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Laboratory Assessment of Rice Varietal Samples for Tolerance To 1.5% NaCl Solution at The Seed Germination Stage

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Abstract: The aim of this study was to evaluate the salinity tolerance of rice seeds at the germination stage under laboratory conditions and to identify promising initial material for further breeding work. A total of 21 rice accessions were evaluated under exposure to a 1.5% NaCl solution. The number of germinated seedlings, shoot length, root length, number of roots, plant biomass, and root biomass were determined as indicators of early growth and development. The results demonstrated differences among the studied accessions in germination and initial growth responses under salt stress. The highest numbers of germinated seedlings were recorded in D-111 (99 seedlings), D-66 (98), D-35 (95), D-12 (93), and D-29 (92). The D-111 accession also showed relatively high shoot length (4.54 cm) and root number (4 roots). However, a high germination rate in some accessions was not always accompanied by intensive biomass accumulation and root development. This finding indicates that the assessment of rice tolerance to salinity should consider not only germination capacity but also a combination of morphological characteristics associated with early seedling development. The obtained results demonstrate the potential of laboratory screening for the selection of promising rice germplasm with improved salinity tolerance and its subsequent use in breeding programs aimed at developing varieties adapted to saline environments.

Keywords: Rice, seeds, germination, germination capacity, salinity, NaCl, salinity tolerance, root system, morphological traits, laboratory screening.

Introduction: Rice (Oryza sativa L.) is one of the major cereal crops and plays an important role in ensuring global food security. However, global climate change, increasing scarcity of irrigation water, and the intensification of soil salinity pose serious threats to the sustainability of rice production. In particular, in salt-affected areas, rice growth, development, and yield can be significantly reduced. Salinity stress induces osmotic stress, disrupts ionic balance, causes toxic effects of sodium and chloride ions, and interferes with water relations in plants. Rice is considered one of the most salt-sensitive crops, and its early developmental stages are particularly vulnerable to salinity stress [1–3].

Salinity tolerance is a complex, polygenic trait that depends on the developmental stage of the plant, genotype, salt concentration, and duration of stress

exposure. Singh et al. reported that salinity tolerance in rice varies among developmental stages and that tolerance during seed germination and the seedling stage is not necessarily fully correlated with tolerance during later reproductive stages. Therefore, evaluating genotypes separately at different developmental stages is important during the early stages of the breeding process [4].

Laboratory methods for evaluating the salinity tolerance of rice genotypes are widely used in different countries around the world. Bui Ba Bong et al. investigated the salinity tolerance of Vietnamese rice varieties at the seed germination and seedling stages. The study found that germination rates of the varieties under a 1.5% NaCl solution ranged from 3% to 81%. The authors noted that a positive correlation between salinity tolerance during seed germination and tolerance at the seedling stage was not consistently observed. These findings indicate the need for differential selection of salinity-tolerant genotypes at the early stages of breeding programs [5].

Wu et al. evaluated 21 rice genotypes at different developmental stages. In the study, dry seeds were germinated in a 1.5% NaCl solution for 8 days, and germination rates were determined. The authors demonstrated substantial variation in germination among genotypes under 1.5% NaCl stress. At the subsequent seedling stage, traits such as relative shoot height, relative root length, leaf mortality, and water content were evaluated. The results demonstrated that salinity tolerance in rice is a developmental-stage-specific trait [6].

In Russia, laboratory screening for the development of salt-tolerant rice forms is also considered an important component of breeding programs. Kostylev et al., in addition to determining the presence of the Saltol gene in rice hybrids, evaluated salinity tolerance by germinating seeds in distilled water and a 1.5% NaCl solution and using the ratio of seedling biomass under stress to that under control conditions. As a result, salt-tolerant lines carrying the Saltol gene in the homozygous state were identified [7].

In another study conducted by Kostylev and Kudashkina, the salinity tolerance of 186 F5 hybrid samples was investigated. The seeds were germinated on filter-paper rolls using 1.5% NaCl solution and distilled water, and germination rate, seedling length, root length, and their relationships with salinity tolerance were evaluated. The researchers identified significant differences among the samples in terms of root and seedling length. A moderate correlation was found between seedling length and salinity tolerance, whereas a strong correlation was observed between root length and salinity tolerance. Based on a combination of traits, 14 superior samples were selected [8].

In subsequent studies by Kostylev, Krasnova, and Kudashkina, the method of germinating seeds in a 1.5% NaCl solution was also used to select salt-tolerant forms. The authors combined laboratory screening with molecular marker analysis, particularly the RM493 and RM7075 markers, to identify the Saltol gene. This approach can improve breeding efficiency by complementing phenotypic evaluation with genetic marker-based selection [9].

Overall, existing studies demonstrate that the use of a 1.5% NaCl solution is an effective approach for the preliminary laboratory screening and differentiation of rice genotypes for salinity tolerance. Rather than relying solely on the number of germinated seeds, a comprehensive assessment of morphological traits, including seedling height, root length, number of roots, and plant and root biomass, provides a more detailed characterization of genotype responses to salinity stress. In particular, for regions such as Karakalpakstan, where soil salinity and water scarcity are major constraints, the identification of salt-tolerant breeding materials from local and introduced rice germplasm is of considerable importance for rice breeding.

In the Republic of Karakalpakstan, soil salinity, water scarcity, and high temperatures are among the major stress factors affecting the efficiency of rice production. In particular, the level of salinity tolerance during germination and early development can substantially influence subsequent plant growth and yield. Therefore, identifying salt-tolerant breeding materials under the conditions of Karakalpakstan is of great importance for rice breeding. The aim of this study was to identify promising salt-tolerant rice varietal samples by evaluating germination, root and shoot development, and biomass-related traits under laboratory conditions using a 1.5% NaCl solution.

METHODS

The study was conducted in the laboratory of the Don and Rice Scientific Production Association, located in Nukus District, Republic of Karakalpakstan, Uzbekistan. A total of 21 rice varietal samples were used as the research material. The experiment was carried out under laboratory conditions by evaluating seed germination and early seedling development under a 1.5% NaCl solution.

The germination method using a 1.5% NaCl solution was employed to assess the salinity tolerance of the seeds. During the experiment, the number of germinated seedlings, shoot (plant) length, root length, number of roots, plant biomass, and root biomass were

determined.

The obtained results were compared among the samples, and seed germination and morphological characteristics of early seedling development under 1.5% NaCl stress were evaluated. The assessment of salinity tolerance was based on the evaluation criteria recommended by the International Rice Research Institute (IRRI).

RESULTS AND DISCUSSION

Significant differences were observed among the 21 rice varietal samples evaluated under a 1.5% NaCl solution under laboratory conditions in terms of their responses to salinity stress. The results showed that seed germination, shoot and root development, and biomass accumulation under salinity stress varied considerably among the rice varietal samples (Table 1).

Table 1.

Assessment of salinity tolerance of rice varietal samples under a 1.5% NaCl solution under laboratory conditions

№	Rice varietal samples	Shoot engtth, cm	Root engtth, cm	Number of roots	Number of germinated seedlings	Plant biomass g	Rotb ioma ss, g
1	D-29(K-127/C7-18) b/ost	3,662	2,865	2	92	0.36	0,555
2	D-61(D-123/60-05-3)	1,686	10,8	1	29	0,475	-
3	D-44(D-112/K38-17) ost	1,8525	1,075	1	64	0,6275	-
4	D-63(K-135) otb	3,1875	3,955	3	81	0,6325	-
5	D-73(D-55/K-175) ost	3,022	1,427	3	49	0,74	-
6	D-56(D-171) (1/10) (5)	2,51	1,28	1	70	0,575	-
7	D-12(Uzin Sali) kor/ost	3	1,5075	3	93	0,6725	-
8	D-34(D-125/K-185) b/ost	2,15	1,38	2	88	0,58	-
9	D-114(otb Jayxun) b/ost	2,26	2,97	2	87	0,50	-
10	D-30(D-13/K-113)(2)b/ost	2,90	2,19	2	70	0,54	-
11	D-111(Uzin Sali) b/ost	4,54	1,49	4	99	0,19	0,50
12	D-119(D-128/K-26-20)ost	3,85	1,67	3	86	0,25	0,68
13	D-35(D-15/76-93-3)ost	3,38	2,07	3	95	0,16	0,54
14	D-74(D-120/42-92-1)	2,59	2	3	87	0,22	0,65
15	D-136(Uzin Sali) ost	3,15	1,88	3	70	0,16	0,57
16	D-91(D-128/otb.K-26-20) ost	3,66	1,66	2	87	0,17	0,58
17	D-94(otb.Lazirniy)	3,60	1,91	3	59	0,15	0,51

18	D-66(D-154/P 4-12-2) iri da'n ost	3,66	1,47	3	98	0,18	0,59
19	D-48(D-134/41-20)	3,81	1,56	3	96	0,16	0,59
20	D-21(K-26-20) ost	3,80	1,37	2	66	0,10	0,59
21	D-24(D-83/D-113/K-334) b/ost	3,68	1,39	2	91	0,11	0,53

The highest seed germination rate was recorded in sample D-111, with 99 seeds germinated. High germination rates were also observed in samples D-66 (98 seedlings), D-48 (96 seedlings), D-35 (95 seedlings), D-12 (93 seedlings), D-29 (92 seedlings), and D-24 (91 seedlings). The lowest germination rate was recorded in sample D-61, with only 29 seeds germinated. This indicates that this sample was relatively sensitive to 1.5% NaCl stress during the seed germination stage.

Regarding shoot length, sample D-111 showed the highest value at 4.54 cm. Relatively high shoot development was also observed in D-48 (3.81 cm), D-21 (3.80 cm), D-24 (3.68 cm), and D-29, D-91, and D-66 (3.66 cm). At the same time, sample D-61 exhibited a root length of 10.8 cm, which was markedly higher than that of the other samples. However, the fact that only 29 seedlings germinated in this sample suggests that it may possess a distinct morphological response under salinity stress.

In terms of the number of roots, sample D-111 recorded the highest value, with 4 roots per seedling. Three roots were recorded in samples D-63, D-73, D-12, D-111, D-119, D-35, D-74, D-136, D-94, D-66, and D-48. Root system development is considered an important morphological trait for evaluating the plant's ability to absorb water and mineral nutrients under saline conditions.

Comparison of plant biomass showed the highest value in D-73 (0.74 g), followed by D-12 (0.6725 g), D-63 (0.6325 g), and D-34 (0.58 g). Although sample D-111 showed high seed germination and shoot length, its plant biomass was only 0.19 g. This finding indicates that salinity tolerance cannot be adequately assessed solely on the basis of germination rate or a single morphological trait.

Overall, the results demonstrated that a 1.5% NaCl solution had differential effects on seed germination and early seedling development among the rice varietal samples. By considering high germination rate, well-developed root systems, and biomass accumulation in combination, samples D-111, D-66, D-48, D-35, D-12, and D-73 were identified as promising materials for further breeding research. However, these samples should also be evaluated under field conditions, since salinity tolerance observed under laboratory conditions does not fully reflect the plant's tolerance throughout the entire growing season.

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