Justification of the need to protect wheat crops against disease agents in the North–Eastern part of the Central Chernozem region

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Abstract. To develop and optimize protective measures in the CCR conditions, an analysis of the epidemic resistance of zoned varieties and hybrid lines of spring wheat to the causative agents of septoria, brown and yellow rust was carried out; the effect of fungicides, biological agents, their binary mixtures was studied for wheat crops. Among the selection material of spring wheat, lines and numbers were identified and selected as potential genetic sources and donors, combining resistance to environmental stress factors (brown and yellow rust, septoria blight) with productivity and adaptability to the conditions of the Central Black Earth Region. Using DNA markers, Lr genes in the lines selected as potential donors of leaf rust resistance were identified. In the genotypes of selection lines, the Lr19 gene dominance was revealed in combination with the weakly effective genes Lr10, Lr 20, and Lr 26. It was observed that the combination of Lr19 + Lr26 increases the level of resistance. All zoned varieties were affected by diseases, which indicates the need for protective measures. The biological effectiveness of chemical and biological agents against aerogenic diseases was established in the range of 82.1-100%. Amistar Extra was effective against septoria, perenophorosis and leaf rust, Rex Duo was effective against leaf rust, Title Duo was effective against powdery mildew. Amist Extra 0.7 l / ha + Biostim 2.0 l / ha was effective against leaf rust (99.4%) and powdery mildew (98.9%). A mixture of Amistar Extra 0.7 l / ha and Alfastim 30 ml / ha was effective against septoria (93.0%) and pyrenoforosis (100%). Mixed forms of Amistar Extra 0.7 l / ha + Alfastim 30 ml / ha (91.3-95.7%) and Amistar Extra 0.7 l / ha + Healthy yield 0.9 l / ha (91.0-95.7%) were effective against septoria spot and brown rust.

1. Introduction
Wheat (Triticum) is an important grain crop all over the world. In 2019-2020 in Russia, it was grown on an area of more than 27.5 million hectares. Wheat is the third crop in the world market after corn and rice. The Russian Federation is the world leader in the export of wheat grain [1].

Like all crops, wheat is affected by many diseases. In the Central Chernozem Region, the following diseases affect wheat: septoria disease (Zinoseptoria tritici), brown rust (Puccinia triticina), powdery mildew (Blumeria graminis), dust and hard smut (Ustilago tritici and Tilletia caries), fusion, mycotic seed depletion. In 2020, yellow rust (P. striiformis) on wheat which is not typical for the region was observed; in 2016, stem rust (P. graminis) was observed. Due to the rapid evolution of the pathogen,
the emergence of new virulent species, and climate changes, serious losses in the wheat yield are observed every year all over the world [2]. The average global crop losses due to diseases and pests are 11-30% [3].

The pathogens negatively affect the quality of agricultural products, primarily due to the contamination of grain with various mycotoxins [4-6].

The cultivation of resistant varieties and the use of fungicides are common measures for controlling phytopathogens. Timely spraying with fungicides can control a disease, but increases the cost of wheat production and can cause environmental pollution [7].

Fungicides often fail to prevent yield losses in highly sensitive varieties under the severe epiphytoties [8].

Therefore, the cultivation of wheat varieties that are resistant to phytopathogens is the most effective, economical and environmentally friendly way to fight diseases and produce stable and high-quality agricultural products [9].

To develop and optimize protective measures in the northeastern part of the Central Chernozem Region, the epidemic resistance of zoned varieties and hybrid lines of spring wheat to pathogens of septoria, brown and yellow rust was assessed; the effect of fungicides, biological agents, and their binary mixtures used for wheat crops was studied.

2. Materials and methods

Varieties and lines of spring wheat served as research materials. The experiments were conducted in infectious nurseries of the Central Russian affiliate of the Michurin FNC". The weather conditions in 2020 differed from the average long-term ones (Table 1).

**Table 1.** Meteorological conditions for the growing season of 2020 (according to the data of the Tambov affiliate"Central Chernozem UGMS")

| Indicator                                      | Decade | Months     |
|-----------------------------------------------|--------|------------|
|                                               | April  | May        | June | July | August |
| Average monthly air temperature, °C           | -      | 6,0        | 12,7 | 19,9 | 20,8   | 19,0   |
| Maximum air temperature, °C                   | -      | 21,4       | 27,4 | 31,0 | 35,3   | 32,6   |
| Minimum air temperature, °C                   | -      | -7,4       | 2,1  | 9,5  | 8,6    | 14,3   |
| Average long-term average monthly air         | -      | 6,8        | 14,5 | 18   | 19,4   | 18,1   |
| temperature, °C                               | I      | 2          | 38,5 | 61,8 | 33,2   | 3,1    |
|                                               | II     | 21         | 17,2 | 0,6  | 2,3    | 8,6    |
|                                               | III    | 4,5        | 16,5 | 43,0 | 10,5   | 4,0    |
| Precipitation by decade, mm                   | Σ=27.5 | 72,2       | 105.4| 46.0 | 15.7   |
| Average long-term precipitation, mm           | 37     | 52         | 56   | 70   | 60     |
|                                               | I      | 43         | 62   | 71   | 63     |
|                                               | II     | 61         | 60   | 54   | 63     |
|                                               | III    | 51,8       | 65   | 63   | 54     |
| Relative humidity, %                          | Average| 52         | 62   | 63   | 60     | 57     |
|                                               | Average long-term | 74     | 62   | 63   | 68     | 69     |

The average monthly air temperature in April was 6.0 °C, which is 0.8 °C higher than the average one. The amount of precipitation was 27 mm (74% of the average).

During the first decade of May, the average air temperature was 13.9 °C, which is 1.1°C higher than the norm. The maximum temperature ranged from 15.1°C to 26.5°C, and the minimum one was
4.1-14.7°C. During the decade, the total amount of precipitation was 38.5 mm (226% of the norm): there were three days with a precipitation amount of more than 5 mm (May 6, 8, 10). The average relative humidity was 62%.

The average air temperature in June was 19.9°C (deviation from the norm was 1.9). The absolute maximum temperature was 31 °C, the absolute minimum air temperature was 9.5°C. The amount of precipitation was 105.4 mm (188% of the monthly norm).

These weather conditions allowed the P. striiformis pathogen to infect wheat crops and cause a yellow rust disease. In 2020, in the Tambov region, yellow rust developed. It reached 70%. This made it possible to carry out a qualitative assessment of the resistance of wheat varieties to P. striiformis.

The assessment of resistance to leaf rust was carried out on an artificial infectious background. The plants were sprayed in the phase of the booting using an aqueous suspension of leaf rust spores with the addition of Tween 80 detergent. After inoculation, the plots were covered with plastic wrap for 16-18 hours. Urediniospores of the Tambov population of P. triticina were used as an inoculum.

The assessment of resistance of wheat cultivars to septoria was carried out in an infectious nursery by infecting plants with Z. tritici in the heading phase. A mixture of Z. tritici isolates was used as an infectious material. The suspension was prepared at a concentration of 10 spores / ml, which was applied to wheat plants with a hand sprayer at the rate of 100 ml/m.

To assess resistance, we used indicators of damage (%) and reaction (points). The intensity of leaf rust damage was assessed by the Peterson et al.’s scale, the yellow rust was assessed by the modified Cobb’s scale. The type of reaction to brown rust was determined on the Mains and Jackson’s scale, to yellow rust by the Gassner and Straib’s scale [10].

The degree of damage to plants by septoria was assessed visually by the Sarri-Prescott’s scale, improved by the information on the damage to plants in points [11].

When studying the type of epidemic resistance to septoria and leaf rust, the specialized method developed by Sanin, Strizhekozin, Chuprina was used [12]. According to this technique, all the varieties were divided into three classes:

- **ER I** - highly resistant (attack rate <15%), intensity of protection is low;
- **ER II** - moderately resistant (15–40% attack rate), medium defense intensity;
- **ER III** - weakly resistant (attack rate> 40%), high protection intensity.

The biological effectiveness of chemical and biological agents that are most effective against aerogenic wheat diseases was assessed against the background of grain-fallow crop rotation on the basis of the Central Russian affiliate of the Federal Research Center named after V.I. IV Michurin” (field and laboratory experiments). The wheat predecessor was pure fallow.

The following materials were used for the research:

- fungicides: Celest Max 1.2 l / t, 1.75 l / t, Scarlet 0.3 l / t, Alto Super 0.5 l / ha, Triada 0.6 l / ha, Amistar Extra 1.0 l / ha, 0.8 l / t, Title Duo 0.3 l / ha, 0.25 l / ha, Rex Duo 0.6 l / ha;
- growth regulators: Biostim 2 l / ha, Alfastim 30 ml / ha;
- fertilizers based on humic acids with a set of macro- and microelements Healthy yield 0.8 l / ha.

### 3. Results and discussion

The test included 33 varieties of SOFT (всегда ставим тип перед сезонностью) spring wheat. Out of these, 4 varieties - Svetlana, Tulaykovskaya 10, Udacha, Favorit - were classified as ER II type of epidemic resistance of varieties in terms of the degree of leaf rust damage (12%). The remaining 29 varieties were classified as ER III type of epidemic resistance (88%). They are poorly resistant to the intensity of leaf rust damage.

In terms of the intensity of infection by septoria, six varieties of spring wheat (18%), namely Anyuta, Biora, L-400, Tulaykovskaya 5, Udacha and Favorit, were classified as epidemic resistance type ER II, the intensity of the pathogen damage did not exceed 40%. The remaining 27 varieties (82%) were poorly resistant; during the epiphytotic development of the disease proper protection will be necessary to properly.

Udacha and Favorit have the ER II type resistance to septoria and leaf rust.
The resistance of 15 varieties of spring durum wheat was assessed. The degree of leaf rust damage to Valentina, Voronezhskaya 7, Donskaya Elegya, Nik, Orenburgskaya 10, Pamyat Chekhovich, Step 3, Kharkovskaya 46 was within 15-40% (ER II). Bezenchukskaya 139, Bezenchukskaya 182, Bezenchukskaya 200 were classified as ER III type of epidemic resistance (weakly resistant).

In relation to the indicator of septoria infection, 5 out of 15 varieties were related to ER II type of epidemic resistance (moderately resistant) (33%). These are Bezenchukskaya 139, Bezenchukskaya 200, Orenburgskaya 10, Pamyati Chekhovich, Step 3. The remaining 10 varieties (67%) were related to ER III type of epidemic resistance (weakly resistant).

Orenburgskaya 10, Pamyati Chekhovich and Step 3 had ER II in relation to septoria and brown rust.

The studies showed that among the zoned varieties of spring wheat, there were no varieties with ER I type of epidemic resistance to pathogens.

The studies involved the lines from the competitive and control nurseries, selected for biological and economic characteristics (yield, lodging, resistance to drought and latent stem pests)

Of the 62 wheat lines, the three ones showed high resistance to leaf rust - ER I (4.8% of those studied). These are Stb-1, Stb-1-1 and Stb-1-3. Their susceptibility to leaf rust was 15%. 37 lines showed moderate resistance to the pathogen and had ER II (59.7% of those studied). These are Stb-5-2, Stb-4, Stb-01-1, Stb-3-2, Stb-3-3, Stb-02, Stb-02-1, Stb-4-1, Stb-4-1-1 et al. The rest of the wheat lines (22 lines or 35.5%) were susceptible; their damage exceeded 40%. They were related to ER III type of epidemiological resistance.

In 2020, the development of yellow rust, which is not typical for the region, was observed, which is an invasive infection for the Central Chernozem region. Of the 62 lines, 19 (30.6%) were affected by yellow rust by less than 15%, they were related to ER I group - highly resistant. These were Stb-4, Stb-03, Stb-03-1, Stb-3-2, Stb-02, Stb-02-1, Stb-4-4, Stb-5, Stb-6-2 and others.

35 hybrid lines of soft wheat Stb-01-1, Stb-9, Stb-9-1, Stb-9-3, Stb-4-2, Stb-4-3, Stb-4-4, Stb-4-5 and others showed moderate resistance (15-40% susceptibility) to yellow rust (56.5% of those studied). The remaining 12.9% were related ER III type of epidemiological resistance.

Lines Stb-1, Stb-1-1, Stb-1-3 showed high resistance to both leaf and yellow rust.

According to the intensity of septoria infection, the Stb-5-2 line was related to ER II (moderately resistant). This line had a degree of damage of 30%. The rest of the wheat lines were related to ER III type of epidemiological resistance (weakly resistant) (98%).

Stb-5-2 line was related to ER II type of epidemic resistance by the degree of infection with brown and yellow rust pathogens.

Using DNA markers, the identification of Lr-genes in selection lines as potential donors of resistance to leaf rust was carried out.

The dominance of the Lr19 gene in combination with the weakly effective genes Lr10, Lr 20 and Lr 26 was revealed. The combination of Lr19 + Lr26 increases the level of resistance.

The combination of genes Lr 19 + Lr 10 is present in Stb -1, Stb -1-1, Stb -1-3, Stb -4, Stb -5-2 lines; in Stb -03, Stb-03-1, Stb -3-2, Stb-02, the combination of Lr19 + Lr10 + Lr20 + Lr 26 was observed.

The variety accessions in the genotypes which contain several Lr genes of different efficiency may be valuable for further selecting for resistance to leaf rust.

The biological effectiveness of chemical and biological agents was established in relation to aerogenic diseases which are widespread in the northeastern part of the Central Chernozem Region within the range of 82.1-100%.

Amistar Extra was more active against septoria, perenophorosis and leaf rust; Rex Duo was effective against leaf rust, Title Duo was effective against powdery mildew.

As for mixed forms, the efficiency of Amistar Extra 0.7 l / ha + Biostim 2.0 l / ha against leaf rust (99.4%) and powdery mildew (98.9%) was observed. A mixture of Amistar Extra 0.7 l / ha and Alfastim 30 ml / ha was effective against septoria (93.0%) and pyrenoforosis (100%). Mixed forms of


Amistar Extra 0.7 l / ha + Alfastim 30 ml / ha (91.3-95.7%) and Amistar Extra 0.7 l / ha + Healthy yield 0.9 l / ha (91.0-95.7%) were effective against septoria and leaf rust.

4. Conclusion
Among the selection material of spring wheat, as a result of the purposeful work aimed at the increase of the effectiveness of resistant varieties to pathogens of harmful diseases, selection lines and numbers combining resistance to environmental stress factors (brown and yellow rust, septoria blight) were identified and selected as potential genetic donors.

The studies showed that among the zoned varieties of spring wheat, there were no varieties with ER I type of epidemic resistance to pathogens; all varieties tested need protective measures.

The effect of fungicides and their binary mixtures with biological agents used on wheat crops, which reduce the harmfulness of aerogenic diseases, was studied for the first time in the Tambov region.

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