Microbial preparations in the cultivation of grain crops in the Priobskaya zone of the Altai region

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Abstract. The article examines the action of biologics of associative nitrogen-fixing bacteria for non-leguminous crops in spring soft and durum wheat and spring barley crops in the steppe zone of the Altai Priobye. The positive effect of biological products in all years of research is established. In different years, the increase in yield of different varieties of wheat from inoculation with monopreparations amounted to 8.0-53.5%, with a minimum tillage of 68.0-89.7%. In drought conditions and in the context of yield reduction, the effect of drugs was higher than in a moister period. The drugs effectiveness increased with mineral fertilizers (a dose of N30P60K60) and mycorrhiza.

1. Introduction
According to I. A. Tikhonovich, and A. A. Zavalin, “To preserve soil fertility and prevent the most dangerous forms of its degradation, an environmentally safe direction of land use is envisaged, based on the need for the maximum possible approach of agriculture to natural analogs…” [1]. In recent decades, microbiological preparations based on rhizosphere bacteria have been developed in Russia. They are distinguished by high physiological activity and have positively proven themselves both in Russia and abroad [2, 7].

Long-term trials of drugs show their high efficiency in a variety of cultures in different soil and climatic zones. Productivity increases on average by 20-40% or more. Being inoculated with preparations, it is comparable or often even exceeds the yield with a full mineral fertilizer NPK with a dose of active substances 60 kg/ha [3, 4, 5].

In Siberia and Altai Region, grain crops occupy more than half of the arable land. However, their potential is not fully realized. Therefore, increasing crop yields (such as wheat and barley) is an important public task. This problem should be solved by applying contemporary achievements of science based on the widespread introduction of qualitatively new technologies using environmentally friendly biological preparations [3, 4, 5, 6, 7].

The purpose of this study is to evaluate the effectiveness of microbial preparations on cereals in the Priobskaya zone of the Altai Region within the framework of the Geographic Test Network.

2. Materials and Methods
Studies have been carried out in small-scale experiments on the training and experimental field of the Altai State Agrarian University since 2000. And also, research was carried out in industrial crops in farms of the region. Years of research were characterized as insufficiently moist (2001, 2007, 2008, 2009, 2012, 2014, 2015), wetted (2016, 2017), and dry (2000, 2010, 2011, 2013).
The predominant soil of the zone is leached chernozem, which is characterized by low humus content of about 5%, pH close to neutral, with a sufficient content of mobile compounds of phosphorus and potassium and low nitrogen.

Over the years, we studied the effect of associative nitrogen-fixing bacteria: Bioplant-K (contains a culture of bacteria Klebsiella planticola), Mobilin (Klebsiella mobile), Mizorin (Arthrobacter mysorens, strain 7), Rizoagrin (Agrobacterium radiobacter, strain 204), Flavobacterin (Flavobacterium sp., strain 30), Azorizin (Azospirillum lipoferum), strain Ya-2 (Corinebacterium freneyi), as well as the mycorrhiza preparation (contains fungus Glomus intraradices, strain 8). In the experiments, we used varieties of spring soft and durum wheat and spring barley, as highly recommended for the zone. Studies were performed according to generally accepted methods in crop production [2, 8, 9].

3. Results
Inoculation of seeds of cereal crops with preparations of rhizosphere diazotrophs helps to stimulate seed germination, increase root biomass, increase the supply of nutrients to the root system, increase growth and, consequently, plant productivity [3, 4, 5, 10].

The results of the 2000-2001 experiment are presented in Table 1. On average, the yield of the spring soft wheat variety Tselinnaya 60 was significantly increased from the use of preparations of diazotrophic bacteria. A less significant effect was obtained from seed inoculation with Rizoagrin (19.2%). And the greatest responsiveness was noted for Agrofil and Mizorin preparations – 32.2 and 34.4%, respectively.

The results of studying the effect of biopreparations on the yield of spring soft wheat varieties Altayskaya 530 and Altayskaya 325 in 2007–2008 showed that inoculation also increased the yield of wheat of both varieties in both years of research. On average, over two years, Rizoagrin was more effective (Table 1).

Table 1. Productivity of spring wheat in the years of research.

| Option       | Tselinnaya 60 variety, average 2000-2001 | Altayskaya 530 variety, average 2007-2008 | Altayskaya 325 variety, average 2007-2008 |
|--------------|----------------------------------------|------------------------------------------|------------------------------------------|
|              | t/ha | increase | t/ha | increase | t/ha | increase |
| Control      | 0.84 | -        | 2.42 | -        | 2.45 | -        |
| Agrofil      | 1.11 | 0.27     | 32.2 | -        | -    | -        |
| Mizorin      | 1.13 | 0.29     | 34.4 | -        | -    | -        |
| Rizoagrin    | 1.00 | 0.16     | 19.2 | 2.80     | 0.38 | 15.7     |
| Flavobacterin| 1.05 | 0.21     | 24.8 | 2.74     | 0.32 | 13.2     |
| Azorizin     | -    | -        | -    | 2.75     | 0.33 | 13.6     |
| HCP_95       | 0.15 | 0.19     | 0.11 |          |      |          |

The Altayskaya 325 variety responded more actively to the processing. In this variety, the reaction to inoculation was higher by 2.7-7.2% than in the Altayskaya variety 530.

In 2009, 2010, and 2012, the test of Bioplant-K biopreparation on spring soft wheat varieties Omskaya 36, Altayskaya 100, and Altayskaya 105 was performed (Table 2). Bacterization of wheat seeds Omskaya 36 with Bioplant-K has contributed to a significant increase in its yield throughout the years of research. Despite the low level of yield in 2010 and 2012 dry years, the increase in inoculation was higher than in humid 2009 and amounted to 73-83%. A slightly smaller gain from the inoculation with Bioplant-K was obtained on wheat varieties Altayskaya 100 and Altayskaya 105 (Table 2). In 2009, it was 10.9-12.3%, but already 53.5-21.6% in 2010. Higher increases were obtained with the use of mineral fertilizers N₂O₃P₂O₅K₆₀. On average, they amounted to 61.4-24.5% over 2 years. At the same time, they were higher than on the background.
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Table 2. Productivity of spring wheat in the years of research.

| Option                  | Altayskaya 100 variety, average 2009-2010 | Altayskaya 105 variety, average 2009-2010 | Omskaya 36 variety, average 2009, 2010 and 2012 |
|-------------------------|------------------------------------------|------------------------------------------|------------------------------------------------|
|                         | t/ha                                     | increase t/ha %                          | t/ha                                         |
| Control                 | 2.64                                     | -                                        | 3.83                                         |
| Bioplan-K               | 3.36                                     | 0.72                                     | 27.3                                         |
| N30P80K40-background     | 3.18                                     | 0.54                                     | 20.5                                         |
| Background + Bioplan    | 4.26                                     | 1.62                                     | 61.4                                         |
| HCP95                   | -                                        | 0.34                                     | -                                            |

In 2011-2013, we tested the effect of the preparations Mizorin, Rizoagrin, and Flavobakterin on two varieties of durum wheat, namely Altaysky yantar and Aleyskaya (Table 3). Bacterization with biological preparations contributed to an increase in the yield of both varieties. Inoculation provided an increase in the Aleyskaya variety yield on average by 8.8-30.9 over 3 years, while inoculation provided an increase in yield by 28.4-43.9% in the Altaysky yantar variety. The maximum effect was obtained from the drug Flavobakterin and a triple combination of drugs.

Table 3. Productivity of spring durum wheat, on average in 2011-2013.

| Option                        | Aleyskaya variety | Altaysky yantar variety |
|-------------------------------|-------------------|-------------------------|
|                              | t/ha have         | increase t/ha %         | t/ha                                       |
| Control                       | 1.81              | 2.23                    |
| Mizorin                       | 2.23              | 2.19                    | 0.42                                     |
| Rizoagrin                     | 1.97              | 2.04                    | 0.16                                     |
| Flavobacterin                | 2.37              | 2.11                    | 0.56                                     |
| Mizorin + rizoagrin + flavobacterin | 2.27        | 2.13                    | 0.46                                     |
| HCP95                         | 0.21              | 0.18                    |

In the experiment conducted in 2015-2017 on spring wheat varieties Stepnaya volna and spring barley varieties Signal, the highest yields were obtained on binary mixtures of Mobilin and strain Ya-2 with mycorrhiza (Table 4). The yield of wheat on the mixture of Mobilin and Mycorrhiza preparations exceeded control by an average of 58.1%; it was by 63.3% after combining strain Ya-2 with Mycorrhiza, amounting to 3.32 and 3.43 t / ha, respectively. On spring barley, a greater effect in the binary combination turned out to be on a mixture of Mobilin and Mycorrhiza (33.2%). When mono-using on wheat, the drug Mobilin was more effective, and on barley was strain Ya-2.

Table 4. Productivity of spring wheat and spring barley, on average in 2015-2017.

| Option                  | Wheat Stepnaya volna variety | Barley Signal variety |
|-------------------------|-----------------------------|-----------------------|
|                         | yield, t/ha                 | increase t/ha %       | yield, t/ha | increase t/ha % |
| Control                 | 2.10                        | -                     | 2.17        | -              |
| Mobilin                 | 2.66                        | 0.56                  | 2.36        | 0.19          | 8.8 |
| Strain Ya-2            | 2.47                        | 0.37                  | 2.84        | 0.67          | 30.9 |
| Mycorrhiza             | 2.24                        | 0.14                  | 2.27        | 0.10          | 4.6  |
| Mobilin + mycorrhiza   | 3.32                        | 1.22                  | 2.89        | 0.72          | 33.2 |
| Strain Ya-2 + mycorrhiza | 3.43                      | 1.33                  | 2.80        | 0.63          | 29.0 |
| HCP95                  | -                           | 0.12                  | -           | 0.26          | -   |
In the experiment conducted under production conditions in the Aley region in the “Mashchensky” farm, a significant increase in the yield of Altayskaya wheat 530 from inoculation with biological preparations is also shown (Table 5).

Table 5. Wheat yield, Altayskaya 530 variety with minimum tillage at the “Mashchensky” farm in Aley district, 2016-2017.

| Option    | Yield, t/ha | Yield, average 2016-2017, t/ha | Increase |
|-----------|-------------|---------------------------------|----------|
|           | 2016 | 2017 | t/ha | % |
| Control   | 0.88 | 1.06 | 0.97 | - | - |
| Rizoagrin | 1.78 | 1.69 | 1.73 | 0.76 | 78.3 |
| Flavobacterin | 1.53 | 1.73 | 1.63 | 0.66 | 68.0 |
| Mizorin   | 1.83 | 1.84 | 1.84 | 0.87 | 89.7 |
| HCP<sub>56</sub> | 0.16 | 0.19 | - | 0.17 | - |

On average, the yield without using drugs was 0.97 t/ha over 2 years and 1.63-1.84 t/ha for biological products, providing an increase of 68.0-89.7%. The drug Mizorin proved to be a more effective drug in these conditions.

Calculating economic efficiency shows that the use of drugs of associative bacteria on grain crops in the Priobskaya zone of the Altai Region is quite profitable. On average, compared to the control, the cost of production of spring soft wheat is reduced by 71.4-1482.2 rubles/ha, and by 104.4-445.4 rubles/ha in spring barley. More than that, the level of profitability of wheat increases by 2.8-86.1% and of barley by 19-84%, respectively.

4. Discussion
In our experiments, the response of wheat plants to inoculation with biological products in different years was slightly different, but the yield on inoculated variants exceeded the control level. The effectiveness of binary combinations of associative rhizosphere bacteria with the Mycorrhiza mushroom preparation is far superior to the effects of monodrugs. Such a productive symbiosis is due to their different mechanism of action on plants, which in sum better provides plants with nutrients, growth stimulants, and fungicidal metabolites, as was already reported in the works of I. A. Tikhonovich and A. A. Zavalin [1, 10], as well as by other authors [7].

The level of grain yield increase depends on agrotechnical methods and soil and climatic conditions; however, biologics help plants to cope with stressful conditions (drought, waterlogging, sudden temperature drops), developing directly in the root zone. High gains with minimal tillage are obtained through the activity of microorganisms in the composition of drugs. In the untreated soils, microbiological activity is strongly suppressed, plants lack many nutrients and nitrogen, especially which reduces the yield. Diazotrophic microorganisms not only provide plants with nitrogen, but they also stimulate the activity of beneficial soil microflora, which mineralizes organic matter and improves plant nutrition.

5. Conclusion
The research conducted allows to make the following conclusions:

1. Studying the effect of biopreparations of root diazotrophs in spring soft and durum wheat crops in different weather conditions in the steppe zone of the Altai Territory showed their rather high efficiency. The increase in wheat yield from inoculation in different years was 8.0-53.5%, and 68.0-89.7% with minimal processing.

2. The plant response to inoculation was very dependent on the variety and weather conditions. In drought conditions, the effect of the action of the drugs was higher than in a moister period.

3. With the mineral fertilizers and Mycorrhiza, the drug effectiveness increases. The effect of drugs on yield is slightly higher than the effect of mineral fertilizers in a dose of N<sub>30</sub>P<sub>60</sub>K<sub>60</sub>. 
4. The economic effect from using biological preparations of root diazotrophs is on average from 100 to 800 rubles/ha.

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