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ASSESSMENT OF DROUGHT RESISTANCE OF SOYBEAN VARIETY SAMPLES DURING SEED GERMINATION UNDER OSMOTIC STRESS CONDITIONS

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Abstract

The article presents the results of a laboratory evaluation of drought resistance in soybean (Glycine max (L.) Merr.) variety samples at the early stages of ontogenesis under simulated water deficit conditions induced by osmotic stress. The study was conducted on 23 soybean variety samples of different ecological-

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geographical and breeding origins (South Korea, Uzbekistan, and the Russian Federation).

Drought resistance was assessed based on seed germination rates during germination in a sucrose solution with high osmotic pressure. A pronounced inter-varietal variability in seed response to osmotic stress was established.

Based on the obtained data, the variety samples were classified into groups according to their level of drought resistance. Genotypes with high germination retention were identified, representing practical value for use in breeding programs aimed at developing drought-resistant soybean varieties.

Keywords: Soybean, drought resistance, osmotic stress, seed germination, sucrose solution, early stages of ontogenesis.

Introduction

Water deficit is one of the most significant environmental factors limiting the growth, development, and productivity of agricultural crops in many regions of the world. Under conditions of global climate change, an increase in the frequency and intensity of drought periods is predicted, which significantly enhances the relevance of research aimed at studying and improving plant drought resistance.

Soybean (Glycine max (L.) Merr.) is among the most important leguminous crops in global agriculture and is widely used in the food, feed, and processing industries. Despite its high economic value, soybean is highly sensitive to moisture deficiency, especially at the early stages of ontogenesis. Disruption of water supply during seed germination and seedling formation leads to reduced field germination, uneven emergence, and, consequently, a decrease in yield.

Modern breeding programs are focused on the early diagnosis of plant resistance to abiotic stresses. Laboratory methods based on drought simulation using osmotically active substances make it possible to effectively evaluate the

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response of seeds to water deficit. Seed germination under conditions of increased osmotic pressure is considered an informative express method reflecting the ability of genotypes to maintain physiological activity under limited water uptake [5,6,7,8,9].

A number of field and laboratory methods are used to diagnose plant drought resistance. Compared varieties and plant species are cultivated in arid regions, and those that show less reduction in yield are considered more drought-resistant. Testing for drought resistance in drought chambers and dry-wind installations makes it possible to expose plants to soil and atmospheric drought at any stage of their vegetation and to evaluate varieties [1,2,3,4,10].

The most drought-resistant soybean varieties under conditions of insufficient soil moisture are characterized by an increased content of tightly bound water in tissues, a high concentration of cell sap, elevated osmotic pressure, lower water deficit, an increased temperature threshold of protein coagulation, and the maintenance of high synthetic activity [10]. The method for evaluating drought resistance based on seed germination in solutions with high osmotic pressure, proposed in the works of N. N. Kozhushko, has become widely used due to its simplicity, reproducibility, and high diagnostic value. The application of this approach makes it possible to carry out the primary selection of promising breeding material at the early stages of ontogenesis.

The aim of the study was to evaluate the drought resistance of soybean variety samples based on seed germination indicators under osmotic stress conditions created by a sucrose solution.

To achieve this aim, the following objectives were defined:

- to carry out laboratory germination of soybean seeds in a sucrose solution and under control conditions;
- to determine the percentage of seed germination on the fifth day of germination;
- to identify variety-specific differences in seed response to osmotic stress;

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- to classify the studied variety samples into drought resistance groups based on quantitative indicators.

The object of the study was soybean (Glycine max (L.) Merr.) variety samples of different ecological-geographical and breeding origin.

The study included the following variety samples: South Korean selection — CH27(-266), CH28(-268), CH7(-014), CH3(-008), CH11(-018), CH30(-969), US-14(-382), US-25(-622), US-44(-641), US-80(-699), US-82(-701), K 09 (339), KO3(-214), KO18, KO20, KO21 (RR-1); Uzbek selection — Uzbekskaya 2, TDAU-5; Russian Federation selection — Avanta, Arleta, Sparta, Selecta 201, Selecta 302.

The subject of the study was the seed germination of the specified soybean variety samples and the degree of its change under osmotic stress conditions at the early stages of ontogenesis.

Materials and Methods

The study was conducted in the laboratory of the Southern Scientific Research Institute of Agriculture. Drought resistance was assessed using the method of seed germination under conditions of increased osmotic pressure according to the methodology of N. N. Kozhushko.

The experiment was carried out in four replications. For each variety sample, 50 seeds were used in each replication. Seed germination was conducted in Petri dishes on filter paper.

In the experimental variants, 10 ml of sucrose solution creating osmotic stress was added to the Petri dishes; in the control variants, 10 ml of distilled water was used. Seed germination was recorded on the 5th day. Seeds with a clearly visible root were considered germinated.

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Drought resistance of the variety samples was evaluated based on the percentage of seed germination in the sucrose solution according to the following classification:

- 0–20% — non-resistant;
- 21–40% — weakly resistant;
- 41–60% — moderately resistant;
- 61–80% — above-average resistant;
- 81–100% — highly drought-resistant.

Results and Discussion

Seed germination in control conditions. In control conditions, the percentage of seed germination varied from 20 to 100%, which reflects differences in the initial viability of the seeds and the genetic characteristics of the variety samples. The highest indicators (95–100%) were observed in most variety samples of South Korean selection, as well as in the varieties of Uzbek selection Uzbekskaya 2 and TDAU-5 and the Russian variety sample Selecta 302. At the same time, the varieties Avanta, Arleta, Sparta and Selecta 201 were characterized by reduced germination already in control conditions.

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Table 1 Laboratory evaluation of drought resistance of variety samples based on seed germination under osmotic stress conditions

№	Variety samples	Control (seed germination in distilled water, %)	Seed germination in sucrose solution (%)
1	CH27(-266)	100	99
2	CH28 (-268)	100	99
3	CH3 (-008)	92	90
4	CH7(-014)	100	98
5	CH11 (-018)	100	99
6	CH30 (-969)	66	48
7	US-25 (-622)	64	56
8	US-14 (-382)	100	84
9	US-44 (-641)	100	92
10	US-80 (-699)	100	94
11	US-82 (-701)	100	92
12	K 09 (339)	96	80
13	KO20	100	92
14	KO3 (-214)	96	67
15	KO21 (RR-1)	96	63
16	KO18	100	98
17	Uzbekskaya 2	96	95
18	TDAU-5	96	92
19	Arleta	44	18
20	Sparta	44	15
21	Avanta	40	32
22	Selecta 201	20	7
23	Selecta 302	100	90

Response of Variety Samples to Osmotic Stress. Germination of seeds in a sucrose solution led to a decrease in germination in all studied variety samples; however, the degree of inhibition differed significantly.

The group of highly drought-resistant (81–100%) included the variety samples CH27(-266), CH28(-268), CH3(-008), CH7(-014), CH11(-018), US-14(-382), US-44(-641), US-80 (-699), US-82 (-701), KO20, KO18, Uzbekskaya 2, TDAU-

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5, and Selecta 302, in which seed germination in the sucrose solution amounted to 84–99%. The group of above-average resistant (61–80%) included the variety samples K09(339), KO3(-214), and KO21 (RR-1), in which the seed germination rate varied within 63–80%.

The group of moderately resistant (41–60%) included the variety samples CH30(-969) and US-25(-622), the seed germination of which under osmotic stress conditions was 48–56%. The group of weakly resistant (21–40%) included the variety sample Avanta, in which seed germination in the sucrose solution decreased to 32%. The group of non-resistant (0–20%) included the variety samples Arleta, Sparta, and Selecta 201, in which seed germination did not exceed 7–18%.

Analysis by Breeding Origin. Variety samples of South Korean breeding generally demonstrated the highest level of drought resistance. Variety samples of Uzbek breeding were also characterized by high retention of germination under stress conditions. Among the Russian varieties, significant variability of responses was revealed — from the highly resistant variety sample Selecta 302 to the non-resistant varieties Arleta, Sparta, and Selecta 201.

Response of Variety Samples to Osmotic Stress. Germination of seeds in a sucrose solution led to a decrease in germination in all studied variety samples; however, the degree of inhibition differed significantly. The group of highly drought-resistant (81–100%) included the variety samples CH27(-266), CH28(-268), CH3(-008), CH7(-014), CH11(-018), US-14(-382), US-44(-641), US-80 (-699), US-82 (-701), KO20, KO18, Uzbekskaya 2, TDAU-5, and Selecta 302, in which seed germination in the sucrose solution amounted to 84–99%. The group of above-average resistant (61–80%) included the variety samples K09(339), KO3(-214), and KO21 (RR-1), in which the seed germination rate varied within 63–80%.

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Conclusions

It was established that the method for evaluating soybean seed germination under conditions of high osmotic pressure of a sucrose solution is a simple, reliable, and express method for diagnosing drought resistance at the early stages of ontogenesis.

As a result of the study, the variety samples were distributed by levels of drought resistance as follows:

- Highly drought-resistant (81–100%) — 14 varieties (60.9%);
- Above-average resistant (61–80%) — 3 varieties (13.0%);
- Moderately resistant (41–60%) — 2 varieties (8.7%);
- Weakly resistant (21–40%) — 1 variety (4.3%);
- Non-resistant (0–20%) — 3 varieties (13.0%).

The most promising for use in breeding programs are the variety samples CH27 (-266), CH28 (-268), CH3 (-008), CH7 (-014), CH11 (-018), US-14 (-382), US-44 (-641), US-80 (-699), US-82 (-701), KO18, KO20, Uzbekskaya 2, TDAU-5, and Selecta 302, which showed high seed germination under osmotic stress conditions.

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The application of this laboratory method makes it possible, in a short time, to carry out a comparative evaluation of a large number of genotypes and to effectively select donors of drought resistance for further breeding work.

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