Improving soil ecology when applying bacterial fertilizers

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Abstract. Increasing the yield of spring barley on light chestnut soils of the Volgograd region is possible through the use of microbiological fertilizers that activate the processes of plant growth and development. The influence of the methods of basic tillage and the application of mineral and bacterial fertilizers "Azotovit" and "Phosphatovit" on the content of nitrogen in the soil was studied. The degree of decomposition of the linen cloths was the maximum for deep flat-cutting processing. According to the binary interaction, the best results were obtained on the variant with deep flat-cutting processing with double application of bacterial fertilizers. The introduction of bacterial fertilizers sharply increases the content of azotobacter, and especially when they are applied twice. The lowest toxicity of the soil in barley crops compared to the control was noted on the variant with deep flat-cutting treatment, and the maximum on the variant of dump treatment. The analysis of data on the structure of the crop also indicates the advantage of the variant of deep flat-cutting tillage with double application of microbiological fertilizers. The most cost-effective variants were with double application of bacterial fertilizers on the background of deep flat-cutting tillage.

1. Introduction
Currently, there is an increased interest in bacterial preparations in agriculture. Their advantage over agrochemicals is the ability to transfer nutrients from fertilizers, root secretions and organic residues into a form accessible to plants. Bacterial preparations are able to absorb atmospheric nitrogen, produce physiologically active substances, and inhibit the development of pathogenic microflora. The use of bacterial fertilizers improves plant growth by reducing the stressful influence of the environment (unfavorable conditions), contributes to the fullest disclosure of the potential of the variety, which relates to both quantitative and qualitative indicators of agricultural products [1, 2, 3].

There are different opinions on the binary effect of mineral fertilizers and bacterial preparations. Thus, there is an increase in yield on sod-podzolic soils when sowing with inoculated seeds against the background of mineral nitrogen [4]. At the same time, it is widely believed that the nitrogen of mineral fertilizers slows down the process of associative nitrogen fixation. According to other data [5, 6, 7], against the background of nitrogen fertilizers, there is an increase in nitrogen fixation by 30-45%, which is probably due to better plant development when applying fertilizers.

In the complex of measures ensuring high and stable yields of agricultural crops and a steady increase in soil fertility, the use of the most rational methods of soil cultivation with the introduction of mineral
and bacterial fertilizers that contribute to an increase in the yield of spring barley in the Volgograd region.

2. Materials and methods
The object of research is spring barley of the Prairie variety. The research was carried out on the experimental field of the educational farm "Gornaya Polyana" of the Volgograd State Agrarian University. The soil of the experimental site is light chestnut. Light chestnut soils traditionally have a low nitrogen and phosphorus content and a high supply of potassium. The content of mobile forms of nitrogen is low, the amount of total nitrogen does not exceed 20 mg/kg of soil. Phosphorus provision is average - 30-35 mg/kg of soil, exchangeable potassium is increased - 350-400 mg/kg of soil.

The assessment of weather conditions was carried out using data from the university's meteorological station, which provided the maximum characteristic for the years of research. The average annual precipitation varied from 300 to 450 mm. In dry years, it fell to 150 mm, and sometimes the difference was 3-4 times. In addition, precipitation fell unevenly according to the seasons and the growing season. The maximum is in the month of May, and the minimum is in September. Moreover, May precipitation, as a rule, was in the nature of a downpour, it happened that more than 25% of the average annual precipitation fell per day. In the summer, precipitation was insignificant.

The studies were carried out in a subzone of light chestnut, weakly solonetz soils with a heavy loamy granulometric composition. The presence of salt licks up to 25-30% with a humus content of 1.8%.

The agrotechnology of cultivating spring barley in the experiments was generally accepted for the Volgograd region.

The basic tillage was carried out according to three variants. For this purpose, a plow PN-4-35 was used for control, in the second and third variants a cultivator KPG 2.2 was used. The studies were carried out in a three-field crop rotation pure steam-winter wheat-barley. After harvesting winter wheat, stubble cultivation was not carried out, as the provided non-moldboard cultivation was carried out. The basic tillage was carried out in August according to the variants of the experiment.

Usually in the first decade of April, the site was harrowed with heavy tooth harrows BZTS-1.0. Then, pre-sowing cultivation of KPS-4 with lancet paws was carried out to a depth of 6-8 cm and sowing with SZ-3.6 seeders across the basic tillage.

Azotobacter accounting was carried out by the method of fouling of soil lumps (on Ashby medium). Biological activity was determined by the method of applications, by laying linen cloths according to the variants of the experiment in the phase of mass emergence of seedlings. Biological toxicity was determined by the method of plant biotests. Barley was used as a test culture in the experiments. Crop accounting was carried out by a continuous method. The grain yield is brought to the standard humidity of 14%. Statistical processing of the research results was carried out by the method of variance analysis according to Dospekhov.

3. Results and discussion
Currently, interest in the introduction of various plant growth stimulants in agricultural production is increasing. The appearance of new, more modern bacterial fertilizers makes it necessary to study them.

We have evaluated the binary effect of the methods of basic tillage and fertilizers on its microbiological parameters, crop structure and yield of spring barley.

Much less attention is paid to the study of biological factors of soil fertility than to physical ones. Meanwhile, the theoretical basis of tillage is the creation of favorable conditions for the development of biological processes in the soil, the accumulation of humus, the purification of the soil from pathogenic microorganisms, the strengthening of the biological activity of the soil.

Azotobacter is a biological indicator of soil fertility, as the most environment-sensitive microorganism (Table 1).
Table 1. Azotobacter content, % of soil clump fouling (on average for 2016-2017).

| Experience variants | Factor A | Factor B | Indicator |
|---------------------|----------|----------|-----------|
| A₁                  | B₁       | 23.3     |
|                     | B₂       | 47.0     |
|                     | B₃       | 70.7     |
|                     | B₄       | 95.7     |
|                     | B₁       | 32.3     |
|                     | B₂       | 55.0     |
| A₂                  | B₃       | 69.22    |
|                     | B₄       | 91.3     |
|                     |          | 98.3     |

2016 Lowest Significant Difference (LSD)₀⁵ = 3.73, LSD₀⁵ A = 1.88, LSD₀⁵ B = 2.17, LSD₀⁵ AB = 1.87; 2017 LSD₀⁵ = 3.88, LSD₀⁵ A = 1.94, LSD₀⁵ B = 2.24, LSD₀⁵ AB = 1.96.

The maximum content of azotobacter in the studies was noted on the variant of flat-cutting processing to a depth of 0.20-0.22 m - 69.22%, which is 10.5% higher than the control - dump processing to the same depth. The introduction of bacterial fertilizers sharply increases the content of azotobacter, and especially when they are applied twice - 95.7% against 23.3% on the variant without fertilizers. According to the binary interaction of factors, the highest percentage of fouling of soil lumps was established on the variant of flat-cutting processing to a depth of 0.20-0.22 m with double application of bacterial fertilizers on the mineral background A₂B₄ - 98.3% [8, 9].

Soil fertility is determined by biological factors, mainly the activity of microorganisms. Plant life is closely related to microorganisms, the influence of which is multifaceted.

Under the influence of microorganisms, the mineralization of organic substances in the soil occurs, as a result of which nutrients pass from an inaccessible state to an accessible one.

The study of biological processes in the soil makes it possible to determine its fertility not only by the level of yield, but also by its biological activity (Table 2). Analysis of microbiological processes in the studied soil was determined by the method of disintegration of linen cloth.

Table 2. Biological activity of the soil in the 0-0.3 m layer, % (on average for 2016-2017).

| Experience variants | Factor A | Loss of fiber |
|---------------------|----------|---------------|
| A₁                  | B₁       | 16.8          |
|                     | B₂       | 22.9          |
|                     | B₃       | 37.4          |
|                     | B₄       | 40.9          |
|                     | B₁       | 17.9          |
|                     | B₂       | 24.5          |
| A₂                  | B₃       | 31.65         |
|                     | B₄       | 39.8          |

It was found that the degree of decomposition of the linen cloth was the maximum for flat-cutting processing to a depth of 0.20-0.22 m. On average, for 2 years, the loss of fiber was 31.6% versus 29.5% in the control.

Fertilization increases the decomposition rate of linen cloth compared to the control (without fertilizers) by 8.3%. The maximum value is set when bacterial fertilizers are applied twice. Its value, on average for the studied methods of tillage, was 30.57%. According to the binary interaction, the best
results were obtained on flat-cutting processing to a depth of 0.20-0.22 m with double application of bacterial fertilizers - 44.4%, which is 8.6% higher than the similar variant on the control [10]. The use of NHK did not increase the intensity of decomposition of linen cloth.

Microorganisms determine not only agronomically useful processes in the soil - biological activity, but also processes that negatively affect its fertility, growth and development of agricultural plants - biological toxicity of the soil.

The works of many authors have shown that the initial decomposition products of straw and root residues are toxic to plants. However, according to these and other scientists, the accumulation of such substances in significant quantities occurs only when plowing a large amount of straw, when it decomposes in relatively anaerobic conditions. If plant residues decompose under conditions of aerobiosis, then the resulting products quickly disintegrate or turn into humus substances that do not have an inhibitory effect on plants, and therefore, after non-dumping treatment, such negative consequences are less noticeable than after dumping (Table 3).

In the practice of agronomic research, the most common method for determining soil phytotoxicity is the method of plant biotests. Barley was used as a test culture in the experiments.

| Table 3. Biological toxicity of soil, layer 0.0-0.3 m, % (average for 2016-2017). |
|-----------------------------------------------|
| **Method of tillage** | **Toxicity to control** |
| **Length of seedlings, mm** | **Weight of seedlings, g** | **Germination, %** | **by the length of the seedlings** | **by weight of seedlings** | **by germination** | **average** |
| Dump to a depth of 0.20-0.22 m | 38 | 2.4 | 90 | 13.2 | 14.9 | 5.2 | 11.1 |
| Flat-cutting to a depth of 0.20-0.22 m | 50 | 3.0 | 97 | 9.8 | 9.2 | 0 | 6.3 |

In our studies, the lowest soil toxicity in barley crops compared to the control was noted on the variant with deep flat-cutting tillage at 0.20-0.22 m - 6.3%, and the largest on dump plowing with a depth of 0.20-0.22 m - 11.1%. Many scientists have proven a positive relationship between the size of the crop and the microbiological processes of the soil [11].

Analysis of data on the structure of the crop (Table 4) indicates the advantage of the option of flat-cutting tillage to a depth of 0.20-0.22 m with double application of bacterial fertilizers.

| Table 4. Structure of spring barley yield (average for 2016-2017). |
|-----------------------------------------------|
| **Experience variants** | **Number of plants, million pcs/ha** | **Number of grains per ear, pcs** | **Weight of grain per ear, g** | **Weight of 1000 grains, g** | **Biological yield, t/ha** |
| **Factor A** | **Factor B** | **A1** | **B1** | 1.69 | 12.6 | 0.49 | 38.9 | 0.83 |
| | **B2** | 2.10 | 14.6 | 0.57 | 39.0 | 1.20 |
| | **B3** | 2.11 | 15.0 | 0.60 | 41.0 | 1.26 |
| | **B4** | 2.13 | 17.3 | 0.75 | 43.3 | 1.60 |
| **A2** | **B1** | 1.78 | 14.3 | 0.56 | 39.1 | 1.00 |
| | **B2** | 2.06 | 16.0 | 0.63 | 39.3 | 1.30 |
### Experience variants

| Factor A | Factor B | Number of plants, million pcs/ha | Number of grains per ear, pcs | Weight of grain per ear, g | Weight of 1000 grains, g | Biological yield, t/ha |
|----------|----------|----------------------------------|------------------------------|---------------------------|-------------------------|-----------------------|
| B₃       |          | 2.07                             | 16.9                         | 0.68                      | 40.5                    | 1.40                  |
| B₄       |          | 2.09                             | 18.3                         | 0.87                      | 47.5                    | 1.82                  |

By the weight of 1000 grains, the number and weight of grains from the ear, this variant exceeds the control by 9.6, 5.7 and 16.0%, respectively. Here, the maximum biological yield of barley was obtained – 1.82 t/ha, which is 0.22 t/ha higher than the similar variant on the treatment taken as control, and 0.99 t/ha higher than the variant without fertilizers.

Crop accounting showed that the use of microbiological fertilizers twice in terms of mineral background contributed to an increase in the productivity of spring barley (Table 5). So, in 2016, against the background of flat-cutting processing to a depth of 0.20-0.22 m with double application of "Azotovit" and "Phosphatovit", the yield of barley was 1.75 t/ha, which is higher than the control for plowing to a similar depth by 1.0 t/ha. The same pattern was observed in 2017. But, in the wetter 2017, the yield of spring barley was 10-15% higher.

| Table 5. Yield of barley grain, t/ha. |
|-------------------------------------|
| Experience variants | Years | 2016 | 2017 | average |
| Factor A | Factor B |       |      |         |
| A₁       | B₁      | 0.75  | 0.84 | 0.80    |
|          | B₂      | 1.09  | 1.13 | 1.11    |
|          | B₃      | 1.35  | 1.44 | 1.40    |
|          | B₄      | 1.49  | 1.55 | 1.52    |
|          | B₁      | 0.90  | 0.94 | 0.92    |
|          | B₂      | 1.20  | 1.24 | 1.22    |
|          | B₃      | 1.50  | 1.65 | 1.58    |
|          | B₄      | 1.75  | 1.81 | 1.78    |
| LSD₉₅ A |          | 0.021 | 0.022 |
| LSD₉₅ B |          | 0.032 | 0.027 |
| LSD₉₅ AB|          | 0.033 | 0.027 |
| LSD₉₅ total|      | 0.051 | 0.034 |

On average, for two years, the maximum yield of barley was formed with the double application of "Azotovit" and "Phosphatovit" by flat-cutting tillage by 0.20-0.22 m and amounted to 1.78 t/ha, which exceeds the control by 44.9%.

The economic assessment was carried out on the basis of operational calculations of direct costs according to technological maps of cultivation of experimental crops and standard production standards and prevailing prices for consumed material and technical resources and sales prices of the received products [12] (Table 6).

From the data given in the table, it can be seen that the most cost-effective options are with double application of bacterial fertilizers against the background of flat-cut tillage at 0.20-0.22 m. The cost of 1 ton of grain on this variant was equal to 3607 rubles, which is lower than the control variant on plowing to a depth of 0.20-0.22 m by 3886 rubles.

From the data shown in the Table 6, it can be seen that the most cost-effective variants are with double application of bacterial fertilizers against the background of flat-cutting tillage at 0.20-0.22 m.
The cost of 1 ton of grain on this variant was equal to 3607 rubles, which is lower than the control variant on plowing to a depth of 0.20-0.22 m by 3886 rubles.

The level of estimated profit on this option is 2892.7 rubles, which is higher than the control by 617.0 rubles.

The maximum level of profitability 80.2% was marked on the A₂B₄ variant, which is 26.3% higher than the similar variant on the control.

| Indicators                          | Variants | A₁          | A₂          |
|-------------------------------------|----------|-------------|-------------|
| Yield, t/ha                         | B₁  | 0.8          | 1.11         |
| Cost of funds per 1 ha, RUB         | B₂  | 5994         | 6345         |
| Labor costs per 1 ha, person/hour   | B₃  | 5994         | 6345         |
| Sale price, RUB                     | B₄  | 6400         | 6421         |
| Cost of 1 ton, RUB                  | B₁  | 6421         | 6732         |
| Cost recovery of 1 ton, RUB         | B₂  | 6322         | 6389         |
| Labor intensity of 1 ton, person/hour | B₃  | 6500         | 6500         |
| Estimated profit on:                | B₄  | 6500         | 6500         |
| 1 ton, RUB                          | -1240.6 | 1377.6       | 1497.1       |
| 1 hectare, RUB                      | -992.5  | 1928.6       | 2275.7       |
| 1 person/hour, RUB                  | -164.0  | 271.2        | 313.5        |
| 1 RUB of costs                      | -0.1    | 0.4          | 0.5          |
| Profitability level, %              | -13.2   | 42.2         | 53.9         |

4. Conclusion
The results of the conducted studies have shown that the use of bacterial fertilizers on a mineral background in combination with flat-cutting processing to a depth of 0.20-0.22 m increases the content of azotobacter to 98.3%.

The analysis of microbiological processes showed the advantage of binary interaction of flat-cutting processing to a depth of 0.20-0.22 m and double application of bacterial fertilizers on a mineral background. The loss of fiber in this variant was 44.4%, which is 8.6% higher than the same variant in the control.

By the weight of 1000 seeds, the number and weight of grains from the ear, this option exceeds the control by 9.6, 5.7 and 16.0%, respectively.

The use of microbiological fertilizers twice in terms of mineral background contributed to an increase in the productivity of spring barley to 1.78 t/ha.
Economic indicators make it possible to recommend the use of flat-cutting processing to a depth of 0.20-0.22 m with double application of bacterial fertilizers "Azotovit" and "Phosphatovit" in the phases of 1-2 leaves and tillering.

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