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IMPACT OF VARIOUS FERTILIZATION TREATMENTS ON GRAIN YIELD AND PROTEIN CONTENT IN WINTER WHEAT

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ABSTRACT

One of the most cultivated agricultural plants is certainly wheat, which is dominantly used for human nutrition in all parts of the world. The irrational use of large amounts of pesticides and mineral fertilizers negatively affects the quality of agricultural land, the environment, the quality of food and human health. The development of new cultivation technologies and the increasing use of microbiological preparations can have a positive impact on the environment. In accordance with world trends, requirements are set for agricultural production aimed at reducing synthetic agents in order to preserve the environment, produce health-safe and economically profitable food. With the development of new cultivation technologies, where the emphasis is on the reduced use of mineral fertilizers in the production of wheat, the application of microbiological fertilizers is becoming more frequent. As material for research in 2016 and 2018, two varieties of wheat selected in domestic institutions and two varieties in French selection houses were used. The varieties used for the research are: PKB Ratarica, Pobeda, Nogal and Apache. The experiment was conducted on the experimental plots of the Institute for Agro-Economics PKB in Padinska Skela. Before sowing wheat, 400 kg ha^{-1} NPK formulation 15:15:15 was applied to the soil. In the spring sowing of wheat, UREA 46% N was used in different amounts according to the treatments. A microbiological preparation with effective microorganisms was used as supplement. The results of the research showed that wheat had the best yield in the T3 treatment with an average yield of 6.47 t ha^{-1}. The aim of the research is to determine the significant influence of different amounts of mineral and microbiological fertilizers on the production properties as well as on the chemical properties of the grains in different genotypes of wheat.

Keywords: wheat, yield, fetilizer, microbiological, protein

INTRODUCTION

Of all cultivated plants for human consumption, rice, wheat and corn are the most cultivated in the world today. Wheat is the most important and most widespread cereal in the world. It can be said that today's bread wheat is *Triticum aestivum L. subsp. aestivum* created by natural hybridization of domesticated *Triticum turgidum* with Aegilops. According to the botanical classification, wheat belongs to the family *Gramineae*, genus *Triticeae*, which contains about 300 different species (Đurić et al., 2017). Wheat is one of the most important strategic crops, as well as the most widespread grain in the world, which has great importance in human nutrition. The production of wheat with a high grain yield and appropriate quality is only possible by choosing a quality assortment, but with suitable growing conditions and appropriate production technology (Đurić et al. 2017). Wheat contributes significantly to the nourishment of humans and has been grown in various environments around the world (Kiszonas and Morris 2018). Wheat production takes place on all continents, including high-altitude areas in the tropics and subtropics (Dodig, 2010; Đurić et al., 2017). Thanks to winter and spring forms, wheat is characterized by great polymorphism. As a basic bread plant, it is represented by 53% in developed countries, and 85% in underdeveloped countries of the total world production (Peña, 2007). Wheat plays an important role in providing essential minerals, carbohydrates and proteins (Akbarabadi et al., 2015). Today, chemical fertilizers are used as the most economical means to achieve maximum production per unit area, which leads to an increase in production costs and a negative impact on biodiversity. Reduction of wheat yield can also be caused by large amounts of fertilizers, which can be harmful economically, but also ecologically as a frequent cause of agroecosystem pollution (Đekić et al. 2014b; Jelić et al. 2015). The production of wheat with high grain yield and appropriate quality is possible only by choosing a quality varieties, but with appropriate growing conditions and appropriate production technology (Đurić et al., 2015). Sustainable agriculture is a method of production that, viewed over a longer period of time, improves the quality of the environment and the resources on which production is based. Sustainable production satisfies human needs for food and fiber, contributes to economic profitability and improves the quality of life of farmers and society as a whole, with minimal use of chemicals in production. The application of microbiological fertilizers in sustainable production systems is imperative in the production of healthy food (Cvijanović et al., 2013). In the last few years, there has been an increasing number of researches related to the interactions of plants and certain groups of microorganisms with the aim of ecologically and economically profitable production (Cvijanović et al., 2012). The application of microbiological preparations affects the creation of "healthy soil", with the potential tendency of the permanent necessary for organic crop production, (Cvijanović i sar. 2010; 2010a).

Wheat production has not been able to keep pace with the increase in world population (1.87% per year in the period 1961-1990) despite the slowdown in the growth of the world's population, which has increased by 1.35% per year in the previous 25 years. The highest production of wheat per capita was in 1990 (112 kg), while today it is somewhat less, around 90 kg (Knežević et al. 2016). Annual consumption of wheat per inhabitant varies depending on the region, from 20 kg in Central America and Africa south of the Sahara, 70 kg in India, to over 150 kg in the Middle East (Shewery Hey, 2015), while in the Republic of Serbia it is about 130 kg (Knežević et al. 2018).

The most populous countries, such as China, India and Russia, had the largest areas under this grain on average. In China, an average of 23 million ha were sown, yielding an average of 6.55 t ha^{-1}. In India, over 30 million ha were sown with a yield of 3.42 t ha^{-1}. In Russia, the area under wheat was more than 28 million ha with a low average yield of 2.93 t ha^{-1}. In Europe, the area under wheat was 62 million ha with a yield of 4.26 t ha^{-1} (Table 1).

Table 1. Areas, production and yield of wheat in the period from 2017-2022.

Region		2017	2018	2019	2020	2021	2022
China	000 ha	24.480	24.268	23.732	23.383	23.570	23.522
	t ha^{-1}	5.48	5.41	5.62	5.74	5.81	5.85
	000 t	134.246	131.446	133.601	134.256	136.949	137.726
India	000 ha	30.785	29.650	29.318	31.357	31.125	30.458
	t ha^{-1}	3.19	3.36	3.53	3.43	3.52	3.53
	000 t	98.510	99.869	103.596	107.860	109.586	107.742
Russia	000 ha	27.517	26.472.	27.558.	28.864	27.918	29.354
	t ha^{-1}	3.12	2.72	2.70	2.97	2.72	3.55
	000 t	86.002	72.136	74.452	85.896	76.060	104.233
Europe	000 ha	61.879	60.613	62.387	61.529	62.882	62.749
	t ha^{-1}	4.40	3.99	4.26	4.14	4.28	4.50
	000 t	272.381	242.187	266.129	254.796	269.344	282.723

Source: (https://www.fao.org/faostat/en/#data/QCL)

MATERIAL AND METODS

In order to assess the impact of the application of NPK fertilizers and the microbiological preparation EM Aktiv (trade name) on wheat yield, a two-year experiment was set up with four varieties of wheat, four different types of fertilization in four repetitions, on the experimental plots of the PKB Agroeconomics Institute, Padinska skela. As research material during 2016/2017, 2017/2018. Wheat varieties selected in domestic institutes (Institute PKB Agroeconomics and Institute of Field and Vegetable Crops, Novi Sad) and two varieties of French selection houses (Florimond Desprez and Limagrain) were used. The test was carried out on the following varieties: PKB Ratarica, Pobeda, Nogal and Apache. The plots were laid out according to a randomized plot design in four replications. The pre-crop in both research years was corn. All measures in production technology were applied in optimal agrotechnical terms (tillage, sowing, spring topdressing, harvest). The obtained measurement results were statistically processed using the method of analysis of variance as a four-factor split-plot experiment in the DSAASTAT program. The significance of differences between treatments was tested with the LSD test at the significance level of $p<0.01$ and $p<0.05$ (Hadzivuković, 1991). Plant samples were taken from the middle of the plots. Grain samples necessary for the calculation of productive and qualitative characteristics of grain were taken after harvest from the entire plot. To ensure proper nutrition, 400 kg ha^{-1} of NPK (15:15:15) was incorporated with soil tillage prior to wheat sowing (Table 2). In treatment T1, there was no foliar treatment because that treatment was the control. In treatment T2, the foliar treatment was performed when the wheat was in the flowering phase, in treatment T3, the foliar treatment was performed in the flowering phase, in treatment T4, the foliar treatment was performed in the phase of flattening, flowering and grain filling. All foliar treatments were at a dose of 6l·ha^{-1}.

Table 2. Variants of fertilization on the experimental plot

Treatments	Before sowing NPK (kg ha^{-1})	In nutrition UREA (kg ha^{-1})	EM Aktiv (6 l ha^{-1})	Total nutrients N : P_2O_5 : K_2O
T 1	400	150	-	129 : 60 : 60
T 2	400	150	1 time	129 : 60 : 60
T 3	400	100	2 times	106 : 60 : 60
T 4	400	50	3 times	83 : 60 : 60

RESULTS AND DISCUSSION

Grain yield is the result of many physiological changes during the development of plants, which are directly influenced by many factors. The yield of wheat grains is influenced by various factors, primarily genotype characteristics, soil fertility and applied agrotechnical measures. Wheat yields vary depending on applied agrotechnical measures: sowing dates, nutrition, protection and agro-meteorological conditions (Pepo, 2007). In addition to the choice of varieties and soil properties, agroclimatic conditions and applied agrotechnics have a significant influence on the yield per unit of area and total production. In the course of its development, wheat goes through a series of stages in the stages of organogenesis and physiological stages, according to a strictly established chronological order that leads to the growth of plants, the development of all necessary organs and the increase of biomass and plant volume (Milošev, 2000). Sugar et al. (2016) concluded that the maximum grain yield was achieved with nitrogen treatments of 80 and 160 kg ha^{-1}, and that a higher amount of nitrogen did not lead to a further increase in yield in any year.

In 2017, the average grain yield was 6.48 t ha^{-1}, and 6.54 t ha^{-1} in 2018. The impact of variety as a significant factor on yield was at a statistical level of $p<0.05\%$, while the significance of other factors was not determined.

Ratarica variety achieved the highest yield (6.98 t ha^{-1}) in 2017, while the yield was 5.91% lower for the Pobeda variety, 6.24% lower for Nogal variety and Apache variety by 20.55%.

The highest yield in 2018 was achieved with the Ratarica variety (6.84 t ha^{-1}), with the Pobeda variety it was lower by 9.44% t ha^{-1}, the Apache variety gave a lower yield by 10.14%, while the Nogal variety recorded the lowest yield by 22.36% lower than the Ratarica variety.

Table 3 shows the average yields per treatment for all varieties that were carried out in 2017. The highest yield per treatment was in treatment T3 (6.69 t ha^{-1}), while in T4 it was lower by 1.82% (6.57 t ha^{-1}), in T2 the yield was lower by 3.56% (6.46 t ha^{-1}), and in T1 the yield was lower by 7.38% (6.23 t ha^{-1}).

In 2018, the highest yield per treatment for all varieties was recorded in treatment T4 (6.45 t ha^{-1}), which is 3.03% higher than T2 (6.26 t ha^{-1}), also lower yields were obtained in treatments T1 (6.09 t ha^{-1}) which was lower by 5.92%, and in treatment T3 (6.08 t ha^{-1}) which was lower by 6.08% compared to T4.

On average for both years, all cultivars and all treatments, the wheat yield on average was the highest in the T4 treatment (6.51 t ha^{-1}), which was higher compared to all three other treatments T3 (6.38 t ha^{-1}) by 2.03%, T2 (6.36 t ha^{-1}) by 2.35%, and T1 (6.16 t ha^{-1}) by 5.68%.

Table 3. Wheat yields in the two growing seasons (2017-2018)

Years (A)	Varieties (B)	Fertilization (C) T1	T2	T3	T4	X̄ A x C	X̄ A
2017	Ratarica	6.63	7.07	7.38	6.85	**6.98**	**6.48**
	Pobeda	6.46	6.17	6.62	7.13	**6.59**	
	Nogal	6.29	6.52	6.64	6.85	**6.57**	
	Apache	5.54	6.08	6.10	5.44	**5.79**	
X̄ A x B x C		**6.23**	**6.46**	**6.69**	**6.57**		
2018	Ratarica	6.63	7.13	6.78	6.82	**6.84**	**6.54**
	Pobeda	6.28	5.65	6.18	6.88	**6.25**	
	Nogal	5.59	6.08	5.25	5.44	**5.59**	
	Apache	5.88	6.19	6.10	6.67	**6.21**	
X̄ A x B x C		**6.09**	**6.26**	**6.08**	**6.45**		
	X̄ C	**6.16**	**6.36**	**6.38**	**6.51**		
		Average 2017-2018					**6.51**

	A^{ns}	B*	C^{ns}	A x B^{ns}	A x C^{ns}	B x C^{ns}
F – test	**9.68**	**3.91**	**0.48**	**0.02**	**2.62**	**1.60**
LSD 5%	**0.27**	**0.34**	**0.27**	**0.48**	**0.38**	**0.54**
LSD 1%	**0.24**	**0.46**	**0.36**	**0.65**	**0.51**	**0.72**

The importance of wheat is mainly attributed to its ability to grind the grain into flour and semolina. By grinding wheat. the anatomical parts of the grain are separated. Wheat flour mainly consists of: starch (70–75%). water (12–14%). protein (8–16%) and other components such as dietary fiber (2–3%). lipids (2%) and ash (1%) (Egesel et al. 2013). The quality of wheat flour depends on the content and characteristics of these components. which differ depending on the variety of wheat. Bekić et al. (2016) determined that the biomass of basil plants and the oil content of the seeds can be increased by applying effective microorganisms. and Filipović et al. (2016) that the use of effective microorganisms in the production of basil increases the yield and quality of dry matter.

Cereal proteins play an important role in human nutrition. due to their nutritional composition and functional properties. Wheat proteins are a group of compounds that are found in the grain immediately after starch. Baking properties and quality of wheat (*Triticum aestivum* L.) and wheat flour depend on the amount and quality of protein from the wheat grain.

The protein content of bread wheat is one of the most important chemical indicators of flour quality. Wheat seed proteins. however. are also the most common cause of allergies. so the composition of wheat proteins as well as their functional characteristics are attracting the attention of researchers and manufacturers (Rasheed et al.. 2014).

The influence of variety and year was statistically significant on protein content. while fertilization was highly significant at the level of ($p<0.01\%$). The interaction between (year x fertilization) and (year x variety) was statistically significant at the level of ($p<0.05\%$). and the interaction between (variety x fertilization) was highly statistically significant at the level of ($p<0.01\%$) (Table 4).

The highest protein content in 2017 was expressed by the variety Nogal (13.66%). and the lowest by the variety Ratarica (13.14%). while in 2018 the variety Ratarica had the highest protein content (13.86%). and Apache variety with the lowest protein content (13.44%). The protein content of the Nogal variety in 2017 was determined to be 0.14% higher than the Pobeda variety (13.64%). and 3.48% higher than the Apache variety (13.20%) and the Ratarica variety (13.14%) by 3.95% (Table 4).

As for fertilization in 2017. the biggest impact was the treatment T3 (13.97%). Compared to treatment T1. the protein content was higher by 6.39%. compared to T2 by 4.17% and T4 by 6.47%. Between treatments T4 (13.12%) and T1 (13.13%) there was no statistically significant difference in the crude protein content. In 2018. treatment T3 (13.90%) had the greatest impact. as in 2017. The protein content in treatment T3 was higher by 3.57% compared to T1 (13.42%) by 0.87%. while compared to T2 (13.78%) by 0.87%. and compared to the T3 treatment (13.60%) by 2.20%.

Cvijanović (2002) in a three-year study of foliar treatment of wheat plants with a mix of free-living bacteria. determined that there was an increase in the content of total proteins in the grain on average from 4.57% to 7.38%.

Table 4. Total protein content in different wheat varieties

Years (A)	Varieties (B)	Fertilization (C) T1	T2	T3	T4	X̄ A x C	X̄ A
2017	Ratarica	13.02	13.39	13.28	12.86	13.14	13.41
	Pobeda	13.19	13.26	14.06	14.03	13.64	
	Nogal	13.64	13.69	14.44	12.88	13.66	
	Apache	12.68	13.29	14.10	12.72	13.20	
X̄ A x B x C		**13.13**	**13.41**	**13.97**	**13.12**		
2018	Ratarica	13.79	14.19	13.47	13.98	13.86	13.67
	Pobeda	13.40	13.52	13.98	14.10	13.75	
	Nogal	13.72	14.09	14.00	12.80	13.65	
	Apache	12.78	13.32	14.15	13.52	13.44	
X̄ A x B x C		**13.42**	**13.78**	**13.90**	**13.60**		
	X̄ C	**13.27**	**13.59**	**13.93**	**13.36**		
					Average 2017-2018		**13.54**

	A*	B*	C**	A x B*	A x C*	B x C**
F – test	**25.60**	**4.72**	**20.82**	**4.14**	**3.40**	**11.05**
LSD 5%	**0.23**	**0.24**	**0.18**	**0.34**	**0.26**	**0.37**
LSD 1%	**0.16**	**0.34**	**0.24**	**0.48**	**0.35**	**0.49**

CONCLUSION

On the basis of two-year research on the impact of top dressing and application of microbiological fertilizer on wheat grain yield (*Triticum aestivum sp.*) and protein content in wheat grain. we can say that the average grain yield was 6.51 t ha^{-1} with significant differences due to the impact treatment. and the dominance of the genotype. The Ratarica variety had a higher grain yield in both examined years. in comparison to all four cultivated varieties. Statistically significant differences in yield were determined by fertilization levels and varieties. The highest yield was found in treatments with a smaller amount of fertilizer and more foliar treatments. In 2017 it was treatment T3 (6.69 t ha^{-1}). while in 2018 the highest yield was achieved with treatment T4 (6.45 t ha^{-1}). The total protein content of the wheat grain was the highest in the T3 treatment. In 2017 the highest protein content was in the Nogal variety (13.66%). while in 2018 it was in the Ratarica variety (13.86%). Finally. it can be concluded that the most positive impact on yield and protein content is reflected in the T3 treatment (400 kg ha^{-1} before sowing. 100 UREA kg ha^{-1} and two foliar treatment with the microbiological fertilizer EM Aktiv). Application of microbiological preparations in wheat production can enable stable production of wheat with high grain yields. which is very important from the aspect of human nutrition.

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