Influence of Azotovite and Phosphatovite on the Productivity of Oats and the Fertility of Sod-Podzolic Soil in the Conditions of the Novgorod Region

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Abstract. Sod-podzolic low-fertile soils (70% of the territory) are mainly widespread in the Novgorod region. According to the granulometric composition, the sown areas are mainly light and medium loamy. Technological operations include two methods of application of microbial fertilizers Azotovit and Phosphatovit: pre-sowing seed treatment (A+Ph, 2 l/t of each preparation) + foliar treatment in the phase of entering the tube (A+Ph, 1 l/ha of each preparation) together with mineral fertilizers (based on the planned yield and reduced by 50%), which contributes to an increase in oat grain production by 32 and 33%, and digestible protein by 30 and 34%, respectively, in relation to background 1 and background 2, where microbial fertilizers were not used. As an organic fertilizer, chopped straw of spring barley was plowed (4 t/ha) with addition of 10 kg of nitrogen for each ton. After harvesting cereals, a disc harrow was used to chop the straw and mix it with the soil at a depth of 0-10 cm. Taking into account the main articles of the arrival of humus (stubble-root residues of cereals and straw) in all variants of the experiment, soil fertility increased and its energy potential increased from 9 up to 16 GJ/ha.

1. Introduction

Oats are the most important food crop in Russia. It is grown for grazing and food purposes. In Russia, oats are concentrated in the Non-Chernozem regions, in the central Volga region, in Siberia. In the Urals and in the Central Black Earth regions, the least of all. Oats are sown mainly in spring. Winter and semi-winter forms are less common. The sown area of oats in Russia from 2001 to 2005 amounted to 4 million hectares, which was more than 9.1% of the total sown area of cereals, the total yield was 6 million tons (7.4% of the total grain yield), and the average yield was 1.7 t/ha. Oat grain contains up to 13% protein, 41% starch and 5% fat [1].

The protein of oat grains contains all the essential amino acids for humans and animals.

In terms of vitamin content, oat grains surpass many cereal crops.

Among food crops, oats have the greatest biological value: for horses, oat grains are the best feed, and in crushed form, they are good feed for dairy cows, especially for young animals. Oats are sown neat or mixed with legumes for use in grain, hay and green forage.

Various types of feed use of oats – straw, chaff, green fodder, cattle grazing and its value as a processing raw material determine its distribution in many countries.

Oats respond well to the application of mineral fertilizers and dramatically increase yields. Nitrogen fertilizers in the cultivation of oats are highly effective on sod-podzolic loamy soils [2].

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In the Novgorod region, sod-podzolic soils occupy 83% of the sown area and have low fertility. The use of new microbial fertilizers containing nitrogen – “Azotovit” (A) and phosphorus – “Phosphatovit” (Ph), helps to increase yields and restore soil fertility.

New microbial fertilizers are irreplaceable sources of plant nutrition, and they increase the efficiency of mineral fertilizers consumption and prevent the loss of technical nitrogen. Azotovit (active ingredient: Azotobakter chroococcum). Mechanism of action: Free-living nitrogen-fixing bacteria capture molecular nitrogen from the atmosphere and convert it into a form that can be assimilated by plants. When adding to the soil, for example, one centner of ammonium nitrate per hectare, the nitrogen consumed by plants is not 50-60%, but much more – 85–90%. Phosphatovit (active ingredient: Bacillus mucilaginosus). The bacteria of the Phosphatovit preparation dissolve silicate minerals, release phosphorus and potassium from complex compounds and turn them into available ones, and increase the consumption rate of phosphorus and potassium fertilizers.

The aim of this study is to study the effect of the combined use of microorganisms with mineral fertilizers on the yield of oat grains and organic matter in the soil in the natural and climatic conditions of the region.

2. Objects and methods of research
The experiments were carried out on medium–cultivated sod-podzolic soil in the experimental field of the Novgorod Research Institute of Agriculture in 2018–2020 on spring oats in the village of Borrus.

The technology of applying microbial fertilizers with mineral fertilizers increases the efficiency of their use. The main dose of mineral fertilizers (N₃P₃K₁) is calculated for the planned yield (3 t/ha of grain), taking into account the removal of the main nutrients from the crop and the availability of phosphorus, potassium and nitrogen from the soil. The next dose of mineral fertilizer (N₂P₂K₂) is half of the main dose.

The use of microbial fertilizers is cost-free as they are applied along with the pesticides.

The research experiment was carried out according to the 2 × 4 scheme and is shown in table 1.

Mineral fertilizers were studied (factor B): B₁ – N₁P₁K₁ for a planned yield of 3 t/ha of oat grain, and B₂ – (N₂P₂K₂) 1/2 of factor B₁, and three types of application of Azotovit and Phosphatovit (factor H): 1. H₀ – is not used A+Ph; 2. H₁ – seed treatment (A+Ph) before sowing; 3. H₂ – foliar treatment at a plant height of up to 30 cm – (A+Ph); 4. H₃ – pre-sowing seed treatment (A+Ph) + foliar treatment at a plant height of up to 30 cm – (A+Ph).

The experiment was carried out in triplicate on the predecessor of spring barley with plowing of the barley straw for organic fertilization. When plowing straw, 10 kg of nitrogen was additionally introduced for each ton of straw due to the high ratio of C:N = 80-90: 1.

The area of the test plot is 100 m². On ½ part of the plot, oat grain was sown, treated before sowing with only a seed dressing agent, and on the other part of the plots, before sowing, the seeds were treated with a dressing agent together with the microbial fertilizers Azotovit + Phosphatovit at a dose of 2.0 l/t of seeds of each preparation. In variants 3 and 4, 7 and 8 foliar treatment was carried out with microbial fertilizers A + Ph, 1 l/ha of each preparation.

The meteorological conditions of the growing season in the years under study are different. In 2018, from May to June, hydrothermic coefficient is 0.5 and 0.9 units. Precipitation in July and August is 25% higher than the average long-term value, the air temperature is 2.5 °C. During the growing season of 2019, warm, but humid weather prevailed with a total hydrothermic coefficient value of 1.7 units. Hydrothermic coefficient in 2020 from May to July was 1.3 units, in August – 0.9 units.

3. Results
In the course of many years of research, the productivity of oat grain in the village of Borrus was considered in the phase of full grain ripeness. With the application of the main dose of mineral fertilizers (background 1), the grain productivity was 3.1 t/ha (option 1). By factor B₂ (background 2), the productivity was 2.4 t/ha (option 5). The difference between the options is significant – 0.7 t/ha (table
1). Thus, an increase in the dose of mineral fertilizers in comparison with background 2 contributed to an increase in grain by 29%, which is confirmed by the data of researchers [3, 4, 5].

**Table 1.** Average productivity of oat grain from the action of Azotovit and Phosphatovit and mineral fertilizers over the years of research.

| Variant No. | Dose of mineral fertilizers, kg a.w./ha (factor B) | Method of using microfertilizers (factor H) | Productivity, t/ha or t. to unit/ha | Increase in productivity to backgrounds, t/ha | Protein, t/ha |
|-------------|---------------------------------------------|----------------------------------|---------------------------------|--------------------------------|----------------|
| 1           | B₁₁, N₅₀P₄₁K₄₇ (background 1)               | H₀                               | 3.1                             | –                             | 0.27           |
| 2           |                                             | H₁                               | 3.5                             | 0.4                           | 0.30           |
| 3           |                                             | H₂                               | 3.6                             | 0.5                           | 0.31           |
| 4           |                                             | H₃                               | 4.1                             | 1.0                           | 0.35           |
| 5           |                                             | H₀                               | 2.4                             | –                             | 0.20           |
| 6           | B₂₂, N₃₁P₂₁K₂₃ (background 2)              | H₁                               | 2.8                             | 0.4                           | 0.24           |
| 7           |                                             | H₂                               | 2.7                             | 0.3                           | 0.23           |
| 8           |                                             | H₃                               | 3.2                             | 0.8                           | 0.27           |

Factor H HCP₀₅₁= 0.2 t/ha (average HCP₀₅₁: H₀ = 2.8 t/ha, H₁ and H₂ = 3.2 t/ha, H₃ = 3.7 t/ha)
Factor B HCP₀₅₁= 0.2 t/ha (average HCP₀₅₁: B₁ = 3.6 t/ha, B₂ = 2.8 t/ha)

For comparison of private average HCP₀₅₁ = 0.5 t/ha

A single use of microbial fertilizers in technological operations (seed dressing before sowing and foliar treatment (factors H₁ and H₂) in options 2 and 3, the yield of oat grain relative to background 1 (factor B₁) increased by 0.4 and 0.5 t/ha (13 and 16%) , in options 6 and 7 by 0.4 and 0.3 t/ha in relation to background 2 (factor B₂, option 5). With the double use of Azotovit and Phosphatovite at two levels of mineral nutrition, options 4 and 8 received the greatest increase in grain 1.0 and 0.8 t/ha in relation to backgrounds 1 and 2 (factor H₂), respectively. Statistical processing of the crop showed the absence of joint interaction of mineral and microbial fertilizers to increase the yield of oat grain. Increase in grain yield when using Azotovit and Phosphatovit (factors H₁, H₂, H₃) on two the backgrounds of mineral nutrition are practically the same in relation to backgrounds 1 and 2. The results obtained in terms of yield are consistent with studies [6, 7, 8, 9].

Structural analysis of test samples of oat plants is fully consistent with the data on yield. In variants 4 and 8, the best quality of 1000 oat grains was obtained – 33.5 and 30.3 g. and the largest number of grains in a panicle is 56 and 52 pcs., respectively.

Protein plays a special role in the nutritional value of feed for farm animals, and protein plays a special role. Using a complete protein of food grain crops can completely solve the problem of providing animals with protein (protein) [10]. In our studies, in variants with the use of microbial fertilizers A and F, the yield of digestible protein in oat grain was 0.23–0.35 t/ha.

Variants 4 and 8 mark good indicators of oat grain production for spring barley: yield 4.1; 3.2 t k. units/ha; energy intensity produced per ton of fodder unit 3.1 and 3.5 GJ and high efficiency of grain production 5.3 and 4.7 units, respectively.

The conditional net profit in these options amounted to 34 and 26 thousand rubles/ha (in prices of 2018), the production profitability is more than 200%.

When calculating the humus balance, we monitored the change in organic matter in the topsoil. The main articles of humus arrival in our studies were stubble-root residues of oats and plowed chopped straw of the grain predecessor. The balance of soil humus according to three-year studies for options 1–8 is positive and amounted to 0.39-0.69 t/ha (table 2), which is confirmed by similar studies in the natural and climatic conditions of the Novgorod region [11].
Table 2. Influence of the complex action of microbial, mineral and organic fertilizers on the quantitative parameters of the soil (average over 3 years).

| Variant No. | Organic fertilizers, t/ha | Stubble-root residues, t/ha | Humification | Humus mineralization, t/ha | Humus balance, ± t/ha |
|-------------|---------------------------|----------------------------|--------------|---------------------------|-----------------------|
| 1           | 0.55                      | 0.55                       | 0.71         | +0.39                     |
| 2           | 0.55                      | 0.65                       | 0.71         | +0.49                     |
| 3           | 0.55                      | 0.66                       | 0.71         | +0.50                     |
| 4           | 0.55                      | 0.85                       | 0.71         | +0.69                     |
| 5           | 0.55                      | 0.63                       | 0.71         | +0.47                     |
| 6           | 0.55                      | 0.58                       | 0.71         | +0.42                     |
| 7           | 0.55                      | 0.55                       | 0.71         | +0.39                     |
| 8           | 0.55                      | 0.78                       | 0.71         | +0.62                     |

4. Conclusion

When sowing spring oats on soddy-podzolic soil in the Novgorod region, it is necessary to include in the technological operations the dual use of microbial fertilizers Azotovit and Phosphatovit (seed dressing and foliar treatment) and mineral fertilizers, which ensures the grain yield of 3.2 and 4.1 t c. u./ha, the yield of digestible protein is more than 0.27 tons per hectare, the low energy consumption of the production of a ton of feed units of the main product is less than 4 GJ, and the high energy efficiency of more than 5 units. When straw was used as an organic fertilizer, the humus content in the soil layer of the cultivated land in all variants of the experiment increased by more than 0.39 t/ha.

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