield (4.910 t/ha), 1000-kernel weight (42.67 g) and test weight (69.85 kg/hl) were obtained by Kg 20 variety. The highest three-year average value of protein content was found in the variety Trijumf (13.157%). Highly significant influence of the year on grain yield, 1000-kernel weight and protein content was established for investigated winter triticale cultivars by variance analysis, and significant influence of the year on the test weight. The influence of the cultivar on grain yield, 1000-kernel weight, test weight and protein content was not statistically significant. Environmental conditions have had a significant effect on grain yield and quality in triticale. Grain yield shows a tendency to increase in the years having a higher total amount and better distribution of rainfall during critical plant development stages.

Key words: grain yield, protein, test weight, triticale

***Apstrakt*:**

Đekić, V., Milivojević, J., Branković, S.: *Interakcija genotipa i vegetacione sezone na prinos i kvalitet komponenti prinosa tritikalea. Biologica Nyssana, 9 (1). Septembar, 2018: 45-53.*

Eksperiment je izveden na oglednom polju Centra za strna žita u Kragujevcu, a istraživane su dve ozime sorte tritikalea. Najveći trogodišnji prinos zrna (4.910 t/ha), masa 1000 zrna (42.67 g) i hektolitarska masa (69.85 kg/hl) ustanovljeni su kod sorte Kg 20. Najveća trogodišnja prosečna vrednost sadržaja proteina dobijena je kod sorte Trijumf (13,157%). Analizom varijanse ustanovljen je visoko značajan uticaj godine na prinos, masu 1000 zrna i sadržaj proteina i značajan za hektolitarsku masu. Uticaj sorte na prinos, masu 1000 zrna, hektolitarsku masu i sadržaj proteina statistički nije bio značajan. Vegetaciona sezona značajno je uticala na prinos i kvalitet prinosa zrna kod ispitivanih sorti tritikalea. Prinos zrna pokazuje tendenciju povećanja u godinama koje imaju veću ukupnu količinu padavina i bolju distribuciju padavina tokom kritičnih faza razvoja biljaka.

Ključne reči: prinos zrna, sadržaj proteina, hektolitarska masa, tritikale

Introduction

The yield per unit area is the result of the action of varieties fertility in interaction with environmental factors. Therefore, the yield is relative term and is determined by the variety, environmental conditions and the level of applied technology. Yield is largely dependent on the genetic potential, which could be defined as yield of variety, grown in conditions on which it had adapted, with adequate amounts of water and nutrients and efficient control of pests, diseases, weeds and other stresses (Milovanovic et al., 1998; Đekić et al., 2014). Yields vary considerably primarily as a result of agro-ecological conditions during the growing season (Tomasović, 2005; Glamočlija et al., 2010; Đekić et al., 2010; Biberdžić et al., 2012; Kondić et al., 2012; Milovanović et al., 2012; Janušauskaitė, 2013; Kendal et al., 2014; Đurić et al., 2016).

The 1000-kernel weight is a direct component of grain yield and changes under the influence of environmental factors, but depends primarily on varietal characteristics. It indicates the grain size and is an important criterion in triticale breeding. Milovanović et al. (2014) consider that the 1000 kernel weight in addition to the number of grains per grain heads is the most important criterion in breeding barley for yield increase. The 1000-grain weight, however, is not only a component of yield, but also a very important component of quality of grains (Milovanović et al., 2011; Đekić et al., 2016; Kendal et al., 2016b).

Test weight is the weight of one hectoliter grain expressed in kilograms and is the oldest and still the most widely used method of evaluating the quality of the grains, because its assessment is quick and easy. Test weight is based on physical measures of size and grain shape, which measures weight in the volume mass density. Larger hectoliter means higher content of starch and protein in relation to the content of fiber and a space filled with air (Milovanovic et al., 2006; Đekić et al., 2014; Kendal and Sayar, 2016a; Kendal et al., 2016b).

The chemical composition and nutritive characteristics of triticale are result of huge number of varieties with a huge spectrum of characteristics (Đekić et al., 2009; Djekic et al., 2011; Janušauskaitė, 2013; Kendal et al., 2016b). Milovanović (1993), emphasizes that different winter triticale genotypes have fluctuated within the two year period from 13.44 up to 16.42%. Since the early 1970s, University of Florida has conducted a triticale-breeding program. Three spring-type cultivars that were selected from the CIMMYT (International Maize and Wheat Improvement Center) nurseries have been released (Barnett et al., 1999). Considerable improvements in increasing grain yield and test weight have been made. The protein content of the three released cultivars is about 12% with 0.45% lysine on a dry matter basis. Within the four year average values, Milovanović et al. (1995), recorded protein content from 14.32% to 16.29% in different winter triticale genotypes, while for the winter wheat varieties, value of 13.70% was recorded. Đekić et al. (2009) reported the protein content of 12.24% for the triticale variety Kg 20, while variety Favorit had 12.55% of dry matter. Perišić et al. (2008) reported that another winter triticale variety, General, had 14.6% of crude proteins. Within six year averages, Djekic et al. (2011) recorded proteins from 11.23 to 13.87% in different winter triticale genotypes. In previous studies, grain protein content in triticale genotypes was reported by many researchers from 11.2% to 16.4% (Milovanović et al., 1995; Janušauskaitė, 2013; Kendal and Sayar, 2016a; Kendal et al., 2016b).

The triticale is considered a prospective crop for conditions of Serbia, especially from the point of the global climate change which has not avoided the agricultural regions of Serbia. The aim of this study was to determine the influence of semi-arid ecological environmental factors of central Serbia on the winter triticale varieties and on their differences in stability and adaptability in regard to the grain yield and parameters of grain chemical quality, as well as specificity of explored varieties in regard to growing conditions.

Material and methods

Materials and field trials

During the 2009/10, 2010/11 and 2011/12 growing seasons, two varieties of winter triticale were investigated (Kg 20 and Trijumf) at the Small Grains Research Centre in Kragujevac (in central Serbia). The experiments were conducted in randomized block systems, with a plot size of 50 m^2 (5 m x 10 m) in five replications. The sowing was carried out using a machine with row spacing of 12.5 cm. The soil on

Table 1. Mean monthly air temperatures and precipitation in Kragujevac, Serbia (2009-2012), in relation to many years average (1960-2009)

	Months									
Interval	X	XI	XII	I	II	III	IV	V	VI	Average
Mean monthly air temperature (ºC)										
2009/10	11.7	8.8	2.6	0.9	3.2	7.2	12.1	16.5	20.2	9.24
2010/11	10.2	11.4	2.4	0.9	0.5	7.2	12.0	15.8	20.9	9.0
2011/12	10.4	3.1	4.6	0.7	-3.7	8.1	12.9	16.1	23.0	8.4
Average	**12.5**	**6.9**	**1.9**	**0.5**	**2.4**	**7.1**	**11.6**	**16.9**	**20.0**	**10.5**
The amount of precipitation (mm)										
2009/10	102.6	77.5	194.2	57.0	150.5	43.3	142.2	116.7	196.7	1080.7
2010/11	86.9	27.9	50.1	29.1	48.5	20.4	20.8	65.8	32.3	381.8
2011/12	33.3	1.3	43.3	117.2	60.1	5.7	74.5	87.3	57.8	480.5
Average	**45.4**	**48.9**	**56.6**	**58.2**	**46.6**	**32.4**	**51.9**	**57.6**	**70.4**	**468.0**

which the trial was conducted was uniform and well prepared. The amount of seed per square meter corresponded to 400-450 viable seeds, depending on the characteristics of varieties. It was sown in the third decade of October, with 400 kg/ha of fertilizer NPK 15:15:15, which was added in the fall, while during the spring, fertilization soil was supplemented with 300 kg/ha (KAN 27%N).

The following properties were analyzed: grain yield (t/ha), 1000-kernel weight (g), test weight (kg/hl) and chemical quality of grain. Grain yields were measured for each plot and converted to yield tons per hectare on the basis of 14% grain moisture. The total protein content in the grain was determined by infrared spectroscopy technique on the apparatus Perten DA 7000 (NIR/VIS Spectro-photometer) employing non-destructive method.

Soil conditions

The trial at the Small Grains Research Centre in Kragujevac (in central Serbia), was performed on soil that is characterized as smonitsa in process of degradation. The physical properties of the soil are very unfavorable, and it belongs to the type of heavy clays. According to the analysis, this is a soil of medium acidity, poor in humus (2.65%), with a substitution and total hydrolytic acidity that were quite high (pH in H_2O=5.99, in KCl=4.91). The soil was moderately provided with total nitrogen (0.14% of N), it is poor in easily accessible phosphorus (P_2O_5≤12 mg/100 g of soil), a medium level of easily accessible potassium (K_2O=14-23 mg/100 g of soil) was recorded.

Meteorological conditions

This study was conducted over a three-year period in the Šumadija region, Central Serbia, on a Vertisol soil, at Kragujevac location, 173-220 m a.s.l. (44° 22′ N, 20° 56′ E), in a temperate continental climate having an average annual temperature of 11.5 °C, typical for Šumadija districts in Serbia and a rainfall amount of about 550 mm. Kragujevac area is characterized by a moderate continental climate, which in general is characterized by uneven distribution of rainfall by month.

The data in **Tab. 1** for the investigated period (2009-2012) clearly indicate that the years in which the researches were conducted differed from the typical multi-year average for Kragujevac region regarding the meteorological conditions. The data presented in **Tab. 1** for the analyzed triticale growing season (2009-2012) clearly suggest differences in weather conditions between the years of the study and the long-term mean for the region. The average air temperatures were by 1.26 °C, 1.5 °C and 2.1 °C lower in 2009/10, 2010/11 and 2011/12, respectively, as compared to the long-term mean, whereas the sums of rainfall were by 612.7 mm and 12.5 mm higher in 2009/10 and 2011/12 years and lower by 86.2 in 2010/11 year as compared to the long-term mean. Compared to the long-term mean, total rainfall values, especially in the first year, second and third year, were considerably higher in February, April and May, whereas total rainfall in April 2010/11 decreased by 31.1 mm. Given the high importance of sufficient rainfall amount during the spring months, particularly April and May, for triticale production, the distribution and amount of rainfall over the growing season 2010/11 were considerably more favorable, resulting in increased yields in this year. Apart from the rainfall deficiency during the spring months and the non-uniform distribution of rainfall across months, an increase in average air temperatures was also observed.

Based on the fact that sufficient amounts of rainfall in these months are very important for the successful production of cereal crops it can be concluded that the years in which the researches were conducted were not favorable for the triticale growing.

Statistical Analysis

On the basis of achieved research results, the usual variational statistical indicators, average values and standard deviations, were calculated. Experimental data were analyzed by descriptive and analytical statistics using the statistics module Analyst Program SAS/STAT (SAS Institute, 2000) for Windows. All evaluations of significance were made on the basis of the ANOVA test at 5% and 1% significance levels. Relative dependence was defined through correlation analysis (Pearson's correlation coefficient), and the obtained coefficients were tested at the 5% and 1% levels of significance.

Results

Grain yield and chemical characteristics

Average values of grain yield, 1000-kernel weight, test weight and protein content of investigated Kragujevac winter triticale varieties are presented in **Tab 2**.

The grain yield of triticale significantly varied across years, from 4.059 t/ha in 2009/10 to 5.615 t/ha in 2010/11 (**Tab. 2**). In the first investigation year (2009/10), variety Kg 20 achieved higher yield of grain (4.104 t/ha), while Trijumf variety yielded 4.014 t/ha. In the second year (2010/11), the grain yield of variety Kg 20 was the highest with 5.868 t/ha, while the slightly lower yield was realized by variety Trijumf (5.362 t/ha). In the third year of research (2011/12), the grain yield of variety Kg 20 was 4.757 t/ha, which was 320 kg more than the yield obtained by the variety Trijumf.

The thousand kernel weight of winter triticale grain was variable, depending on environmental conditions. Thousand kernel weight in the test period was the highest in 2010/11 (45.34 g) but had significantly lower values in 2009/10 (by 5.72 g or 12.62%) and also significantly decreased in 2011/12 (by 3.91 g or 9%). Average thousand kernel weight observed in the three-year period was the highest in Kg 20 variety (42.67 g), while the Trijumf cultivar had lower yield (41.59 g).

Tab. 2 presents average values for grain test weight across years and varieties. The average values for test weight in both cultivars were as follows: 70.34 kg/hl in 2009/10, 70.84 kg/hl in 2010/11 and 68.02 kg/hl in 2011/12, suggesting significant variations in test weight during the three years of the study.

The average crude protein content of triticale significantly varied across years, from 12.345% in 2010/11 to 13.796% in 2010/11 (**Tab. 2**). During all three years of investigation (2009/10, 2010/11 and 2011/12), the variety Trijumf achieved higher average protein content (14.010%, 12.386% and 13.073%).

Table 2. Average values of characteristics of investigated triticale varieties

Varieties	2009/10		2010/11		2011/12		Average	
	$\bar{x}$	S	$\bar{x}$	S	$\bar{x}$	S	$\bar{x}$	S
Grain yield, (t/ha)								
Kg 20	4.104	0.674	5.868	0.373	4.757	0.527	4.910	0.904
Trijumf	4.014	0.732	5.362	0.669	4.544	0.437	4.640	0.815
Average	4.059	0.665	5.615	0.576	4.651	0.470	4.775	0.857
1000-kernel weight, (g)								
Kg 20	40.02	1.154	45.88	0.460	42.10	1.557	42.67	2.727
Trijumf	39.22	0.549	44.80	1.000	40.76	3.038	41.59	2.990
Average	39.62	0.951	45.34	0.929	41.43	2.383	42.13	2.864
Test weight, (kg/hl)								
Kg 20	70.11	3.171	70.89	1.699	68.56	2.533	69.85	2.557
Trijumf	70.57	2.834	70.80	1.724	67.48	1.583	69.62	2.513
Average	70.34	2.846	70.84	1.615	68.02	2.071	69.73	2.494
Proteins content,(%)								
Kg 20	13.581	0.361	12.300	0.454	12.919	0.637	12.935	0.709
Trijumf	14.010	0.528	12.386	0.846	13.073	0.331	13.157	0.889
Average	13.796	0.483	12.345	0.642	12.996	0.485	13.046	0.798

Table 3. ANOVA values of characteristics in investigated triticale varieties

Effect of year on the traits analyzed				
Traits	Mean sqr Effect	Mean sqr Error	F (2,27)	*p*-level
Grain yield (t/ha)	6.167350	0.331817	18.58659**	0.000008
1000-kernel weight (g)	85.47100	2.481519	34.44302**	0.000000
Test weight (kg/hl)	22.69675	4.997861	4.54129*	0.019948
Protein content (%)	5.280500	0.293349	18.00073**	0.000011
Effect of cultivar on the traits analyzed				
Traits	Mean sqr Effect	Mean sqr Error	F (2,27)	*p*-level
Grain yield (t/ha)	0.545940	0.740994	0.736768	0.397987
1000-kernel weight (g)	8.640333	8.189382	1.055066	0.313136
Test weight (kg/hl)	0.420083	6.425560	0.065377	0.800060
Protein content (%)	0.369408	0.646858	0.571080	0.456141
Effect of the year x cultivar interaction				
Traits	Mean sqr Effect	Mean sqr Error	F (2,24)	*p*-level
Grain yield (t/ha)	0.114417	0.341012	0.335523	0.718264
1000-kernel weight (g)	0.182333	2.416500	0.075453	0.927542
Test weight (kg/hl)	1.522583	5.478209	0.277935	0.759751
Protein content (%)	0.083670	0.307654	0.271961	0.764201

Analysis of variance between observed traits of triticale

The analysis of yield variance of 1000-kernel weight, test weight and protein content of the tested winter triticale varieties grown at investigated in Kragujevac during three growing seasons 2009/10, 2010/11 and 2011/12, are shown in **Tab. 3**.

Based on the analysis of variance, it can be concluded that there were highly significant differences in grain yield in regard to the year of investigation (F_{exp}=18.58659**), while among the investigated triticale varieties the differences were not significant. Analysis of variance found highly significant effect of year on the 1000-kernel weight (F_{exp}=34.44302**), protein content (F_{exp}=18.00073**), and significant effect on the test weight (F_{exp}=4.54129*).

Based on the analysis of variance, it can be concluded that there were no significant differences in grain yield, 1000-kernel weight, test weight and protein content in investigated triticale varieties relative to the cultivar of investigation (**Tab. 3**). The interaction of the investigated factors (Y x G) exhibited no statistically significant effect on grain yield, 1000-kernel weight, test weight and protein content ($p > 0.05$).

Discussion

In regard to the tested winter triticale genotypes, variety Kg 20 achieved higher yield of grain (4.910 t/ha). During the research, the values obtained in the second investigation year were significantly different from the first and third year. In year 2009/10, the lowest yield was achieved (4.059 t/ha), while the highest yield was achieved in year 2010/11 (5.615 t/ha). However, determined grain yields of triticale genotypes reported by Kendal and Sayar (2016a) ranged between 3.680 t/ha to 9.250 t/ha. In another study of Kendal et al. (2016b), grain yield of genotypes ranged from 2.92 t/ha in 2013/14 to 6.61 t/ha in 2012/13 season (normal season). Barnett et al. (2006) examined 22 genotypes of the winter and spring triticale in four geographically different locations (Quincy, FL, USA; Plains, GA, USA; Bozeman, MT USA and Aberdeen, ID, USA) during two vegetation seasons. The same authors have also established the genetic diversity of yields of the tested triticale genotypes at different locations. The grain yield ranged from 4.709 t/ha in California to 6.133 t/ha in Georgia. In the first year of the study (1997/98), grain yield of the tested triticale genotypes at different locations ranged from 2.507 t/ha to 7.245 t/ha, while in the second year of the research (1998/99) yield varied in the range of 2.341-8.033 t/ha. In these studies, a significantly higher yield of triticale in northern locations (Aberdeen, Bozeman) was found in relation to the southern (Quincy, Plains). The average grain yield values differed statistically significantly between the investigated triticale genotypes, between the investigated varieties and between the investigated sites (Barnett et al., 2006). Kendal et al. (2016b) have indicated that the yield of triticale genotypes in the 2012/13 season have ranged from 4.66 t/ha to 7.67 t/ha. The average grain yield was found to be 6.61 t/ha in this season.

Milovanovic et al. (2001) suggested that spring triticale is more prone to the negative impact of abiotic stress than winter triticale. Milovanović et al. (2011) have observed significantly ($p < 0.05$) higher yield stability of hybrids compared to lines for triticale crops. The enhanced yield stability represents a major step forward, facilitating coping with the increasing abiotic stress expected from the predicted climate change. Achieved statistically significantly higher yields in 2010/11 were primarily the result of heavy rainfall and their good distribution as well as favorable air temperatures during the vegetation period (**Tab. 1**). Đekić et al. (2016) stated in their research that the air temperatures and the rainfall amount and distribution during the triticale growing season have the greatest impact on high yields and grain quality. The significant difference in triticale grain yield was also indicated by Barnett et al. (2006), Janušauskaitė (2013) and Kendal et al. (2016a). For the Southeastern Anatolia Region, the results of the study of Kendal et al. (2014), demonstrated that the triticale grain yield is higher than those of durum and bread wheat varieties under more extreme growing conditions of the Kiziltepe region. Milovanovic et al. (2001) stated that in the domestic production conditions, higher yields are achieved by varieties with the shorter growing season because they manage to form the largest part of the yield before the incidence of high temperatures. In this study, in both years, the triticale was not exposed to extremely high temperatures so early growth did not come into its own.

Variety Kg 20, compared to the other genotype Trijumf, in the three-year period, had significantly higher value for the thousand kernel weight (42.67 g). The thousand kernel weight of triticale significantly varied across years, from 39.62 g in 2009/10 to 45.34 g in 2010/11. Highly significant influence of the year on 1000-kernel weight was established in investigated winter triticale varieties by variance analysis. Milovanović (1993) stated that the 1000 grain weight, however, is not only a component of yield but also a very important component of quality of grains. Milovanovic et al. (1998) reported that good quality grain needs to have the 1000 grain weight of 45-50 g. Kendal et al. (2014) have found that the thousand kernel weight in the tested triticale varieties ranged from 32.9 to 42.7 g in 2010/11. The same authors indicated that the new spring varieties are more suitable than wheat for more extreme growing conditions of Southeastern Anatolia Region. Heavier grains will have more starch and less protein (Filipčev et al., 2005). A number of authors (Đekić et al., 2010; Milovanović et al., 2012; Janušauskaitė, 2013; Kendal et al., 2014, 2016b; Đurić et al., 2016) have underlined that 1000-grain weight is a cultivar-specific trait, with considerably higher variations being observed among genotypes than among treatments or environmental factors. Previously, many researchers have reported that the thousand kernel weight values of triticale genotypes have ranged from 23.9 g to 54.9 g. (Janušauskaitė, 2013; Đekić et al., 2014; Kendal et al., 2014, 2016b; Kendal and Sayar, 2016a).

Test weight depends on many factors such as grain filling and shape, chemical composition, the content of impurities and moisture. Low test weight may be due to pre-harvest sprouting (Milovanović, 1993). Higher test weight means the higher content of starch and protein in relation to the content of fiber and a space filled with air (Milovanović et al. 1995; Filipčev et al. 2005). The genotype Kg 20 had an extreme value (70.89 kg/hl) in the second year (2010/11). All three years are different in regard to the test weight. Particularly in the third year (68.02 kg/hl), genotypes had significantly lower test weight compared to other years. Based on the analysis of variance, it can be concluded that there were significant differences in test weight in regard to the year of investigation, which is in accordance with the results obtained by Đekić et al. (2016). Kendal et al. (2016b) recorded an average value of test weight between 73.0 up to 78.6 kg/hl during two growing seasons (2012/13-2013/14) in 25 genotypes, including 20 advanced lines (from CIMMYT), three triticale varieties (Presto, Tacettinbey and Karma) and two candidate lines (G15 and G10). Barnett et al. (2006) have analyzed the yield and hectoliter mass of the 22 triticale genotypes in four ecologically diverse geographical locations (Quincy, FL, USA (AGC)=30ºN84ºW, approximate elevation (AE)=58 m), Plains, GA, USA (AGC=32ºN84ºW, AE=76 m), Bozeman, MT USA (AGC=45ºN 111ºW, AE=1458 m), and Aberdeen, ID, USA (AGC=42ºN 112ºW, Aberdeen, ID, USA (AGC=42ºN 112ºW, AE=1360 m). Field trials were carried out with the winter triticale, which was sowed during a two year period, 1997 and 1998, while the spring sowing of triticale was carried out in 1998 and 1999. The average value of the hectoliter mass in these studies ranged from 68.3 kg/hl to 75.0 kg/hl in the Florida area. Winter forms of triticale had higher average test weight (75.7 kg/hl) compared to the spring forms (73.4 kg/hl). Statistically significant differences between the tested triticale genotypes and investigated sites were determined by analyzing variance of average values of the test weight. In the study reported here, considerable genetic diversity in triticale for test weight at diverse geographic areas was found indicating that selection for specific environments would be possible. Generally, the test weight of triticale ranged from 63 to 72 kg/hl, while in dehulled triticale values were up to 80 kg/hl (Barnett et al., 2006; Janušauskaitė, 2013; Đekić et al., 2014; Kendal et al., 2014; Kendal and Sayar, 2016a).

Protein content differed very significantly between years and the average for all genotypes was higher in 2009/10 (13.796%) compared to 2010/11 (12.345%). Kendal et al. (2014) have recorded an average value of protein content between 13.3 and 14.7% in the three different triticale genotypes (Tacettinbey, Karma 2000 and Presto), during the growing season 2010/11. Perišić et al. (2008) reported 14.6% of crude proteins in winter triticale. Djekic et al. (2011) recorded values ranging from 11.23 to 13.87% of proteins in different winter triticale genotypes. In different spring triticale genotypes, Kendal et al. (2016b) recorded two year (2012/13 and 2013/14) average from 12.9 to 18.4% of proteins. During the 2012/13 season, which was considered a normal season, protein content ranged from 12.0% to 14.9%. During the 2013/14 season, the protein content ranged from 16.3% to 20.8%. The protein content in triticale genotypes, as reported by researchers Kendal and Sayar (2016a), ranged from 12.7% to 14.7% and by researcher Janušauskaitė (2013), from 11.4% to 14.3% proteins. Many authors have pointed that spring triticale varieties have more proteins compared to winter varieties (Djekic et al., 2011a; Kendal and Sayar, 2016a; Kendal et al., 2014, 2016b).

Humid 2010/11 was more favorable year for protein synthesis. Our results are consistent with the results obtained by Đekić et al. (2016) and Milovanovic et al. (2001), where the authors stated that the growing conditions in the observed years had a very significant impact on protein content. Analysis of variance showed highly significant effect of year on the protein content (p<0.01). Realized average values for these characteristics in the study were slightly higher than the values obtained by Djekic et al. (2011b).

Janušauskaitė (2013) has recorded an increase of the yield of triticale grain achieved by fertilization by 35.7%, compared with the unfertilized control treatment. The analysis of variance of the average grain yield over the four years showed that year significantly influenced the grain yield. The influence of N rate on the grain yield was significant in basic fertilization almost in all the cases; however, the influence of N splitting regime on the yield was insignificant. Utilization of fertilizers and certain supplements on extremely acid soils in certain years, particularly those less favorable for production, almost certainly had different effect on grain filling, resulting in diverse relationships between productive and qualitative traits (Biberdžić et al., 2012; Đekić et al., 2014; Janušauskaitė, 2013). Presented results confirm the opinion of many authors that the traits analyzed are genetically determined, but strongly modified by the nutrient status of the environment as well as weather conditions (Tomasović, 2005; Glamočlija et al., 2010; Kondić et al., 2012; Milovanović et al., 2012; Đurić et al., 2016; Kendal et al., 2016a,b).

The study results indicate that under the influence of the year, highly significant differences are recorded in all of the investigated traits. Also, Kendal and Sayar (2016a) and Kendal et al. (2016b) have indicated that in the assessment of genotypes more locations and years could increase the reliability of plant breeding programs and they have drawn attention to the fact that multi-location trials were more important than multi-year trials on the same location in determining performance of tested genotypes in terms of investigated traits in plant breeding programs.

Conclusion

Based on the results obtained during the three-year investigation of the two winter triticale varieties, it can be concluded that the highest three-year average and the best adaptability in semi-arid climate of central Serbia for properties grain yield and 1000-kernel weight were recorded for the variety Kg 20.

Highly significant influence of the year on grain yield, 1000-kernel weight, test weight and protein content was established in investigated winter triticale varieties by variance analysis, while genotype influence on grain yield, 1000-kernel weight, test weight and protein content was not statistically significant.

Acknowledgements. Investigations presented in this paper are part of the project TP 31054 "Development of new cereals cultivation technologies on acid soils by usage of modern biotechnology", financed by the Ministry of Education and Science of Republic of Serbia.

References

Barnett, R.D., Blount, A.R., Pfahler, P.L. 1999: Benefits of the UF/IFAS Small Grain Breeding Program to Florida and the Southeastern United States. *Soil and Crop Science Society of Florida Proceedings*, 58: 20-23.

Barnett, R.D., Blount, A.R., Pfahler, P.L., Bruckner, P.L., Wesenberg, D.M., Johnson, J.W. 2006: Environmental stability and heritability estimates for grain yield and test weight in triticale. *Journal of Applied Genetics*, 47: 207-213.

Biberdžić, M., Jelić, M., Deletić, M., Barać, S., Stojković, S. 2012: Effects of agroklimatic conditions at trial locations and fertilization on grain yield of triticale. *Research Journal of Agricultural Science*, 44(1): 3-8.

Glamočlija, Đ., Staletić, M., Ikanović, J., Spasić, M., Đekić, V., Davidović, M. 2010: Possibilities alternative grain production in the highlands area of central Serbia. *Economics of Agriculture-Multifunctional Agriculture and Rural Development* (V), Belgrade, EP, 57(SI-2): 71-77.

Đekić, V., Glamočlija, Đ., Staletić, M., Perišić, V. 2009: Variability of grain yield and yield components of Kg winter triticale cultivars. *Journal of Scientific Agricultural Research*, 70(3): 55-60.

Đekić, V., Milovanović, M., Glamočlija, Đ., Staletić, M. 2010: Influence of variety and year on grain yield and quality of triticale varieties of Kragujevac. *45^rd^ Croatian and 5^rd^ International Symposium on Agriculture*, 15.-19. February 2010, Opatija, Croatia, 707-711.

Djekic, V., Mitrovic, S., Milovanovic, M., Djuric, N., Kresovic, B., Tapanarova, A., Djermanovic, V., Mitrovic, M. 2011: Implementation of triticale in nutrition of non-ruminant animals. *African Journal of Biotechnology*, Nigeria, Afrika, 10 (30): 5697-5704.

Đekić, V., Milovanović, M., Popović, V., Milivojević, J., Staletić, M., Jelić, M., Perišić, V. 2014: Effects of fertilization on yield and grain quality in winter triticale. *Romanian Agricultural Researc*h, DII 2067-5720 RAR 2012-255, 31: 175-183.

Đekić, V., Milivojević, J., Perišić, V., Luković, K., Jelić, M., Janjić, S., Terzić, D. 2016: Maximum profitability of triticale to optimizing nutrition. Correlations between the triticale yield of mineral nutrition. *Proceedings, XX International Eco-Conference® 2016, 9th Eco-Conference® on Safe Food*, 28-30. September 2016, Novi Sad, 251-260.

Đurić, N., Cvijanović, G., Matković, M., Dozet, G., Đekić, V., Trkulja, V. 2016: Effect of the year on grain yield of some winter triticale varieties. *PKB Agroekonomik*, 22(1-2): 37-42.

Filipčev, B., Mastilović, J., Bodroža-Solarov, M. 2005: Hemical composition of triticale and winter barley varieties in 2002-2004, *Cereal bread*, 32(3): 85-88.

Janušauskaitė, D. 2013: Spring triticale yield formation and nitrogen use efficiencyas affected by nitrogen rate and its splitting. *Zemdirbyste-Agriculture*, 100(4): 383–392.

Kendal, E., Sayar, M.S. 2016a: The stability of Some Spring Triticale Genotypes Using Biplot Analysis. *The Journal of Animal & Plant Sciences*, 26(3): 754-765.

Kendal, E., Sayar, M.S., Tekdal, S., Aktas, H., Karaman, M. 2016b: Assessment of the impact of ecological factors on yield and quality parameters in triticale using GGE Biplot and AMMI Analysis. *Pakistan Journal of Botany*, 48(5): 1903-1913.

Kendal, E., Tekdal, S. Aktas, H., Karaman, M. 2014: Determınation compliance abilities of some triticale varieties and comparıson with wheat in Southeastern Anatolia condıtıons of Turkey. *Communications in Agricultural and Applıed Biologıcal Science*, 79(4): 192-200.

Kondić, D., Knežević, D., Paunović, A. 2012: Grain weight of genotypes of triticale (x *Triticosecale* Wittmack) in agroekological conditions of Banja Luka. *Genetics*, 44(2): 419-428.

Milovanović, M. 1993: Investigation of yield and technological traits of grain of the intergenus hybrids triticale (X Triticosecale Wittmack). *Rewiew of Research Work at the Faculty of Agriculture*, Zemun-Belgrade, 38(2): 71-82.

Milovanović, M., Kuburović, M., Stojanović, S., Ognjanović, R. 1995: Some recent results of winter triticale breeding in Kragujevac. *Proceedings of 1^st^ Balkan Symposium "Breeding and cultivation of wheat, sunflower and legume crops*", Albena-IWS, Bulgaria, 125-129.

Milovanovic, M., Kuburovic, M. Stojanovic, S., Kovacevic, B. 1998: Some results of investigations and winter 6x triticale breeding in Kragujevac. *Proceedings, Internernational Symposium "Breeding of Small Grains",* Kragujevac, Yugoslavia, 225-231.

Milovanovic, S.M., Rigin, V.B., Xynias, N.I. 2001: Genetic and breeding studies on triticale (X *Triticosecale* Wittmack). In: *Genetics and breeding of small grains*. Ari Serbia, Belgrade, 235-298.

Milovanovic, M.., Perisic, V., Staletic, M. 2006: Favorit-new vinter triticale cultivar for intensive growing conditions. *A Collection of Articles from the Technical Vocational College in Pozarevac*, 1-2: 93-97.

Milovanović, M., Staletić, M., Đekić, V., Nikolić, O., Luković, K. 2011: Seed production and contribution of KG varieties to biodiversity of small grains in the period 2006-2010. 01.-02. December 2011, Beograd, *Economics of agriculture*, Book II, 58(СБ/SI-1): 103-111.

Milovanović, M, Perišić, V., Staletić, M., Cvijanović, D., Đekić, V. 2012: Recent results of triticale breeding in Kragujevac. *Proceedings, 47^th^ Croatian and 7^th^ International Symposium on Agriculture*, 13.-17. Februar, Opatija, Croatia, 294-298.

Milovanovic, M., Perishic, V., Staletic, M., Đekic, V., Nikolic, O., Prodanovic, S., Lukovic, K. 2014: Diallel Analysis of Grain Number per Spike in

Triticale. *Bulgarian Journal of Agricultural Science*, 20(5): 1109-1115.

Perišić, V., Milovanović, M., Bratković, K. 2008: New Cultivar of Winter Triticale-General. *A Collection of Articles from the Technical Vocational College in Pozarevac*, 1-2, 59-64.

Tomasović, S. 2005: A newly registered winter triticale developed by the Zagreb Bc Institute. *Annual Wheat Newsletter*, 51: 23-24, Kansas State University, USA.