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EFFECT OF CULTIVAR AND INCREASED NITROGEN QUANTITIES ON SOME PRODUCTIVE TRAITS OF TRITICALE

SUMMARY

In the research carried out in the period from 2009–2012, in the north of Montenegro, the influence of cultivar and different amounts of nitrogen on the productive traits of winter triticale was examined. The research covered 5 cultivars of winter triticale (Odyssey, Kg-20, Triumph, Rtanj and Tango). The experiment was set up by random block system in four repetitions. Unfertilized plot (the control) and three steps of N fertilization (60, 90 and 120 kg ha^{-1} N) on the same level of phosphorus and potassium (80 kg $ha^{-1}$$P_2O_5$ + 80 kg ha^{-1} K_2O) were applied.

The results showed that genotypes respond to the application of mineral nutrients, as well as to the increased nitrogen levels by changing productive properties.

Variety Tango had the highest average grain yield, while Kg-20 had the lowest. Also, Tango had the highest value of the 1000 grain weight, while variety Triumph had the highest value of hectolitre weight. The application of fertilizers has led to a very large and significant increase of yield compared to the control. Based on the analysis of variance, it can be concluded that there were highly significant differences in grain yield among years of the research and significant differences at the 1000 grain weight and hectolitre weight.

Key words: *fertilization, yield components, variety, winter triticale.*

INTRODUCTION

Triticale, a hybrid species created by crossbreeding wheat and rye, is a promising species that takes a significant place in both crop and livestock production. As a species, it exhibited high adaptability in our agroecological conditions, which resulted in stable yields. Triticale is suitable for cultivation at higher altitudes, on soils with poor physicochemical properties, saline and acidic soil with pronounced resistance to biotic and abiotic stresses (Epure et al. 2015; Fras et al. 2016). According to the results of Stošović (2009), triticale achieved high yields in the hilly-mountainous region and in the application of lower cultivation technology, while under optimal conditions, in terms of grain yield, it

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has mostly reached the leading varieties of wheat, and outreached the varieties of rye, barley and oats (Biberdžić et al. 2012). Also, Estrada-Campuzano et al. (2012) point out that new cultivars of triticale achieve higher yields and show better adaptation to soil and climatic conditions compared to wheat.

The great possibility of using triticale for different purposes, as well as the emphasized varietal differences, require the need and importance of more detailed studying of new varieties, with the aim of their more efficient utilization in wide production. Triticale plants, which are characterized by very rapid growth and development, are adaptable to different cultivation technologies and achieve high and stable grain yields (Kendal and Sayar 2016).

Different cultivars have different requirements for applying agrotechnical measures. Nitrogen is an element that has the greatest influence on the vegetative growth of the plant, its photosynthetic capacity and yield. Also, nitrogen positively affects the activity of the root system and its penetration into deeper soil layers. However, it makes a big difference for the plants in what ration they will adopt the necessary elements. It is known that increasing the amount of nitrogen in the soil increases the needs of plants for phosphorus and potassium, and the needs of plants for mineral elements vary greatly depending on climatic factors, primarily from precipitation (Biberdžić et al. 2011).

Popović et al. (2011), Jelić et al. (2013) and Rajičić et al (2019) underlined that mineral fertilizers play a vital role in increasing crop yields, but one of the main constraints in achieving proven crop potential is an unbalanced use of nutrients, in particular a low use of phosphorus in comparison to nitrogen. The optimum rate of phosphorus is important for grain yields improving. Djekić et al. (2014) pointed out that the lack of nutrients in the soil causes shortening of the period of grain and grain filling, which has a negative effect on the yield and quality of grain.

Cultivars of triticale are distinguished by high genetic potential for yield, and that is why triticale can be considered a perspective plant species, especially from the point of view of climate change, which through increasing temperatures and drought show an even more intense influence on cultivated plants. For this reason, it is necessary to spread species, such as triticale, that are more tolerant to stress conditions, in the production.

The aim of this research was to study the influence of the increased nitrogen levels on the productive properties on the tested cultivars, for this area a relatively new plant species. Also, the goal was to distinguish those cultivars of triticale which, under certain conditions of growth, give the highest yield of grain and the best quality.

MATERIAL AND METHODS

The three-year experiment (2009-2012) was carried out in the agroecological conditions of the north of Montenegro in the vicinity of Bijelo Polje (Sutivan) (43°09′ N, 19°77′ E). The soil on which the experiment was carried out belongs to the type of Eutric Cambisol (CM-eu) on alluvial coating.

The experiment was set up by random block system in four repetitions, with the size of an elementary plot of $6m^2$ (3x2 m), including 5 cultivars (Odyssey, Kg-20, Triumph, Rtanj and Tango) of winter triticale (×*Triticosecale Wittmack*). The study included the following varieties of fertilizers: unfertilized plot (0 - the control) and three variants of fertilization (N_1 – 60 kg ha^{-1} N, 80 kg ha^{-1} P_2O_5, 80 kg ha^{-1} K_2O; N_2 – 90 kg ha^{-1} N, 80 kg ha^{-1} P_2O_5, 80 kg ha^{-1} K_2O and N_3-120 kg ha^{-1} N, 80 kg ha^{-1} P_2O_5, 80 kg ha^{-1} K_2O). Phosphorus and potassium were used in equal amounts (80 kg ha^{-1}) before the sowing period, while nitrogen was used in small amounts before the sowing period, and the rest of the planned amount was used as fertilization at the end of March. Common agronomical practices were used in the experiment. Sowing was carried out by manual method in optimal term (second decade of October). At full maturity, a random sample of 30 plants was collected from each plot for hectoliter weight and 1000 grain weight measurements. Grain yield was determined after the harvest. Upon harvest, the grain yield of each plot was measured and calculated as t ha^{-1}.

Soil and weather conditions

Before setting up the experiment, soil sampling was carried out from two depths from 0 to 10 cm and from 10 to 30 cm. Samples were analysed in the Agrochemical Laboratory of the Centre for Cereal Grains in Kragujevac. The applied soil testing methods were adopted by the Yugoslav Society for Soil Studies (JDPZ). In the tested soil samples, which were pre-dried to air-dry state and crushed in a porcelain mortar to a particle size of 2 mm, the following chemical and physical properties were determined: land reaction (pHKCl) by the combined glass electrode, the content of humus by the Kotzman method, content of $CaCO_3$ volumetric, using Scheibler calcimeter (Džamić et al., 1996) and the content of the easy-access P and K by the Al-method, by Egner-Riehm (1960). The obtained results showed that the tested soil had an acid reaction, well supplied by humus 3.35–3.96% and poor in available phosphorus (5.12–4.24 mg 100 g^{-1} soil) and potassium (7.5–3.8 mg 100 g^{-1} soil). The soil was weakly calcareous, too (the total content of carbonate being 2.4–2.44%).

Meteorological conditions, temperature and precipitation are the main non-genetic factors that determine the success of cultivation of winter triticale and other small grains. In the growing season 2009–2010 there were 881 mm of rainfall which is 116 mm more than in the second year and 329 mm more compared to the third year of the research.

Figure 1 showed that in the period from October to July 2009–2010, the highest rainfall was recorded in October, and the lowest in June. In this same interval during 2010–2011, the highest rainfall was in December, and the lowest in March, while in the third year of the study the highest precipitation was recorded in February, and the lowest in November. From the above it can be concluded that conditions for germination and autumn plant development were considerably favourable during the first two years compared to the third year of research. Also, the amount of rainfall in the period from April to June in the first year of research was higher compared to the other two years of research.

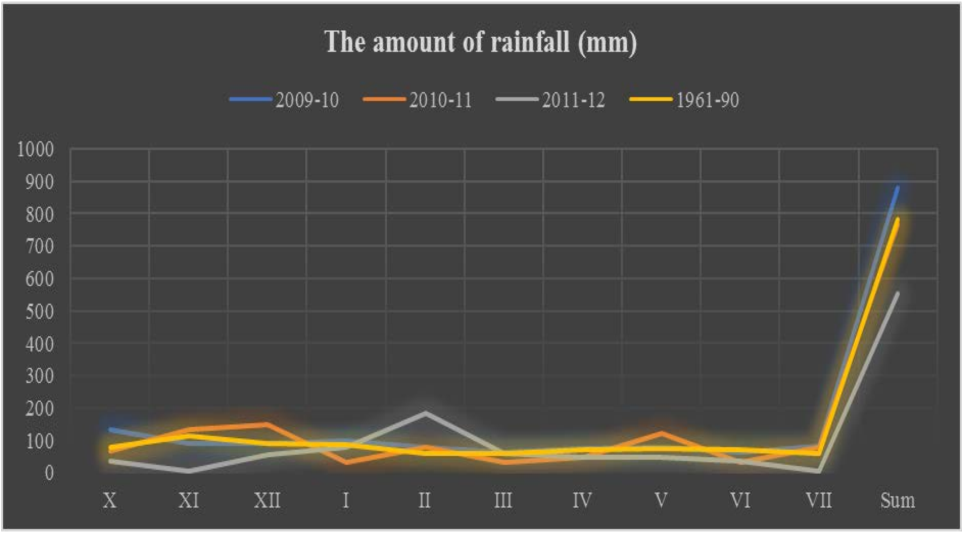

Figure 1. Rainfall distribution during the growing seasons (2009–2012) and multi-year average

Unlike the first two years of the study, in the second decade of November in 2011, air temperatures were significantly lower, which slowed down the development of plants in the initial stages (Fig. 2).

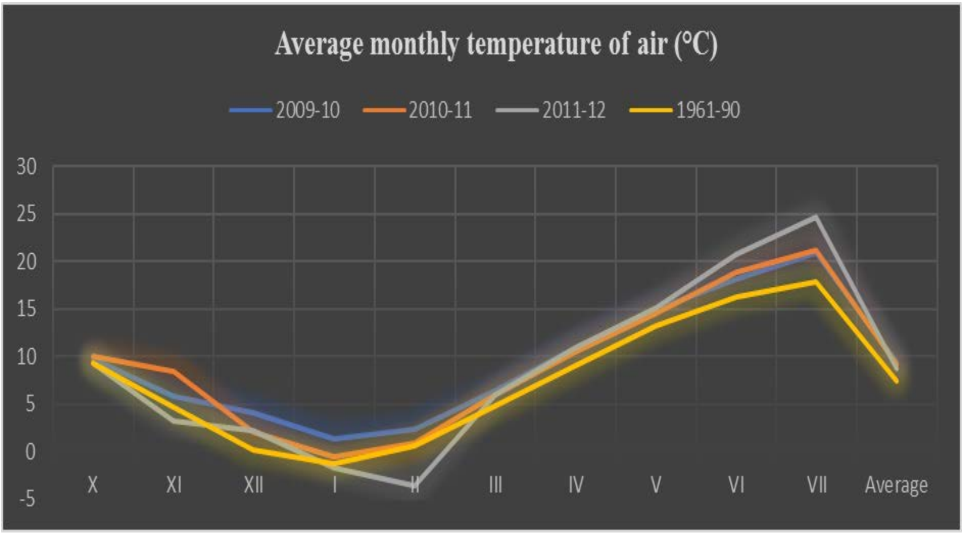

Figure 2. Middle monthly air temperature during the growing seasons (2009–2012) and multilevel average (1961-1990)

The biggest differences were observed in the coldest months, December, January and February. In February 2012, a lot of low temperatures were observed, especially in the first decade, when the temperature was −9.6°C. The snow cover in this year has significantly contributed to the protection of plants from freezing, but its long retention slowed down the vegetation in the spring.

The favourable air temperatures in May and June, in the first two years of the study, followed by a satisfactory amount of precipitation allowed the proper formation and filling of grains in relation to the third year. The high air temperatures in July 2012 with the modest moisture reserves led to distortion of the filling phase and forced ripening, which had a negative impact on the yield.

Computation and data analysis

Analysis of variance (ANOVA) was performed using the WASP 1.0. statistical package with two-way factors, fertilization and variety, to establish the treatment effects. The importance of differences among the observed elements was tested by Fisher′s protected least significant difference (LSD) test at $P \leq 0.05$ and $P \leq 0.01$.

RESULTS AND DISCUSSION

The results of our research have shown that there are significant differences in the values of 1000 grain weight among the tested triticale cultivars (Table 1.). Also, it was noted that the conditions of the external environment as well as the certain nutritional elements significantly influenced the observed trait. The application of the highest nitrogen dose in combination with phosphorus and potassium, in all three years of the research, resulted in the highest average 1000 grain weight in all cultivars included in the study, which is in agreement with Jaćimović et al. (2008) who found that 1000 grain weight is significantly higher in intensive fertilization treatments, especially by nitrogen.

Our results are in agreement with the results of Djekić et al. (2010; 2012), Djurić et al. (2013) and Jelić et al. (2013) which pointed out that 1000 grain weight is a cultivar specific trait, with considerably higher variations being observed among genotypes than among treatments or factors of environment. Bielski et al. (2015), according to their research, pointed out that the application of nitrogen in the amount of 120kg ha-1 led to a significant decrease of 1000 grain weight compared to the application of nitrogen in the amount of 30kg ha-1. However, the same author emphasized that the application of nitrogen in the amount of 150kg ha-1 led slightly to the increase of 1000 grain weight.

The highest average 1000 grain weight in the three-year study period was achieved by the cultivar Tango (48.2 g), and the lowest by the cultivar Kg-20 (32.8 g). Also, the lowest 1000 grain weight was noted in the first year of the research (40.9 g), which was the climate most favourable, while the highest one was achieved in the third year (44.2 g). Climatic conditions are especially important during the filling of the grain, because the lack of moisture and high temperature during this period influence the reduction of the 1000 grains weight (Bielski 2015), which is confirmed by the results of this research.

Table 1. 1000 grain weight (g) per cultivars, fertilizing variants and years

Varieties (A)	1000 grain weight (g)														
	2009-2010					2010-2011					2011-2012				
	Fertilization variant (B)														
	0	N_1	N_2	N_3	Aver.	0	N_1	N_2	N_3	Aver.	0	N_1	N_2	N_3	Aver.
Odyssey	39.0	40.3	42.8	45.7	41.9	39.4	40.2	40.5	42.3	40.6	41.4	44.0	45.5	47.9	44.7
Kg-20	27.0	31.7	32.9	33.4	31.6	30.7	35.7	31.3	34.6	33.1	28.8	31.8	35.8	38.1	33.6
Triumph	38.2	41.8	40.6	45.1	41.4	39.0	40.7	41.2	42.8	40.9	43.4	47.8	48.1	48.9	47.0
Rtanj	37.2	41.5	43.2	43.8	41.4	44.4	46.1	46.4	46.3	45.8	44.7	45.8	46.7	49.0	46.5
Tango	45.0	48.3	50.7	49.8	48.4	44.5	48.0	47.1	48.9	47.1	43.8	46.8	52.6	53.8	49.2
Average	37.3	40.7	42.0	43.6	40.9	39.6	42.1	41.3	43.0	41.5	40.4	43.2	45.7	47.5	44.2

Table 2. The analysis of variance for 1000 grain weight

Source of variation	Degrees of freedom	2009-2010 Sum of squares	Mean sum of squares	F	2010-2011 Sum of squares	Mean sum of squares	F	2011-2012 Sum of squares	Mean sum of squares	F
Replicat.	2	3.826	1.913	1.510	2.073	1.037	0.761	1.460	0.730	0.631
Treatm.	19	2193.690	115.457	91.150	1598.655	84.140	61.795	2323.199	122.274	105.697
Factor A	4	1827.354	456.838	360.659**	1469.241	367.310	269.766**	1814.758	453.689	392.182**
Factor B	3	322.452	107.484	84.855**	92.909	30.970	22.745**	430.427	143.476	124.025**
A x B	12	43.883	3.657	2.887**	36.506	3.048	2.234**	78.014	6.501	5.620**
Error	38	48.134	1.267	-	51.740	1.362	-	43.960	1.157	-
Total	59	-	-	-	-	-	-	-	-	-

LSD	2009-2010 0.05	0.01	2010-2011 0.05	0.01	2011-2012 0.05	0.01
A	0.930	1.246	0.964	1.292	0.889	1.191
B	0.832	1.115	0.862	1.156	0.795	1.065
A x B	1.860	2.492	1.928	2.584	1.777	2.382

*significant at 0.05; ** significant at 0.01

From the data in Table 3. it can be noticed that all cultivars had the lowest value of hectolitre weight in control. The application of fertilizers led to a very significant increase in the value of this trait in all three years of the research, while the application of different fertilization variants did not significantly affect this trait. Also, the influence of the year on the observed trait was noticed, since the lowest average value of the hectolitre weight was recorded in the third year, according to climatic conditions, the most unfavourable year. The influence of meteorological factors on this trait was confirmed earlier in the research by Djekić et al. (2009) and Stošović et al. (2010).

Grain yield is the safest indicator of the existence of differences in productivity among varieties and their specificity towards mineral nutrition, because it is precisely the end result of both external factors on the plant and the biorhythmic activity of certain physiological and biochemical processes. The data in the Table 5. show that the use of mineral fertilizers has led to a significantly very high yield increase in all tested cultivars compared to the control.

The research has shown that winter triticale achieves high yields in the use of nitrogen in the amount of 120 kg ha^{-1} and phosphorus and potassium in the amount of 80 kg ha^{-1}, as confirmed by Knapowski et al. (2009) and Pecio (2010), who, in their researches, obtained the highest grain yields when using nitrogen in the amount of 120 kg ha^{-1}. In the trial run by Bielski (2015) the highest yield was harvested from treatments fertilised with the highest dose of nitrogen (150 kg ha^{-1}).

Table 3. Hectolitre weight (kg) per cultivars, fertilizing variants and years

Varieties (A)	Hectolitre weight (kg)														
	2009-2010					2010-2011					2011-2012				
	Fertilization variant (B)														
	0	N_1	N_2	N_3	Aver.	0	N_1	N_2	N_3	Aver.	0	N_1	N_2	N_3	Aver.
Odyssey	65.9	76.2	76.3	73.2	72.9	66.2	70.8	67.0	68.3	68.1	65.8	67.6	69.2	69.2	68.0
Kg-20	61.5	67.4	66.3	68.9	66.0	69.1	69.5	70.3	71.7	70.1	64.2	65.5	63.2	62.3	63.8
Triumph	72.5	75.7	76.6	77.5	75.6	69.2	69.5	69.9	71.6	70.0	68.6	70.5	71.4	70.3	70.2
Rtanj	68.3	69.1	71.8	71.3	70.1	65.6	64.9	66.7	68.4	66.4	67.1	67.9	64.8	65.2	66.2
Tango	73.0	72.7	72.9	73.3	73.0	63.8	65.3	64.6	66.8	65.1	67.7	69.6	68.4	71.2	69.2
Average	68.2	72.2	72.8	72.8	71.5	66.8	68.0	67.7	69.4	67.9	66.7	68.2	67.4	67.6	67.5

Table 4. The analysis of variance for hectolitre weight

Source of variation	Degrees of freedom	2009-2010 Sum of squares	Mean sum of squares	F	2010-2011 Sum of squares	Mean sum of squares	F	2011-2012 Sum of squares	Mean sum of squares	F
Replicat.	2	7.314	3.657	2.182	5.055	2.528	0.930	1.801	0.901	0.208
Treatm.	19	1000.872	52.677	31.426	337.501	17.763	6.532	400.156	21.061	4.861
Factor A	4	629.628	157.407	93.904**	244.580	61.145	22.486**	304.721	76.068	17.556**
Factor B	3	216.619	72.206	43.076**	48.536	16.179	5.950	23.002	7.667	1.770**
A x B	12	154.625	12.885	7.687**	44.385	3.699	1.360**	72.883	6.074	1.402**
Error	38	63.698	1.676	-	103.332	2.719	-	164.649	4.333	-
Total	59	-	-	-	-	-	-	-	-	-
LSD		0.05		0.01	0.05		0.01	0.05		0.01
A		1.070		1.433	1.363		1.826	1.720		2.305
B		0.957		1.282	1.219		1.633	1.538		2.061
A x B		2.140		2.867	2.725		3.651	3.440		4.609

*significant at 0.05; ** significant at 0.01

Table 5. Grain yield ($t\ ha^{-1}$) per cultivars, fertilizing variants and years

Varieties (A)	Grain yield ($t\ ha^{-1}$)														
	2009-2010					2010-2011					2011-2012				
	Fertilization variant (B)														
	0 Aver.	N_1	N_2	N_3	Aver.	0	N_1	N_2	N_3	Aver.	0	N_1	N_2	N_3	
Odyssey	4.31	5.43	5.53	6.28	5.39	3.75	5.03	5.24	5.49	4.88	3.12	4.94	5.02	5.23	4.58
Kg-20	3.74	4.52	5.45	5.28	4.75	3.12	4.61	4.73	4.86	4.33	2.99	4.54	4.42	4.45	4.10
Triumph	4.11	5.28	6.13	6.25	5.44	3.66	5.21	5.81	5.88	5.14	3.23	5.01	4.84	4.90	4.49
Rtanj	3.87	5.02	5.93	6.00	5.20	3.59	5.57	5.68	6.24	5.27	3.34	4.97	5.11	5.22	4.66
Tango	4.17	5.64	6.73	7.14	5.92	3.96	6.03	6.39	6.73	5.78	3.40	5.14	5.21	5.29	4.76
Average	4.04	5.18	5.95	6.19	5.34	3.62	5.29	5.57	5.84	5.08	3.22	4.92	4.92	5.02	4.52

Table 6. The analysis of variance for grain yield

Source of variation	Degrees of freedom	2009-2010 Sum of squares	Mean sum of squares	F	2010-2011 Sum of squares	Mean sum of squares	F	2011-2012 Sum of squares	Mean sum of squares	F
Replicat.	2	0.429	0.215	3.093	0.159	0.080	0.429	1.621	0.811	2.587
Treatm.	19	53.122	2.796	40.284	61.245	3.223	17.380	37.714	1.985	6.334
Factor A	4	7.341	1.835	26.443**	11.588	2.897	15.620**	3.105	0.776	2.477*
Factor B	3	42.527	14.176	204.246**	47.288	15.763	84.988**	34.106	11.369	36.277**
A x B	12	3.254	0.271	3.908**	2.368	0.197	1.064**	0.502	0.042	0.133 **
Error	38	2.637	0.069	-	7.048	0.185	-	11.909	0.313	-
Total	59	-	-	-	-	-	-	-	-	-
LSD		0.05		0.01	0.05		0.01	0.05		0.01
A		0.218		0.292	0.356		0.477	0.463		0.620
B		0.195		0.261	0.318		0.426	0.414		0.554
A x B		0.435		0.583	0.712		0.954	0.925		1.240

*significant at 0.05; ** significant at 0.01

The greatest impact on the yield and yield structure had the years during which the experiment was carried out, followed by cultivar and distribution of nitrogen fertilization dosing (Alaru et al. 2004). The positive effects of mineral nutrition, especially nitrogen, on the grain yield of triticale were pointed out earlier and by other authors (Bojović 2010; Lestingi et al. 2010). As a result of the influence of various climatic factors, variation in yields by the years of testing was also noted. The highest grain yield was recorded in the vegetation year 2009/10, which was the most favourable in terms of quantity and precipitation. The unfavourable weather conditions for the cultivation of winter triticale in the third year of the study had a negative impact on the yield level in relation to the previous two years. Significantly smaller amounts of precipitation in the last three months of the year, which are important for planting and initial development of plants, resulted in later incomplete emergence. Also, the heavy snowfall in February 2012, as well as the long retention of snow cover led to a slowdown of vegetation in spring, later sowing and flowering. The high air temperatures in June and July, in the same year, caused a shortening of the period of filling of the grain, accelerated ripening and reduction of the yield.

The results of this study showed that the influence of nitrogen fertilization on the grain yield, components of the yield and the quality of grain, do not depend only on the dose of fertilizers, but also on the climatic conditions, as Janušauskaitė (2013), Ivanova and Kirchev (2014), Djurić et al. (2015), Madić et al. (2018), Terzić et al. (2018) and Đekić et al. (2019) had confirmed previously in their researches. (Djekić et al. 2012; 2014), as well as many other authors, point out that the high quality of grain and the best triticale yields are obtained in the years with warm bright spring weather conditions and cold summers without excessive precipitation during the grain filling stage, which is in agreement with this study.

CONCLUSIONS

The results of this study showed that the values of the examined productive traits of the genotypes of winter triticale varied depending on the applied dose of nitrogen, weather conditions and cultivar. On average over the three-year period of the study, the N_3 variant of fertilization had the greatest positive effect on most parameters affecting productivity. The cultivar Tango had the highest average yield (5.49 t ha^{-1}) while Kg-20 had the lowest (4.39 t ha^{-1}). Also, Tango had the highest value of 1000 grain weight, while Triumph had the highest value of hectolitre weight. The differences in yields that have been shown in the cultivars included in the research are the result of varietal specificity, which is largely genetically conditioned. The results of the research can be of great importance for the popularization of triticale as a species in this production area for the improvement of production practice in Montenegro and beyond. Also, the results are important for cattle-oriented farms, where the main priority is to ensure a sufficient amount of quality food.

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