Biological preparations based on strains of associative bacteria in the cultivation of oats in central Yakutia

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Abstract. The research was conducted in the Republic of Sakha (Yakutia) from 2015 to 2020. Cryogenic-taiga-leached soils with low humus content are common in Central Yakutia. The use of biological products of associative bacteria is an environmentally friendly way to increase crop yields and improve soil fertility. The effect of pre-sowing inoculation of oat seeds with various biological preparations of associative bacteria: Mizorin, Agrophile, Rizoagrin, Mobilin, Flavobacterin was studied.As a control, a variant without inoculation was investigated. The responsiveness of the culture to the use of biological preparations was noted: inoculation of seeds contributed to the formation of oat grain yield. In the experimental variants, a significant increase in the yield of oat grain was noted — up to 2 t/ha in the variant with the use of the preparation mobilin. Inoculation of oat seeds by strains of associative bacteria affected the biochemical composition of oats. The largest number of grains was formed in the mobilin variant – 58 pcs., in the control variant – 51 pcs. In comparison with the variant without inoculation, the humus content in the arable layer of cryogenic-taiga-leached soil in the variant with mizorin is 3.20%, and with the Yakut strain No. 1 - 3.00% (in the control variant – 2.87%). Thus, the use of the studied biological products based on strains of associative bacteria had a positive effect on both the growth and development of plants and the yield of oat grain.

1 Introduction

Many scientific studies, including foreign ones, have proved the beneficial effect of associative nitrogen-fixing bacteria on the productivity of agricultural crops. Strains of associative bacteria propagated in special substrates have been isolated and used in production. In Russia, the Institute of Agricultural Microbiology (St. Petersburg) has a collection of production strains of associative bacteria, new breeding numbers are being created for use in agricultural production.

The rational use of bacterial preparations makes it possible, with a lower consumption of nitrogen fertilizers, to significantly increase the productivity and quality of products of the most important agricultural crops. At the same time, the chemical load on the soil decreases

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and its biological activity increases. In the composition of biopreparations, bacteria more actively fix atmospheric nitrogen, as well as enhance its absorption from mineral fertilizers and soil, stimulate the growth and development of plants, thereby accelerating the ripening of the crop. Bacteria contribute to the optimal use of mineral and organic fertilizers. In addition, free-living bacteria protect plant roots from the penetration of pathogenic microflora.

Any bacterial preparation is based on a strain. A strain (German "stamm" – stem, base, family) is a pure culture of bacteria with stable signs. Different strains of the same type of bacteria may differ in physiological and biochemical properties, nitrogen fixation intensity, virulence.

One of the ways to restore and increase soil fertility, increase the yield of agricultural crops: cabbage, oats and obtain environmentally friendly products is the use of biological bacterial preparations in the soil. As such preparations, it is possible to use strains based on rhizobacteria for crops that have useful properties, especially at the first stages of plant development. These microbial preparations are capable of performing a number of functions: microorganisms, which are the basis of biological products, interact closely with plants and are able to perform a number of functions useful for plants: enhance the fixation of atmospheric nitrogen on plant roots, the size of which is equivalent to the introduction of 25-49 kg/ha of mineral nitrogen fertilizers; stimulate the growth and development of plants by producing physiologically active substances (accelerating the maturation of products for 10-15 days); inhibit the development of phytopathogenic microorganisms, reducing the incidence of plant diseases by 1.5 – 10 times, while improving the phytosanitary situation in the soil; strengthen the resistance of plants to adverse conditions (drought, frost, increased salt content, adverse reaction of soil solution); increase the utilization rate of mineral fertilizers and nutrients from the soil; regulate the accumulation of heavy metals, nitrates and other harmful compounds in plants.

The scientific novelty lies in increasing the yield of oats using pre-sowing inoculation with strains of nitrogen-fixing rhizobacteria in Central Yakutia.

Nitrogen-fixing activity is an important indicator for agricultural crops. They are able to actively assimilate molecular nitrogen of the atmosphere that is difficult to reach for other plants and contribute to increasing their yield and nutritional value, significantly improving soil fertility, thereby reducing pollution with environmentally hazardous nitrogen compounds.

Thus, the study of new environmentally safe biological preparations to increase the productivity of agricultural crops, improve soil fertility, including through the use of free nitrogen fixation is an urgent, scientifically significant problem.

In this regard, the aim of the research is to study the effect of pre-sowing inoculation with biological preparations of seeds based on rhizobacteria on oat yield and soil fertility.

2 Research methodology

Field experiments were laid at the scientific station of the Yakut Agricultural Research Institute. The isolation of soil microorganisms was carried out according to the methodological recommendations of the All-Russian Research Institute of Agricultural Microbiology (Khotyanovich, 1991).

Control – without inoculation. Records and observations were carried out according to the methods and recommendations of the All-Union Research Institute of Plant Breeding (VIR), All-Russian Research Institute of Agricultural Microbiology (VNIISHM).

Laboratory studies were carried out on the basis of agroecology and biochemistry laboratories existing at the Institute using the Spectra Star 2200 infrared analyzer. Mathematical data processing is carried out according to B.A. Dospekhov "Methodology of

field experience" (1985) [1]. Technology of application of biological preparations in crop production according to the methodology of the All-Russian Research Institute of Agricultural Meteorology "Methodology for evaluating the effectiveness of the use of microorganisms to enhance plant productivity" (2012) [6]. Economic efficiency is calculated according to the methodological recommendations "On determining the overall economic effect of using the results of research and development work in the agro-industrial complex" (2007) [4].

Scheme of the experiment: To study the effect of associative rhizobacteria on the yield of oats of the Pokrovsky variety. The variety has been recognized in the Republic of Sakha (Yakutia) since 1982.

Experiment variants:

1. Control without inoculation;
2. Agrophile
3. Mizorin
4. Yakut No. 1

The plot area is 25 m2, the repetition is fourfold, 8x15 cm, 0.012 m2 The seeding rate of oat seeds is 4 million of germinating seeds per hectare, the method of sowing is row-crop planting with row spacing of 15 cm. The total area of the experiment is 1600 m2. Sowing was carried out with a manual seeding machine "Senior", treated with a biological preparation before sowing with a rate of consumption of the drug 200 g per hectare of seeds. The oats were harvested by the SampoRosenlew 130 combine harvester.

In 2015, the research was conducted in Khangalassky ulus, on the II above-floodplain terrace of the middle Lena River at the field station of the Laboratory of Potato Growing and Agroecology of the Yakut Agricultural Research Institute.

Experiment 1. To study the effect of associative rhizobacteria on the yield of oats of the Pokrovsky variety. The variety has been recognized in the Republic of Sakha (Yakutia) since 1982.

Experiment variants:

1. Control without inoculation;
2. Rhizoagrin
3. Mobilin
4. Flavobacterin

The object of research is the Pokrovsky variety of oats zoned in the Republic of Sakha (Yakutia). Bacterial preparations (Rhizoagrin, Flavobacterin and Mizorin) were provided by the Laboratory of Ecology of Soil Microorganisms of the All-Russian Research Institute of Agricultural Microbiology (St. Petersburg, Pushkin).

The Pokrovsky oat variety was bred by the Yakut Agricultural Research Institute. The variety is mid-season. The growing season is 62-65 days. Resistant to shedding and lodging, leveled for maturation. Post-harvest germination is 86 - 99%.The yield is 23-37 kg/ha.

The research is carried out in Khangalassky ulus, on the II above-floodplain terrace of the middle course of the Lena River at the field station of the Laboratory of Agroecology of the Yakut Agricultural Research Institute.

According to the morphological description, the soil of the experimental site is cryogenic-taiga-leached. Before establishing the experiments, the humus content in the arable horizon, on average, was 2.84%. The content of nitrate nitrogen in the range of 0.10-0.17 mg per 100 g of soil, total nitrogen 0.51%-0.56%. Reaction of soil medium is pH water 8.56-8.88, pH salt 7.6-7.9. The phosphorus content is 217.8 mg/kg, potassium – 255.8 mg/kg.

The object of research is the Pokrovsky variety of oats zoned in the Republic of Sakha (Yakutia). Bacterial preparations (agrophile and mizorin) were provided by the Laboratory of Ecology of Symbiotic and Associative Rhizobacteria of the All-Russian Research Institute of Agricultural Microbiology (St. Petersburg).

Agrophile (in the figures – A) is an environmentally friendly preparation based on soil microorganisms *Agrobacterium radiobacter*, intended to preserve soil fertility, increase yields and improve the quality of crops.

Mizorin (in the figures – M) is a new environmentally safe biological product of complex action to increase the yield and improve the quality of products of fodder crops (perennial grasses), spring wheat, sunflower, potatoes, increases the effectiveness of inoculants of leguminous crops when used together. The strain of bacteria *Arthrobachtermysorens*, which is part of the preparation, has a wide spectrum of action on almost all groups of crops.

Yakut No. 1 Sinorhizobiummeliloti - For the first time in permafrost soils of Central Yakutia in 1999, a local strain of nodule bacteria Yakut No. 1 of the Yakut yellow alfalfa variety was isolated. Patent for invention No. 2299188 was obtained, registered in the State Register of Inventions of the Russian Federation on May 20, 2007. An environmentally safe biological product based on Sinorhizobiummeliloti bacteria to increase yields and improve the quality of agricultural products. Intended for pre-sowing treatment of leguminous seeds. The preparation (at the rate of 300-400 g per hectare of seeds) is diluted in clean water at the rate of 5-10 liters per ton of seeds and, without allowing the suspension to settle, it is applied to the seeds, which are then mixed until the preparation is evenly distributed. Treated seeds should be sown on the same day in moist soil, they should be protected from direct sunlight.

Flavobacterin is intended for the treatment of seed material and during the growing season of plants such as beets, rapeseed, potatoes, wheat.

Increases the yield of fodder crops by 18-35%, cereals by 12-15%. Improves product quality by increasing the sugar content by 1 -1.5, protein by 0.5 – 1.2%. Stimulates the growth and development of plants by producing physiologically active substances. Reduces the development of diseases such as root rot, anthracnose, powdery mildew, late blight, scab. Allows to get environmentally friendly products.

Rhizoagrin is intended for pre-sowing treatment of seeds of cereals wheat, oats, rye, barley. The biopreparation is based on a strain of associative bacteria (agrobacterium radiobacter). Bacteria populate the root zone of plants, secrete growth stimulating substances. Increases grain yields by 3-6 kg/ha. Increases the content of raw protein in grain by 0.5 – 1%.

Mobilin is intended for pre-sowing treatment of seeds and seedlings of agricultural crops. It is of great importance when treating plants during the growing season. Bacterial preparation created on the basis of Pseudomonossp strains. PG-5 belonging to the genus Azospirillum. Rhizospheric bacteria inhabit the root zone of plants (rhizosphere) and the surface of the roots, displace pathogenic bacteria, depriving them of space and food. Growth-stimulating substances and vitamins are isolated for plants. Additionally, plants are fed with water, nitrogen, potassium and other nutrients, transferring them from hard-to-reach forms.

The treatment of the seed material with a biopreparation is carried out on the day of sowing. Preparation of suspension for seed treatment: 200 g of a solid or 200 ml of a liquid preparation is diluted in 1 liter of water and thoroughly mixed.

3 Research results

Studies on the selection of the best strains of associative rhizobacteria and the study of their effect on oat yield have been started in the soil and climatic conditions of the Khangalassky ulus since 2013.

The establishment of reconnaissance experiment on the use of rhizobacteria inoculation on oat crops for grain fodder was carried out. For 2 years, on average, the best variants, when inoculated with rhizobacteria of oats, gave a significant increase in grain yield (Table 3). It follows from the data that the increase in yield was obtained due to pre-sowing inoculation with strains 7 (Mizorin), 10 (Agrophile) and Yakut No. 1 - on average from 9 to 13%.

Table 1. Effect of associative bacterial strains on oat yield, t/ha.

Strains	Grain yield	Increase in yield	
		+ - to control	%
2013 - 2014			
Monitoring	1.5	-	-
Agrophile	1.7	+0.2	9%
Mizorin	1.9	+0.4	13%
Yakut No. 1	1.9	+0.4	13%
$LSD_{0.5}$	0.4		
	2015		
Monitoring	1.4	-	-
Rhizoagrin	1.5	+0.1	7%
Mobilin	2.0	+0.6	42%
Flavobacterin	1.8	+0.2	11%
LSD 0.5	0.35		

Thus, according to 2013-2014 data, inoculation with rhizobacteria strains after their use has a positive effect on oat yield.

All variants, when inoculated with rhizobacteria of oats, gave a significant increase in grain yield. It follows from the data that the increase in yield was obtained due to pre-sowing inoculation with the strains of Mobilin, Rhizoagrin, Flavobacterin - on average from 7 to 42%.

Thus, according to 2015 data, inoculation with rhizobacteria strains after their application has a positive effect on oat yield.

Pre-sowing inoculation has a positive effect on the biochemical composition of plants (Table 4). Inoculation with Yakut strain No. 1 contributed to an increase in the content of crude protein in grain by 0.6% (in the control variant – 20.3%), a decrease in crude fiber by 0.2% (in the control variant – 14.0%), the content of the remaining elements is within the zootechnical norm. Thus, according to the data of the growing season 2013 - 2014, when inoculated with nitrogen-fixing bacteria, oats have a beneficial effect on improving the quality of oats. Pre-sowing inoculation in 2015 has a positive effect on the biochemical composition of oats. Flavobacterin inoculation contributed to an increase in the content of crude protein in grain by 0.54% (in the control variant – 19.31%), a decrease in crude fiber by 0.16% (in the control variant – 12.88%), the content of the remaining elements is within the zootechnical norm. Thus, according to the data of the growing season of 2015, when inoculated with associative rhizobacteria, oats favorably affect the improvement of grain quality.

Table 2. The effect of rhizobacteria on the quality of oats.

Strains	Crude protein	Crude fat	Crude fiber	Crude ash	Nitrogen-free extractive substance
2013 - 2014					
Control without inoculation	20.3	6.5	14.0	2.6	56.6
Agrophile	20.2	6.6	14.1	2.6	56.5
Mizorin	20.4	6.1	14.0	2.7	56.8
Yakut No. 1	20.9	6.0	13.8	2.6	57.1
2015					
Control without inoculation	19.31	5.7	12.88	2.60	59.51
Rhizoagrin	18.94	5.7	12.92	2.49	59.95
Mobilin	19.41	6.4	12.76	2.52	58.91
Flavobacterin	19.85	5.7	12.72	2.65	59.08

Pre-sowing inoculation of seeds with associative rhizobacteria affects the growth indicators of oats (Table 5). We have studied the effect of bacterial preparations on such growth indicators of oats as plant height, number of internodes, number of grains, weight of roots, leaves, inflorescences, straw. The data show that pre-sowing inoculation of oat seeds contributed to increased plant growth in height (up to 6.25%), an increase in the amount of grain (up to 13%), the number of internodes (up to 25%). Also, an increase in the mass of roots (up to 43%), leaves (up to 30%), inflorescences (up to 19%), straw (up to 60%).

Thus, in the field experiment, we noted the responsiveness of oats to inoculation with rhizobacteria strains. Pre-sowing inoculation of oat seeds contributed to the strengthening of growth indicators and the accumulation of plant biomass. The most effective preparations were Mizorin and Flavobacterin.

Table 3. Influence of associative rhizobacteria on oat growth indicators.

No.	Variants	height, cm	Number of grains	Number of m/nodes, pcs	Weight, g			
					root	leaves	inflorescence	straw
1	Monitoring	96	51	4	16.0	26.0	57.0	25.0
2	Flavobacterin	101	54	5	17.0	29.0	58.0	34.0
3	Mobilin	102	58	5	23.0	34.0	68.0	40.0
4	Rhizoagrin	94	48	4	19.0	27.0	60.0	30.0

To study the effect of pre-sowing inoculation on the agrochemical composition of the soil on oat crops, soil samples were taken (Table 6).

In comparison with the variant without inoculation, the humus content in the arable layer of cryogenic-taiga-leached soil in the variant with mizorin is 0.33% higher, and with the Yakut strain No. 1 by 0.13% (in the control variant – 2.87%), the content of mobile potassium is 53 mg/kg higher than the control variant. (LSD05 – 0.19). The humus content in the soil before sowing oats is 2.68%. Comparison of data on the agrochemical composition of the soil before sowing oats, the humus content with the mizorin variant increased by 0.33%, with the Yakut strain No. 1 by 0.13%.

Table 4. The effect of nitrogen-fixing rhizobacteria on the agrochemical composition of cryogenic-taiga-leached soil.

Strains	Horizons	Humus,%	pH water	pH salt	Phosphorus, mg/kg	Potassium, mg/kg
before sowing	0-30	2.68	8.61	7.91	217	231
monitoring	0-30	2.87	9.00	7.79	221	247
agrophile	0-30	2.99	9.49	8.48	223	300
Mizorin	0-30	3.20	8.90	7.70	220	253
Yakut No. 1	0-30	3.00	8.90	7.70	219	248
LSD_{05}		0.19				

Thus, according to preliminary data, pre-sowing inoculation with nitrogen-fixing bacteria of oats has a positive effect on the accumulation of humus in permafrost soils.

4 Conclusion

In the conditions of cryogenic-taiga-leached soils of Central Yakutia, the use of nitrogen-fixing bacteria helps to increase the yield of grain crops, improve the quality of grain fodder,

reduce the cost of vegetable protein production and increase the humus content in the arable soil layer.

Pre-sowing inoculation with associative rhizobacteria of grain crops in the conditions of Central Yakutia positively affected the productivity of Pokrovsky oats.

6 biological preparations based on nitrogen-fixing bacteria strains were tested.

On the crops of oats of the Pokrovsky variety, it positively affected the main indicators:
- the increase in oat yield from control without inoculation is 13% - 42%;
- when inoculated with Yakut No. 1 and Flavobacterin, the quality of oat grain improves by 3%;
- the humus content in cryogenic-taiga-leached soil using Yakut No. 1 and mizorin is 0.13% - 0.33% higher than in the control variant (Control – 2.87%).

References

1. B. A. Dospekhov, *Metodika polevogo opyta* (1985)
2. A. P. Kozhemyakov, L. M. Dorosinskij, Byullyuten' VNIISKHM **34**, 3-6 (1981)
3. A. P. Kozhemyakov, *Osnovnye itogi raboty s nitraginom. Tekhnologiya proizvodstva i effektivnost' primeneniya bakterial'nyh udobrenij* (M., 1982)
4. A. P. Kozhemyakov, Yu. V. Laktionov, T. A. Popova, *Metodika ocenki effektivnosti primeneniya mikroorganizmov, povyshayushchih produktivnost' rastenij* (S –Pb, 2012)
5. A. P. Kozhemyakov, VNIISKHM **59**, 117. (1989)
6. Metodicheskie rekomendacii «Po opredeleniyu obshchego ekonomicheskogo effekta ot ispol'zovaniya rezul'tatov nauchno-issledovatel'skih i opytno – konstruktorskih rabot v APK» (M., 2007)
7. A. A. Zavalin, *Ocenka effektivnosti mikrobnyh preparatov v zemledelii* (RASKHN, M., 2000)
8. A. A. Zavalin, A. P. Kozhemyakov, *Novye tekhnologii proizvodstva i primeneniya biopreparatov kompleksnogo dejstviya* (HIMIZDAT, S-Pb, 2010)
9. A. V. Hotyanovich, *Metody kul'tivirovaniya azotfiksiruyushchih bakterij. Sposoby polucheniya i primeneniya preparatov na ih osnove* (VNIISKHM, Leningrad 1991)
10. M. T. Yakovleva, A. G. Emel'yanova, *Primenenie biologicheskih preparatov na osnove shtammov associativnyh rizobakterij na urozhajnost' lyucerny v usloviyah Central'noj Yakutii* (Yakutsk, 2010)
11. Vliyanie biopreparatov na osnove shtammov associativnyh rizobakterij na produktivnost' ovsa i plodorodie pochv v Central'noj Yakutii tirazh (2019)
12. “Primenenie mikrobnyh preparatov na osnove shtammov associativnyh bakterij na urozhajnost' yarovoj pshenicy v usloviyah Central'noj Yakutii”, in *Mezhdunarodnyj sel'skohozyajstvennyj zhurnal* (2018)