Economic Efficiency of Biological Preparation – Sternifag, WP in Protection Systems of Winter Wheat

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Abstract. Experimental treatments were carried out to protect winter wheat crops from harmful objects for several seasons during 2018–2020 in Belgorod region. The article presents an economic assessment of the costs and profits from the introduction of the biological preparation Sternifag, WP, which was used against the background of 3 culture protection systems (chemical, integrated and biologized). It was found that, despite the additional costs for the introduction of Sternifag, high indicators of additional yield (from 13.6 to 28.4 c/ha) and profit (from 10846.83 to 30009.02 rubles/ha) were obtained. Calculations showed that treatment with Sternifag in the field gave a high profitability from 158 to 434%. The results obtained made it possible to evaluate the effect of the microbiological preparation Sternifag, WP as a stimulating and protective agent for winter wheat.

1. Introduction

Winter wheat is one of the most important agricultural crops necessary for the food supply of the country’s population. It is necessary to carry out a whole range of protective measures to obtain high sustainable yields of this crop. A prerequisite for modern agricultural production is the use of biological preparations that allow not only to preserve the harvest, but also avoid a negative impact on the environment [1]. Therefore, all countries work to find new and safe drugs for biological plant protection and soil health [2, 3].

For several years, the All-Russian Research Institute for Plant Protection (VIZR) has been successfully developing biological preparations that have a depressing effect on harmful objects in the soil and a positive effect on cultivated plants [4].

These preparations include a new microbiological drug Sternifag WP developed by VIZR specialists together with “Agrobiotechnologiya”, which has already been tested in several regions of the Russian Federation [5].

The drug was obtained based on a selected strain of fungi of the genus Trichoderma, which are natural biodegradants of plant residues. They have high hyperparasitic and antagonistic activity, as well as activity against phytopathogenic soil micromycetes, increase plant disease resistance, have a phytoregulatory effect, and enrich the soil with nutrients available to plants due to the decomposition of complex organic compounds [6]. An important property of this fungus strain, especially in the
cultivation of winter crops in the northern regions of Russia, is their ability to maintain viability and biological activity at low temperatures [7].

The preparation Sternifag, WP (Trichoderma harzianum, strain VKM F-4099D (titer 1010 CFU g)), having high biological effectiveness, is safe for plants, animals, and humans. The task of our research was to determine the economic efficiency of the use of the preparation Sternifag, WP during experimental treatments for 3 different systems of protection of winter wheat.

2. Objects and methods of research
Tests were carried out for several years in a field hospital of the Scientific Research Center “Agrobiotechnology” in the form of a small-plot field experiment using chemical and biological pesticides in 3 different plant protection systems in Belgorod region to identify the environmental and economic benefits of the microbiological preparation Sternifag, WP. In addition to biological products, the biologized defense system includes a chemical insecticide (Break, ME), therefore it is not designated as biological. The combination of biological and chemical preparations that were used in treatments according to the variants of the experiment (according to the protection systems) are presented in table 1.

Table 1. Scheme of the use of preparations on winter wheat by options (protection systems).

| Preparations | Options, winter wheat protection systems |
|--------------|-----------------------------------------|
|              | Chemical | Integrated | Biologized | Control |
| Seed dressing, preparation consumption rate: kg/t, l/t |
| Vial TrustT, WSC (60 g/l tebuconazole + 80 g/l thiaben-dazol) | 0.4 l/t | 0.3 l/t | + | + |
| Tabu, WSC (500 g/l imidacloprid) | 0.8 l/t | 0.4 l/t | + | + |
| Vitaplan, WP (titer 1010 CFU/g Bacillus subtilis strain VKM B-2604D + 1010 CFU/g Bac.subtilis strain VKM B-2605D) | 20 g/t | 20 g/t | + | + |
| Trichocin, WP spore of the fungus Trichoderma harzianum, strain G30 VIZR (titer 1010 CFU/g) | 20 g/t | 20 g/t | |
| Autumn application of Sternifag, WP in the soil, before sowing | |
| Sternifag, WP, (Trichoderma harzianum, strain VKM F-4099D (titer 1010 CFU/g) + ammonium nitrate | 80 g/ha + | 80 g/ha + | 80 g/ha+ | |
| Variants without Sternifag, WP, | 5 kg | 5 kg | 5kg | |
| Treatment against pests, mixed with fungicides, insecticide consumption rate, l/ha |
| Break, ME (100 g/l lambda-cyhalothrin) | 0.1 l/ha | 0.1 l/ha | 0.1 l/ha | |
| Treatment against diseases, fungicide consumption rate: l/ha, g/ha |
| Credo, SC (Carbendazim, 500 g/l) | 0.6l/ha | 0.5 | - |
| Alirin-B, Zh (titer not less than 109 CFU/ml Bacillus subtilis, strain V-10 VIZR) | - | + | 2 l/ha |
| Colossal PRO, KME- (300 g/l propiconazole + 200 g/l tebuconazole) | 0.4l/ha | - | 0.3 l/ha | - |
| Vitaplan, WP | + | 40 g/ha | - |
| Trichocin, C | - | 40 g/ha | |

Experimental treatments were carried out on winter wheat (Triticum aestivum L.) breed “Bezostaya-100”, which was sown in a crop rotation consisting of 5 other crops. A field experiment with a sequential arrangement of repetitions of plots, is carried out in accordance with the “Methodological guidelines for
registration tests” of 2009 of the All-Russian Research Institute of Plant Protection (FGBNU “VIZR”), on registration plots in 4 replicates (0.5 m² each).

Biological preparations were used on winter wheat for experimental treatments, in addition to Sternifag, SP: Trichocin, WP and Alirin-B, Zh, which are biological fungicides that effectively suppress pathogens of fungal diseases (root rot, spotting) on various crops. We also used a natural fungicide and bactericide – Vitaplan, WP.

The introduction of Sternifag, WP requires strict adherence to technology. The treatment was carried out in autumn, at the rate of application of the drug 80 g/ha and 200 liters of water with the obligatory addition of 5 kg of ammonium nitrate. Within 3–5 hours after the treatment, the preparation was embedded in the soil with disc harrows. Sternifag cultivation and compliance with crop rotation, as shown by tests, contributed to a significant reduction in the number of weeds in winter wheat crops, so no herbicides were applied.

During the experimental treatments, the technologies for applying the preparations and the approved rates of their consumption were observed. Economic calculations were carried out using new developments of VIZR [8, 9, 10] and works of foreign authors [11]. The economic calculations considered the following: technical characteristics of the tractor and agricultural machines, their annual load, and rates of deductions for depreciation, storage and technical repairs, the number of maintenance personnel, their salary with accruals (30.2%) and other indicators that were determined according to reference documentation considering the practice and technological maps of LLC “Agrobiotechnology”. The calculations include the cost of fuel, electricity, and water.

The operational characteristics of the tractor and agricultural machines are presented in the Table 2.

| Measures to protect winter wheat | Agricultural machines brands | Book value, thousand rubles. |
|---------------------------------|------------------------------|-----------------------------|
| Seed dressing before sowing     | PS-5                         | 135                         |
| Applicaton of Sternifag, WP in autumn | (OP -600) + MTP-82 BDF-2,1 | 250 1200 175 |
| Disking for embedding the preparation | tractor MTP-82 MTP-82 + MTP-82 + BDF-2,1 | 1200 1200 |
| Spraying vegetative plants     | (OP -600) + tractor MTP-82 | 250 1200 |

Before sowing, winter wheat seeds were treated with a ST-5 seed treater, which was served by 2 people. We considered the standard deductions for the operation and repair of the machine, the consumption of electricity and water, and their cost specifically for the enterprise to calculate the costs of seed processing.

Protective treatments for growing plants of winter wheat were carried out with an aggregate consisting of an MTP-82 tractor and an OP-600 mounted sprayer. The same machines were used to inject the biological preparation Sternifag into the soil, then they were immediately sealed with a tractor with disc harrows (MTP-82 +BDF-2,1).

3. Results and discussion
It was necessary to collect data on the income received from the protection of the culture and the costs that were spent on them to determine the economic efficiency of the protective measures carried out. Income was determined by the yield saved from plant protection (table 3).

The biological efficiency of our experimental treatments can be judged by the obtained wheat yield. It was high in all plant protection systems: from 74 to 97.9 c/ha, and it was 69.5 c/ha in the control one.
Table 3. Productivity of winter wheat, breed “Bezostaya-100”.

| Processing option                  | Average yield, c/ha | Saved yield, c/ha | Cost of saved yield, rub/ha * |
|-----------------------------------|---------------------|-------------------|-----------------------------|
| Chemical protection system        | + Sternifag, WP     | 83.1              | 13.6                        | 17680                      |
|                                   | without Sternifag   | 74.0              | 4.5                         | 5850                       |
| Integrated protection system      | + Sternifag, WP     | 97.9              | 28.4                        | 36920                      |
|                                   | without Sternifag   | 74.6              | 5.1                         | 6630                       |
| Biologized protection system      | + Sternifag, WP     | 85.7              | 16.2                        | 21060                      |
|                                   | without Sternifag   | 83.0              | 13.5                        | 17550                      |
| Control (without treatments and introduction of Sternifag, WP) | 69.5 | - | - |

*The grain sale price is accepted for calculations of 13 thousand rubles/ton

The difference between yields in the control and other options is an indicator of the yield saved or additionally obtained yield that is obtained through protective treatments. It ranged from 4.5 c/ha with a chemical system to 13.5 c/ha in a biologized system, options without autumn introduction of Sternifag.

In variants with Sternifag, these indicators are much higher: from 13.6 to 28.4 c/ha. This clearly shows the stimulating and protective effect of the biological product Sternifag, WP on winter wheat. It should be noted that in both variants of the biologized defense system, wheat yield was high, which is determined by the positive effect on plants used in the treatments of other biological preparations (Vitaplan, Trichocin, Alirin).

Multiplying the saved harvest by the purchase price (13000 rubles/ton) of grain allows estimating the income from each of the crop protection systems. In variants with the biological preparation Sternifag, WP, the highest indicators of the saved yield were noted, and an income was obtained from 21060 to 36920 rubles per hectare. Calculations considering the initial data made it possible to determine the main costs that were spent on the protection of experimental crops of winter wheat.

In the variants without the introduction of Sternifag, in addition to the costs of seed treatment, 2 treatments of vegetative plants were carried out. The obtained indicators are presented in table 4. As can be seen from table 4, in the variants without the introduction of Sternifag, the largest monetary costs were obtained in systems with the use of chemicals, in a biologized protection system it was spent less by 1856.52 rubles/ha. This is because the cost of chemical pesticides is more than the cost of biological preparations.

It is also known that most of the costs are associated with the purchase of plant protection products. In our experiments, when spraying plants, the following amount of funds was spent on preparations from the total cost of treatment: in the chemical system – 78%, in the integrated system – 80% and 71% in the biologized system.

However, it should be borne in mind that when modern and expensive agricultural machinery is used at plant protection events, the share of costs for preparations decreases.

Table 4. The cost of carrying out protective measures in winter wheat variety “Bezostaya-100”, by systems, without Sternifag.

| Indicators                               | Chemical          | Integrated       | Biologized       | Seed treatment |
|------------------------------------------|-------------------|------------------|------------------|----------------|
| Total costs of PS-5 operation, rubles/ha | 333.58            |                  |                  |                |
| Expenses for preparations, rubles/ha     | 1331.0            | 753.17           | 66.18            |                |
| Total costs rub/ha                       | 1664.58           | 1086.75          | 399.76           |                |
| Treatment for vegetative plants          |                   |                  |                  |                |
| Total for treatment (MTP-82+OP-600)      | 244.69            |                  |                  |                |
The introduction of Sternifag, naturally, required large expenditures for plant protection treatments and the incorporation of the preparation into the soil. Thus, the costs of protection systems increased accordingly by: 1959.74; 2470.79 and 1729.35 rubles/ha (table 5).

Table 5. The cost of carrying out protective measures in winter wheat with autumn application of Sternifag, WP, by protection systems.

| Indicators                                                    | Crop protection systems |
|--------------------------------------------------------------|------------------------|
|                                                              | Chemical | Integrated | Biologized |
| Seed treatment                                               |          |            |            |
| Total costs of PS-5 operation, rubles/ha                     | 333.58   |            |            |
| Expenses for preparations, rubles/ha                        | 1331.0   | 753.17     | 66.18      |
| Total costs for treatment, rubles/ha                        | 1664.58  | 1086.75    | 399.76     |
| Costs for the autumn introduction of Sternifag, WP          |          |            |            |
| Preparation Sternifag, WP, rubles/ha, (0.08 kg/ha) + 5kg of am. nit. | 605.0    |            |            |
| For 1 soil spraying (MTP-82 + OP -600)                      | 244.69   |            |            |
| Disking MTP-82 + BDF-2,1 ammort. and tech. repairs.        | 76.7     |            |            |
| Fuels and lubricants, (7 l/ha x 47 rub/l)                   | 329      |            |            |
| Salary for disking with accruals (30.2%), rubles/ha         | 80.55+24.2=104.75 |          |            |
| Total                                                        | 1360.09  |            |            |
| Treatment for vegetative plants                             |          |            |            |
| For 1 soil spraying (MTP-82 + OP -600)                      | 244.69   |            |            |
| Spraying costs, rub/ha (2 treatments)                       | 489.38   | 489.38     | 489.38     |
| Expenses for preparations, rubles/ha                        | 1806.32  | 2004.9     | 1254.07    |
| Total costs for spraying, rub/ha                            | 2295.7   | 2494.28    | 1743.45    |
| Total costs of protecting the winter wheat, rub/ha          | 5320.37  | 4941.12    | 3503.3     |
| Costs for harvesting of saved yield, rub/ha                 | 408      | 852        | 486        |
| Overheads, 20%                                              | 1145.7   | 1158.6     | 797.86     |
| Total costs, rub/ha                                         | 6874.07  | 6951.72    | 4787.16    |

We found that due to the low cost of the biological product Sternifag, WP (530 rubles/ha), the percentage of costs for the purchase of preparations, for options with this biological preparation, decreased to 35–38% of the total costs.

The analysis of the obtained economic data showed that the microbiological preparation Sternifag, utilizing plant residues and clearing the soil of phytopathogens, contributes to an increase in the yield of winter wheat. Significant additional increases in yield in all variants of the experiment determined the receipt of significant profits. Especially high profits were noted in variants with Sternifag: from 10846.83 to 30009.02 rubles per hectare (table 6).
Table 6. Cost effectiveness of protective measures on winter wheat.

| Indicators of effectiveness | Chemical Without Sternifag g. WP | Chemical Without Sternifag g. WP | Chemical Without Sternifag g. WP | Chemical Without Sternifag g. WP |
|----------------------------|----------------------------------|----------------------------------|----------------------------------|----------------------------------|
| Total costs, rub/ha         | 4914.28                          | 6833.17                          | 4480.83                          | 6910.98                          |
| Income from saved crop, rub/ha | 5850                             | 17680                            | 6630                             | 36920                            |
| Profit, rub/ha              | 935.72                           | 10846.8                          | 2149.17                          | 30009.0                          |
| Profitability, %            | 19                               | 158                              | 47                               | 434                              |

The costs, naturally, were higher in these variants than in the variants without the introduction of Sternifag. However, the profitability of using this microbiological preparation turned out to be very high, respectively, in terms of protection systems: 158% – for chemical, 434% – for integrated and 352% – for biologized.

In the integrated and biologized protection systems, the high profitability of treatments is also noted, even in the version without Sternifag. This can be explained by the use of other biological preparations in these systems (vitaplan, trichocin, alirin), which, unlike chemical pesticides, do not have a depressing effect on winter wheat plants.

4. Conclusion

Our economic analysis of the experimental use of the microbiological preparation Sternifag, WP (Trichoderma harzianum, strain VKM F-4099D (titer 1010 CFU/g)) clearly proved that, having high biological efficiency, this preparation is economically beneficial, profitable for an agricultural producer, and contributes to an increase in winter wheat productivity and allows getting significant profit even with an increase in the cost of its use.

In all 3 experimental systems of protection of winter wheat, the preparation Sternifag, WP showed high efficiency. Undoubtedly, considering safety for humans and the environment, the preparation Sternifag, SP is promising for use in agriculture.

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