The yield formation of winter wheat under the influence of fertilization systems using two field experiments as an example

A Kh Kulikova[1], *E S* Volkova[1*], *E A* Yashin[1], *A V* Karpov[1], and *T Yu* Volkov[1]

[1]P. A. Stolypin Ulyanovsk State Agrarian University, 1, Novy Venets boulevard, 432017, Ulyanovsk, Russia

Abstract. The paper presents experimental data on the change in the winter wheat yield when using straw, green manure, and a biological preparation as a fertilizer in one field experiment and using different doses of zeolite and its modifications in another. It has been ascertained that organic and organo-mineral fertilization systems have a positive effect on the winter wheat grain yield. The application of straw, green manure, and a biological preparation in the technology of winter wheat cultivation made it possible to increase the yield of winter wheat by 7-13%. It is quite difficult to ensure the volume of the produce obtained at the level of mineral fertilizers using only the system of organic fertilizers. The latter is possible when applying a new generation of fertilizers based on high-silicon rocks in the technology of cultivating agricultural crops, which are natural environmentally friendly materials. The grain yield increased in the latter case by 7-56%.

1 Introduction

One of the most important problems of farming is to develop such a cultivation technology of agricultural crops, which will eliminate the contradictions between the functioning of agroecosystems and human activities to ensure food, environmental and economic security of the country, as well as to preserve and increase soil fertility. Organic fertilizers, primarily straw of grain crops, play an important role in solving this problem. However, due to its chemical composition, straw is not easily decomposed; therefore, the use of biological preparations that accelerate the activity of soil microorganisms is required [1-3].

The use of zeolite and organo-mineral fertilizers based on it is determined by a high efficiency of silicon (silicate) fertilizers, which is secured by the effect of silicon on the "soil-plant" system, on the one hand, and on the other hand, by the lack of its available compounds in the soil due to the constant uptake by agricultural crops . It has been found that silicon, as well as the main elements of plant nutrition (nitrogen, phosphorus, potassium), is an integral factor in the productivity of agricultural crops [4-9].

* Corresponding author: volkova-ivinaelena@yandex.ru

The foregoing determined the purpose of our research - to study the formation of the winter wheat grain yield under the influence of different fertilization systems using two field experiments as an example.

2 Materials and methods

Studies on the effect of different fertilization systems on the winter wheat grain yield were carried out in two field experiments on the experimental field of the Federal State Budgetary Educational Institution of Higher Education of Ulyanovsk State Agrarian University in 2021. In the first experiment, the effectiveness of the use of straw, green manure and biological preparations as a winter wheat fertilizer was studied. Biological preparation - Biocomposite-correct is produced by Schelkovo Agrokhim JSC. In the second field experiment, the focus was on the change in the winter wheat yield under the influence of high-silica rocks, in particular zeolite, as well as its modifications with amino acids and carbamide in different doses. Enrichment of the zeolite with amino acids was carried out and presented for testing by BioResource LLC (Ulyanovsk).

The design of the first field experiment (Experiment No. 1) included 10 variants:

- Control
- Straw + green manure.
- Straw + N 10 kg/т + green manure.
- Straw + green manure + Biocomposite-correct.
- Green manure + Biocomposite-correct.
- N40P40K40 (NPK).
- Straw + N10 kg /t + NPK.
- Straw + Biocomposite-correct + NPK.
- Biocomposite-correct + NPK.
- Straw + Biocomposite-correct + N10 kg/т + NPK.

The variants of the second field experiment (Experiment №2) are the following:

- Control.
- Zeolite, 250 kg/ha.
- Zeolite, 500 kg/ha.
- Zeolite, enriched with carbamide, 250 kg/ha.
- Zeolite, enriched with carbamide, 500 kg/ha.
- Zeolite, enriched with amino acids, 250 kg/ha.
- Zeolite, enriched with amino acids, 500 kg/ha.
- N40P40K40 (NPK).
- Zeolite, 250 kg/ha + NPK.
- Zeolite, 500 kg/ha + NPK.
- Zeolite, enriched with carbamide, 250 kg/ha + NPK.
- Zeolite, enriched with carbamide, 500 kg/ha + NPK.
- Zeolite, enriched with amino acids, 250 kg/ha + NPK.
- Zeolite, enriched with amino acids, 500 kg/ha + NPK.

The soil of the experimental field is a typical medium thick medium loamy chernozem. The content of exchangeable potassium and mobile phosphorus in the soil is high. The reaction of the soil medium is neutral. The location of the plots is randomized, the repetition is four times. The winter wheat variety is Saratovskaya 17. This variety has the following properties: resistance to lodging, frost resistance, drought resistance.

3 Results

The grain yields of winter wheat in all the variants of the experiment are given in Tables 1 and 2.

Table 1. The grain yields of winter wheat depending on the fertilization system (Experiment No. 1).

No.	Variants	Yield, t/ha	Deviation from control	
			t/ha	%
1	Control	3.11	-	-
2	Straw + green manure	3.36	0.25	7
3	Straw + N 10 kg/t + green manure	3.54	0.43	12
4	Straw + green manure + Biocomposite-correct	3.56	0.45	13
5	Green manure + Biocomposite-correct	3.32	0.21	6
6	$N_{40}P_{40}K_{40}$ (NPK)	4.25	1.14	27
7	Straw + N10 kg / t + NPK	4.49	1.38	31
8	Straw + Biocomposite-correct + NPK	4.48	1.37	31
9	Biocomposite-correct + NPK	4.31	1.2	28
10	Straw + Biocomposite-correct+N10kg/t + NPK	4.73	1.62	34
LSD_{05}		0.12		

Table 2. The grain yields of winter wheat depending on the fertilization system (Experiment No. 2).

No.	Variants	Yield, t/ha	Deviation from control	
			t/ha	%
1	Control	3.37	-	-
2	Zeolite, 250 kg/ha	3.61	0.24	7
3	Zeolite, 500 kg/ha	3.77	0.40	12
4	Zeolite, enriched with carbamide, 250 kg/ha	4.08	0.71	21
5	Zeolite, enriched with carbamide, 500 kg/ha	4.17	0.80	24
6	Zeolite, enriched with amino acids, 250 kg/ha	4.04	0.67	20
7	Zeolite, enriched with amino acids, 500 kg/ha	4.12	0.75	22
8	$N_{40}P_{40}K_{40}$ (NPK)	4.13	0.76	23
9	Zeolite, 250 kg/ha + NPK	4.40	1.03	31
10	Zeolite, 500 kg/ha + NPK	4.60	1.23	37
11	Zeolite, enriched with carbamide, 250 kg/ha + NPK	4.78	1.41	42
12	Zeolite, enriched with carbamide, 500 kg/ha + NPK	5.27	1.90	56
13	Zeolite, enriched with amino acids, 250 kg/ha + NPK	5.17	1.80	53
14	Zeolite, enriched with amino acids, 500 kg/ha + NPK	5.25	1.88	56
LSD_{05}		0.23		

The research results showed a close relationship between the crop yield and the available forms of nutrients in the soil, the content of which is determined by the fertilization system (Table 3, Figures 1-4).

Table 3. Relationship between the grain yield of winter wheat and content of nutritive substances in the arable layer of the soil.

Field experiment	Regression equation	Reliability criteria
Relationship between the grain yield of winter wheat and the content of mineral nitrogen in the soil		
Experiment No. 1	Y = 0.29x - 0.79	$R^2 = 0.88$
Experiment No. 2	Y = 0.35x -1.65	$R^2 = 0.92$
Relationship between the grain yield of winter wheat and the content of mobile phosphorus in the soil		
Experiment No. 1	Y = 0.09x - 10.58	$R^2 = 0.92$
Experiment No. 2	Y = 0.04x-3.73	$R^2 = 0.86$
Relationship between the grain yield of winter wheat and the content of exchangeable potassium in the soil		
Experiment No. 1	Y = 0.08x - 8.11	$R^2 = 0.82$
Experiment No. 2	Y = 0.07x - 2.71	$R^2 = 0.64$

*Note: Y − yield, t/ha, x – content of the soil - of mineral nitrogen, mobile phosphorus, exchangeable potassium, mg/kg .

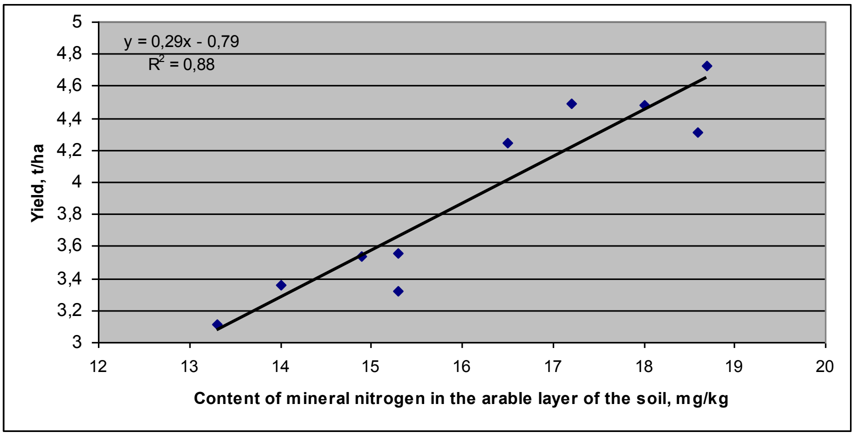

Fig. 1. Relationship between the grain yield of winter wheat and the content of mineral nitrogen (N-NH_4+N-NO_3) in the arable layer of the soil (Experiment No. 1).

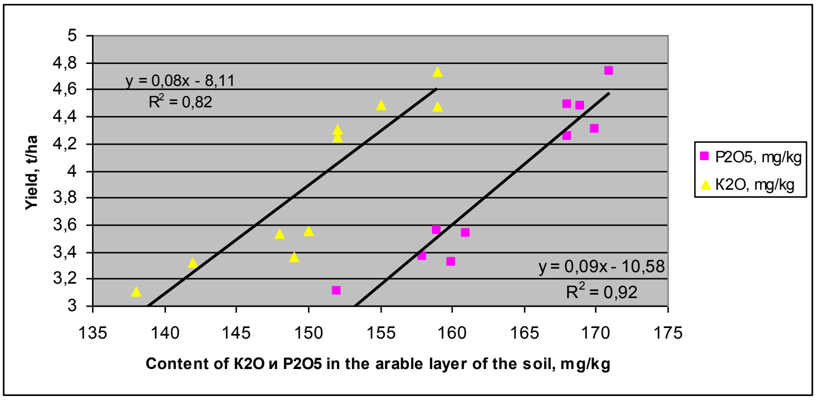

Fig. 2. Relationship between the grain yield of winter wheat and the content of mobile phosphorus and exchangeable potassium in the arable layer of the soil (Experiment No. 1).

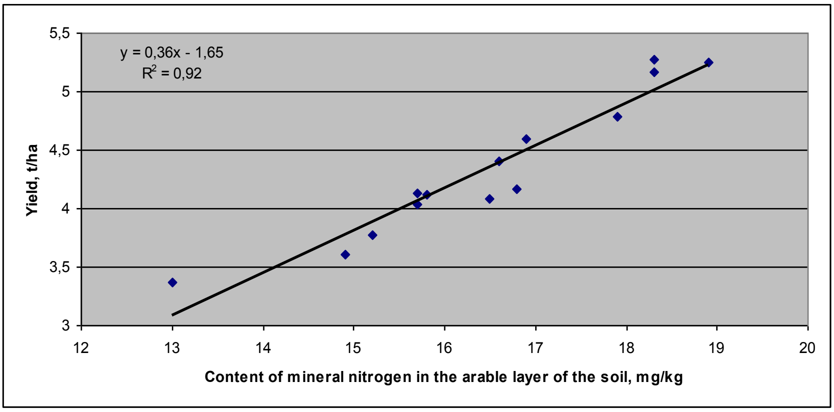

Fig. 3. Relationship between the grain yield of winter wheat and the content of mineral nitrogen (N-NH_4+N-NO_3) in the arable layer of the soil (Experiment No. 2).

 https://doi.org/10.1051/bioconf/20237101053

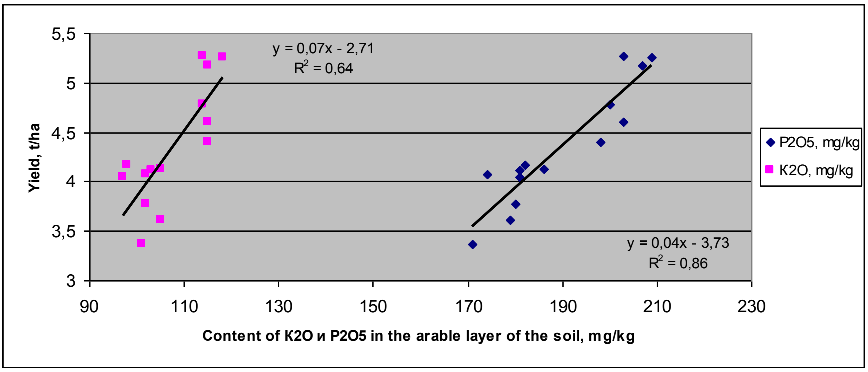

Fig. 4. Relationship between the grain yield of winter wheat and the content of mobile phosphorus and exchangeable potassium in the arable soil layer (Experiment No. 2).

4 Discussion

A positive change in the nutrient regime of the soil was observed when using straw, green manure, a biological preparation in various combinations, as well as together with NPK. On average, over the growing season, the content of mineral nitrogen in the soil increased from 5% in the variant - straw + green manure to 29% in the variant - straw + Biocomposite-correct + N10t/ha + NPK, the content of mobile phosphorus increased by 4 - 11%, exchangeable potassium by 7.4 - 13.2% (figures 1and 2).

The use of silicon fertilizers based on zeolite in the second experiment, both in pure form and when enriched with amino acids and carbamide, as well as in combination with a complex of nitrogen-phosphorus-potassium fertilizers, contributed to the improvement of the nutrient regime of the soil. On average, over the growing season, the content of ammonium and nitrate nitrogen in the arable soil layer exceeded the control from 13% in the variant using zeolite at a dose of 250 kg/ha to 31.2% when using zeolite enriched with amino acids at a dose of 500 kg/ha with NPK, the content of mobile phosphorus increased by 1.7-18.2%, exchangeable potassium by 1.0-14.4% (figures 3 and 4).

Accordingly, the improvement of the nutrient regime of the soil contributed to the formation of a higher grain yield of winter wheat. Analysis of data on the yield of winter wheat shows that in favorable years in the conditions of the forest-steppe of the Volga region, winter wheat can form a yield of 6 tons per hectare, and with the use of fertilizers - up to 7 t/ha or more. The data obtained confirm how important the climatic factor is in agriculture in the Volga region and how important it is to develop technologies that allow maximum adaptation to the prevailing growing conditions [7].

In 2021, when the weather conditions during the entire growing season of the crop were quite variable, the grain yield of winter wheat in the first experiment in the control sample was 3.11 t/ha, and when using a complex of biological methods in the form of introducing straw, green manure, and a biological preparation into the soil - 4.73 t/ha. A higher yield was expectedly observed in contrast to the use of mineral fertilizers, where nutrients are introduced into the soil in a soluble form and their amount significantly exceeds the amount supplied with straw and green manure. The yield increase for the variant with the introduction of NPK was more than one ton per hectare (Table 1).

The yield of winter wheat grain when using a complex of organic fertilizers in the form of straw, the biological preparation Biocomposite-correct, a vetch-oat mixture as green manure was slightly inferior to the variant with the use of a complete mineral fertilizer and amounted to 3.56 t/ha.

The increase in the grain yield of winter wheat when using an organic fertilizer system (straw + green manure, straw + biological product + green manure, biological preparation + green manure) amounted to 0.25, 0.45 and 0.21 t/ha, respectively, organic-mineral (straw + N10kg/ t + green manure) by 0.43 t ha. The highest yield of winter wheat was formed with a combination of straw, the biological preparation, and mineral fertilizers - 4.73 t/ha.

The results of the analysis of Table 2 show that the use of zeolite and its modifications in the fertilization system makes it possible to increase the grain yield of winter wheat from 7% when zeolite is applied to the soil at a dose of 250 kg/ha to 56% when zeolite is used in combination with amino acids and NPK.

The calculations showed that there is a positive relationship between the grain yield of winter wheat and the content of mineral nitrogen, exchangeable potassium, and mobile phosphorus in the arable soil layer, described by the regression equations presented in table 3 and figures 1-4.

5 Conclusion

On average, during the growing season of the crop, when fertilizers were applied to the soil both in the first experiment and in the second, the content of all nutrients was maintained at a higher level.

The improvement of the agrochemical state of the arable soil layer, respectively, contributed to the formation of a higher yield of winter wheat grain.

The winter wheat grain yield when using a complex of organic fertilizers in the form of straw, the biological preparation Biocomposite-correct, the vetch-oat mixture as green manure was slightly inferior to the variant with the use of a complete mineral fertilizer and amounted to 3.56 t/ha.

However, using only a system of organic fertilizers, it is rather difficult to ensure the volume of the produce obtained at the level of mineral fertilizers. The latter is possible when using in the technology of cultivating agricultural crops a new generation of fertilizers based on high-silicon rocks, which are natural environmentally friendly materials. The yield when using zeolite and its modifications in the technology of cultivation of winter wheat increased by 7-56%, depending on the variants used.

Acknowledgement

The research project was carried out in accordance with the thematic plan-assignment of the Ministry of Agriculture of the Russian Federation, registration number EGISU NIOKTR 1022041500051-7-4.1.6 on the topic "Development of a system for reproducing soil fertility and increasing crop yields, including using organomineral fertilizers based on high-siliceous rocks, in the conditions of the Middle Volga region (No. 164)".

References

1. A. Kvashin, N. Neshchadim, K. Gorpinchenko, Yield and quality of grain, winter wheat in conditions of insufficient moisture in the Krasnodar territory Polythematic online Electronic, Scientific Journal of Kuban State Agrarian University, **128**, 985-1003 (2017)
2. H. Shaji, V. Chandran, L. Mathew, Organic fertilizers as a route to controlled release of nutrients, Controlled Release Fertilizers for Sustainable Agriculture, 231-245 (2021)

3. Sh. Jaffri, Kh. Ahmad, A. Jabeen, Biofertilizers functionality in organic agriculture entrenching sustainability and ecological protection, Biofertilizers, 211-219 (2021)
4. M. Greger, T. Landberg, S. Nazaralian, *Plant uptake of silicon nanoparticles*, 7th Int. Conf. Silicon Agricult. Proced. Abstracts, 68 (2017)
5. N. Yamaji, N. Mitani-Veno, G. Sakurai, J. Ma, *A cooperative system of silicon transport in plants*, 7 th Inter. Conf. Silicon Agricult. Proced. Abstracts, 36 (2017)
6. P. Van Soest, Rice straw, the role of silica and treatments to improve quality, Animal Feed Sci. Technology, **130**,137-171 (2006)
7. A. Artyszak, Effect of Silicon Fertilization on Crop Yield Quantity and Quality—A Literature Review in Europe, Plants, **7**, **3**, 54 (2018)
8. W. Zellener, B. Tubana, F. Rodrigues, L. Datnoff, Silicon's Role In Plant Stress Reduction And Why This Element Is Not Used Routinely For Managing Plant Health, Plant Disease, **105**, 2033–2049 (2021)
9. N. Samsonova, Silicon in plant and animal organisms, Agrochemistry, **1**, 86–96 (2019)
10. A. Kulikova, E. Yashin, E. Volkova, Siliceous rocks in the winter wheat fertilization system, Bulletin of the Ulyanovsk State Agricultural Academy, **3**, **51**, 53-59 (2020)