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Evaluation of Physiological Parameters of Autumn Rye (Secale Cereale L.) under Drought

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Abstract In the article, the relative ability of five rye cultivars to measure different morpho-physiological parameters of drought tolerance, i.e. seed germination percentage, root length, shoot length and tolerance index were studied.

Keywords Rye, Seed germination, Drought tolerance, Sucrose, Osmotic pressure, Biomass, Depression, Ear length, Number of grains per ear, Mass of 1000 grains

1. Introduction

Drought resistance is one of the important biological and economically valuable characteristics of plants, which is the ability to use moisture in conditions of lack of moisture, especially in the first stages of growth and development [1]. The term "drought tolerance" refers to the ability of plants to withstand unfavorable growing conditions without reducing yield [2].

Winter rye is relatively drought-resistant and is a water-efficient crop due to its well-developed root system. However, the lack of moisture in each of the important periods of water use (germination stage, autumn processing, from the emergence of the tube to the ear, the period of grain filling) slows down the processes of morphogenesis and decreases the parameters of productivity, including the length of the ear, the number of grains in the ear, the weight of 1000 grains. In addition, dry weather during the period of sprouting and flowering reduces the readiness of crops for wintering [3].

In regions with sufficient moisture, the negative effects of drought on agricultural crops are more pronounced than in dry regions. In the years with a moisture deficit during the periods of increased water demand of the plants, the yield of autumn rye is significantly reduced, which determines the relevance of the research conducted to evaluate the relative drought resistance of the cultivated varieties [4].

2. Materials and Methods

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Indirect methods of assessing relative drought resistance include the method of determining the germination of seeds in a solution with increased osmotic pressure that simulates a lack of water (for example, sucrose solution). Cultivars that can germinate under osmotic stress and develop a strong primary root system can subsequently be drought tolerant under natural field conditions [5]. This method makes it possible to isolate promising drought-resistant material at the early stages of organogenesis, which is important for the cultivation of autumn drought-resistant winter crop varieties [5]. The concentration of the osmotic solution should be such that the differences in the stability of the evaluated objects have the largest amplitude [6]. Correctly selected concentration gives a clearer picture of the relative drought resistance of the varieties.

For research, five autumn rye varieties – Vakhsh, Pamirskaya, Dubinskaya, Saratovskaya and Shalola were selected. The sample size consists of 30 seeds of each variety. Seed germination was carried out in Petri dishes on filter paper. In the experimental variants, sucrose solutions of different concentrations were added to the cups and osmotic pressures of 6, 9, and 12 atmospheres (atm) were created: In the control variant, the seeds were collected with the addition of distilled water. On the tenth day, the germination of seeds was determined (P, %). For this, the number of seeds that gave the root of the minimum length in the experimental and control variants was counted, and then the average number of germinated seeds in sucrose solution (a) was expressed as a percentage compared to the number of germinated seeds. In control (b), that is, $P = (a/b) \times 100\%$. The higher the percentage of seed germination in the sucrose solution, the more drought-resistant the sample is.

3. Result and Discussion

As a result of studying the germination of seeds of Vakhsh, Pamirskaya, Dubinskaya, Saratovskaya and Shalola varieties under different water deficit conditions (different concentrations of sucrose solution), it was found that the germination varies from 60.0% to 86.7%, depending on the conditions and genotype. According to the results of the analysis, it was found that there are statistically significant differences in the degree of seed germination according to the factor "variety" and "concentration of sucrose solution" (Fig. 1).

In all samples, the percentage of seed germination decreased with increasing solution concentration and osmotic pressure.

Among the studied concentrations, the greatest change in the "seed germination" indicator was found at the concentration of 10.5% sucrose solution, which creates an osmotic pressure of 12 atm.

Vakhsh, Pamirskaya, Dubinskaya, Saratovskaya and Shalola cultivars were observed to have statistically significant differences in seed germination rate in the control option compared to the 6, 9 and 12 atm options. The difference in growth between varieties at 12 atm was not statistically significant, but the range of variation was higher in the osmotic pressure of 6, 9 and 12 atm, indicating greater sign variation. (Figure 1).

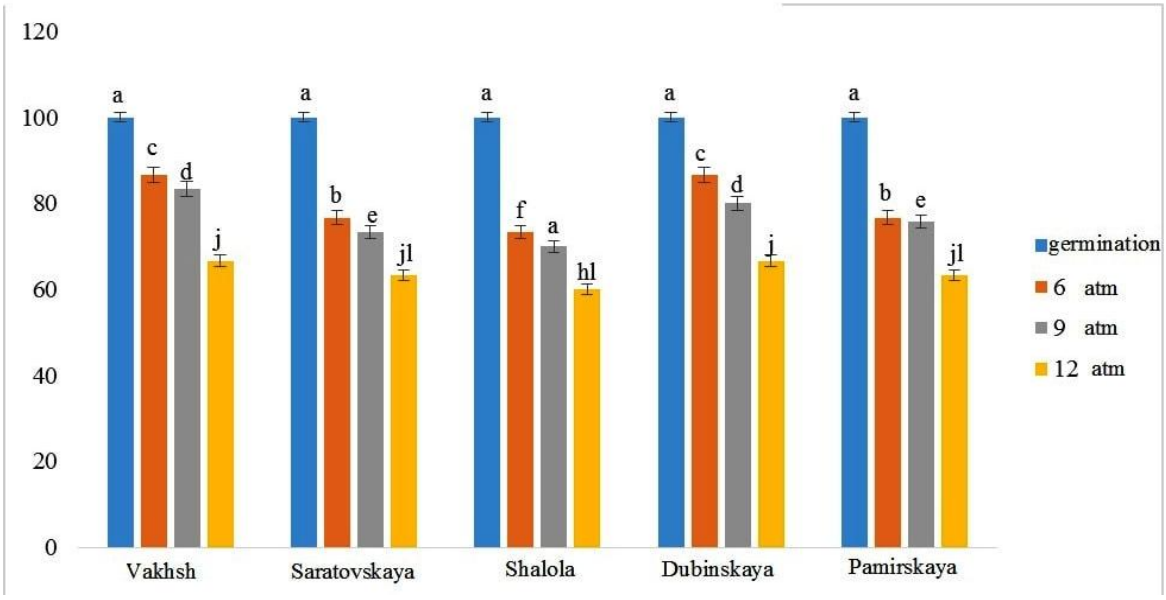

Figure 1. Effect of different levels of osmotic pressure on winter rye seed germination

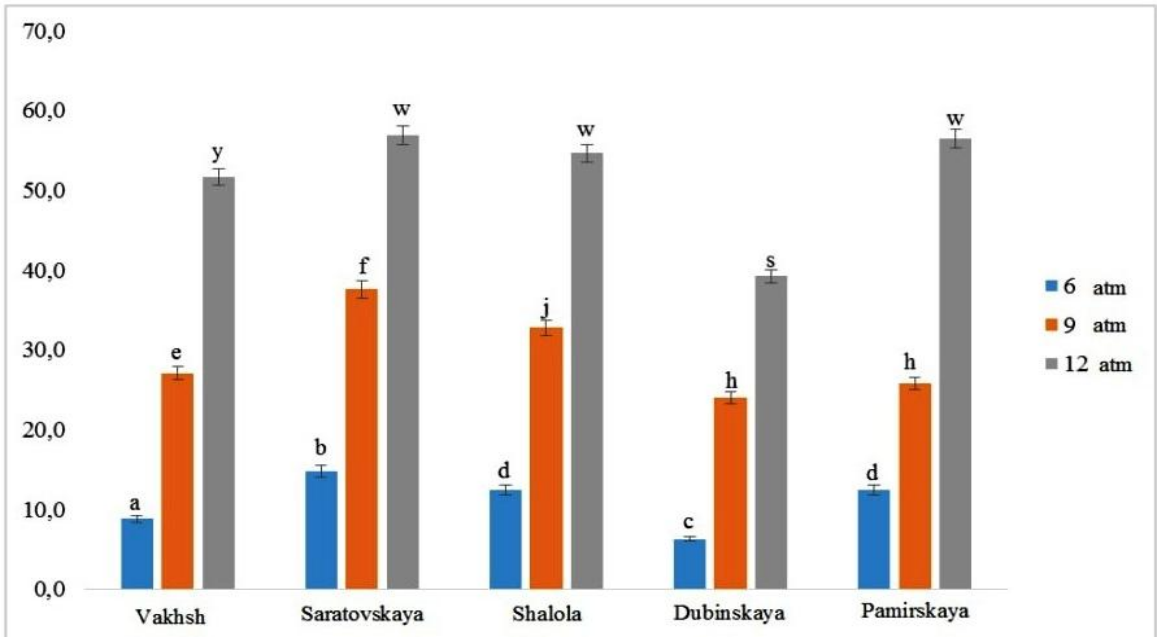

Figure 2. Depression of autumn rye varieties during growth

The degree of reduction (depression) of growth processes (Z, %) was determined by the loss of dry weight of seedlings (roots and shoots) in the experiment (y) compared to the same indicator in the control version (x), the Z index describes the degree of growth processes with an increase in osmotic pressure.

$$Z = 100 - \frac{y}{x} \times 100\%$$

More drought-resistant samples are characterized by less depression of growth processes at high osmotic pressure, which is manifested by less decrease in biomass accumulation by seedlings.

In our research, the confidence interval of the value of the seed germination characteristic was determined for each sample when differentiating according to the level of drought tolerance, and then the group interval value was calculated.

Evaluation of the depression of dry biomass accumulation in the experiments of Vakhsh, Pamirskaya, Dubinskaya, Saratovskaya and Shalola varieties using the Fisher test of the StatView program showed that they had statistically significant differences compared to the 6, 9 and 12 atm options. It turned out that the Dubinskaya variety was less depressed than other varieties in all variants (Fig. 2).

Rye (Secale cereale L.) is an important food crop in Central Asia and Eastern Europe. In these regions, rye is mainly planted as grain in autumn on 4.8 million hectares [9]. Rye has been recognized to be more drought tolerant than other crops [10].

Drought is the most limiting abiotic stress on crop productivity, affecting all phenological stages throughout their life cycle [7]. For example, drought during the vegetative period affects the grain yield mainly by reducing plant density and number of grains, and drought during grain filling causes a decrease in grain weight [8].

During our research, we also studied the length of shoots in rye cultivars at different concentrations of sucrose solution.

It was found that the shoot length in the studied rye cultivars had statistically significant differences in the control variant compared to the 6, 9 and 12 atm variants.

In the control variant, the highest indicator was observed in the Saratovskaya variety and the lowest indicator of the sign compared to other varieties was recorded in the Shalola variety. The remaining Dubinskaya, Pamirskaya and Vakhsh cultivars were not statistically significantly different from each other in terms of shoot length.

Among these cultivars, Dubinskaya, Vakhsh, Saratovskaya, and Shalola cultivars were statistically not significantly different from each other when the length of sprouts was analyzed in a 6-atmosphere sucrose solution. The Pamirskaya variety was statistically close to the Saratovskaya and Shalola varieties. 12 atmosphere Dubinskaya variety recorded the highest result compared to other varieties, while Pamirskaya variety was statistically close to it. It was found that the other varieties Vakhsh, Saratovskaya, and Shalola were not reliably distinguished from each other from a statistical point of view (Fig. 3).

Today, there are many physiological methods for assessing drought resistance of field plants. Relatively simple, relative methods for mass assessment of drought resistance are based on the determination of seed germination and the growth of seedlings in a solution of osmotic agents simulating low humidity.

Germination of seeds under these conditions is reflected, on the one hand, in the property of reproductive germination in a relatively small amount of water, and on the other hand, in the presence of a high absorption force that ensures the rapid absorption of a sufficient amount of water.

A positive correlation between the ability of seeds to germinate in osmotic solutions and drought resistance has long been noted.

The high nutritional power of the seeds leads to the formation of a stronger root system (primary), which is important not only for the lack of moisture, but also for the further vital activity of plants, especially during drought, that is, the characteristics of the seedling have a great impact on the formation of drought resistance in high plants.

In our research, we also analyzed the root length of rye cultivars in different concentrations of sucrose solution.

Similar data were obtained here as above. For example, it was noted that all variants of rye cultivars have statistically significant differences in root length compared to each other.

In the control variant, Dubinskaya, Pamirskaya, and Vakhsh varieties obtained statistically similar results in terms of root length, while Saratovskaya variety was not superior to all varieties. The low indicator of the sign compared to other varieties was recorded in the Shalola variety.

In addition, when the root length of these varieties was analyzed in 6 atmospheres of sucrose solution, Shalola, Dubinskaya and Pamirskaya varieties were not statistically reliably different from each other, while Vakhsh and Saratovskaya varieties were statistically close to each other.

At 12 atmospheric pressure of sucrose solution, it was found that Shalola cultivar has statistically significant differences compared to Vakhsh Saratovskaya Dubinskaya and Pamirskaya varieties.

The low indicator of the sign compared to other varieties was recorded in the Shalola variety (Fig. 4).

4. Conclusions

The laboratory method of growing winter rye seeds in sucrose solution allows indirect assessment of samples for drought tolerance. With the increase in solution concentration and osmotic pressure, a decrease in the percentage of seed germination was noted in all studied samples.

The analysis of varieties carried out according to the established methodology allows to divide winter rye varieties into groups. Samples with less depression in osmotic stress can be considered promising for further study

of drought tolerance under natural field conditions.

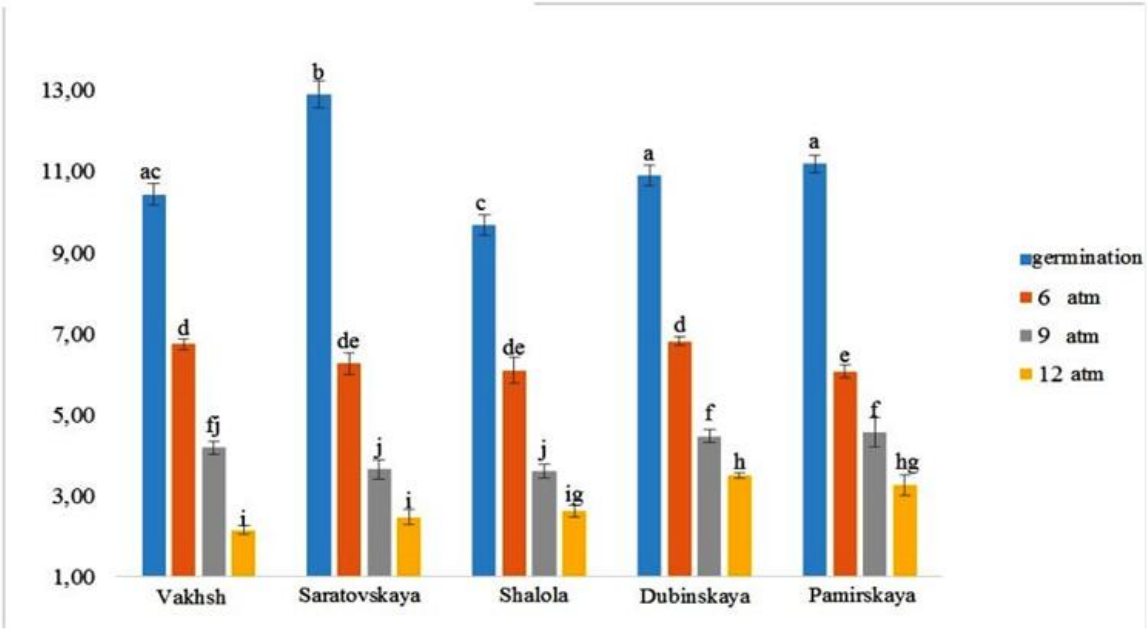

Figure 3. Effect of different levels of osmotic pressure on the development of winter rye cultivars

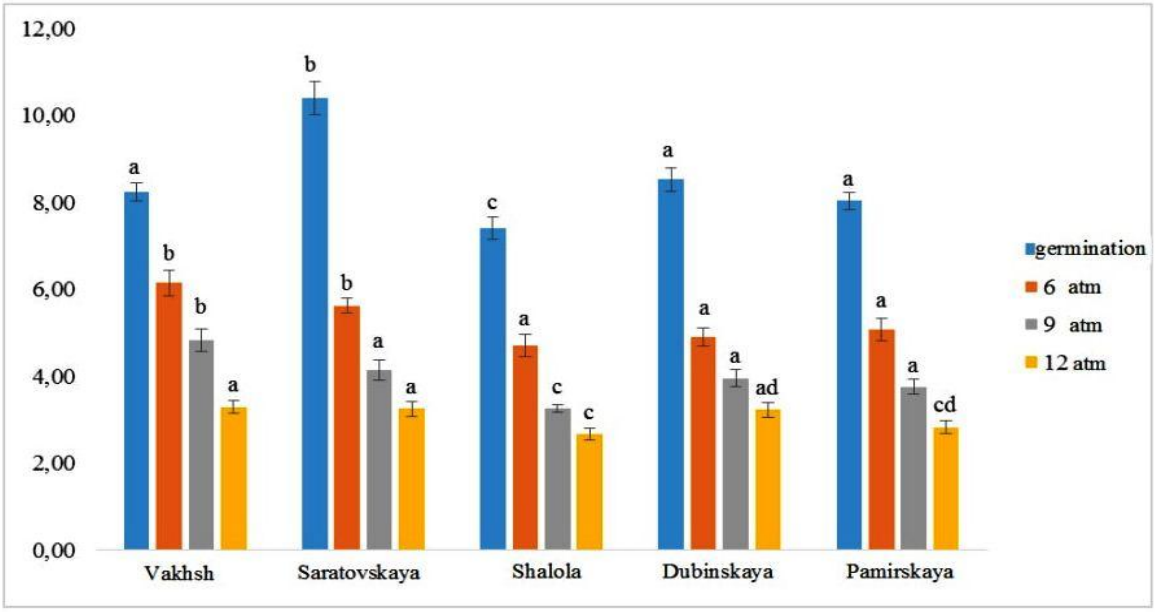

Figure 4. Effect of different levels of osmotic pressure on root length of winter rye cultivars

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