Economic efficiency of fungicide application on spring wheat in the southern forest-steppe of Western Siberia

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Abstract. The work presents the results of studying the development of leaf diseases on soft spring wheat. The damage to plants was largely determined by the hydrothermal conditions of the crop vegetation, agricultural technology, and the applied plant protection products. Fungicidal treatment of crops with the chemical Abacus Ultra in the phase of entering the tube allowed to significantly reduce the development of infection on the upper layer of leaves: with brown rust to 0.2%, septoria - up to 0.3-0.7% and powdery mildew - up to 0.1-0.7%. Net income amounted to 28.228 – 38.609 rubles/ha, profitability 152-207%.

Keywords: spring wheat, fungicides, yield, Pseudo-bacterin-3, biological fungicide, Abacus Ultra, chemical fungicide, economic efficiency.

1. Introduction

Of the total world economic production, the agricultural sector accounts for 6%, the largest leaders are the United States, Russia, China, India, Brazil and agricultural production of Argentina. At present days, the protection of plants from various infections, including bacteria, phytopathogenic fungi, viruses, etc., is the most important economic and social problem due to losses in crop production, reaching 20% of the yield in some countries. Chemical control methods are widely used to protect plants. Modern intensive farming is impossible without pesticides [1]. Global losses of potential yield due to pests reach 37%, 13% - insects, 12% - weeds, and 12% due to diseases [2].

Wheat is currently the most demanded food crop in Russia. In the Omsk region, it occupies more than 80% in the grain wedge (1.6 million hectares), which actually leads to its cultivation in monoculture, causing a number of agrotechnical and economic problems [3]. A significant reserve for the growth of high-quality grain production in the region is the protection of crops from leaf-stem diseases - the yield can increase by 40-60% or more.

The purpose of the research is to study the economic efficiency of the use of various types of fungicides, depending on the peculiarities of the formation of the phytosanitary situation in the crops of soft spring wheat in the southern forest-steppe of Western Siberia.

2. Research methodology and conditions

The studies were carried out in accordance with the research plan of the laboratory of resource-saving agricultural technologies of the Omsk Agrarian Scientific Centre.
The objects of study were: soft spring wheat "Omskaya 36"; fungicides: Pseudobacterin-3 (biological), Abacus Ultra (chemical). The objects of research are linked into a single complex by agrotechnical measures and soil and climatic conditions.

Field experiments were carried out in a long-term (laying in 1972) station on the basis of a five-field grain-fallow crop rotation. The predecessor is the second wheat. The total area of the plot is 396 m², the accounting area is 36 m².

For the observations, two agricultural technologies were selected with different intensity of mechanical impact on the soil: dump to a depth of 20-22 cm and minimum - without autumn cultivation. On these backgrounds, intensification means were used: before sowing, background application of mineral fertilizers at a dose of 60 kg / hectare, including N24P36; herbicides - preparations against bluegrass and dicotyledonous weeds. Fertilizers were applied locally with a SZ-3.6 seeder across the main tillage to the depth of seeding, herbicides were applied in the tillering phase of the crop.

The scheme of the experiment is presented in Table 1. Arrangement of variants is systematic in 4-fold repetition.

Wheat sowing was carried out at the optimum time using a Salford sowing complex to a depth of 5-6 cm with a seeding rate of 4.5 million germinating seeds per hectare. Grain harvesting was carried out in a single-phase method in the phase of full ripeness using a Samp-130 combine harvester.

The soil of the experimental field is meadow-chernozemic medium-thick heavy loamy, the reaction of the environment is close to neutral. This soil subtype of the forest-steppe zone is formed at a groundwater level of 3 to 6 m or with a mixed type of moisture and is more widespread. In terms of morphological characteristics, meadow-chernozem soils within the first meter do not differ from chernozems. They are characterized by the same humus profile with low and medium humus content, lumpy structure and fractured constitution [4,5].

The climate of the southern forest-steppe of the West Siberian Plain is typically continental, formed mainly under the influence of the properties of the Asian continent. Differs in dryness, lack of precipitation, little cloudiness. Both cold arctic and warm air masses, dry from the deserts and steppes of Kazakhstan and Central Asia, freely penetrate into the zone. This leads to instability of weather phenomena, sharp fluctuations in temperature throughout the year, which is its distinctive feature.

Thermal resources of the subzone of the southern forest-steppe, where the experiment was laid, are satisfactory, moisture is insufficient [3].

In terms of meteorological indicators, the growing seasons during the years of the study differed significantly. The year 2019 was close to the average long-term indicators: in terms of temperature (-0.2°C), precipitation amounted to 93.7% of the climatic norm (GTC 0.99). The 2020 season was characterized as hot and dry. The average monthly temperature is above the climatic norm by 6°C, precipitation fell by 37.3 mm (GTC 0.60).

3. Research results

Fungal diseases are a limiting factor in increasing the yield of spring wheat. Protecting it from leaf-stem infections during the period of stemming - the beginning of flowering - is the most phytosanitary stage, since diseases of vegetative organs (Puccinia triticina brown rust, Septoria tritici septoria, Erysiphe graminis powdery mildew) cause the greatest damage to the crop. With the epiphytotic development of leaf-stem infections, especially in wet years, yield losses can reach 25-40%, and its quality deteriorates [6].

In our studies, it was found that the development of leaf diseases depended on a number of factors and, first of all, on a combination of meteorological indicators that had a significant effect on the damage to plants by aerogenic infections, Table 1.
Table 1. Development of leaf diseases on the flag leaf of common spring wheat in the southern forest-steppe of Western Siberia (%)

| Means of chemicalization | Brown leaf rust | Septoria | Powdery mildew |
|--------------------------|----------------|----------|----------------|
|                          | mold.¹ BE     | min.² BE | Mold.¹ BE      | min.² BE | mold.¹ BE |
| Control                  | 45.0          | 32.5     | 7.5            | 5.0      | 3.0        | 3.0 |
| HF                       | 42.5          | 5.6      | 40.0           | 12.5     | 5.0        | 3.0 | 1.0 | 66.7 |
| HF+Pseudo                | 45.0          | 30.0     | 7.7            | 5.0      | 33.3       | 10.0 | 3.0 | 1.0 | 66.7 |
| HFF                      | 0.0           | 100.0    | 0.0            | 0.2      | 97.3       | 0.3 | 94.0 | 0.0 | 100.0 | 0.2 | 93.3 |
| Average                  | 33.1          | 26.4     | 25.6           | 21.2     | 6.3        | 16.0 | 5.1 | 2.0 | 2.3 | 23.3 | 1.3 | 56.7 |

HCP0.1 1.78

| Control                  | 13.4          | 8.9      | 4.3            | 4.0      | 1.3        | 1.3 |
| HF                       | 10.0          | 25.4     | 10.0           | 5.0      | 5.0        | 1.0 | 23.1 | 1.0 | 23.1 |
| HF+Pseudo                | 0.2           | 98.5     | 0.2            | 97.8     | 0.2        | 95.3 | 0.0 | 100.0 | 0.5 | 61.5 | 0.8 | 38.5 |
| HFF                      | 0.3           | 97.8     | 0.1            | 98.9     | 1.0        | 76.7 | 0.4 | 90.0 | 0.8 | 38.5 | 0.6 | 53.9 |
| Average                  | 6.0           | 55.2     | 4.8            | 46.1     | 2.6        | 39.5 | 2.4 | 40.0 | 0.9 | 30.8 | 0.9 | 30.8 |

HCP0.99

Note: 1 - moldboard tillage; 2 - minimal tillage; HF - herbicides + fertilizers; HF + Pseudo - herbicides + fertilizers + Pseudobacterin-3; HFF - herbicides + fertilizers + fungicide Abacus Ultra; BE - coefficient of biological effectiveness.

The development of leaf-stem diseases in the control variant, in the more humid year 2019, was very significant and averaged on the upper layer of leaves: brown rust 38.8%, septoria - 6.3%, and only powdery mildew was infected below the severity threshold of 3.0%. In the hot and dry season of 2020, there was a significantly less leaf rust infection (3.5 times as much), septoria blight - 1.5 times as much, and powdery mildew - 2.3 times as much. Despite the fact that the maximum decrease was noted for brown rust, its development exceeded the harmfulness threshold (5%). The minimum level’s decrease was noted for septoria.

This fact is explained by the research carried out by E Yu Toropova and others (2016) in the Novosibirsk region, which showed that the exacerbation of the phytosanitary situation for Septoria blight in the last decade is associated with the introduction of resource-saving soil cultivation systems, the accumulation of plant residues on the soil surface and the contamination of fields with cereal weeds - reserves of the causative agents of Septoria [7].

Two agricultural technologies with different intensity of mechanical impact on the soil used in the experiment also had a "stimulating" effect on the development of diseases, regardless of the combination of meteorological indicators of the year of research, or the means of intensification used. In the variants with moldboard tillage to a depth of 20-22 cm, the greatest development of diseases was observed than with the minimum - without autumn tillage (33.1 and 25.6%, respectively). In the growing season favorable in terms of moisture regime, this was more pronounced.

To the greatest extent, spring wheat plants suffered from leaf-stem infections in the variant of combined application of fertilizers and herbicides. Because of this the lesion of the upper layer of leaves by leaf rust with the development of infection averaged 41.3% according to agricultural technologies, 8.8% by septoria, and slightly up to 2.0% by powdery mildew. The increase in leaf rust and septoria blight relative to the control variant was significant, while the harmfulness threshold was exceeded. To a greater extent, this manifested itself with a favorable combination of meteorological factors for the development of culture. Such a result, most likely, was obtained due to the action of fertilizers, which
contributed to the better development of plant biomass, they, in turn, were more "pampered" and, therefore, more susceptible to infection.

While the complex using of chemicals with fungicidal treatment with the biological preparation of Pseudobacterin-3, a significant decrease in the degree of damage to wheat leaves by leaf rust (by 98.1%), septoria (by 97.7%) and powdery mildew (by 50%) was noted, but only in hot and dry conditions. With meteorological data close to the average long-term, no positive effect of the drug was noted.

The use of complex chemicalization with fungicidal treatment with Abacus Ultra practically completely suppressed the development of brown rust, septoria and powdery mildew (from 76.7 to 100%), regardless of the conditions of the growing season.

The predominant function of landscapes is to ensure for a long time the production of agricultural crops of the required quality and quantity without an increase in the level of costs for their cultivation and reproduction of soil fertility [8]. One of the ways to improve the ecological state of agricultural products and soils is the rational use of chemicals in crop production and the expansion of the use of biological preparations [9].

Accounting for the productivity of spring wheat showed that the complex use of intensification means (herbicides, fertilizer and fungicide) provided the greatest increase in grain (Table 2).

Table 2. Productivity of soft spring wheat grain in the southern forest-steppe of Western Siberia, (t / ha)

| Means of chemicalization | Tillage type | 2019 |          |          | 2020 |          |
|--------------------------|--------------|------|----------|----------|------|----------|
|                          |              | Moldboard | Minimal |          | Moldboard | Minimal |          |
| Control                  |              | 0.67 | -        | 0.66     | 0.42 | -        | 0.32     | -        |
| HF                       |              | 1.17 | 0.50     | 1.20     | 1.25 | 0.83     | 0.84     | 0.52     |
| HF+Pseudo                |              | 1.10 | 0.43     | 1.18     | 4.00 | 3.58     | 3.92     | 3.60     |
| HFF                      |              | 3.36 | 2.69     | 3.42     | 4.28 | 3.86     | 4.19     | 2.50     |
| HFP                      |              | 1.58 | 0.91     | 1.61     | 2.49 | 2.07     | 1.98     | 1.66     |
| HCP50 0.33               |              |      |          |          |      |          |          |
| Control                  |              | 0.42 | -        | 0.32     | 0.25 | 0.83     | 0.84     | 0.52     |
| HF                       |              | 1.25 | 0.83     | 1.84     | 4.00 | 3.58     | 3.92     | 3.60     |
| HF+Pseudo                |              | 4.00 | 3.58     | 3.92     | 4.28 | 3.86     | 4.19     | 2.50     |
| HFP                      |              | 4.28 | 3.86     | 4.19     | 2.49 | 2.07     | 1.98     | 1.66     |
| HCP50 0.42               |              |      |          |          |      |          |          |

The yield of repeated sowing of wheat after fallow on the control was extremely low (0.37-0.66 t / hectare) and insignificant (1.05-1.18 t / hectare) when using herbicides with fertilizers without fungicidal treatment.

Observations showed that intensification agents had the most significant effect on the productivity of soft spring wheat plants. Higher productivity of the crop was obtained in the variant with the combined use of herbicides, fertilizers and fungicide Abakus Ultra and averaged 3.39-3.55 t / hectare. Spraying plants with a biological preparation Pseudobacterin-3 contributed to a decrease in grain yield by 2.25 t / hectare or 66% in comparison with the chemical fungicide Abakus Ultra. The complex application of chemicals with plant protection increased the grain yield on average from 0.66 to 3.39 t / hectare, or 5.1 times as much.
The complex application of chemicals with the additional use of pseudobacterin helped to protect plants from infections and increased the productivity of spring wheat to 4.00 t / hectare, including fungicidal treatment - by 2.34 t / hectare (3.3 times as much) more. On average, for all the options for the use of chemicalization agents, the highest crop productivity was obtained in moldboard tillage - 4.28 t / hectare, exceeding the minimum by 1.5 times as much.

The relationship between the development of septoria, leaf rust and powdery mildew with the yield of wheat grain, respectively, was: \( r = -0.78, r = -0.60, r = -0.72 \).

Observations of T.G. Volova (2017) showed that the effectiveness of agricultural technologies in food production is determined by various factors, including environmental, geographical and economic ones [2].

It is not enough for the practice of agricultural production to assess the agronomic significance. It is necessary to take into account economic indicators, choose less expensive technologies and include them into production.

In modern conditions, the most effective methods of cultivation of spring wheat are those which provide an increase in productivity and determine the provision of the population with food and industry with raw materials. In this regard, the article discusses the issues of economic evaluation of the productivity of soft spring wheat when using fungicides (Figure 1).

![Figure 1. Profitability of growing soft spring wheat depending on soil cultivation and means of intensification](image)

The relative indicator of efficiency - profitability - comprehensively reflects the degree of efficiency of the material, labor and monetary resources used [10]. The economic assessment of the cultivation of spring wheat indicates that the best profitability indicators were observed with the use of classical moldboard agricultural technology (106 and 207%) in combination with a full range of plant protection.

4. Conclusion
The study of spring wheat plants in combination with agricultural technologies and means of intensification showed that the effectiveness of a particular method is largely determined by the conditions of the year and the factor of chemicalization.

The development of leaf diseases was largely determined by the hydrothermal conditions of the crop vegetation, agricultural technology, and the plant protection products used. Fungicidal treatment of soft spring wheat crops with the chemical Abakus Ultra during the tube emergence phase allowed to reduce...
the development of infection on the upper layer of leaves significantly: brown rust to 0.2%, septoria blight - to 0.3 - 0.7% and powdery mildew - to 0.1 - 0.7%.

Economic indicators varied depending on the means of intensification and types of agricultural technologies used: net income was 28,228 - 38,609 rubles / hectare, profitability 152 - 207%.

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