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Efficacy of biological and chemical protection agents in barley cultivation

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Abstract. The study investigated the efficacy of biological and chemical protection agents in barley cultivation. The experiment was performed on leached chernozem soil, with four replications and 0.1 ha plot sizes. The spring barley variety 'Oplot' was sown using an SN-16 seeder at a rate of 4.5 million germinating seeds per hectare. The study compared three treatments: control (no protection agents), biological protection scheme, and chemical protection scheme. Pre-sowing seed treatment with biological and chemical agents reduced spore count on grain by 81.7% and 83.5%, respectively, while increasing laboratory germination rates by 12.3-13.4% compared to the control. Plant survival rates at harvest improved by 15.0% with biological agents and 16.4% with chemical agents. The technological efficacy of the chemical protectant Kolosal PRO, KME was 91.8%, while the biological agent Fitosporin-AS achieved 90.9% efficacy. Results demonstrated that both protection schemes significantly increased barley yield. The biological protection scheme yielded 2.9 t/ha (a 0.5 t/ha increase over the control), while the chemical protection scheme produced 3.1 t/ha (a 0.7 t/ha increase over the control).

1 Introduction

In modern agriculture, great importance is placed on obtaining maximum yields of environmentally friendly products, and as a result, environmentally safe production methods are being increasingly applied. The implementation of measures to protect seeds and plants from phytopathogens allows for reducing their negative impact and significantly increasing crop yields [1,2].

The most common method of protection against harmful organisms is the use of pesticides. However, this method is associated with a number of negative consequences: intensive or improper use of pesticides can lead to environmental pollution and contamination of crop products, as well as the development of resistance in harmful organisms. Moreover, pesticides pose a danger to humans, which requires additional precautionary measures when treating crops [3,4].

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In the context of deteriorating environmental conditions, there is a need to tighten control over the use of pesticides and develop safer plant protection methods. One possible solution to this problem is the application of the biological method based on the use of biopesticides - microbiological preparations created from microorganisms such as bacteria, fungi, and viruses [5]. The advantages of this method include the possibility of completely or partially abandoning the use of chemical protective agents, which helps reduce the pesticide load on agrocenoses, the absence of negative effects on beneficial organisms and humans, and the fact that these preparations only affect the harmful target. Additionally, the level of resistance is significantly lower compared to chemical protective agents [6].

Biological preparations are most widely used in agriculture in the European Union, where their share of use may increase to 50% in the coming years. In Russia, as of 2023, there are about 70 registrant companies, with more than 100 biopesticides registered, accounting for 5% of all pesticides registered in the country. A significant portion of biopesticides registered in the State Catalog of Pesticides and Agrochemicals belongs to the group of insecticides (27% of the total number of biopesticides) and fungicides (23% of the total number of biopesticides) [7].

In the Krasnoyarsk Territory, spring barley is a crop of versatile use: various cereals - pearl barley and pot barley - are prepared from barley grain. Barley grain is an indispensable raw material for the brewing industry. Additionally, it is used for fattening farm animals. Mixed with oats, barley grain is widely used in feeding cattle.

The effectiveness of biological plant protection agents based on different types of microorganisms raises doubts. However, the question of the degree of effectiveness of biological preparations compared to chemical ones has not yet been fully studied.

The aim of the work is to conduct a comparative analysis of the application of biological preparations based on Trichoderma (Trichoderma harzianum subsp. Trigo) and chemical plant protection agents in the cultivation of spring barley variety Oplot in the conditions of the Krasnoyarsk forest-steppe.

2 Materials and methods

The field experiment was conducted at the "Minino" stationary site of the Krasnoyarsk Research Institute of Agriculture (KrasNIISH), Federal Research Center "Krasnoyarsk Science Center of the Siberian Branch of the Russian Academy of Sciences" (FRC KSC SB RAS), located in the Yemelyanovsky District of Krasnoyarsk Krai.

The experimental design included the following treatments:

- Control (no pre-sowing seed treatment).
- Chemical protection scheme: pre-sowing seed treatment, weed, disease, and pest control.
- Biological protection scheme: pre-sowing seed treatment combined with two applications of a biopreparation during the growing season.

In the biological protection scheme, seeds were treated before sowing with Bio Trichoderma, based on Trichoderma harzianum subsp. Trigo, at a dose of 2.0 kg/t. During the tillering and heading stages, plants were treated against foliar and stem diseases with Phytosporin-AS, a preparation based on Trichoderma and Bacillus subtilis, at a dose of 2.0 L/ha. In the chemical protection scheme, crops were treated with a tank mixture of herbicides Balerina Super (active ingredients: 2-ethylhexyl ester of 2,4-D acid, 410 g/L + florasulam, 15 g/L) at a dose of 0.5 L/t and Elastic Extra (active ingredients: fenoxaprop-P-ethyl, 70 g/L + antidote cloquintocet-mexyl, 40 g/L) at a dose of 1.0 L/t. At the heading stage, fungicide Kolosal PRO, KME (active ingredients: propiconazole, 300 g/L + tebuconazole, 200 g/L) was applied at a dose of 0.4 L/ha, along with insecticide Borey Neo, SC (active ingredients: alpha-cypermethrin, 125 g/L; imidacloprid, 100 g/L; and clothianidin, 50 g/L) at a dose of

0.2 L/ha. The soil in the experimental plot was leached chernozem. The experiment was conducted in four replicates with an experimental plot size of 0.1 ha. Soil tillage followed standard practices for the region. Sowing was performed using an SN-16 seeder at a seeding rate of 4.5 million viable seeds per hectare.

The study focused on the spring barley variety Oplot, which is mid-early maturing with a growing period ranging from 68 to 78 days. The weight of 1,000 grains ranged from 41.5 to 56.5 g. The variety demonstrated high resistance to lodging and drought and had a protein content of up to 14.0%. Agrochemical analysis of soil samples from the experimental plots was conducted in accordance with GOST standards: GOST 26213-84 for humus content, GOST 26951-86 for nitrate nitrogen content, and GOST 26204-91 for available phosphorus and potassium compounds.

Pesticide treatments were applied using a Demorol-600 sprayer with a working width of 12 m. Harvesting was carried out using a Sampo-500 combine harvester. Statistical analysis of the obtained data was performed using analysis of variance (ANOVA) with the SNEDECOR statistical software package. Weather conditions during the growing season were characterized by a moisture deficit throughout the entire period. June and August were particularly dry months, with precipitation levels falling below the long-term average by 22.6 mm and 35.0 mm, respectively. Temperatures during the growing season exceeded long-term averages by 1.6–2.4°C.

3 Results and discussion

Pre-sowing treatment of spring barley seeds of the Oplot variety contributed to a reduction in the number of spores on the grain (Table 1). In the control variant (without pre-sowing treatment), the number of spores was 4,250 per grain. Seed treatment with the chemical protectant Het-Trik, SC reduced the number of spores to 700, while treatment of barley seeds with a biological preparation based on Trichoderma (Trichoderma harzianum subsp. Trigo) reduced their number to 775.

Table 1. Phytosanitary examination of spring barley seeds of the Oplot variety after pre-sowing treatment.

Variant	Repetition				Average root damage score	Average number of spores squared	Number of spores per grain
	I	II	III	IV			
Control	0.8	0.5	0.7	0.6	0.65	1.7	4250
Het-Trick, SK	0.01	0.03	0.03	0.04	0.03	0.28	700
Biological product based on Trichoderma harzianum subsp. Trigo	0.04	0.03	0.05	0.06	0.04	0.31	775

Pre-sowing seed treatment of spring barley resulted in increased laboratory germination rates (Table 2). The application of the chemical seed treatment Khet-Trik, SC led to a 13.4% increase in laboratory germination, while the use of a biological preparation resulted in a 12.3% increase compared to the control samples.

Table 2. Laboratory germination rates of spring barley seeds (Oplot variety) depending on pre-sowing treatment, %.

Variant	Repetition				Average, %	Difference, %
	I	II	III	IV		
Control	79.6	82.3	76.8	75.1	78.5	Control
Het-Trick, SK	88.9	91.3	93.4	94.0	91.9	+ 13.4
Biological product based on Trichoderma harzianum subsp. Trigo	90.5	92.2	91.0	89.5	90.8	+ 12.3
HCP_{05}						**4.8**

Treatment of spring barley seeds of the Oplot variety resulted in a significant increase in the biometric parameters of seedlings. Specifically, the length of seedlings increased by 4.2–4.3 cm, while the length of the coleoptile increased by 2.9–3.0 cm compared to the control variant (Table 3). Furthermore, seed treatment had a positive effect on root system development. The number of roots increased by 1.7–1.8 units, the average length of a single root increased by 1.1–1.3 cm, and the sum of root lengths increased by 6.5–6.7 cm compared to the variant without pre-sowing treatment.

Table 3. Effect of pre-sowing treatment of spring barley seeds on biometric parameters of seedlings.

Experiment variant	Sprout length, cm	Coleoptile length, cm	Number of roots, pcs.	Average sum of root lengths, cm	Average length of one root, cm
Control	9.5	3.2	3.6	36.0	5.7
Het-Trick, SK	13.7	6.1	5.4	42.7	7.0
Biological product based on Trichoderma harzianum subsp. Trigo	13.8	6.2	5.3	42.5	6.8
HCP_{05}	**0.57**	**0.75**	**0.47**	**1.51**	**0.96**

The use of both biological and chemical plant protection agents significantly increased the percentage of plant survival by the time of harvest (Table 4). In the control variant (without the application of plant protection agents), the survival rate was 61.9%. The use of chemical agents for protection increased survival by 16.4%, while biological agents increased it by 15.0% compared to the control.

Table 4. Survival rate of spring barley variety Oplot depending on the method of protection.

Experiment variant	Number of plants, pcs/m^2		Survival rate at harvest, %
	in the germination phase	at harvest	
Control	276.9	170.8	61.9
Het-Trick, SK	389.1	304.7	78.3
Biological product based on Trichoderma harzianum subsp. Trigo	372.1	286.0	76.9
HCP_{05}	**19.7**	**11.6**	**4.9**

The assessment of leaf and stem diseases revealed the presence of Septoria leaf blotch (Septoria graminum), spot blotch (Bipolaris sorokiniana Shoemaker), and brown rust (Puccinia recondita f. sp. tritici) in the spring barley crop. The technological efficacy of the chemical seed treatment Kolosal PRO, KME was 91.8%, while the biological preparation Fitosporin-AS demonstrated an efficacy of 90.9%.

Table 5. Results of chemical and biological preparations application for protection against leaf and stem diseases in spring barley crop, variety Oplot.

Plant disease	Number of affected plants, pcs/m^2			Technological efficiency, %	
	Control	Kolosal PRO, KME	Fitosporin-AS	Kolosal PRO, KME	Fitosporin-AS
Septoria leaf spot (Septoria graminum)	14.9	1.1	1.6	92.6	89.3
Helminthosporium leaf spot (Bipolaris sorokiniana Shoemaker)	5.4	0.7	1.1	87.0	79.6
Brown rust (Puccinia recondita f. sp. tritici)	4.0	0.4	0.7	90.0	82.5
TOTAL	24.3	2.0	2.2	91.8	90.9

The yield assessment of the Oplot barley cultivar demonstrated an increase in yield for the experimental variants with plant protection measures (Table 6). The yield in the control variant was 2.4 t/ha. The application of chemical plant protection agents resulted in a yield of 3.1 t/ha, representing an increase of 0.7 t/ha or 22.6% compared to the control. In the experimental variant using biological preparations, a yield of 2.9 t/ha was obtained, showing an increase of 0.5 t/ha or 17.2% compared to the control.

Table 6. Yield of spring barley cultivar Oplot depending on the plant protection method, t/ha.

Experiment variant	Repetition				Average harvest, t/ha	Increase	HCP_{05}
	I	II	III	IV			
Control	2.2	2.6	2.3	2.3	2.4	**Control**	0.45
Chemical method of protection	3.2	3.4	2.8	2.9	3.1	+ 0.7 (22.6 %)	
Biological method of protection	3.1	2.6	2.9	3.0	2.9	+ 0.5 (17.2 %)	

4 Conclusion

The pre-sowing treatment of spring barley seeds using chemical and biological agents significantly reduced the number of spores on the grains to 700 (for the chemical agent) and

775 (for the biological agent). This treatment also improved laboratory germination rates by 12.3% to 13.4% compared to the control group.

Furthermore, the health of the planting material and the reduction of harmful organisms' adverse effects on spring barley plants resulted in an increased survival rate of plants at harvest, with a 16.4% increase for chemical agents and a 15.0% increase for biological agents compared to the control.

The treatment of spring barley crops contributed to a decrease in the number of plants affected by leaf-stem diseases. The technological efficiency of the chemical agent Kolosal PRO, KME was found to be 91.8%, while the biological agent Fitosporin-AS demonstrated an efficiency of 90.9%.

The application of both chemical and biological plant protection schemes led to a statistically significant increase in spring barley yield. In the experimental variant utilizing biological protection methods, the yield reached 2.9 t/ha, representing an increase of 0.5 t/ha or 17.2% over the control. The maximum yield was obtained with chemical plant protection methods, achieving 3.1 t/ha, which is an increase of 0.7 t/ha or 22.6% compared to the control.

The conducted research indicated that chemical plant protection methods exhibited greater effectiveness compared to biological ones, whose efficacy largely depends on annual weather conditions. The use of biological agents promotes the production of environmentally friendly products and mitigates adverse impacts on the surrounding environment.

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