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Assesment of salt tolerance of a collection of sorghum genotypes

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The area of solonetzes in the Central Ciscaucasia is 1.5 million hectares. Salinity of the soil is one of the main abiotic stresses that do reduce agricultural productivity. Laboratory methods determined the level of salt tolerance in 81 new varieties, lines, hybrids of sorghum and sorghum-sudank combinations with exogenous exposure to NaCl in doses of 0.1%; 0.15%; 0.3%; 0.6%; 1.0%; 1.5%. Studies showed that the concentration of sodium chloride solution of 0.15% and 0.3% in a main part of the studied samples does not significantly reduce laboratory germination, the size of the roots and stems of sorghum. The dose of saline 1.0% NaCl reduces the laboratory germination of sorghum seeds to 33-93%. In 15 samples studied, this trait had a value of 33-60%. 19 pieces were obtained of medium sensitive samples of sorghum with a germination rate of 60 to 80%. 47 variants had a germination rate of more than 80%. It was set to the maximum at numbers K-9693, K-1596, Volzhskoe 51, Kinelskoe 3, Listvenny and exceeded 91%. A significant amount of the studied samples of sorghum can be grown on soils with a salt concentration of 1%. In the presence of 1.5% NaCl in the solution, the highest seed germination rates were obtained for K-1596 (59%), K-9693 (56%), Yantar krasny (40%), K-4015 (45%), Capitan (34 %), Larets (29%), Listvenny (30%), Sahara (28%), Kinelskoe 3 (41%), K-1358 (23%), K-115 (18%). It is advisable to use them in future breeding programs.

Keywords: salt tolerance, selection, sorghum, sorghum, sorghum-sudank hybrids.

INTRODUCTION

In the western part of the Stavropol Territory, up to 38% of its territory is being occupied by black soil. Their pH ranges from 6.9 to 8.0. The eastern part of the region (43% of the area) is represented by chestnut soils with a pH of 7.76-8.10. The rest of the region includes salt marshes, salt marshes, sandy and floodplain meadow soils. The total area of solonetzes in the Stavropol Territory is approximately 1.5 million hectares. They have a very blocky structure, high density, low porosity. In solonetzic soils, the amount of exchangeable sodium ranges from 3-5 to 15-20% of the absorption capacity, and in the suns - more than 20%. Having a complex of unfavorable physicomechanical and water properties, solonetzes are relatively rich in nutrients; therefore, it is effective to grow salt tolerant crops on them. Salinity of the soil is one of the main abiotic stresses, which may reduce agricultural productivity (Ding et al., 2018, Shrestha et al., 2016).

Both domestic and foreign varieties and hybrids of sorghum are being characterized by good drought tolerance, however, their cultivation is often associated with a high NaCl content in solonetzic soils (Baranovsky et al., 2019, Kapustin et al., 2019, Volodin et al., 2018). To obtain the

most salt-tolerant varieties, special programs for breeding sorghum crops are being developed (Gull et al., 2019). Humic and jasmonic acids increase antioxidant enzymes that mitigate damage caused by salinity stress (Ali et al., 2017). Locations of loci of quantitative signs of adaptability of salt stress have been established. To improve salt tolerance, they serve as target sites for selection using the MAS marker (Zhang et al., 2020).

Sakharnoe sorghum reduces the content of Na^+ in the roots, which ensures its low concentration in shoots by protecting photosynthesis structures (Yang et al., 2018, Yang et al., 2020). Under conditions of salt stress, transgenic hybrids show a higher chlorophyll content and a better yield level (Ahire et al., 2018, Kandula et al., 2019). A number of published sources indicate that the introduction of $NH4^+$ improves the salt tolerance of the plant by limiting the accumulation of Na^+ (Baranovsky et al., 2020, Kapustin et al., 2018, Miranda et al., 2017). Silicon (Yin et al., 2016), and arbuscular mycorrhiza (Wang et al., 2019) and other factors (Nurbaity et al., 2019, Villalobos et al., 2019) play a positive role in increasing salt tolerance. Seed treatment with sorghum extracts improves resistance to salt stress in wheat and other crops (Bajwa et al., 2018, Guo et al., 2018). Indicators of salt tolerance largely determine the density and timing of sowing sorghum crops (Kapustin et al., 2020). Seed germination rates are indicative and do not always correlate with the true salt tolerance of varieties, hybrids, and the best correlation with productivity in the field was established when assessing salinity resistance along the length of the sprout (Ivanov et al., 1970).

The purpose of research. Improvement of laboratory methods for assessing salt tolerance and determining its level in new varieties, lines, hybrids of sorghum and sorghum-sorghum combinations of selection of the North Caucasus Federal Agricultural Research Center, as well as other breeding centers of the Russian Federation under exogenous exposure to sodium chloride.

MATERIALS AND METHODS

Detailed information on the degree of salt tolerance of plants in the first period of growth contributes to their cost-effective cultivation on saline soils. The objective of the research was the selection of seed cultivation conditions, NaCl concentrations, as well as the study of the growth results under the exogenous effect of this stress factor.

The objects of research were seeds of 60 varieties, 3 fertile and 2 sterile lines, 12 hybrids of grain and Sakharnoe sorghum, 4 sorghum-sudank hybrids created by breeders of the North Caucasus Federal Agricultural Research Center, as well as obtained from Zernograd (6 pcs.), Samara (4 pcs.), Saratov (5 pcs.). A total of 81 samples were studied. Sodium chloride salt was used as a factor imitating salinity. When creating chloride salinization, NaCl solutions were used in concentrations: 0.1%; 0.15%; 0.3%; 0.6%; 1.0%; 1.5%.

For research, seeds of the same size were selected, without visible infection, and before the experiment was started, chloramine was sterilized. Seeds were germinated in sterile Petri dishes containing NaCl solutions of various concentrations on filter paper moistened with distilled water (control) or salt solutions (experimental versions). The sample size is 50 seeds of four replicates for each variant. All options were kept for 7-8 days in a thermostat with a temperature of 24-25°C. Laboratory germination, shoot length and root were taken into account. The methodologies of Yu.M. Ivanova and G.V. Udovenko (Ivanov et al., 1970) were taken as the basis for assessing salt tolerance.

RESULTS AND DISCUSSION

The less the growth and accumulation of biomass of sorghum seedlings in a NaCl solution is suppressed as compared to the control, the more stable the sample. As a result of studies of varietal salt tolerance polymorphism on varieties, lines and hybrids of sorghum crops, a high germination rate of seeds was revealed in the control variant. The minimum in the experiment, it was 93.4%. When a minimum dose of NaCl (0.1%) was introduced into the solution, it was established as a decrease in the germination ability of a number of samples by 3-10% (Zersta 90 C, Navigator, K-737, K-449, Sakharnoe 20, K-4659, Moment), and its increase by 2-4% (Stavropolskoe 36, K-9293, K-9259, K-592, K-1358, K-1596, K-3048, Yantar krasny, L-7859, Listvenny).

In addition to improving germination, the length of the root and stem increased. So, in K-592, the root length increased by 3.45 cm, and the stem - 0.89 cm in L-7859, respectively, by 1.20 cm and 0.84 cm. In the Yantar krasny variety, the stem was longer by 1.54 cm. This indicates the stimulating role of low concentrations of NaCl for the germination of some samples of sorghum. At the same time, in the main part of the studied

samples, the minimal salinity of the solution did not cause significant changes in seed germination rates.

Table 1: Seed germination and length of sorghum seedlings depending on the degree of salinity of the aqueous solution

Name of variety, line, hybrid	NaCl concentration								
	0.3%			1.0%			1.5%		
	Seed germin, %	length		Seed germin, %	length		seed germin, %	length	
		stem, sm	root, sm		Stem, sm	root, sm		stem, sm	root, sm
Resistant (80-100% germination at 1.0% NaCl solution concentration)									
Zersta 90C	95.4	3.62	2.72	80.6	1.16	1.08	12.0	0.93	0.95
Galia	93.4	2.86	3.94	86.6	1.34	1.57	21.0	0.81	0.91
K-1670	92.0	3.85	2.23	86.0	1.69	0.24	10.5	1.24	1.21
K-1877	97.0	3.84	2.40	87.0	2.16	2.80	9.0	0.60	0.16
K-2352	82.0	2.76	4.92	81.0	1.58	3.36	7.0	0.31	0.26
K-9293	99.0	2.42	2.90	92.0	1.18	4.62	6.0	0.87	1.26
K-226	94.5	5.56	4.66	85.0	2.16	1.62	2.0	0.30	0.10
K-9259	98.0	2.26	3.66	87.0	0.80	1.48	7.0	0.31	0.25
K-3627	97.0	4.56	6.72	82.0	2.90	1.34	4.0	0.30	0.60
K-1383	93.0	3.68	4.38	89.0	2..68	2.72	14.0	0.70	0.60
K-1596	96.0	3.74	3.84	91.0	2.66	3.64	59.0	0.84	0.66
K-9283	90.0	3.90	4.58	85.0	2.34	2.92	50.0	0.76	1.38
Volzhskoe 51	100.0	5.40	1.28	93.0	2.28	1.54	14.0	0.60	0.20
Kinelskoe 3	98.0	2.90	2.38	93.0	2.10	1.68	41.0	0.80	1.00
Stavropolskoe 59	99.0	4.22	3.20	85.0	2.64	2.66	9.0	0.22	0.72
Yantar krasny	100.0	3.10	3.74	82.0	2.56	2.14	40.0	0.41	1.66
K-4015	100.0	1.92	4.46	99.0	2.02	3.54	45.0	0.78	2.36
L-7859	98.0	4.56	5.84	89.0	2.78	2.76	6.0	0.48	0.86
Listvenny	97.0	2.48	3.86	91.0	2.40	3.08	30.0	0.56	0.90
Sahara	97.0	6.70	5.72	87.0	3.00	3.96	28.0	0.96	0.12
Capitan	94.0	4.13	3.22	86.0	1.79	2.22	34.0	0.35	0.93

An increase in the concentration of NaCl solution to 0.3% in a main part of the studied samples did not lead to a significant decrease in seed germination, and in 28 rooms it was at the level of control variants with distilled water (96-100%). Exceeding the standards for germination by 1-3% was found in K-9293, K-9259, K-3627, K-1596, K-4015, K-1798, K-470, K-1359, L-7859, L-7812 , Volzhskoe 51, Kinelskoe 3, Yantar krasny, Severnoe 44, Stavropolskoe 59 (Table 1). Thus, the concentration of 0.3% NaCl solution did not lead to a significant decrease in seed germination, and the indicated samples showed resistance to this salt solution. On the 8th day of germination determination, a high length of roots and stems (4.66-9.62 cm) was obtained for variants Stavropolskoe 36, Larets, K-226, K-310, K-1358, L-7812, Debut, Sahara, Zernogradsky yantar.

Determination of the germination of sorghum seeds in a solution of 0.6% NaCl showed a decrease in their germination in most samples by 1.2-22.7% in comparison with a concentration of 0.3%. However, it was found that in 26 cases it was above 90%. Maximum performance was obtained with L-7813 (97%), L-7812 (95%), L-7859 (95%), Kinelskoe 3 (97%), L-1596 (94%), K-226 (94%) , K-4015 (99%), K-1877 (99%), KiM (93%), Larets (94%), Sahara (96%), Seviliya (97%), Zernogradsky yantar (96%). The length of the stem and root was most significant for Zernogradsky yantar (5.12 and 6.72 cm, respectively), Listvenny (4.74 and 6.06 cm), Larets (5.34 and 5.23 cm). A further increase in the concentration of saline (1.0%) reduced the laboratory germination of seeds to 33-93%. In 15 studied samples, germination varied from 33 to 60%. They are sensitive to a given salt concentration (Table 2).

19 susceptible samples of sorghum with a germination rate of 60 to 80% were obtained. The remaining options in the amount of 47 pieces had a germination rate of more than 80%. The maximum number was set for 5 rooms - K-9293 (92%), K-1596 (91%), Volzhskoe 51 (93%), Kinelskoe 3 (93%), Listvenny (91%). The root lengths of these samples ranged from 1.54 to 4.12

cm, and the stems 1.18-2.40 cm. Thus, even at a NaCl concentration (1.0%), a significant amount of the studied sorghum samples can be grown on soils with a similar salt concentration.

Table 2: Germination rates and seedling lengths of medium tolerant and sensitive samples of sorghum

Name of variety, line, hybrid	NaCl concentration								
	0.3%			1.0%			1.5%		
	seed germin, %	length		seed germin, %	length		seed germin, %	length	
		stem, sm	root, sm		stem, sm	root, sm		stem, sm	root, sm
Medium resistant (germination 60-80% at a concentration of NaCl solution of 1.0%)									
KiM	95.4	3.60	4.80	79.8	1.80	4.56	12.0	0.91	1.14
Navigator	86.6	4.52	3.08	68.6	2.00	2.73	14.0	1.31	1.21
Stavropolskoe 36	93.4	8.10	7.60	76.7	3.60	4.40	8.0	1.12	0.91
K-176	88.6	5.52	7.40	67.4	3.52	3.18	7.0	0.64	0.84
K-600	96.0	5.72	4.58	68.6	0.94	3.88	9.0	0.73	0.96
K-1651	97.0	3.86	5.72	75.0	1.04	3.36	6.0	0.12	0.64
K-310	89.0	6.38	9.62	72.0	3.40	3.86	16.0	0.30	1.12
K-258	96.0	4.06	3.50	74.0	3.40	2.20	6.0	2.80	0.80
K-470	100.0	3.10	2.84	73.0	4.60	2.14	11.0	0.32	0.20
K-3048	93.0	4.04	5.44	74.0	3.90	4.70	33.0	0.68	1.46
Severnoe 44	99.0	3.40	4.68	77.0	2.54	2.04	29.0	0.62	0.92
K-4659	100.0	7.54	6.62	79.0	2.80	2.96	12.0	0.80	0.36
L-7813	94.0	3.68	2.06	76.0	2.56	0.98	4.0	0.27	0.50
Moment	76.0	3.42	3.30	75.0	2.04	2.56	2.0	0.40	0.12
Sensitive (germination 30-60% at a concentration of NaCl solution of 1.0%)									
K-1583	82.0	5.48	3.58	44.0	0.58	2.76	0	0	0
Sakharnoe 20	58.0	3.44	1.29	39.0	1.98	1.26	0	0	0
Zernogradsky yantar	96.0	6.10	5.70	56.0	2.98	1.26	0	0	0
K-737	90.0	4.70	4.90	47.3	2.40	1.90	2.0	0.24	0.31

The presence of NaCl in an amount of 1.5% in the solution reduced seed germination to 1.0-10.0%, and in 12 cases this indicator was not established at all. However, even with this concentration of the solution, the laboratory germination rate was from 18 to 59%. The following forms stood out: K-1596 (59%), K-9293 (50%), Yantar krasny (40%), K-4015 (45%), Capitan (34%), Larets (29%), Listvenny (30 %), Sahara (28%), Kinelskoe 3 (41%), K-1358 (23%), K-115 (18%). The root lengths of the best options ranged from 0.98 to 2.36 cm, the size of the stems did not exceed 1.24 cm.

CONCLUSION

The concentration of saline 1.0% NaCl reduces the laboratory germination of sorghum seeds to 33-93%. In 15 samples studied, this trait had a value of 33-60%. 19 pieces were obtained of medium sensitive samples of sorghum with a germination rate of 60 to 80%. 47 variants had a germination rate of more than 80%. It was set to the maximum at numbers K-9693, K-1596, Volzhskoe 51, Kinelskoe 3, Listvenny and exceeded 91%. A significant amount of the studied samples of sorghum can be grown on soils with a salt concentration of 1%.

In the presence of 1.5% NaCl in the solution, the highest seed germination rates were obtained for K-1596 (59%), K-9693 (56%), Yantar krasny (40%), K-4015 (45%), Capitan (34 %), Larets (29%), Listvenny (30%), Sahara (28%), Kinelskoe 3 (41%), K-1358 (23%), K-115 (18%). It is advisable to use them in further breeding programs.

CONFLICT OF INTEREST

The authors declared that present study was performed in absence of any conflict of interest.

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AUTHOR CONTRIBUTIONS

SIK and ABV designed and performed the experiments. SIK and ASK wrote the manuscript. SIK and ASK performed data analysis. All authors

read and approved the final version.

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