Control of airborne infections of wheat

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Abstract. Leaf-stem infections damage the wheat crop. *Puccinia recondite* and *Blumeria graminis* are especially harmful. There were outbreaks of septoriosis and pyrenophoresis (*Stagonospora nodorum, Pyrenophora tritici-repentis*) and linear rust (*Puccinia graminis*). The lack of spring wheat crops and deterioration in the grain quality caused by epiphytoties is 25-50%. An effective method for controlling aerogenic infections is the use of fungicides. Studies on the effectiveness and feasibility of fungicidal protection of wheat against pathogens were carried out in Kurgan region. It is economically feasible to use *Bacillus subtilis*-based substances to prevent wheat infections. In case of a moderate wheat damage, it is recommended to use tank mixes (1/2 of systemic fungicide + hay-bacillus-based biofungicide). In case of mass development of leaf-stem infections, it is necessary to protect the crops using systemic fungicides if there is primary infection of a lower tier of leaves and weather conditions are favorable for pathogens. The use of fungicides preserved more than 30% of the wheat crops and improved the quality of grain. Profitability of chemical protection options increased by 20-26%.

1. Introduction
The use of pesticides is a prerequisite for producing the high quality crop. However, their mass use has a number of negative aspects (environmental risks, food contamination with residual quantities of pesticides, degradation of beneficial soil microflora and deterioration of soil fertility).

Leaf-stem infections damage the wheat crop. *Puccinia recondite* and *Blumeria graminis* are especially harmful. There were outbreaks of septoriosis and pyrenophoresis (*Stagonospora nodorum, Pyrenophora tritici-repentis*) and linear rust (*Puccinia graminis*). The lack of spring wheat crops and deterioration in the grain quality caused by epiphytoties is 25-50% [1-4]. In the Ural region, the development of septoria and pyrenophorosis is moderate, the diseases develop on stubble backgrounds. It is difficult to diagnose these diseases and control them in case of early damage. Due to the emergence of new aggressive types of the causative agent of stem rust and expansion of their range, there is a threat of destabilization of food security of the population of the entire planet [3,5,6]. In 2015-2017, in the West Siberian and Ural regions, there was a significant damage to wheat by linear rust which caused losses in yield and deteriorated the grain quality. All cultivated varieties were affected by the phytopathogen. Fungal protection systems are aimed at controlling leaf infections. Crops are treated in phases 37-50 (Zadoks scale), and the stems are affected during the period when the fungicidal protection weakens.
It is not easy to answer the question about the expediency of using fungicides, since their use is an investment in an unpredictable future. In order for protective measures to be justified, fungicides should be introduced taking into account a phytosanitary situation, a drug spectrum, price categories for grain and pesticides. The patterns of development of the epiphytotic process and numerous literary data show that infections may not always cause the massive development of the disease. It is important to monitor the development of phytopathogens and weather conditions during the growing season.

The aim of the research is to determine the biological and economic efficiency of the fungicides on spring wheat for the effective control of aerogenic infections.

2. Materials and methods
The experiments were conducted in 2010-2018 at the Central Experimental Field of Kurgan Research Institute of Agriculture - branch of Federal state budget scientific institution «Ural Federal agrarian scientific centre of Ural Branch of Russian Academy of Sciences». The research objects are spring wheat and fungicidal agents. The soil of the experimental plot is leached, medium loamy, medium humus chernozem. The forerunner is pure early fallow. The plot area is 20 m². The repetition is fourfold, the placement of plots is systematic. Observations and surveys were carried out according to the generally accepted methods (VIZR, State variety testing of agricultural crops). The composition of fungicides is as follows: Falcon (spiroxamine 250 + tebuconazole 167 + triadimenol 43 g/l), Alto super (propiconazole 250 g/l + cyproconazole 80 g/l), Kolosal PRO (propiconazole 250 + tebuconazole 200 g/l), Abacus Ultra (pyraclostrobin 62.5 + epoxiconazole 62.5 g/l), Rex Duo (thiophanate-methyl 310 + epoxiconazole 187 g/l). Biopreparation - Fitosporin-M (Bacillus subtilis, strain 26D, trace elements).

3. Results
Significant development of infections is observed when a “disease triangle” develops, that is, there are a susceptible organism, an infection and favorable weather conditions.

It was determined that in 2010-2018, in 44% of cases, leaf infections were characterized as epiphytotics; in 22% of cases, leaf infections were moderate. In these years, it was required to protect crops from fungal infections in order to preserve the grain yield and its quality.

The research data indicate that in cases of massive development of leaf-stem infections, it is necessary to protect the crops using the fungicides when there is primary lesion of the lower tier of leaves and weather conditions are favorable for pathogens.

In case of development of epiphytotics of leaf phytopathogens, the fungicidal protection of crops preserved more than 30% of the wheat crop and improved the quality of grain; profitability increased by 20-26 %. In case of severe damage to crops caused by brown rust, powdery mildew, stem rust, the stability of protection, high economic efficiency and payback were provided on the basis of such active substances as [thiophanate methyl 310 g/l + epoxiconazole 187 g/l], [spiroxamin 250 + tebuconazole 167 + triadimenol 43 g/l], [propiconazole 300 + tebuconazole 200 g/l], [propiconazole 140 + tebuconazole 140 + epoxiconazole 72 g/l].

Over the years of mass development of aerogenic wheat infections, the economic efficiency of fungicidal preparations was significant (33%), the biological efficiency was more than 80%.

In severely arid conditions (hydrothermal coefficient 0.3), single (less than 1-3%) leaf infections were observed, and measures to protect against diseases were not required.

In the years when wheat is weakly affected by aerogenic infections (less than 5%), it is economically feasible to use Bacillus subtilis-based preparations.
Table 1. The effectiveness of wheat fungicidal protection depending on the level of development of aerogenic infections, 2010-2018

| Variant                     | Productivity, t/ha | Economic efficiency, % | Development of diseases in the earring phase, % | Profitability, %** |
|-----------------------------|--------------------|------------------------|-----------------------------------------------|--------------------|
| Single leaf damage, 2010, 2012 |                    |                        |                                               |                    |
| Control                     | 1.20               | -                      | 0.8                                           | -12                |
| Systemic fungicide *        | 1.20               | 0                      | 0.3                                           | -22                |
| Biofungicide                | 1.37               | 14                     | 0.1                                           | -4                 |
| Depression of leaf infections, 2018 |            |                        |                                               |                    |
| Control                     | 2.86               | -                      | 3.4                                           | 93                 |
| Systemic fungicide          | 3.12               | 9                      | 1.9                                           | 88                 |
| Biofungicide                | 2.98               | 4                      | 1.6                                           | 94                 |
| Moderate disease development, 2011, 2015 | |                        |                                               |                    |
| Control                     | 2.79               | -                      | 9.9                                           | 89                 |
| Systemic fungicide          | 3.28               | 18                     | 3.8                                           | 96                 |
| Biofungicide                | 3.05               | 9                      | 4.4                                           | 100                |
| Mass development of leaf infections, 2013, 2014, 2016, 2017 | |                        |                                               |                    |
| Control                     | 2.05               | -                      | 42.2                                          | 44                 |
| Systemic fungicide          | 2.73               | 33                     | 7.3                                           | 67                 |
| Biofungicide                | 2.19               | 7                      | 23.1                                          | 48                 |

Note: * an average by the line of the studied drugs; ** – calculations in the prices of 2018

For moderate damages to plants (5-10% at the beginning of the earring phase), the use of chemical fungicides is recommended. To reduce the pesticide load and the cost of protective treatment, it is advisable to use a tank mixture of Bacillus subtilis-based fungicides. This reduces the fungicidal load on the spring wheat, provides reliable protection of crops against leaf spots (77-81%), increases the economic efficiency of plant protection. The yield of spring wheat increased by 0.53 t/ha with a production profitability of 71% (profitability of biological protection is higher than chemical protection by 13 percentage). Biofungicide had a low biological efficacy against pathogens of powdery mildew and helminthosporia of wheat leaves (46%) (table 2).

Table 2. The effectiveness of chemical and biological fungicides in spring wheat crops, 2011-2014

| Variant                             | Productivity, t/ha | Yield increase to control, t/ha | Biological efficacy of the drug, % | Profitability, %* |
|-------------------------------------|--------------------|---------------------------------|-----------------------------------|-------------------|
| Control                             | 2.30               | -                               |                                   | 44                |
| Biofungicide (Bacillus subtilis - Fitosporin M 1.5 l/ha) | 2.54               | 0.37                            | 46                                | 61                |
| Systemic fungicide (spiraxamine + tebuconazole + triadimenol 43 g/l - Falcon 0.6 l/ha) | 2.64               | 0.47                            | 83                                | 58                |
| Systemic fungicide ½ consumption rate + biofungicide (Fitosporin-M 1.0 l/ha + Falcon 0.3 l/ha) | 2.70               | 0.53                            | 79                                | 71                |

4. Conclusion
Thus, in case of mass development of leaf-stem infections, it is necessary to protect the crops using systemic fungicides when there is primary lesion of the lower tier of leaves and weather conditions are favorable for pathogens. In case of development of epiphytotics of leaf phytopathogens, the fungicidal protection of crops preserved more than 30% of the wheat crop and improved the quality of grain;
profitability increased by 20-26%. In case of severe damage to crops caused by brown rust, powdery mildew, stem rust, the stability of protection, high economic efficiency and payback were provided on the basis of such active substances as [thiophanate methyl 310 g/l + epoxiconazole 187 g/l], [spiroxam 250 + tebuconazole 167 + triadimenol 43 g/l], [propiconazole 300 + tebuconazole 200 g/l], [propiconazole 140 + tebuconazole 140 + epoxiconazole 72 g/l].

In the years of weak damage caused by aerogenic infections, it is economically feasible to use Bacillus subtilis-based preparations. During the years of moderate development of leaf diseases, it is recommended to use systemic fungicides for highly productive crops of especially valuable wheat varieties, and tank mixtures – to reduce the pesticidal load (1/2 of systemic fungicide + hay bacculus-based biofungicide).

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