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Yield Performance of Rice Genotypes under Salinity Stress and the Selection of Primary Breeding Sources

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Abstract: This study evaluated the adaptability of rice genotypes to the sulfate-chloride saline soils of the Khorezm region. Under severe chloride salinity ($Cl > 0.2\%$), a sharp decline in grain yield (GY) and total grain number per panicle (TNG) was observed across all varieties. Although the Gigant variety achieved the highest yield (80.2 c/ha) and 1,000-grain weight (33.0 g) in the control group, its yield plummeted to 8.6 c/ha under stress conditions. Conversely, the Manzur (46.1-52.8 c/ha) and Yo'ldosh (47.9-52.7 c/ha) varieties demonstrated high adaptability and are recommended as primary genetic sources for cultivation in saline fields.

Keywords: rice, salinity, grain yield, Manzur, Gigant, Yo'ldosh, Khorezm.

Introduction

Rice (*Oryza sativa* L.) belongs to the Poaceae family and is genetically characterized as a diploid ($2n = 12$) plant [1]. Today, rice is a staple food for the global population, particularly for the peoples of the Asian region, providing 50-80% of the daily caloric requirements for over three billion people. However, the rapid growth of the global population necessitates an increase in rice production from 560 million tons to 850 million tons by 2025-2030 [2]. Throughout its growth and development phases, rice cultivation is constantly exposed to various biotic and abiotic stress factors [3]. Among abiotic stresses, soil salinity is one of the most pressing issues, ranking second only to drought in its negative impact on crop productivity [4]. According to statistical data, more than 800 million hectares worldwide are affected by salt accumulation, representing 12% of the global land area and approximately 20% of all arable land [5]. Currently, 1,500 million hectares of rainfed and 230 million hectares of irrigated agricultural land are subjected to varying degrees of salinity, and 33% of agricultural land is undergoing degradation due to high salt concentrations [6].

In the Aral Sea region of Uzbekistan, specifically in the Khorezm region located in the lower reaches of the Amu Darya river, soil salinity is considered the most critical issue. The proximity of groundwater (1.2-2.0 m) and high evaporation rates have led to secondary salinization in 90-95 percent of the irrigated lands in the area. In this context, rice cultivation is of significant strategic importance, serving not only as a food source but also as a vital tool for soil reclamation (leaching of salts).

However, under conditions of severe sulfate-chloride salinity, the productivity of traditional rice varieties is declining sharply. Consequently, yields are decreasing while the number of unfilled grains per panicle is increasing. Therefore, the breeding of new, salt-tolerant, and early-maturing rice genotypes adapted to the harsh climatic conditions of Khorezm is one of the highest priorities for ensuring global food security [7].

Study area

The research was conducted during the period of 2023-2025 at the Khorezm scientific-experimental station of the Research Institute of Cereal and Leguminous Crops, located in the Urgench district of the Khorezm region, Uzbekistan.

Materials

In this study, 67 rice genotypes from the world germplasm were evaluated under various salinity conditions. To conduct a comparative assessment of the results, the varieties Nukus-2, Iskandar, and Lazurniy were used as controls. Based on their morpho-physiological stability and salt tolerance, four of the most promising genotypes-Lider, Manzur (KC-2022.2), Gigant (GG-2022.2), and Yo'ldosh (NZ-2022.2)-were selected for further research stages.

Methodology

The research was conducted at the Khorezm scientific-experimental station under sulfate-chloride salinity conditions. Yield components, including panicle length (PL), total grain number per panicle (TNG), and 1,000-grain weight (TGW), were determined using 10 representative plants per variant based on international IRRI protocols. Total grain yield (GY, c/ha) was calculated according to the grain weight per plot. Statistical analysis of the data was performed using OriginPro software, applying ANOVA and LSD ($P < 0.05$) tests.

Results

The yield parameters (GY) and biometric traits of rice genotypes varied significantly depending on the type and concentration of soil salinity. Analysis revealed that in the control variant ($Cl < 0.01\%$), the highest grain yields were recorded in Gigant (80.2 c/ha) and Manzur (74.0 c/ha) varieties. However, a sharp decline in productivity was observed under severe chloride salinity ($Cl > 0.2\%$). Specifically, the yield of the Gigant variety decreased by 9.3 times compared to the control, amounting to only 8.6 c/ha. In contrast, the Yo'ldosh variety maintained a yield of 21.3 c/ha under high chloride salinity, demonstrating superior adaptability compared to other genotypes. Sulfate salinity ($SO_4 > 3.0$) exhibited a lower toxic effect on the plants than the chloride environment. For instance, while the Manzur variety yielded 18.7 c/ha in the sulfate environment, this figure was only 13.3 c/ha in the chloride environment at the same concentration level. The Iskandar variety, used as a standard, showed moderate resilience with a yield of 33.2 c/ha under severe chloride salinity. However, the performance of Manzur (13.3 c/ha) and Lider (13.1 c/ha) under severe chloride stress was significantly lower than that of the standard variety. Soil salinity seriously affected not only the yield of rice genotypes but also the morphological formation of their reproductive organs. The highest values for panicle length (PL) in the control variant were recorded in Gigant (21.5 cm) and Yo'ldosh (21.0 cm) varieties; however, under severe chloride salinity ($Cl > 0.2\%$), this parameter decreased by an average of 26-29% across all genotypes.

Table 1. Yield parameters of rice varieties

Varieties	Variant	PL	GWP	TNG	TGW	GY
LIDER	Cl<0,01	19,5	2,62	98,5	31	71
	Cl 0,03-0,1	17	2,4	90,5	30,6	43,4
	Cl > 0,2	13,8	2,15	82,5	29,7	13,1
	SO4 1,0-2,0	17,5	2,45	92,8	30,5	49,5
	SO4 > 3,0	14,5	2,22	85,2	29,5	16,7
MANZUR	Cl<0,01	19,8	2,58	96,2	32	74
	Cl 0,03-0,1	17,2	2,35	88,4	31,2	46,1
	Cl > 0,2	13,5	2,05	78,4	29,5	13,3
	SO4 1,0-2,0	17,8	2,42	90,5	31,5	52,8
	SO4 > 3,0	14,8	2,15	82,1	29,7	18,7
GIGANT	Cl<0,01	21,5	2,58	98,5	33	80,2
	Cl 0,03-0,1	19	2,42	91,4	32,2	46,9
	Cl > 0,2	15,2	2,15	82,4	30,5	8,6
	SO4 1,0-2,0	19,8	2,45	92,8	32,2	52,9
	SO4 > 3,0	16	2,22	84,1	31	10,7
YO'LDOSH	Cl<0,01	21	3,08	116,7	31,3	69
	Cl 0,03-0,1	18,8	2,82	108,2	30,5	47,9
	Cl > 0,2	15,4	2,42	93,4	29,7	21,3
	SO4 1,0-2,0	19,2	2,88	110	30,5	52,7
	SO4 > 3,0	16,2	2,55	98,9	29,5	24,5
St, Iskandar	Cl<0,01	20,5	2,7	105	28,8	58,6
	Cl 0,03-0,1	19,2	2,4	99	27,4	48,2
	Cl > 0,2	17,8	2,05	94	26,3	33,2
	SO4 1,0-2,0	18,8	1,85	89	27,9	30,9
	SO4 > 3,0	17,5	1,65	90	27,5	29,9
LSD05		1,15	0,22	6,42	1,08	4,12
V (%)		16,4	12,8	10,5	5,8	71,4

Specifically, while a sharp decrease in panicle length from 19.8 cm to 13.5 cm was observed in the Manzur variety, the standard Iskandar variety exhibited relative stability (17.8 cm) regarding this trait. The total grain number per panicle (TNG) was studied as a key factor determining productivity. In this regard, the Yo'ldosh variety formed 116.7 grains per panicle in the control and maintained a high level of 93.4 grains under stress, demonstrating its superior reproductive capacity. The grain weight per panicle (GWP) also varied depending on the type of salinity, decreasing to a range of 2.05-2.42 g across all varieties in a severe chloride environment; however, the Yo'ldosh variety maintained the highest result even under sulfate stress with a value of 2.55 g.

Throughout the research, the 1,000-grain weight (TGW) proved to be the most resilient and stable trait against the salinity factor. Across all genotypes, this parameter decreased by only 1.5-3.0 grams as the salinity level increased. The Gigant variety stood out as the largest-grained genotype with 33.0 g in the control and 30.5 g under stress, while the lowest grain weight (26.3-28.8 g) was recorded in the standard Iskandar variety. Overall analysis indicates that salinity causes a decrease in total grain yield primarily by reducing panicle length and grain number; in this context, it was proven that the Yo‘ldosh and Manzur varieties possess the highest genetic potential for preserving yield components.

Conclusions

The study reveals that chloride salinity ($Cl > 0.2\%$) is more toxic to rice yield than sulfate environments. While yield (GY), panicle length (PL), and grain number (TNG) significantly decreased under stress, 1,000-grain weight (TGW) remained the most stable trait. The Gigant variety proved highly salt-sensitive, whereas Yo‘ldosh and Manzur demonstrated high resilience, making them ideal breeding sources for saline soils.

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