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YIELD OF SOME WHEAT VARIETIES DEPENDING ON FERTILIZATION WITH A COMBINATION OF MINERAL FERTILIZERS AND ZEOLITES

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Abstract: *Zeolite improves the structure of the soil and reduces acidity, which is of great significance for agricultural production that happens on soils with low pH values. It has shown exceptional results in improving soil characteristics, thus increasing the yield and quality of cultivated plants. The aim of our study was to determine the yield and some qualitative properties of numerous wheat varieties, depending on the mineral fertilizers and zeolites application. The experiments were performed in 2018/19 and 2019/20, in the area of Southern Serbia (Bojnik). The research involved 4 wheat varieties and 4 variants of fertilization, including mineral fertilizers and zeolite. The combination of mineral fertilizers and zeolites did not show noteworthy differences in the mass of 1000 grains when it comes to both varieties and fertilization variants. Hectolitre weight of grain was significantly higher on the variant with a combination of mineral fertilizers and zeolites than on the control variant. All fertilization variants had a significantly higher grain yield compared to the control variant. The variant on which the combination of mineral fertilizers and a higher dose of zeolite were applied achieved a significantly higher grain yield compared to the variant with mineral fertilizers. Varieties Pobeda and Nikol, with the application of mineral fertilizers and zeolite combination, achieved the highest yields. On acid soils, it is necessary to apply fertilizers and soil improvers so that the yields of cultivated plants will be satisfactory.*

Keywords: *wheat, NPK fertilizers, zeolite, yield.*

INTRODUCTION

Zeolite is well known for having wide applications in agriculture, industry, and environmental protection. Due to its properties (ion-exchange, adsorption, and catalytic), it has shown outstanding results in improving soil characteristics, thus increasing the yield and quality of cultivated plants (Kulasekaran et al, 2011). Zeolite has the ability to prevent the leakage of nutrients from the soil, the capacity to adsorb soil nutrients (fertilizer ingredients), and to release them gradually during the growing season. Also, zeolite improves the structure of the soil and reduces acidity, which is of great significance for agricultural production that happens on soils with low pH values. Zeolite in the soil is a tank of water and nutrients. It improves plant nutrition, develops the root system, intensifies growth and fertility, reduces diseases, and strengthens plant immunity. Zeolite contains the essential elements for development such as magnesium, potassium, and calcium.

Ghanbari and Ariafar (2013) indicate that natural zeolite can be used to improve soil, thus making it a vital alternative for reducing the effects of drought in arid and semi-arid regions.

According to the research of Oljača et al. (2009), the application of zeolite in combination with mineral fertilizers proved to be very efficient in barley production as it has increased yields. The research of Sushenitsa (2007) claims that zeolite combined with mineral fertilizers improves the agrochemical and agrophysical properties of the soil, shifting the pH value of the soil by 0.34-0.68 units.

Liliya et al. (2020) in the research emphasize the value of zeolite in improving the agrochemical and agrophysical properties of soil, which increases the yield of cultivated plants. Kulasekaran et al. (2011) also claim that zeolite in the soil is not only a trap for heavy metals, but is also a carrier of slow-release fertilizers, thus increasing the yields of cultivated plants. Zeolites are useful and sought after in farming thanks to their high porosity, high cation exchange capacity, and neutralization of chemicals used in plant production (Sangeetha and Baskar, 2016). Aghaalikhani et al. (2011) point out that zeolites increase the yield of many crops, particularly when combined with mineral and organic fertilizers, which may be associated with improved soil structure and nutrients.

The soil is one of the most significant environmental factors whose quality has to be preserved (Ghaemi et al., 2014). Therefore, Cairo et al. (2017) emphasize the importance of repairing soil properties by applying zeolite in combination with mineral and organic fertilizers, which also increases the yields of cultivated plants. The main aim of our research was to determine the yield, weight of 1000 grains, and hectolitre weight of several wheat varieties based on the application of mineral fertilizers and zeolites.

MATERIAL AND METHODS OF WORK

The experiments were performed in 2018/19 and 2019/20, in the area of Southern Serbia (Bojnik). Four wheat varieties were involved: Nikol, Avenue and Sosthene (LG France), and Pobeda, and 4 variants of fertilization (1.Control, 2. NPK, 3. NPK + 300 kg ha^{-1} zeolite, and 4. NPK + 500 kg ha^{-1} zeolite). Of the zeolites, Zeo Min was used, whose chemical composition is the following: calcium (CaO) 41%; magnesium (MgO) 17%: iron (Fe2O3) 1.63%; zinc (Zn) 0.43%; copper (Cu) 0.25%; manganese (Mn) 0.35% and silicon (SiO) 12.8%.

The experiment was set up according to the block system in three repetitions. Corn was the preculture. The cultivation of the soil included plating in two passages where 200 kg ha^{-1} NPK (16:16:16) fertilizer was applied. Together with NPK fertilizers, zeolite was dispersed (included) in appropriate quantities. The 2018/19 sowing was done on December 8th, and 2019/20 on October 30th. Before setting the experiment, soil samples were taken from the parcels for chemical analysis. Fertilization with KAN fertilizer in the amount of 200 kg ha^{-1} was done in March, and treatment against weeds and diseases was performed in April with Metmark WG in the dose of 0.01% and Excort in the amount of 0.5 l/ha. The harvest was done in the phase of full maturity. The yield was calculated on each plot and reduced to 14% grain moisture. The results were statistically processed, through the analysis of variance using WASP 1.0 software and they are tabulated.

Climatic and soil characteristics

Tables 1 and 2 show the full amount of precipitation and average air temperatures during the vegetation period and the chemical analysis of the soil.

Table 1. Precipitation (mm) and mean air-temperature (^{0}C) in Leskovac.

Mounth	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May.	Jun.	Oct/Jun
The 2018/2019 growing season										
Mm	5.0	57	19	58	55.5	8.0	38	99	68	407.5
^{0}C	12.9	7.3	4.4	-0.3	3.7	9.3	13.8	15.5	22.2	9.9
The 2019/2020 growing season										
Mm	8	43	53	15	65	100	47	69	121	521
^{0}C	14.5	11.9	4.6	0.7	6	8.20	11.6	16.6	19.6	10.4

During 2018/2019, the year which was unfavorable for wheat production, the total amount of precipitation during the vegetation period was small and amounted to 407.5 mm, while the average temperature was 9.9 ^{0}C. The dry period which took place during autumn throughout this vegetation year has to be emphasized, as a total of 83 mm of precipitation that fell in October, November, and December was insufficient to prepare the land for sowing. Thus, that year's sowing was not done until the beginning of December. In addition, average negative temperatures during the winter were recorded, which all resulted in a decrease in wheat grain yield that year.
During 2019/2020, the total amount of precipitation during the vegetation was 521 mm, which is 113.5 mm more than in the preceding season. Throughout this vegetation year, it is essential to point out the larger total amount of precipitation, which was quite well distributed, especially in the spring part of the vegetation. Average temperatures during the vegetation were 10.4 ^{0}C. No negative average monthly temperatures were recorded in the winter months, which had a positive effect on wheat production.

Table 2. Chemical properties of the soil.

Type of soil	pH		Humus (%)	Nitrogen (%)	Available (mg/100g of soil)	
	H_2O	KCl			P_2O_5	K_2O
Smonica	5.88	4.9	2.64	0.18	6.4	19.0

Soil acidity was determined using the Kappen method, humus was determined by the Kotzman method, total nitrogen by the Kjeldahl method, and available phosphorus and potassium by the Engner-Riehm Al method. According to the pH values in KCl (4.90), Vertisol belongs to the group of acid soils. When the content of humus in the arable layer is in question, they belong to the group of weakly humus soils (according to Gračanin and Škorić). According to the content of total nitrogen, Vertisol belongs to the group with a moderate amount of it. Phosphorus content (6.4) classifies this soil in the group of poorly supplied, and in terms of potassium content (19.00) in the group of medium provided. From these data, it can be concluded that Vertisol has limited production characteristics, especially in terms of acidity and low phosphorus content, which should be corrected by appropriate agro-ameliorative measures so that successful production is reached.

RESEARCH RESULTS AND DISCUSSIONS

Wheat grain yield and some of its qualitative characteristics such as weight of 1000 grains and hectolitre weight are all conditioned by a number of

environmental factors, applied agrotechnical, and variety selection. Fertilization is one of the very important agro-technical measures, which determines the wheat grain yield to a good extent. In table 3, the yield and some qualitative properties of wheat grains depending on the application of mineral fertilizers and zeolites are presented.

Table 3. Yield and some qualitative properties of wheat grains depending on fertilization and year

No.	A.Varieties	1000 grains weight (g)				Hectoliter weight (kg hl^{-1})				Grain yield (kg ha^{-1})			
		A. Fertilisers											
		The 2018/2019 growing season											
		1	2	3	4	1	2	3	4	1	2	3	4
1.	Pobeda	39.0	40.0	41.0	41.0	62.9	67.1	69.8	70.6	2.55	3.89	4.40	4.61
2.	Avenue	38.0	39.5	40.0	40.5	60.0	66.5	69.5	69.5	2.87	3.64	4.00	3.88
3.	Sosthene	38.5	39.0	40.0	40.0	61.5	67.5	68.5	68.0	2.33	3.72	3.85	3.90
4.	Nikol	38.5	39.0	40.0	40.0	59.6	66.8	69.9	68.5	2.48	3.56	4.00	4.05
Average		38.5	39.4	40.2	40.4	61.0	66.9	69.4	69.1	2.56	3.70	4.06	4.11
The 2019/2020 growing season													
1.	Pobeda	39.5	41.2	41.0	43.0	62.9	68.1	69.8	71.8	2.80	4.80	5.10	5.31
2.	Avenue	39.2	41.0.	40.8	42.2	60.0	68.5	69.5	70.5	2.87	4.44	4.65	4.80
3.	Sosthene	38.8	40.5	41.6	41.0	63.5	67.7	68.8	69.0	2.77	4.42	4.50	4.55
4.	Nikol	39.7	41.0	42.5	43.0	63.9	69.8	70.1	70.5	3.08	4.76	4.90	5.08
Average		39.3	40.9	41.5	42.3	62.6	68.5	69.5	70.4	2.88	4.60	4.79	4.93

1. control; 2.NPK; 3.NPK+300 kg ha^{-1} zeolite; 4.NPK+500 kg ha^{-1} zeolite

The data in the table shows that the yield and the weight of 1000 grains and hectolitre weight in the 2019/2020 season were higher in all varieties than in the preceding season. These differences at 1000 grain weight and hectoliter weight are less obvious than at grain yield. Thus, the average grain yield for all varieties, in the 2019/2020 season, depending on the combination of mineral

fertilizers and zeolites, was higher by 730 to 900 kg ha^{-1} than in the 2018/2019 season. Pobeda achieved the highest yield in both seasons (5.31 and 4.61 t ha^{-1}), while Avenue achieved the lowest (3.88 t ha^{-1} and 4.55 t ha^{-1}). Besides Pobeda, Nikol proved to be a yielding variety (4.05 and 5.08 t ha^{-1}) in both seasons, thus making it an interesting variety for these areas. The main reason for the better results of the mentioned parameters in the 2019/2020 season is the more favorable agroclimatic conditions during this year. It should be pointed out that due to the dry period in the fall of 2018/2019, sowing was delayed and was not done until December 8th, which was reflected in the reduction of the yield of wheat varieties. Thus, the average decrease in yield was 16.6%. Nikol had the highest percentage of yield reduction of 20.2%. Many researchers emphasize the importance of the optimal sowing date, due to the fact that late sowing can significantly reduce yields, which was actually the case in the 2018/2019 season. So Aćin et al. (2016) point out that sowing in December reduces the wheat yield by 20% compared to sowing in the optimal time (first decade of October). Our results are consistent with the results of many authors (Iqbal et al., 2001; Shah et al., 2006; Qasim et al., 2008; Gupta et al., 2017; Yadav et al., 2018), who points out a significant reduction in wheat yield of 27 to 58% when sown outside the optimal period.

The following table shows the average two-year results that were processed by variance analysis.

Table 4. Yield and some qualitative properties of wheat grains depending on fertilization (2018/2020)

No.	A. Varieties	1000 grains weight (g)					Hectoliter weight (kg hl^{-1})					Grain yield (kg ha^{-1})				
		A. Fertilisers														
		1	2	3	4	Aver age	1	2	3	4	Aver age	1	2	3	4	Ave.
1.	Pobeda	39.2	40.6	41.0	42.0	40.7	62.9	67.6	69.8	71.2	67.8	2.67	4.34	4.75	4.96	4.18
2.	Avenue	38.6	39.5	40.4	41.3	39.9	60.0	67.5	69.5	70.0	66.7	2.87	4.04	4.32	4.34	3.89
3.	Sosthene	38.6	39.7	40.8	40.5	39.9	62.5	67.6	68.6	68.5	66.8	2.55	4.07	4.17	4.22	3.75
4.	Nikol	39.1	40.0	41.2	41.5	40.4	61.7	68.3	70.0	69.5	67.4	2.78	4.16	4.45	4.56	3.98
Average		38.9	40.1	40.8	41.3	40.2	61.8	67.7	69.4	69.7	67.2	2.72	4.15	4.42	4.52	3.95
LSD			A	B	AxB			A	B	AxB			A	B	AxB	
		5%	4.7	4.7	9.4			7.4	7.4	14.8			0.33	0.33	0.67	
		1%	6.33	6.33	12.6			9.9	9.9	19.9			0.45	0.45	0.90	

1. control; 2.NPK; 3.NPK+300 kg ha^{-1} zeolite; 4.NPK+500 kg ha^{-1} zeolite

1000 grains weight. Grain yield depends on this property to a large extent. The

average weight of 1000 grains for all fertilization variants was 40.2 g. The lowest was in Avenue and Sosthene varieties (39.9 g) and the highest in the variety Pobeda (40.7 g). Differences between varieties were not statistically significant. The average 1000 grains weight for all varieties ranged from 38.9 g on the control to 41.3 g on the variety where a combination of NPK fertilizer and a higher dose of zeolite were applied. No statistically significant differences were found between the fertilization variants and the control variant. Pobeda had the highest 1000 grains weight (42.0 g) which was grown in a combination of mineral fertilizers and a higher dose of zeolite, while Avenue and Sosthene varieties on the control variant had the lowest weight (38.6 g).

Hectolitre weight. This is a very important characteristic when buying wheat and it is an indicator of grain size and fullness. The average hectoliter weight for all fertilization variants was 67.2 kg. Avenue had the smallest one (66.7 kg) while Pobeda had the largest (67.8 kg), although the differences between the varieties were not statistically significant. The average hectolitre weight for all varieties ranged from 61.8 kg in the control variant to 69.7 kg in the variant where a combination of mineral fertilizers and a higher dose of zeolite were applied. The hectoliter grain weight on the variant with a combination of mineral fertilizers and a higher dose of zeolite was statistically significantly higher than on the control variant, while no statistically significant differences between the fertilization variants were observed. Pobeda which was grown in a combination of mineral fertilizers and a higher dose of zeolite had the highest hectoliter weight (71.2 kg) while the variety Avenue on the control variant had the lowest (60.0 kg).

Grain yield. That is the goal that producers strive for. It depends on a number of agroecological factors, applied agrotechnics, and variety selection. The average yield for all fertilization variants was 3.95 t ha^{-1}. Sosthene had the smallest one (3.75 t ha^{-1}) while Pobeda had the largest (4.18 t ha-1) and this difference was statistically significant. The average yield for all sorts ranged from 2.72 t ha^{-1} on the control to 4.52 t ha^{-1} on the variant where a combination of NPK fertilizer and a higher dose of zeolite were applied. All fertilization variants had a significantly higher yield compared to the control. The variant on which the combination of mineral fertilizers and a higher dose of zeolite were applied achieved a statistically significantly higher grain yield compared to the variant with mineral fertilizers. Pobeda which was grown in a combination of mineral fertilizers and a higher dose of zeolite achieved the highest average grain yield (4.96 t ha^{-1}) while Sosthene on the control variant achieved the lowest (2.55 t ha^{-1}). The Nikol variety proved to be profitable and stable, as well as Pobeda, so we recommend them for growing on acid soils in the South of Serbia. It can be concluded that there are no good yields without

the use of fertilizers. The application of zeolite, especially the variant with increased content (NPK + 500 kg ha^{-1} zeolite) in combination with mineral fertilizers increased the yields compared to only mineral fertilizers, by an average of 370 kg ha^{-1}. Our results are consistent with the results reported by Liliya et al. (2020) where they emphasize that the application of zeolite with mineral fertilizers increases the yield of cultivated plants by 0.3 to 0.5 t ha^{-1}. Similar results of the effect of zeolite in combination with mineral fertilizers on barley yield of 4.6 t ha^{-1} are pointed out by Oljača et al. (2009). Being the production of wheat on heavy and acid soils is unstable, it is necessary to repair and enrich the soil using zeolite or some other improvers. Zeolites are not an expensive material, but can significantly improve the production properties of acid soils and stabilize the yields of cultivated plants on them, especially in years that are unfavorable for production.

On the other hand, in the coming period, Serbia will not be able to export any agricultural product without a certificate of land quality as a critical place in primary agricultural production. These are the conditions of the concept of "HACCP" (Hazard Analysis Critical Control Point) and "GAP" (Good Agricultural Practices) for the production of safe food (Grubišić, 2017). This is the case where zeolites can find their place as heavy metal cleaners from the soil.

CONCLUSION

Based on the research results, we can conclude the following:

- The combination of mineral fertilizers and zeolites did not show noteworthy differences in the mass of 1000 grains when it comes to both varieties and fertilization variants.
- Hectolitre weight of grain was significantly higher on the variant with a combination of mineral fertilizers and zeolites than on the control variant.
- All fertilization variants had a very significantly higher yield when compared to the control.
- The variant on which the combination of mineral fertilizers and zeolites was applied achieved a significantly higher grain yield than the variant with mineral fertilizers.
- The application of zeolite combined with mineral fertilizers increased the wheat yield compared to mineral fertilizers alone, by an average of 370 kg ha^{-1}.
- Varieties Pobeda and Nikol, with the application of mineral fertilizers and zeolite combination, achieved the highest yields.
- On acid soils, it is necessary to apply fertilizers and soil improvers so that the yields of cultivated plants will be satisfactory.
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