

DIFFERENCES IN GRAIN YIELD AND GRAIN QUALITY TRAITS OF WINTER TRITICALE DEPENDING ON THE VARIETY, FERTILIZER AND WEATHER CONDITIONS

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Abstract. The research conducted in the north of Montenegro in the period from 2017-2019 aimed to examine the impact of different fertilizer variants on the yield and grain quality traits in four varieties of winter triticale. The research included the control and three variants of nitrogen fertilization: 60 kg ha⁻¹ (N₁), 100 kg ha⁻¹ (N₂) and 120 kg ha⁻¹ (N₃). In all fertilizer variants, in addition to nitrogen, another 100 kg of ha⁻¹ phosphorus and potassium were used. The results of the research showed that all examined varieties reacted positively to the application of mineral nutrition both by changing the productive characteristics and by changing the grain quality. The greatest positive effect on all examined parameters that affect productivity had the variant of fertilization in which nitrogen was used in the amount of 120 kg ha⁻¹. The variety PKB Vožd had the highest yield (5.79 t ha⁻¹) in both years of research, while the cultivar Favorit had the lowest yield (4.67 t ha⁻¹). The variance analysis clearly indicated that the individual effects of variety and fertilization, as well as the effects of the interaction between variety x fertilization and fertilization x year on grain yield in the examined winter triticale varieties were significant (p<0.01).

Keywords: *triticale, mineral nutrition, nitrogen, productive characteristics, grain quality*

Introduction

The emergence of a new, more demanding range of triticale, accompanied by constant changes in agroecological conditions and soil characteristics, especially when we talk about its fertility, emphasizes the need to research the mineral nutrition of triticale while determining optimal amounts and ratios of nutrients in specific agroecological conditions. The increase in the number of inhabitants, accompanied by the problem that the world production of basic cereals intended for human consumption is not in proportion to the number of the human population, has produced the need to find new ways of production. Also, the current pandemic has shown how important each country's own production, compared to the import of goods, is in overcoming the global crisis. Created with the idea of combining the good properties of wheat and rye by intergenus hybridization, triticale is characterized today by the existence of a large number of varieties marked by high tolerance to adverse biotic and abiotic factors (Massimi et al., 2016) which reduces the requirements for chemical protection (Losert, 2017) and fertilization. On the other hand, triticale provides high grain yields and high biomass even in marginal environments that cannot be used for growing food crops (Bezabih et al., 2019; Kucukozydemir et al., 2021), but also in arid areas that are becoming more widespread due to global climate change (Blum, 2014; Cantale et al., 2016). High productivity with lower initial investments, better adaptation to moist,

acidic and alkaline soils with the lack of nutrients compared to other cereals, good grain quality with high protein content (Epure et al., 2015; Bezabih et al., 2019) are some of the properties of triticale. Triticale is an excellent component for preparing feed mixtures and can partially or completely replace other, more expensive nutrients, and thanks to nutritional values higher than corn, breeders and livestock experts have so far recommended it in the diet of all domestic animals (Đekić et al., 2012), while Glamočlija et al. (2018) point out that it has given the best results so far in the diet of poultry and dairy cattle. Mature grain can be used, but also green, ensiled, alone or in combination with other ensiled legumes. Despite the fact that the problems of mineral nutrition have been researched a lot and that there are a lot of available results, many questions will always be relevant, while some will reappear in a new form. In support of this is the fact that the results of experiments with fertilization are directly or indirectly influenced by numerous factors, including climatic conditions of the region and year, soil fertility, fertilization preceding crops, nutrient composition, time and manner of its introduction, etc. (Kirchev et al., 2014; Gerdzhikova, 2014; Madić et al., 2015; Terzić et al., 2018).

According to Jaćimović et al. (2012) for achieving adequate quality and yield of small grains, one of the key factors is a well-balanced mineral diet where the full effect of NPK nutrients can be achieved only if other factors that model yield are brought to optimum, especially weather conditions of the growing season (Janušauskaite, 2014). Dumbravă et al. (2016) state that one of the most important agro-technical factors on which the grain yield depends and enables farmers to use the production potential of cereals is mineral nutrition, with special emphasis on the use of nitrogen due to its impact on grain yield and quality. Namely, high grain yield of good quality in intensive agricultural production can be achieved only in the conditions of application of a sufficient amount of nitrogen in the periods of vegetation when it is most needed by plants (Janušauskaite, 2013). Nikolić et al. (2012), Novak et al. (2019) and Hirzel et al. (2020) state that among the nutrients, nitrogen certainly has the greatest impact on yield elements and its quality, both through its presence in the soil and its deficiency, which in critical phases can lead to irreversible loss of yield (Estrada-Campuzano et al., 2012), so this justifies the fact that its impact on the yield is the subject of numerous studies. When we talk about the quantities of mineral fertilizers, different data are given in the literature precisely because of the different conditions of the survey, climatic and soil factors, variety potential, preceding crop (Gerdzhikova et al., 2017; Darguza and Gaile, 2020).

Therefore, the production of small grains requires constant improvement when we talk about nutrient intake systems, and we should always take into account its economic moments.

Montenegro, despite the favorable climatic conditions for the cultivation of cereals and the available arable land that can be used for these purposes, meets its needs in cereals mainly from imports. The importance of triticale cultivation intended for domestic animals in the hilly and mountainous area of northern Montenegro requires the need for more detailed study and popularization of this type of grain with the aim of its fuller use in large-scale production. According to Peltonen-Sainio et al. (2009), the prevalence of winter cereals in the northern regions will be much higher in the future than at present. Taking into account that plant nutrition, i.e. nutrient intake is more regional in nature, that agricultural producers do not have enough information about the use of nitrogen fertilizers, its amounts in soil and that the research is conducted in rural

areas, the aim is to determine optimal fertilization systems which would result in high and stable yields of satisfactory quality. The results of the research would enable giving reliable recommendations to producers of this type of grain for variety selection and determining optimal quantities of the most important nutrients in a specific production area, because the production potential of the variety can be used only by applying varietal agrotechnics, by educating producers and faster transfer of scientific knowledge into production.

Materials and methods

In order to examine the effect of different amounts of nitrogen in combination with phosphorus and potassium on the productivity and protein content of triticale grain, an experiment was set up in the vicinity of Bijelo Polje (Montenegro) at 43°05'25"N and 19°46'10"E, at an altitude of 562 m. The experiment set up according to a random block system in four repetitions was performed in the period from 2017-2019. The size of the elementary plot was 6 m² (3x2 m). The land on which the survey was performed belongs to the type of Eutric Cambisol on alluvial and colluvial deposits with low carbonate content (2.38-2.45%), which is a characteristic of most of these lands in the Lim river valley. The soil is humic (3.37-3.98%), low pH value (pH (KCl) = 5.01-4.94) with low content of easily accessible phosphorus and potassium (below 10 mg 100 g⁻¹ soil).

Four varieties of winter triticale (Kg-20, Favorit, Tango and PKB Vožd) were used as test material, of which the first two were selected at the Center for Small Grains in Kragujevac (Serbia), the variety Tango was created at the Center for Agricultural and Technological research in Zajecar (Serbia) and the variety PKB Vožd in the Institute PKB (Padinska Skela – Serbia). Sowing in both years of research was done manually in the optimal time for this area (second decade of October) with a row spacing of 12.5 cm and sowing density of 600 germinated seeds per m². Additional tillage performed just before sowing was preceded by basic tillage at a depth of 25 cm. The research included the control and three variants of nitrogen fertilization: 60 kg ha⁻¹ (N₁), 100 kg ha⁻¹ (N₂) and 120 kg ha⁻¹ (N₃), where nitrogen was used in the form of calcium-ammonium nitrate (KAN - 27% N). In all fertilizer variants, in addition to nitrogen, another 100 kg of ha⁻¹ phosphorus in the form of super phosphate and 100 kg of ha⁻¹ potassium in the form of 60% potassium salt were used. Fertilizers were used so that the entire amount of phosphorus and potassium together with half of nitrogen fertilizers was applied in the autumn period together with pre-sowing soil preparation, and the other half in fertilization in mid-March in the phase of full flowering of plants. Other production technology applied to the experiment was standard. The harvest was carried out manually in the phase of full maturity in the middle of July, during which the measured grain yield was corrected to 14% moisture. Also, the values of hectoliter weight were determined by measuring 48 samples on a hectoliter scale (volume 250 ml) and the mass of 1000 grains. The nitrogen content in the grain of the tested triticale cultivars was determined by the Kjeldah method, whereby the obtained values were multiplied by a coefficient of 6.25.

The obtained results presented through average values were statistically processed by the method of variance analysis, where the significance of differences in treatment environments was tested by LSD test, at significance thresholds of 1 and 5%, using WASP 2.0 Statistics Software Package (free version, Indian Council of Agricultural

Research [ICAR] - Central Coastal Agricultural Research Institute [CCARI], Ela, Goa, India).

Climatic data of the experimental area

Meteorological conditions, air temperatures and precipitation for crop growing seasons are shown in *Table 1*. The data for the research period (2017-2019) clearly show that the years in which the research was conducted differed in temperature and quantity and distribution of precipitation between each other and with a perennial average.

Table 1. Climatic data of the region (2017-2019 growing seasons)

Month	Temperature (°C)			Precipitation (mm)		
	Year		Long term average (1991-2020)	Year		Long term average (1991-2020)
	2017/18	2018/19		2017/18	2018/19	
October	10.4	13.5	10.8	50.1	38.0	85.7
November	5.1	7.0	5.5	88.9	119.7	100.0
December	1.8	0.8	0.8	158.4	49.1	89.9
January	2.6	-1.2	-0.4	38.2	71.9	63.6
February	2.4	2.9	1.6	114.7	60.2	77.6
March	6.4	7.0	5.7	103.2	13.6	67.7
April	15.0	11.8	10.4	39.5	44.0	70.9
May	15.3	13.2	14.6	101.7	230.2	81.4
June	18.9	20.6	18.4	90.8	125.1	72.4
July	20.4	20.5	20.1	79.0	97.7	69.3
Mean / total	9.8	9.6	8.7	864.5	849.5	778.5

The average air temperature and the amount of precipitation during the vegetation period in both years of research was higher than the multi-year average. In the first year of research (2017/18), the average air temperature was 1.12 °C higher compared to the multi-year average, while in the second year of research (2018/19) the difference was 0.86 °C. Large amounts of precipitation in the second year of research in May, June and July compared to the first year of research, but also the long-term average, adversely affected both plant development and the process of their maturation, which resulted in lower yields.

Results and discussion

The data obtained during the research showed the existence of significant differences in the values of the mass of 1000 grains of the examined triticale cultivars (*Table 2*).

Also, it was noticed that the environmental conditions as well as certain nutrients significantly affected the observed trait. Average values for all variants of fertilization show that the variety PKB Vožd in both years of research achieved the highest mass of 1000 grains and it amounted to 49.8 g and 48.5 g, respectively. The lowest average mass of 1000 grains, in both years of research, was recorded in the cultivar Favorit. The results of two years of research show that the average mass of 1000 grains for all varieties was the highest in the variant where nitrogen was used in the amount of 120 kg ha⁻¹ and it was 44.3 g in the first year and 43.2 g in the second, which is in accordance with the results of Oral et al. (2018) who point out that even the smallest

amounts of nitrogen used in triticale cultivation affect a significant increase in the value of this trait.

Table 2. Thousand grain weight (g) of triticale as affected by varieties, nitrogen application and year

Variety (A)	Year (C)									
	2017/18					2018/19				
	Fertilization variant (B)					Fertilization variant (B)				
	0	N ₁	N ₂	N ₃	Average	0	N ₁	N ₂	N ₃	Average
Kg-20	33.5	36.2	37.0	38.6	36.3	33.7	36.7	37.0	38.8	36.5
Favorit	31.0	34.8	35.4	36.0	34.3	30.8	33.0	35.4	36.0	33.8
Tango	45.1	47.9	47.8	49.0	47.4	42.4	46.1	46.0	47.2	45.4
PKBVožd	43.8	49.2	52.6	53.8	49.8	45.1	48.1	50.0	50.9	48.5
Average	38.3	42.0	43.2	44.3	41.9	38.0	41.0	42.1	43.2	41.0

Anova Table

Source of variation	Degrees of freedom	Sum of squares	Mean sum of squares	F cal	F prob			
Replications	3	6.370	2.123	-	-			
Factor A	3	392.947	130.982	166.851***	0.000			
Factor B	3	5216.678	1738.893	2215.081***	0.000			
Factor C	1	1.033	1.033	1.316 ^{ns}	0.254			
AxB	9	68.644	7.627	9.716***	0.000			
AxC	3	28.401	9.467	12.059***	0.000			
BxC	3	212.457	70.819	90.213***	0.000			
AxBxC	9	38.385	4.265	5.433***	0.000			
Error	93	73.007	0.785	-	-			
Total	127	6037.923	-	-	-			
Lsd		A	B	C	AxB	AxC	BxC	AxBxC
	0.05	0.440	0.440	0.311	0.880	0.622	0.622	1.244
	0.01	0.583	0.583	0.412	1.165	0.824	0.824	1.648

0 – control (without fertilization), N₁ - 60 kg ha⁻¹ of nitrogen, N₂ - 100 kg ha⁻¹ of nitrogen, N₃ - 120 kg ha⁻¹ of nitrogen. ***Significant at p < 0.01; ns – non-significant

And while the values of the mass of 1000 grains in our research and the research of Oral et al. (2018) increase with the increasing amount of nitrogen used in fertilization (36.4 g - N₀ to 38.0 g – N₃ (120 kg ha⁻¹ N)), Bielski et al. (2020) based on their research, state that even the use of small amounts of nitrogen in fertilization leads to a significant increase in the mass of 1000 grains. The mentioned authors obtained the highest mass of 1000 grains when using the least amount of nitrogen (40 kg ha⁻¹), while a further increase in the amount of nitrogen resulted in so-called post fertilization diminution of grains followed by a decrease in the mass of 1000 grains. Accordingly, the results of these authors show that the use of nitrogen in the amount of 120 kg ha⁻¹ caused a significant decrease in the value of 1000 grains and that a similar trend was observed with a further increase in nitrogen (160 kg ha⁻¹). In contrast, the results of the study by Dumbravă et al. (2016) showed that the highest values of mass of 1000 grain were recorded on non-fertilized variants where the number of grains per ear and the number of ears per m² were lower and that this property significantly depends on other yield parameters. By analysis of variance, individual influences of cultivar and fertilization on the mass of 1000 grains were significant at the 0.01 level, as well as the effects of interaction of cultivars x fertilization, cultivar x years, fertilization x years and cultivar x

fertilization x years. The individual effect of the year on the mass of 1000 grains in the observed varieties of winter triticale was not statistically significant.

The results of our research show that the use of mineral fertilizers caused a significant increase in hectoliter weight compared to the control, but that a similar trend was observed with increasing doses of nitrogen. Jelić et al. (2013) point out that the hectoliter weight in small grains is the trait which is genetically defined but also strongly modified by the nutrient status of the environment and weather conditions. On the other hand, the results of Dumbravá et al. (2016) indicate that hectolitre weight, in addition to quantity, is largely conditioned by the distribution of nitrogen fertilizers during vegetation, where they obtained the highest values of this trait on non-fertilized treatments with the lowest number of spikes / m² followed by the lowest number of grains per spike.

From the data in *Table 3*, it can be seen that the variety Tango, on average in both years of research, achieved the highest hectoliter weight and it amounted to 70.9 kg hl⁻¹ in the first and 67.9 kg hl⁻¹ in the second year of research.

Table 3. Hectolitre weight (kg hl⁻¹) of triticale as affected by varieties, nitrogen application and year

Variety (A)	Year (C)									
	2017/18					2018/19				
	Fertilization variant (B)					Fertilization variant (B)				
	0	N ₁	N ₂	N ₃	Average	0	N ₁	N ₂	N ₃	Average
Kg-20	66.7	68.3	72.5	74.4	70.5	63.3	65.9	66.9	68.0	66.0
Favorit	65.4	68.1	70.2	71.1	68.7	62.3	64.4	65.6	67.0	64.8
Tango	66.1	71.0	73.5	73.2	70.9	65.0	66.3	70.0	70.5	67.9
PKBVožd	66.5	70.3	69.9	71.1	69.4	65.6	65.1	68.0	69.3	67.0
Average	66.2	69.4	71.5	72.4	69.9	64.0	65.4	67.6	68.7	66.4

Anova Table

Source of variation	Degrees of freedom	Sum of squares	Mean sum of squares	F cal	F prob			
Replications	3	9.604	3.201	-	-			
Factor A	3	848.487	282.829	277.985***	0.000			
Factor B	3	147.523	49.174	48.332***	0.000			
Factor C	1	0.546	0.546	0.537 ^{ns}	0.466			
AxB	9	76.018	8.446	8.302***	0.000			
AxC	3	2.732	0.911	0.895 ^{ns}	0.447			
BxC	3	59.486	19.829	19.489***	0.000			
AxBxC	9	35.662	3.962	3.895***	0.000			
Error	93	94.621	1.017	-	-			
Total	127	1274.679	-	-	-			
Lsd	0.05	0.501	0.501	0.354	1.002	0.708	0.708	1.416
	0.01	0.663	0.663	0.469	1.326	0.938	0.938	1.876

0 – control (without fertilization), N₁ - 60 kg ha⁻¹ of nitrogen, N₂ - 100 kg ha⁻¹ of nitrogen, N₃ - 120 kg ha⁻¹ of nitrogen. ***Significant at p < 0.01; ns – non-significant

The analysis of variance determined very highly significant statistical effects of variety and fertilization on the achieved values of hectoliter weight as well as the interaction of variety x fertilization, fertilization x years and variety x fertilization x years. The individual effect of year as well as the effects of interactions between variety x year on hectoliter weight in the studied winter triticale varieties were statistically

nonsignificant. This confirms the fact that hectoliter grain weight is a complex property controlled by a large number of genes, that it is conditioned by the genotype and whose values can vary significantly according to soil tillage, preceding crop and nitrogen fertilization conditions (Dumbravá et al., 2016; Kucukozdemir et al., 2019).

Studies have shown that mineral nutrition specifically affects the yield and its components in the tested varieties. Also, statistically significant differences in yield height and between examined varieties were observed. Grain yield on average for all cultivars and variants of fertilization in the first year of research was 5.43 t ha⁻¹ and was higher compared to the second year of research, thanks to more favorable meteorological conditions, which is in accordance with the results of Studnicki et al. (2019) who pointed out that the variety, meteorological conditions in certain years and agro-ecological conditions of the region are the main factors influencing the yield. Dumbrava et al. (2016) add the importance of tillage and crop fertilization, with a special emphasis on nitrogen fertilization. Our results are in agreement with the results of Estrada-Campuzano et al. (2012) and Wójcik-Gront et al. (2021) who state that generally, starting in May, both spring and winter triticale prefer drier conditions with higher solar radiation to obtain higher yields. Certainly, the importance of applied agricultural techniques during plant breeding should not be neglected. The average grain yield, for all varieties in both years of research, was the lowest in the control and amounted to 3.56 t ha⁻¹ in the first and 3.25 t ha⁻¹ in the second year of research (Table 4).

Table 4. Grain yield (t ha⁻¹) of triticale as affected by varieties, nitrogen application and year

Variety (A)	Year (C)									
	2017/18					2018/19				
	Fertilization variant (B)					Fertilization variant (B)				
	0	N ₁	N ₂	N ₃	Average	0	N ₁	N ₂	N ₃	Average
Kg-20	3.58	5.20	5.71	6.55	5.26	3.10	5.09	5.46	5.99	4.91
Favorit	3.02	4.95	5.35	5.75	4.77	2.91	4.44	5.31	5.63	4.57
Tango	3.75	5.70	6.39	6.91	5.69	3.41	5.14	6.08	6.80	5.36
PKBVožd	3.89	6.14	6.81	7.20	6.01	3.60	5.15	6.51	7.08	5.58
Average	3.56	5.50	6.06	6.60	5.43	3.25	4.95	5.84	6.37	5.10

Anova Table

Source of variation	Degrees of freedom	Sum of squares	Mean sum of squares	F cal	F prob			
Replications	3	2.280	0.760	-	-			
Factor A	3	119.733	39.911	360.531***	0.000			
Factor B	3	64.016	21.339	192.760***	0.000			
Factor C	1	0.158	0.158	1.423 ^{ns}	0.236			
AxB	9	15.538	1.726	15.596***	0.000			
AxC	3	0.194	0.065	0.584 ^{ns}	0.627			
BxC	3	3.955	1.318	11.910***	0.000			
AxBxC	9	0.736	0.082	0.739 ^{ns}	0.673			
Error	93	10.295	0.111	-	-			
Total	127	216.905	-	-	-			
Lsd		A	B	C	AxB	AxC	BxC	AxBxC
	0.05	0.165	0.165	0.117	0.330	0.234	0.234	0.467
	0.01	0.219	0.219	0.155	0.438	0.309	0.309	0.619

0 – control (without fertilization), N₁ - 60 kg ha⁻¹ of nitrogen, N₂ - 100 kg ha⁻¹ of nitrogen, N₃ - 120 kg ha⁻¹ of nitrogen. ***Significant at p < 0.01; ns – non-significant

Fertilization in both experimental years significantly affected the increase in average yield ($p < 0.01$). The same trend was noticed with the application of fertilizers with increasing amounts of nitrogen, so the grain yield achieved on fertilization variants in which nitrogen was used in the amount of 120 kg ha^{-1} was higher than the average yields on all other fertilization variants ($p < 0.01$). The lowest average yield, observed for all variants of fertilization in both years of testing, had the variety Favorit (4.77 t ha^{-1} in the first and 4.57 t ha^{-1} in the second year), and the highest variety PKB Vožd (in the first 6.01 t ha^{-1} , and in the second 5.58 t ha^{-1}). The PKB Vožd variety had a significantly higher grain yield in both years compared to other tested varieties in contrast to the previously obtained results of Lalević et al. (2019) when we talk about this area, where the Tango variety stood out as the most productive variety. Precisely such results indicate the importance of repeating the research in an area with a comparative examination of some other varieties in order to single out the one that best suits the area in terms of yield and quality.

The results of the analysis of variance clearly indicate that the individual effects of variety and fertilization, as well as the effects of the interaction between variety \times fertilization and fertilization \times year on grain yield in the examined winter triticale varieties indicate the existence of a significant ($p < 0.01$). Variance analysis indicated that the individual effect of year as well as the effects of interactions between cultivar \times fertilization \times year on grain in our study were not statistically significant. The importance of fertilization in agricultural production has been emphasized by other authors, and Nogalska et al. (2012) point out that fertilization has the strongest impact on increasing yields, while Ivanova and Tsenov (2014 a,b) add meteorological conditions during the year to fertilization. While Gerdzhikova et al. (2017) recommend nitrogen doses of 80 to 120 kg ha^{-1} in production when triticale growing after legume predecessors and 180 kg ha^{-1} of nitrogen after the cereal precursors and sunflower and on poorer soils, Ivanova and Tsenov (2014 a,b) state that new varieties of triticale respond to an increase in the amount of fertilizer by increasing productivity. Oral (2018) points out that for the realization of high genetic potential for yield, plants need nitrogen, especially in the early stages of development, and Alazmani (2015) calls nitrogen a key element in plant nutrition whose intake directly affects the increase in yield. The influence of phosphorus and potassium on the grain yield should certainly not be neglected, considering that the soil on which the experiment was performed is poor in the mentioned elements, as a result of which they must be added in the form of fertilizers. Phosphorus and potassium from the used fertilizers move slowly through the soil, are not subject to leaching and usually remain in the soil layer where they are introduced and available to plants for a long time. However, one should also take into account the economic and ecological justification of the application of larger quantities of mineral fertilizers in the cultivation of plants, since their large quantities can often be the cause of ecosystem pollution, agricultural inefficiency (Wójcik-Gront, 2018) and nitrogen leaching (Roques et al., 2017).

According to the results of many researchers, triticale is a cereal that is characterized by a high content of protein in the grain, and that is exactly one of its most important positive properties. The protein content in the grain of the tested triticale cultivars in our study ranged from 11.08% in the cultivar Tango on the variant without fertilization in the second year of research to 14.64% in the cultivar Favorit on the variant using 100 kg ha^{-1} nitrogen in the first year of research. The values in *Table 5*. show that the

established values of protein content in the grain differed both between the examined varieties and between the variants of fertilization and the years of research.

Table 5. Protein content (%) of triticale as affected by varieties, nitrogen application and year

Variety (A)	Year (C)									
	2017/18					2018/19				
	Fertilization variant (B)					Fertilization variant (B)				
	0	N ₁	N ₂	N ₃	Average	0	N ₁	N ₂	N ₃	Average
Kg-20	12.15	14.35	14.51	13.68	13.67	12.53	13.96	13.21	12.34	13.01
Favorit	12.24	14.41	14.64	13.74	13.76	12.72	14.12	13.39	13.07	13.32
Tango	11.87	14.06	13.57	13.12	13.15	11.08	12.94	12.45	12.08	12.14
PKBVožd	11.84	13.77	13.84	13.19	13.16	11.16	12.92	12.51	12.36	12.24
Average	12.02	14.15	14.14	13.43	13.43	11.87	13.48	12.89	12.46	12.68

Anova Table								
Source of variation	Degrees of freedom	Sum of squares	Mean sum of squares	F cal	F prob			
Replications	3	2.211	0.737	-	-			
Factor A	3	25.148	8.383	18.768***	0.000			
Factor B	3	39.148	13.049	29.216***	0.000			
Factor C	1	0.195	0.195	0.437 ^{ns}	0.510			
AxB	9	56.570	6.286	14.073***	0.000			
AxC	3	0.586	0.195	0.437 ^{ns}	0.727			
BxC	3	0.336	0.112	0.251 ^{ns}	0.861			
AxBxC	9	0.508	0.056	0.126 ^{ns}	0.999			
Error	93	41.539	0.447	-	-			
Total	127	166.242	-	-	-			
Lsd		A	B	C	AxB	AxC	BxC	AxBxC
	0.332	0.332	0.235	0.664	0.469	0.469	0.939	0.332
	0.439	0.439	0.311	0.879	0.621	0.621	1.243	0.439

0 – control (without fertilization), N₁ - 60 kg ha⁻¹ of nitrogen, N₂ - 100 kg ha⁻¹ of nitrogen, N₃ - 120 kg ha⁻¹ of nitrogen. ***Significant at p < 0.01; ns – non-significant

Analysis of variance showed that the protein content in grain in all tested varieties in both years of research on fertilized variants was higher (p < 0.01) compared to those achieved in the control (variant without fertilization), with the highest average protein content in all varieties, observed using the lowest dose of nitrogen (60 kg ha⁻¹). A further increase in the amount of nitrogen simultaneously accompanied by an increase in yield led to a decrease in grain protein content in varieties Tango and PKB Vožd while varieties Kg-20 and Favorit had the highest protein content in grain in the variant where nitrogen was used in 100 kg ha⁻¹, but only in the first year. These differences were not statistically significant. On average, the Favorit variety had the highest protein content in both years of research. At the same time, the mentioned variety achieved the lowest yield.

On the other hand, the lowest average protein content was found in the grain of the Tango variety. Flajšman et al. (2020) based on their research found that the use of mineral nitrogen reduces the protein content, which is contrary to the results of La Menza et al. (2017). The data in Table 5 indicate a statistically highly significant influence of variety specificity and fertilization on the protein content in the grain and

that the same tendency was observed in the interactions of varieties x fertilization. The individual effect of year and the effects of interactions between cultivar x fertilization, fertilization x year and cultivar x fertilization x year on grain protein content in the studied winter triticale varieties was statistically nonsignificant. Our results partially confirm the results of Janušauskaitė (2014) who stated that the yield and quality of triticale in addition to fertilization also depends on climatic conditions, and Salehi and Arzani (2013) add the influence of genotype. The fact that we have established significant differences in the mentioned trait in different cultivars, and on the same variants of fertilization, indicates how much influence the genotype can have on the protein content in the grain.

The results of two-year research, based on the Pearson coefficient, indicate the existence of a negative correlation between grain yield and protein content in grain ($r = -0.92$; $R^2 = 0.85$, *Figure 1*), which is in line with the results of Salehi and Arzani (2013) who also noticed in their experiments the appearance of a negative correlation between the mentioned quantities ($r = -0.92$ or $r = -0.72$) and that this is a well-known fact when it comes to cereals. In contrast, Kara and Uysal (2009) stated in their paper that the results of their research indicate the existence of a significant ($p < 0.01$) positive association ($r^2 = 0.451$) between grain protein content and triticale grain yield.

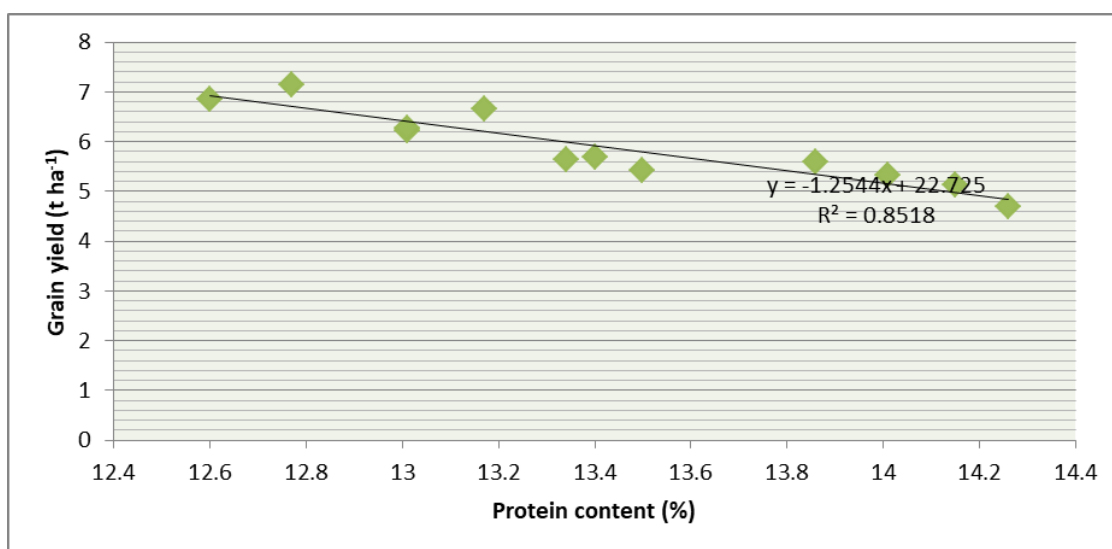


Figure 1. Relationship between grain yield and protein content over two years

Precisely because of that, protein yield per unit area is of special importance, so in our research it was on average for all varieties from 0.38 t ha^{-1} in the control variant in the second year of research to 0.89 t ha^{-1} in the first year and in the variant where nitrogen was used in the amount of 120 kg ha^{-1} . If we look at the varieties individually, then we can point out that the PKB Vožd variety achieved the highest protein yield and that it was the highest in the variant of fertilization where nitrogen was used in the amount of 120 kg ha^{-1} in both years of research (*Figure 2*). In this regard, he singles out the PKB Vožd variety as the most suitable for the conditions in which the research was conducted.

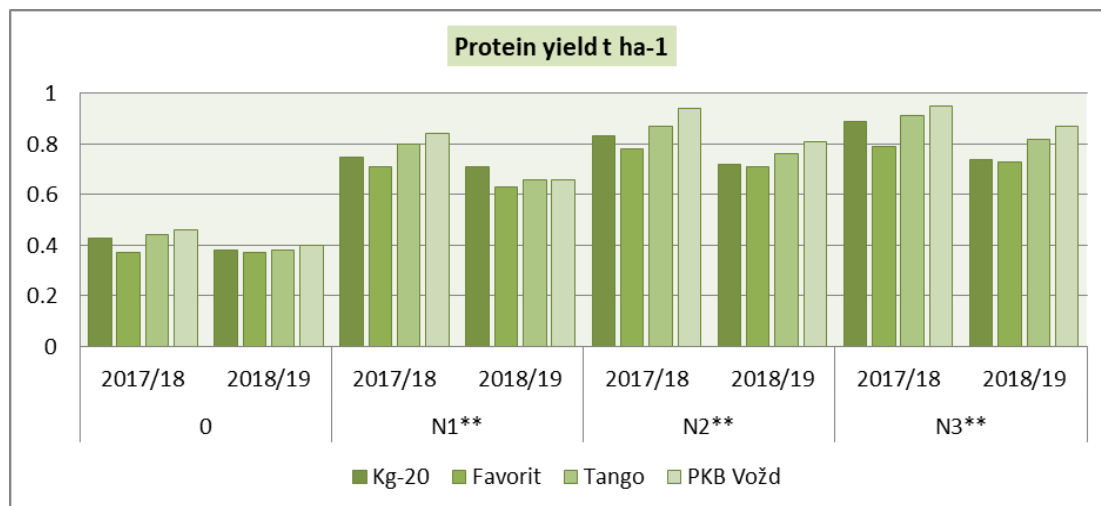


Figure 2. Protein yield ($t\ ha^{-1}$) depending on variety, year and fertilization variant. 0 – control; N_1 - $60\ kg\ ha^{-1}$, $100\ kg\ ha^{-1}\ P_2O_5$, $100\ kg\ ha^{-1}\ K_2O$; N_2 - $100\ kg\ ha^{-1}$, $100\ kg\ ha^{-1}\ P_2O_5$, $100\ kg\ ha^{-1}\ K_2O$; N_3 - $120\ kg\ ha^{-1}$, $100\ kg\ ha^{-1}\ P_2O_5$, $100\ kg\ ha^{-1}\ K_2O$. ** significant at $p < 0.05$

Conclusion

The results of examining the influence of variety and different fertilizer variants on yield, yield components and protein content in triticale grain during the two-year period indicate the existence of differences in the achieved results both between the varieties and between the fertilization variants.

The PKB Vožd variety and the use of nitrogen in the amount of $120\ kg\ ha^{-1}$ in combination with phosphorus and potassium in the amount of $100\ kg\ ha^{-1}$ in the observed conditions gives the best results in terms of yield.

When we talk about quality parameters, the mentioned variety had the highest mass of 1000 grains in both years of research. The results of two years of research show that the average mass of 1000 grains for all varieties was the highest in the variant where nitrogen was used in the amount of $120\ kg\ ha^{-1}$.

The highest hectoliter weight, on average in both years of research, achieved the variety Tango.

On average, the Favorit variety had the highest protein content in both years of research.

Variety PKB Vožd had the highest protein yield per unit area, which, in addition to the highest grain yield and mass of 1000 grains, recommends it for wider production in this production area. Variance analysis indicated that the individual effect of variety, fertilization, as well as the effects of interaction between variety x fertilization and fertilization x year, for all observed traits in the examined winter triticale varieties were statistical significant ($p < 0.01$). The year did not have a statistically significant influence on the values of the observed parameters.

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