Cross-adaptation of wheat seedlings in hyperthermia and infection with Bipolaris sorokiniana Shoem

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Abstract. The article presents the results of studies of adaptive reactions of 10-day-old seedlings of wheat varieties Novosibirskaya 18, Novosibirskaya 44, Sibirskaya 21 and Omskaya 18 under combined stress. It was found that the preliminary hyperthermia of the seeds increased the resistance of seedlings by the type of cross-adaptation to the subsequent action of B. sorokiniana (decrease in EC to 71.9%, DI to 29.7%, inhibition of biomass accumulation and growth to 95.4%). The varietal specificity of the formation of adaptive reactions under the combined action of stressors was revealed. The protective effect of hyperthermia is most pronounced in the varieties Novosibirskaya 18 and Omskaya 18.

1. Introduction

It is necessary to study the adaptive potential of a variety simultaneously to several environmental stressors in breeding and crop production. In the Siberian region, extreme temperature fluctuations, especially in early spring, and various types of infection are among the limiting factors for wheat yields. One of the most widespread diseases is common root rot of cereals, the causative agent of which is Bipolaris sorokiniana Shoem. (B. sorokiniana) which infests 70-75% of arable chernozems in Western Siberia and reduces the yield and deteriorates its quality by 10-15% [1]. In recent years there have been reports of an increase in the harmfulness of the disease in the forest-steppe of Western Siberia [2].

It is known about the ambiguous response of plants to combined biotic and abiotic stress - from intensifying to compensating for the negative effect of the stressors that occur when they act simultaneously [3, 4]. Cross-adaptation - the process of increasing the body's resistance to a particular stressor as a result of adapting to a factor of a different nature - occurs when stressors are applied in succession. According to current thinking, cross-adaptation is based primarily on the functioning of common (non-specific) resistance mechanisms in plants to two or more factors of different nature. These mechanisms are aimed at conserving the energy and structural resources of plant organisms under stressful conditions [5]. The induction of cross-adaptation is thought to be caused by overlapping plant signaling pathways and systems, most notably the antioxidant defense system [6, 7].

The aim of the research is to study the adaptive responses of soft spring wheat varieties under separate and combined action of the common root rot pathogen and elevated temperature in order to assess their resistance.

2. Material and methods

Experimental work was carried out in the laboratory for studying physical processes in agrophytocenoses at the Siberian Institute of Physics and Technology, SFSCA RAS.
To study adaptive reactions, vegetative experiments (water crops) were carried out in laboratory conditions on seedlings of released varieties of spring wheat: Novosibirskaya 44, Novosibirskaya 18, Sibirskaya 21 - Siberian selection of SRIPPB -ICG SB RAS and Omskaya 18 - selection of the Omsk Agrarian Scientific Center.

Experiment options:
- a) control (seeds without heating) and elevated temperature (seed heating at + 43°C);
- b) seeds without heating + infection with *B. sorokiniana*;
- c) heating the seeds + infection with *B. sorokiniana*.

The pre-selected and sterilized seeds were heated for 20 minutes in hot water in a water bath according to the VIR method [8]. Seed infection was carried out in the germination phase (on the third day of cultivation) with a conidial suspension of a mixture of medium pathogenic isolates of *B. sorokiniana* prepared on 0.1% aqueous agar (one drop per grain).

The levels of stress loads - conidial suspension of *B. sorokiniana* 5000 conidia per grain and temperature + 43 °C - were determined by us in specially conducted vegetative experiments as allowing to differentiate wheat varieties of Siberian selection in evaluation of their resistance to these stress factors [9, 10].

Seedlings were then grown in a Biotron-7 climate chamber in a roll crop on tap water at 16- and 8-hours photoperiod “day-night” respectively, 20,000 and 0 lux (“day-night”) illumination, 22 and 18 °C (“day-night”) temperatures and 60 % humidity.

The adaptive response of 10-day-old wheat seedlings was evaluated by a complex of indices: the change in cell membrane permeability by specific electrical conductivity (SEC) of leaf infusions, the disease progression index (DI), by linear size and accumulation of crude and dry biomass of seedlings and roots [11]. The specific conductivity was measured on a laboratory conductometer edge EC, HANNA Instruments (Germany).

Variety response was determined by the relative change in measured seedling parameters after exposure of the plants to the stressors. The smaller the change in parameters, the higher the resistance of the variety in the studied group of varieties. Repetition of the experiments was 4-6 times. Representative sample was 200 seedlings in each variant of the experiment. The experimental data were mathematically processed using standard statistical programs. The average error did not exceed 3-5%. Three series of experiments were carried out.

**3. Results and discussion**

**3.1. Adaptive responses of wheat cultivars upon infection with *B. sorokiniana* without preliminary heating of seeds**

Under the action of the causative agent of root rot in cereal plants, the processes of energy storage, respiration, enzyme activity are modified, the integrity of the membranes is disrupted, which leads to a partial leakage of electrolytes from the cells [12]. The level of tolerance of varieties to the pathogen is determined by their response to stress during growth and development.

Infection of unheated seeds with a conidial suspension of *B. sorokiniana* isolates resulted in an increased degree of infestation of primary roots and coleoptiles of seedlings; the DI significantly increased in all varieties in the range from 81.2% (Novosibirskaya 44) to 180.7% (Novosibirskaya 18) compared to the control (Table 1). The action of the pathogen caused instability in the cell membranes of seedling leaves, the EC index in all cultivars increased from 22.9% (variety Sibirskaya 21) to 65.7% (Novosibirskaya 18) compared to the control. At the same time, there was a synchronous change in the SEC and DI indicators. The effect of the pathogen on growth processes and raw and dry biomass accumulation revealed a different varietal response. The pathogen did not affect the growth and accumulation of wet and dry biomass of seedlings of varieties Sibirskaya 21 and Novosibirskaya 18 with the exception of indicators of wet and dry biomass of roots and seedling of Novosibirskaya 44 – a reliable decrease by 17.1-29.7% compared with control. we observed a significant reduction in growth and biomass accumulation compared to control in Novosibirskaya 18 and Omskaya 18, the most pronounced effect in Novosibirskaya 18, especially the dry sprout biomass and crude root biomass.
(36.1 and 37.2% respectively). As a result of the ranking of changes in seedling indices, the resistance of varieties to \textit{B. sorokiniana} changed in a descending order: Sibirskaya 21 - Novosibirskaya 44 - Omskaya 18 - Novosibirskaya 18.

### Table 1. Spring wheat seedling performance when exposed to \textit{B. sorokiniana}, without seed heating $(M±m)$

| Option          | Disease progression index (%) | Specific electrical conductivity (cm/m) | Seedling length (mm) | Raw seedling biomass (mg) | Seedling dry biomass (mg) |
|-----------------|-------------------------------|----------------------------------------|----------------------|--------------------------|----------------------------|
| Control         | 1.6±0.02                      | 4.3±0.01                               | 24.6±0.7             | 176.4±3.4                | 24.0±0.6                   |
| \textit{B. sorokiniana} | 2.9±0.03$^a$                     | 5.9±0.01$^a$                           | 21.9±0.4$^a$         | 145.6±1.5$^a$            | 19.9±0.3$^a$               |
| Control         | 1.5±0.01                      | 3.5±0.01                               | 33.4±0.5             | 185.1±5.2                | 25.0±1.3                   |
| \textit{B. sorokiniana} | 4.2±0.03$^b$                     | 5.8±0.01$^a$                           | 25.3±1.2$^a$         | 128.1±2.2$^a$            | 16.0±0.1$^a$               |
| Control         | 2.5±0.03                      | 4.4±0.02                               | 27.3±0.7             | 190.0±1.4                | 23.9±0.6                   |
| \textit{B. sorokiniana} | 6.0±0.03$^a$                     | 6.5±0.03$^a$                           | 22.7±0.4$^a$         | 153.1±1.0$^a$            | 19.4±1.1$^a$               |
| Control         | 1.8±0.02                      | 4.8±0.02                               | 25.9±0.9             | 165.9±3.5                | 23.1±1.3                   |
| \textit{B. sorokiniana} | 4.0±0.03$^a$                     | 5.9±0.01$^a$                           | 26.9±1.1             | 174.7±2.8                | 22.9±0.4                   |

$^a$ Differences with control are valid at 5% significance level.

$^b$ Differences with control are valid at 1% significance level.

In the more resistant cultivar Sibirskaya 21 under the action of the pathogen only three indicators were significantly changed: SEC, DI and dry root biomass increased by 22.9, 122.0 and 15.7% respectively, while other indicators did not change significantly.

#### 3.2. Adaptive responses of wheat cultivars upon infection with \textit{B. sorokiniana} after preliminary heating of seeds

Temperature is known to affect plant disease resistance. High temperature often suppresses plant immunity or disease resistance [13, 14]. In our experiments, after seed pre-heating and subsequent infection with \textit{B. sorokiniana}, we observed cross-adaptation expressed as a weakening of the pathological action of the pathogen on the seedlings, as well as varietal specificity of the manifestation of the responses (Table 2).

### Table 2. Parameters of seedlings of spring wheat varieties under the action of \textit{B. sorokiniana}, $(M±m)$

| Option          | Disease progression index (%) | Specific electrical conductivity (cm/m) | Seedling length (mm) | Raw seedling biomass (mg) | Seedling dry biomass (mg) |
|-----------------|-------------------------------|----------------------------------------|----------------------|--------------------------|----------------------------|
| Control         | 1.4±0.03                      | 5.7±0.01                               | 21.5±0.06            | 147.1±2.9                | 19.2±0.5                   |
| \textit{B. sorokiniana} | 2.2±0.04$^a$                     | 2.9±0.01$^a$                           | 21.6±0.8$^a$         | 136.9±2.0$^a$            | 19.8±0.4                   |
| Control         | 1.2±0.02                      | 3.8±0.04                               | 28.4±0.07            | 157.0±1.6                | 21.6±1.0                   |
| \textit{B. sorokiniana} | 3.1±0.09$^b$                     | 3.1±0.01                               | 28.1±2.2             | 134.3±1.2$^a$            | 20.1±0.5                   |
| Control         | 1.7±0.03                      | 4.1±0.01                               | 24.7±1.2             | 173.0±4.1                | 24.3±1.4                   |
| \textit{B. sorokiniana} | 3.9±0.04$^a$                     | 4.7±0.01$^a$                           | 24.5±0.8$^a$         | 160.0±2.0                | 21.3±0.4$^a$               |

Novosibirskaya 44

Novosibirskaya 18

Omskaya 18

Sibirskaya 21
Control & 1.4±0.02 & 6.9±0.01 & 22.6±1.8 & 149.1±6.3 & 20.6±1.3 \\ \hline
B. sorokiniana & 2.7±0.05\textsuperscript{a} & 5.5±0.02\textsuperscript{a} & 22.9±0.3 & 141.0±3.1 & 20.4±0.7 \\
\textsuperscript{a} Differences with control are valid at 5% significance level. \\
\textsuperscript{b} Differences with control are valid at 1% significance level.

The following indicators were found to reduce inhibition: SEC in all varieties ranging from 12.0% (Novosibirskaya 21) to 71.9% (Novosibirskaya 18), DI in all varieties from 12.6% (Novosibirskaya 18) to 29.7% (Novosibirskaya 44), growth and accumulation of wet and dry biomass in Novosibirskaya 18, Omskaya 18 from 34.0% to 95.4% compared to the variant without heating the seeds. In varieties Sibirskaya 21 and Novosibirskaya 44 reliable effect of preheating of seeds on growth and accumulation of seedling biomass was not revealed.

Thus, the Novosibirskaya 18 and Omskaya 18 varieties showed a more pronounced response to biostress in the absence of seed hyperthermia, and at the same time a stronger adaptability to the pathogen after seed temperature hardening, especially in Novosibirskaya 18 (Figure 1).

**Figure 1.** Changes in seedling parameters of Novosibirskaya 18 when infected with B. sorokiniana

Sibirskaya 21 and Novosibirskaya 44 varieties proved to be more resistant to the pathogen also after seed warming - only SEC and DI significantly changed compared to control. However, cross-adaptation also manifested itself in them as a decrease of inhibition of significantly changing indices of SEC, DI and dry biomass of sprouts, roots and seedlings ranging from 23.8% to 91.7% compared to the variant without seed warming. It can be assumed that pre-heating the seeds activates the defense mechanisms of the plants and keeps them active for a long time. Subsequent pathogen action increases the level of signaling molecules and already activated defense systems try to prevent the development of biotic stress.

**4. Conclusion**

The action of B. sorokiniana on seedlings of the four wheat cultivars caused mainly a decrease in adaptability and loss of resistance in the cultivars, expressed as inhibition of growth and accumulation of crude and dry biomass to 37.2%, an increase in DI and SEC to 180.7 and 65.7% respectively compared to control. A more resistant variety to B. sorokiniana, Sibirskaya 21, has been identified.

Preliminary hyperthermia of seeds increased the resistance of the seedlings (cross-adaptation type) to the subsequent action of B. sorokiniana. This was reflected in a decrease in inhibition of SEC to 71.9 %, DI to 29.7 %, a decrease in inhibition of biomass accumulation and growth processes to 95.4 % compared to the variant without seed heating. The stimulating effect of hyperthermia on the subsequent action of B. sorokiniana was most pronounced in the Novosibirskaya 18 and Omskaya 18 varieties.
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