The influence of biopolymer modification of mineral fertilizers on main agrochemical parameters of soil

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\textbf{Abstract.} This paper demonstrates the possibility of increasing the productivity of crops, while improving the parameters of soil fertility is significantly limited in modern conditions. This trend is associated with low activity of innovation and innovative activities in the field of mineral nutrition of plants. Nevertheless, the existing work in this area clearly indicates the presence of effective recommendations aren’t only to limit the growth of costs for the fertilizer system but to increase its efficiency, besides, to improve the agro-ecological soil parameters.

1. Introduction

In the matter of increasing the productivity of field crops, along with the use of high-quality seed material, a special role belongs to the science-based fertilizer system. Technological audit of crop enterprises demonstrates a low degree of production adaptation to the annually increasing costs for the purchase of fuel, agricultural equipment, seeds, plant protection products, fertilizers, and etc. The part of the cost of mineral fertilizers in the structure of all costs in some cases may exceed 20\% \cite{3}.

In this regard, the optimization of the fertilizer system by increasing the utilization of nutrients by cultivated plants is an important condition for increasing the profitability of the entire plant industry. The use of biopolymer (biodegradable) materials in agricultural production, in particular to improve the fertilizer system of cultivated plants, meets the challenges faced by the modern agro-industrial complexes program of the Russian Federation \cite{7}. The environmental and economic problems that will be solved through the use of biopolymers primarily include the degradation of soil fertility, results reduce implementation of the genetic potential of crops, as well as an increase in production costs \cite{2}. For a long time, the modification of the mineral system of the fertilizer occurred due to the inclusion of the missing, macro-, meso- and microelements into the complex fertilizers \cite{1}.

Recently, there has been a tendency towards modernisation due to the use of microorganisms and organic substances. At the same time, the creation of organo-mineral fertilizer mixtures is associated with the difficulty of imparting the corresponding physical parameters to the organic components. The most difficult to obtain granules from organic raw materials (peat, compost, etc.), have a spherical shape the diameter of which would coincide with the diameters of the granules of mineral fertilizers. Different
density is also an obstacle that does not allow to achieve uniformity in the ratio of mineral and organic parts in fertilizer mixtures [4]. At the same time, the presence of an organic component in the mineral system of fertilizer is one of the most important conditions for the full development of agricultural plants and the formation of a high-quality harvest. Carbon substances determine the sequence of transformation processes of nitrogen in the plant body. The transformation of nitrate nitrogen compounds into protein substances requires the presence of carbohydrate conversion products. In the present paper it is proposed to use as an organic component one of the most common biopolymers in nature – starch-based biodegradable polymer, where the monomer is an alpha-glucose. The advantage of starch is that it is a renewable resource, as it can be synthesised by various plants in chloroplasts under the action of light during photosynthesis [8].

2. Materials and methods
The studies were conducted in 2019 under production conditions in the Kursk region of the Stavropol Territory (Ltd. StavAgroCom). In order to determine the effect of modification of mineral fertilizers with a biopolymer substance, a micro-plot experiment was established on winter wheat crops. The area of the plots was 0.25 m². The feeding was carried out with a complex mineral fertilizer (NPK - 16:16:16) at the rate of 200 kg / ha. The biopolymer was applied to the fertilizer by dusting with pre-wetting of the granules. In order to avoid fertilizer dissolution between spraying moisture and applying a biopolymer, the process of coating was kept for a minimum time. The final stage of coating the biopolymer was carried out in a microwave oven. The rate of consumption of biopolymer was based on 5 kg per 1 ton of fertilizer.

Table 1. Experience scheme.

| Control                     | Without feeding                      |
|-----------------------------|--------------------------------------|
| Option 1                    | NPK 16:16:16                          |
| Option 2                    | NPK 16:16:16 + biopolymer + water    |
| Option 3                    | NPK 16:16:16 + biopolymer + lemon acid|

Evaluation of the impact of biopolymer modification of fertilizers was carried out by counting the number of stems and by changing the agrochemical soil parameters in the dynamics: EC; pH; N-NO₃; N-NH₄; P₂O₅; K₂O. Repetitions 3 times.

The agrochemical analysis of the soil was carried out in the laboratory of LLC Agrochemistry (KBR, Nartkala, Stepnaya str., 2). Soil samples were numbered as 215-239. Techniques were used:

- GOST 26205-91 Determination of mobile compounds of phosphorus and potassium according to the method of Machigin in the modification of CINAO.
- GOST 26951-86. Determination of nitrates by the ionometric method.
- GOST 26489-85. Determination of exchange ammonium according to the CINAO method.
- GOST 26487-85 - pH, electrical conductivity.

Table 2. Temporary sampling points.

| Selection 1 | 18 March 2019 г. | Selection of soil before fertilizing |
|-------------|------------------|-------------------------------------|
| Selection 2 | 08 April 2019г. | First time point                     |
| Selection 3 | 09 May 2019г.   | Second time point                    |
| Selection 4 | 30 May 2019 г.  | Accounting for the number of stems   |

3. Results and discussion
The results of the experiment indicate that, the modification of mineral fertilizers has a positive potential productivity of winter wheat, stimulating an increase in the number of stems.
Table 3. The number of stems on winter wheat.

| Option     | Repetitions | Average |
|------------|-------------|---------|
| Control    | 162         |         |
|            | 130         |         |
|            | 143         | 145     |
| Option 1   | 146         | 154.7   |
|            | 149         |         |
|            | 169         |         |
| Option 2   | 192         | 171.3   |
|            | 167         |         |
|            | 155         |         |
| Option 3   | 155         | 171.7   |
|            | 192         |         |
|            | 168         |         |

Table 3 demonstrates that the use of biopolymer entails an increase in the number of stems in the experience relative to the control by an average of 18.1% (options 3 and 4), while the use of unmodified fertilizer (option 1) increases this figure by only 6.7%. The use of complex mineral fertilizers is a standard technique in crop production, and therefore it is more correct to conduct a comparative assessment of innovative solutions with respect to reference technologies. Comparing option 1 and options 2,3 there is an increase in the number of stems under the action of the biopolymer by 11%. The organic-mineral form of fertilizers always exceeded the efficiency of mineral fertilizers. The advantage is associated with the high role of carbon-containing substances, which act as an energetic material for soil microflora, as well as directly involved in the formation of protein compounds in the body of the plant.

Agrochemical indicators of the soil also varied depending on the options of the experiment.

Table 4. Agrochemical indicators of the soil.

| The content of nitrates in the soil, mg / kg |
|--------------------------------------------|
| Options | Selection 1 | Selection 2 | Selection 3 |
| Control | 6.2         | 8.5         | 3.1         |
| Option 1 | 6.2         | 6.8         | 2.6         |
| Option 2 | 6.2         | 7.0         | 3.4         |
| Option 3 | 6.2         | 5.3         | 3.0         |

| Exchange ammonium content, mg / kg |
|-----------------------------------|
| Options                           |
| Control                           | 11.3         | 24.4       | 24.1       |
| Option 1                          | 11.3         | 23.6       | 26.6       |
| Option 2                          | 11.3         | 24.7       | 36.0       |
| Option 3                          | 11.3         | 28.3       | 47.9       |

| The total content of mineral nitrogen, mg / kg |
|-----------------------------------------------|
| Options                                      |
| Control                                      | 17.5         | 32.9       | 27.2       |
| Option 1                                     | 17.5         | 30.4       | 29.2       |
| Option 2                                     | 17.5         | 31.7       | 39.4       |
| Option 3                                     | 17.5         | 33.6       | 50.9       |

Among the elements of mineral nutrition of plants, nitrogen occupies a special place. It is a part of the protein substances that form the basis of the protoplasm of the cell and part of all enzymes. The total
nitrogen content indicates the potential fertility of the soil, and the content of mineral compounds on the degree of intensity of biochemical processes in it [5].

Winter wheat plants make high demands on the availability of nutrients to the soil (especially NPK) throughout the entire growing season. But considering that by the middle of the growing season wheat consumes only 30-35% of mineral substances, the creation of conditions for the provision of plants to the end of the growing season is a priority task in the field of agricultural chemistry. The diagram (figure 1) demonstrates that the total content of mineral nitrogen in the soil varies depending on the time of selection. In the control section and in the variant with the use of NPK (option 1), an increase in the concentration of nitrogen to the second time point and a subsequent decrease to the third time point are observed. The reduction is 21 and 4.1%, respectively. At the same time, the amount of mineral nitrogen in variants 2 and 3 continues to grow throughout the entire observation period. The increase was 24.3% (option 2) and 51.5% (option 3).

The change in the content of mineral nitrogen in the soil under the influence of a biopolymer indicates its positive effect on the microbiological activity, including the respiration of the soil, as a result of which the resulting carbon dioxide improves the nutritional regime of the soil [6].

The transformation of nitrogen in the soil occurs due to the two main groups of microorganisms in the soil - nitrifying and ammonifying agents. The degree of correlation between these parameters reaches $r = 0.8-0.9$. [3]. Noting the role of biopolymer as a component of the organo-mineral fertilizer system, it should be noted that the importance of the choice of the liquid used in the fertilizer preparation process. So in options 2 and 3 water and citric acid solution were used, respectively.

From the diagram (figure 1) it can be seen that the concentration of mineral nitrogen in the soil increased in option 3 with respect to option 2 (using water) by 29.2%. Through this information, it is possible to predict the production of winter wheat grain in option 3 with enhanced quality characteristics.

| Table 5. Agrochemical parameters of the soil. |
|-----------------------------------------------|
| Content of $P_2O_5$ in soil, mg / kg           |
| Options | Select 1 | Select 2 | Select 3 |
| Control | 28,7     | 34,0     | 30,5     |
| Option 1| 28,7     | 33,9     | 30,5     |
| Option 2| 28,7     | 42,5     | 36,4     |
| Option 3| 28,7     | 33,7     | 28,8     |
| Content, of $K_2$O, mg / kg                   |
| Control | 169,5    | 285,2    | 163,4    |
| Option 1| 169,5    | 277,1    | 153,2    |
| Option 2| 169,5    | 325,5    | 170,1    |
| Option 3| 169,5    | 297,6    | 146,0    |
The need of plants for phosphorus in quantitative expression is significantly lower than that of nitrogen and potassium. But at the same time phosphorus is crucial for the rapid growth and proper development of plants. The most important functions of phosphorus in a plant are the storage and transfer of energy and the transfer of genetic material. The peculiarity of plant nutrition with phosphorus is associated with the impossibility of filling its deficit in the initial periods with abundant fertilizer at a later date.

From table 5 it can be seen that during the period of tillering (selection 2), the stock of mobile phosphorus in the soil is maximum in option 2, where biopolymer is used together with water. The difference in concentration in relation to other options is on average 25%. The trend of increased phosphorus content in option 2 is noted in the dynamics (figure 2). In the last period of time of removal of soil samples, the difference in its concentration is maintained at 19.3-26.4%, depending on the options.

![Figure 2. Dynamics of the content of mobile phosphorus in the soil.](image)

A similar trend is observed in the behavior of potassium in option 2.

![Figure 3. Dynamics of the content of mobile potassium in the soil.](image)

Given that potassium is involved in the process of transfer of assimilates, activation of many enzymes, regulation of the water regime of plants, the use of biopolymers for the modification of mineral complex fertilizers is a reasonable technique in crop production. The content of mobile potassium under the action of the biopolymer in variant 2 with respect to the control variant in the second selection increases by 14.1%, with respect to the standard (variant 1) - by 17.5%.

4. Conclusion
To sum up, it is increasingly noted that the soil factor limiting productivity has shifted from the mineral component to the organic component. Improvement of the fertilizer system based on consideration of
the basic parameters of the soil and the responsiveness of agricultural crops is a guarantee of increasing the productivity of the crop industry. The inclusion of biopolymer compounds, in particular starch, in the system of mineral nutrition of plants, as well as the production of appropriate fertilizer mixtures at a high technological level, meets the demands of the modern plant industry.

Thus, the inclusion of 5% biopolymer in the mineral system significantly increases the coefficient of realization of the genetic potential of winter wheat varieties to 11-18.1% (table 3), as well as the agrochemical parameters of the soil. In particular, the possible increase in the concentration of mineral nitrogen, mobile compounds of phosphorus and potassium, on the basis of the experiment performed, reaches 29.2%, 25 and 17.5%, respectively.

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