Adaptation of wheat varieties under combined stress

T A Gurova
Siberian Federal Scientific Center of Agro-Bio Technologies of the Russian Academy of Sciences, Krasnoobsk, Novosibirsk Region, Russia

E-mail: guro-tamara@yandex.ru

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. The indices of growth, accumulation of wet and dry biomass and permeability of cell membranes by specific electrical conductivity (EC) of leaf extracts under the combined action of chloride salinity (1.3%) and hyperthermia of seeds (43 ºС) were studied. Chloride salinization without preliminary heating of seeds caused mainly a decrease in adaptive capacity and a loss of cultivar resistance (a decrease in growth to 57.2%, a decrease in biomass to 35.2%, an increase in EC up to 5.7 times). The most resistant cultivar is Omskaya 18. Preliminary hyperthermia of seeds increased the resistance of seedlings to the subsequent action of chloride salinization (decrease in EC to 56.2%, inhibition of biomass accumulation and growth by up to 14 times). The protective effect of hyperthermia during the subsequent action of salinity is most pronounced in the Sibirskaya 21 variety.

1. Introduction
Spring wheat in the Siberian region is cultivated under conditions of climate change, characterized by sharp temperature fluctuations, which, according to one of the climate change scenarios, will increase, especially in the early spring growing season [1]. In addition to the unfavorable temperature regime, soil salinity negatively affects the growth and development of wheat [2,3]. In the West Siberian region, the total area of saline soils are 8.8 million hectares, including arable land - 4.4 million hectares [4]. One of the ways to reduce the negative impact of the complex of stressors and to obtain high and stable grain yields of spring wheat is a reasonable choice of varieties resistant to stressors [5]. Therefore, studies of the adaptive potential of varieties simultaneously to several stress factors of the environment at the early stages of organogenesis are important and relevant for the subsequent assessment of their resistance.

The aim of the study was to study the adaptive responses of soft spring wheat varieties under the combined action of chloride salinity and elevated temperature to assess their resistance.

2. Conditions, materials and methods
The experimental work was carried out in the laboratory for the study of physical processes in agrophytocenoses of the Siberian Institute of Physics and Technology (SFNCA RAS).

To study adaptive reactions, vegetation experiments (water crops) were carried out in laboratory conditions on seedlings of zoned varieties of spring wheat: Novosibirskaya 44, Novosibirskaya 18, Sibirskaya 21 - breeding of SibNIIRS – ICG SB RAS and Omskaya 18 - selections of Omsk ANC.

Experiment options:
• control (seeds without heating) and increased temperature (heating seeds at + 43 °C);
• seeds without heating + chloride salinity 1.3%;
• warming up seeds + chloride salinity 1.3%.

The pre-selected and sterilized seeds were heated for 20 minutes in hot water in a water bath according to the VIR method [6]. Sodium chloride (NaCl) solution was used as saline. The levels of stress loads — sodium chloride (NaCl) concentration of 1.3% and temperature + 43 °C were determined by us in specially conducted vegetation experiments as allowing differentiation of Siberian wheat varieties when assessing their resistance to these stress factors [7, 8].

Then, the seedlings were grown in the "Biotron-8" climatic chamber in a roll culture on tap water (control option) and sodium chloride at a day-night photoperiod of 16 and 8 hours, respectively, illumination of 20,000 and 0 lx ("day-night"), temperature 22 and 18 ºC ("day-night"), humidity 60%.

The adaptive response of 10-day old seedlings of wheat cultivars was assessed by a set of indicators: changes in the permeability of cell membranes in terms of specific electrical conductivity (EC) of leaf infusions, linear dimensions, and accumulation of raw and dry biomass of shoots and roots [9]. Specific electrical conductivity was measured on an edge EC laboratory conductometer, HANNA Instruments (Germany).

The response of the cultivar was determined by the relative change in the measured parameters of seedlings after exposure of plants to stressors. The smaller the change in parameters, the higher the resistance of the variety in the studied group of varieties. The experiments were repeated 4-6 times. A representative sample of 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 Discussions

3.1. Adaptive reactions of wheat varieties under chloride salinization without preliminary heating of seeds
Salinization of the environment negatively affects plant metabolism, causing ionic toxicity, osmotic and oxidative stress [10]. One of the visible symptoms of the action of salinity is the disturbance of the growth of seedlings, which is expressed in the inhibition of the growth of the root and shoot. In addition, salts cause disorganization of cell membranes and change its ionic permeability [11].

In the variant without heating the seeds, chloride salinization at a concentration of 1.3% had a strong destructive effect on the state of the cell membranes of seedlings, the EC increased in the range from 2.1 (varieties Novosibirskaya 44 and Omskaya 18) to 5.7 times (variety Novosibirskaya 18) compared to the control (table 1).

Table 1. Indicators of seedlings of wheat varieties under the action of chloride salinity without heating the seeds (M ± m).
3.2. **Adaptive reactions of wheat varieties under chloride salinization after preliminary heating of seeds**

It is known that with the sequential action of stressors, cross-adaptation occurs - the process of increasing the body's resistance to a specific stress factor as a result of adaptation to a factor of a different nature. According to modern concepts, cross-adaptation is based primarily on the functioning in plants of general (nonspecific) mechanisms of resistance to two or more factors of different nature. These mechanisms are aimed at saving energy and structural resources of plant organisms under stressful conditions [13].

In our experiments, preliminary temperature heating of seeds with subsequent chloride salinization stimulated the manifestation of the hardening effect (cross-adaptation) in seedlings of wheat varieties to varying degrees (Table 2).

An increase in adaptive properties (resistance) after heating the seeds was manifested in a decrease in growth inhibition, especially root length, in all varieties in the range from 16.0% (variety Novosibirskaya 18) to 14 times (variety Sibirskaya 21), a decrease in inhibition of raw biomass from 20.4% (variety Novosibirskaya 18) to 5.2 times (variety Sibirskaya 21), as well as a decrease in dry biomass inhibition from 20.6% (cultivar Sibirskaya 21) to 5 times (variety Novosibirskaya 18) compared with the option without heating the seeds.

**Table 2.** Indicators of seedlings of wheat varieties under the action of chloride salinity with heating of seeds to 43 °C (M ± m).

| Version | Specific electrical conductivity (S/m) | Seedling length (mm) | Raw seedling biomass (mg) | Dry seedling biomass (mg) |
|---------|---------------------------------------|----------------------|--------------------------|--------------------------|
| Control | 5.7±0.1 b | 21.5±0.6 | 147.1±2.9 | 19.2±0.5 |
| NaCl | 22.0±0.2 b | 18.2±0.6 a | 140.6±2.4 | 19.7±0.5 |
| Novosibirskaya 44 | | | | |
| Control | 3.8±0.4 | 28.4±0.7 | 157.0±1.6 | 21.6±1.0 |
| NaCl | 26.3±0.6 b | 19.3±0.3 a | 170.0±0.3 a | 18.7±0.6 a |
| Novosibirskaya 18 | | | | |
| Control | 4.1±0.1 | 24.7±1.2 | 173.0±4.1 | 24.3±1.4 |
| NaCl | 8.5±0.2 b | 21.6±0.6 a | 143.0±2.4 a | 21.6±0.5 |
| Omskaya 18 | | | | |
| Control | 6.9±0.1 | 22.6±1.8 | 149.1±6.3 | 20.6±1.3 |
| NaCl | 13.2±0.2 b | 19.0±0.7 a | 142.5±1.7 | 19.6±0.5 |
| Sibirskaya 21 | | | | |

*Note: a Differences with control are significant at the 5% significance level. b Differences with control are significant at the 1% significance level.*
membranes of seedlings led to an increase in the release of electrolytes from cells and an increase in the EC in the varieties Novosibirskaya 18 and Novosibirskaya 44 by 24.9% and 2.5 times, respectively. In the Novosibirskaya 18 variety, the EC changed insignificantly, while in the Sibirskaya 21 variety it decreased by 56.2% compared to the variant without heating the seeds.

As a result of the ranking, the resistance of varieties to chloride salinity changed in the descending order: Sibirskaya 21 - Omskaya 18 - Novosibirskaya 44 - Novosibirskaya 18. The protective systems of varieties Sibirskaya 21 and Omskaya 18 were more liable; in these varieties, preliminary heating of seeds reduced the development of destructive processes during chloride salinity (figure 1).

![Figure 1. Changes in the parameters of seedlings of Sibirskaya 21 variety under chloride salinization: a) – without seed heating; b – seed heated up to 43 °C.](image)

Thus, under the conditions of this experiment, the adaptive reactions under the action of stressors have a variety specificity. Preliminary hyperthermia of seeds leads to an increase in the resistance of seedlings of wheat varieties under the subsequent action of chloride salinization.

4. Conclusion
The effect of chloride salinity (1.3%) on seedlings of 4 wheat varieties caused mainly a decrease in the adaptive capacity and loss of resistance of varieties, expressed as inhibition of growth to 57.2%, a decrease in the accumulation of wet and dry biomass to 35.2%, and an increase in EC up to 5.7 times. A more resistant variety to chloride salinization, Omskaya 18, was identified.

Preliminary hyperthermia of seeds increased the resistance of seedlings to the subsequent action of chloride salinity (1.3%). This was expressed in a decrease in EC to 56.2%, a decrease in inhibition of biomass accumulation and growth processes up to 14 times. The most pronounced stimulating effect of hyperthermia with the subsequent action of salinity in the Sibirskaya 21 variety.

References
[1] Paramonov V, Zemtsev V and Kopysov S 2017 Bull. of the Tomsk Polytechnic University. Resource engineering 328(1) 62-74. URI: http://earchive.tpu.ru/handle/11683/36657
[2] Marchenkova L, Davydova N, Chaidar R, Orlova T, Kazachenko A, Gracheva A and Shirokolava A 2017 Bull. of the Altai State Agrarian University 5(151) 9-15
[3] Houshmand S, Arzani A and Mirmohammadi-Maibody S 2014 Communications in soil science and plant analysis 45(3) 297-308. DOI: doi.org/10.1080/00103624.2013.861911
[4] The development of the solonetz lands of Baraba and Northern Kulunda: method. allowance 2006 28
[5] Kononenko N, Dilovarova T, Kanavsky R, Lebedev S, Baranova E and Fedoreeva L 2019 Bull. of the Peoples’ Friendship University of Russia. Series: Agronomy and Livestock 14(1) 18-39 DOI: 10.22363 / 2312-797X-2019-14-1-18-39
[6] Udovenko G 1988 *Diagnostics of plant resistance to stress: method. recommendations* 228
[7] Gurova T A, Berezina V Yu and Kotserubava N S 2010 *Pat. of the Russian Federation No 2446671* appl. 21.06.2010, publ. 10.04.2012
[8] Gurova T, Lugovskaya O and Svezhintseva E 2019 *Siberian Herald of Agricultural Science* **49(3)** 31-40 DOI 10.26898/0370-8799-2019-3-4
[9] Gurova T, Denisyuk S, Lugovskaya O, Zvegintseva E and Mineev V 2017 *Methodological provisions for early diagnostics of resistance of spring wheat and barley varieties to the combined effect of stressors* 62
[10] Wenji L, Xiaoli M and Peng W 2018 *Biochemical and Biophysical Research Communications* **495**(1) 286-91 DOI: 10.1016/j.bbrc.2017.11.043
[11] Jian-Kang Zhu 2016 *Cell* **167**(2) 313-24 DOI: https://doi.org/10.1016/j.cell.2016.08.029
[12] Munns R and Tester M 2008 *Annual Review of Plant Biology* **59** 651-81 DOI: https://doi.org/10.1146/annurev.arplant.59.032607.092911
[13] Zhong-Guang L and Ming G 2011 *Journal Plant Biology* **54** 358-64 DOI: https://doi.org/10.1007/s12374-011-9178-3