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Research Article

To assess the performance of F1 hybrids and their parents of rice (*Oryza sativa* L.) at different levels of salt stress under the hydroponic condition

Arshad Ali Kaleri[1*], Shabana Memon[1], Aisha Shereen[2] , Zahoor Ahmed Soomro[1], Rafia Sahar[3], Tariq Majidano[4] and Naveed Yaseen Sial[5]
1. Department of Plant Breeding and Genetics, SAU Tandojam, Pakistan
2. Nuclear Institute of Agriculture (NIA) Tandojam, Pakistan
3. Federal Seed Certification and Registration Department Karachi, Sindh, Pakistan
4. Pakistan Tobacco Board, MNFS&R, Pakistan
5. Department of Agriculture, University College of Dera Murad Jamali, Naseerabad, Pakistan
**Corresponding author's email:* ali.breeder110@gmail.com

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Abstract

World is facing the foremost challenges of abiotic stresses in agriculture among which salinity is one of the disastrous factors towards rice production. Rice is a salinity sensitive crop; however, the level of salinity varies in different cultivars. Hence, for this scenario salt tolerant genotypes are required to enhance the productivity of rice, to overcome the demand of world's population. The present research was carried out to evaluate the performance of fifteen F1 hybrids and their parents of (Oryza sativa) at different intensities of salt stress under hydroponic condition (green house) at Plant Physiology Division, Nuclear Institute of Agriculture (NIA), Tandojam during Kharif season of 2021 by using Factorial Design in (RCBD). Based on the performance of., by using three different treatments of salt stress such as (T1 = control 0.0 dS m^{-1}, T2 = 6 dS m^{-1} and T3 = 8 dS m^{-1} NaCl). During experiment, morphological attributes under observations were, root length (cm), shoot length (cm), root fresh weight (g), shoot fresh weight (g) and root, and shoot dry weight (g). Fifteen F1 hybrids and six parents were assessed for various morphological traits under various salt treatments at hydroponic condition and showed significant variation for genotypes, treatments and interaction at $P<0.01$ probability under both saline stress T2 = 6 dS m^{-1} and T3 = 8 dS m^{-1} NaCl. The superior hybrids as (KSK-133xHHZ-10-SAL-DT1 DT1) (90.38cm), (RST-177x Kharagnjia), (HHZ-10 SALxGML-498), (HHZ-10-SAL DT1 DT1x Kharaganjia) and (FL-478xKharangania) observed short stature height, more number of grains $panicle^{-1}$ and seed yield $plant^{-1}$ than their parents under both T2 = 6 dS m^{-1} and T3 = 8 dS m^{-1} conditions of NaCl which indicate high tolerability of genotypes. The crosses KSK-133 x RST-177, HHZ-10-SAL x FL-478, HHZ-10-SAL x FL-478, GML-498 x Kharaganjia, HHZ-10-SAL x FL-478, KSK-133 x RST-177, KSK-133 x HHZ-10-SAL DT1 DT1, RST-177 xHHZ-10-SAL DT1 DT1, RST-177 x GML-498 exhibited greater performance in morphological and yield associated traits in control and saline stress, respectively. Hence, FL-478 x GML-498, KSK-133 x 44 RST-177, RST-177 x FL-478, HHZ-10-SAL x GML-498, GML-498 x Kharaganjia, KSK- 133 x

GML-498, HHZ-10-SAL x Kharaganjia, RST-177 x Kharagnjia and HHZ-10-SAL x GML-498 can be recommended as salt tolerant genotypes and can be used for further breeding program. Therefore, such hybrids and parents with potential yield and salt tolerance are required to provide healthy rice genotypes to grown under saline fields which may acquire better yield production

Keywords: F1 Hybrids; Hydroponic; Panicle; Parents; and Salinity

Introduction

Rice crop and salinity

Rice is considered susceptible to salinity, particularly during early vegetative and later at the reproductive stages **[1].** Rice genotypes vary considerably in salinity tolerance that is principally due to additive gene effects **[2]**. One major approach to generate salt-tolerant rice cultivars through breeding is to maximize the genetic diversity between parental genotypes that is usually estimated by measurements of morphological and physiological differences. This conventional approach for screening rice genotypes can be costly, space- and time-consuming and labor-intensive, and requires large sample size. Moreover, salt tolerance among genotypes can be altered by other environmental factors other than salinity such as temperature, light or humidity **[3]**. It's difficult to determine the level of salinity tolerance during vegetative and reproductive stages. Rice plant gains tolerance to salinity at reproductive stage. Plant height, root length, tillering ability, and biomass decrease when affected by salinity. At reproductive stage, salinity causes an increase in sterile florets by affecting panicle initiation, spikelet formation, fertilization, and germination of pollen. Salinity also reduces panicle length, number of primary branches and spikelets per panicle, fertility and panicle weight, thus reducing grain yield **[4]**.

Defense mechanism of rice plant against the stress of NaCl

Salinity stress is a physiological outcome of excessive salt in plant cell which has detrimental effects on plant's metabolism. Soils are stratified as saline when the ECe (Electrical Conductivity of a saturated soil Extract) is ≥ 4 dS m^{-1} which is roughly equivalent to 40 mM NaCl and approximately give rise to osmotic pressure of 0.2 megapascal (MPa) **[5]**.Soil salinity typically inhibits plant growth and reproduction through an initial osmotic stress phase followed by ionic toxicity due to the accumulation of Na^+ and $Cl^−$ ions in the cell cytosol that results ultimately in oxidative stress and nutritional deprivation **[6]**. Salt stress or salinity stress occurs when plants uptake overabundant ions, such as Na+, Ca2+, Mg2+, SO4 2- and Cl **[1]**. Saline soils cause two major problems for plants (1) high concentration of salts decreases soil water potential making water uptake difficult (2) accumulation of high concentration of Na+ and Cl- is toxic to plant cells **[1, 7, 8]**. Salt tolerant plants evolve several mechanisms for salinity tolerance including the modification of membrane characteristics involved in ion absorption, translocation, compartmentation and excretion of salt **[9]**. These tolerance mechanisms facilitate retention and acquisition of water, protect chloroplast functions, and maintain ion homeostasis. Essential pathways that lead to synthesis of osmotically active metabolites (such as proline, glycine betaine, sugars, etc.) and certain free radical scavenging enzymes help control ion and water flux and support scavenging of oxygen radicals **[10]**. Physiological characters which have usually been used for screening rice cultivars for salinity tolerance at the seedling stage included plant survival, plant dried weight, leaf injury and Na+ /K+ ratio **[11, 12]**. Recently, several authors found that salt-susceptible rice cultivars accumulated higher level of proline under salt stress than the salt-tolerant ones **[13, 14]**. High salinity injects Na^+ or Cl^- in plants which mark them with necrosis and leaf tip burn **[15]**. There was a variable response to Na^+ uptake by different genotypes and tolerant genotypes showed less Na^+ uptake than sensitive ones. Potassium is one of the three essential macronutrients required in large quantities for plant growth and yield [16]. In most cases, K is lost from soils through leaching and burning or removal of plant residues.

Salt toxicity

Salt stress is one of the most severe environmental stresses. The effects of salt stress on plants include osmotic stress, ionic toxicity, and nutritional deficiencies and eventually lead to growth inhibition and crop yield losses [17]. Soil salinization is mainly caused by poor-quality drainage and irrigation systems, climate change (which leads to sea level rise), and drought [18]. Soil salinity is a global problem that affects more than 20% of cultivated land, including half of all irrigated areas, and this percentage is expected to increase [19]. Therefore, improving the salt tolerance of crops would not only lead to the effective use of saline-alkali land, but also support sustainable agriculture and alleviate the world food crisis.

To date, studies related to salt tolerance mechanisms have indicated that the reduction of plant growth and yield under salinity is generally attributed to combined effects of lower osmotic potential of soil solution, disturbances in nutrients uptake and toxic effects of harmful ions [20]. Accumulation of toxic salts mainly sodium and chloride ions are the main causative factors for the physiological damage under salinity, disturbs cellular metabolic processes and all morpho-physiological traits. These include the suppression of many vital processes primarily starting from limited water uptake and absorption of many important nutrients, such as potassium, calcium and magnesium results in reduced turgidity and growth [21, 22]. Rice (*Oryza sativa* L.) is usually considered as moderately sensitive to salt stress. Salt tolerance is a polygenic character regulates by interaction of many genes control physiological traits. These physiological traits indicate genetic variability for salt tolerance. Thus, there is a need to explore physiological significance of particular traits in plant adaptation and productivity under saline conditions [20]. The threshold (maximum soil salinity level without yield loss) of rice is EC 3 dS/m, beyond this level yield starts decreasing and is drastically reduced at EC 10 dS/m. The most obvious mechanism of salt tolerance is morphological adaptation. Rice adopts two mechanisms to tolerate salinity i.e. osmotic tolerance and ion exclusion [23]. These mechanisms are further categorized into tissue tolerance, osmotic tolerance and ion exclusion [24]. The K: Na is considered as a good indicator for salt tolerance of a crop. In saline environment plants take up excess of Na^+ at the cost of K^+ and $Ca2^+$. The exchange of shoot K+ by Na+ has been noted earlier and this sparing of K^+ by Na+ has been observed to be closely related to salt tolerance. [25] observed that salinity had positive association with Na/K ratio while it had negative association with yield. [26] studied one salt tolerant fine rice variety (Shaheen Basmati) which was solely developed/evolved as salt tolerant. To dissect the physiological mechanism involved in salt tolerance of this variety an experiment was conducted in water culture. In all levels of salt stress, the ionic concentration of K^+ significantly decreased. Plant response to salt stress in hydroponics culture is well documented as using Yoshida's hydroponic nutrient solution under control, 50 and 100 mM salt stress at seedling stage while at germination stage, 15 genotypes including Nona Bokra, Sonahri, Kangni, 7421, 7423 and 7467, whereas at seedling stage, 28 genotypes including Nona Bokra, Jajai-77, KSK-133, KSK-282, Fakhre-Malakand, Pakhal, IR-6, Khushboo-95, Shahkar and Shua-92 were found salt tolerant. Basmati-

370, Mushkan, Homo-46 and accessions 7436, 7437 and 7720 were sensitive to salinity at both germination and seedling stage.

Materials and Methods

The experiment was conducted at Nuclear Institute of Agriculture (NIA), Tandojam at hydroponic condition (green house) during Kharif season 2021. The design used was Factorial Design (RCBD) with three replications. The F_1 Hybrids and their parents were sown under saline and control conditions (green house) at NIA Tandojam, in a randomized complete block design (factorial design) with three replications, so that to endure salt stress in hybrids of best parental lines under salt stress on the basis of Morphological parameters in F_1 hybrids and their parents by using these three treatments as T1 = 0.0 dS m^{-1} (control), T2 = 6.0 dS m^{-1} and T3 = 8.0 dS m^{-1} NaCl. The observations regarding morphological basis were Plant height, number pf productive tillers plant^{1}, panicle length, number of spikelrtes panicle^{-1}, number of grains panicle^{-1}, 1000 grain weight and Seed yield plant^{-1} were recorded during this experiment.

Results and Discussion

The seed of F_1 hybrids along with six parents were sown during kharif season of 2021 under different levels of salt stress in order to assess their performance related to yield and salt tolerance by using morphological characters base. The analysis of variance specified that the parents and F_1 hybrids showed considerable significant variation among the genotypes, treatments, and interactions under salinity stress. Various morphological characters such as plant height (cm), number of productive tillers, panicle length (cm), number of panicles panicle^{-1}, number of grains panicle^{-1}, 1000 grain weight, and grain yield plant^{-1} and harvest index (%) showed significant variation at at $P \leq 0.01$ probability level for genotypes, treatments, and interaction as shown in (Table 1).

The present study was used to select promising genotypes, therefore F_1 hybrids and parents were sown under different salt treatments as T1 = control, T2 = 6 dS m^{-1} and T2 = 8 dS m^{-1} NaCl. The mean performance of various characters using these genotypes under salt stress are as below.

Table 1. Analysis of variance of different morphological traits in F_1 hybrids and their parents obtained through 6 x 6 half diallel fashions under salinity stress

	Mean Squares of ANOVA of morphological parameters				
Characters	**Replications df=2**	**Treatments df=2**	**Genotypes df=20**	**T x G df=40**	**Error df=124**
Plant height (cm)	10.790	6874.74**	296.05**	152.86**	2.66
Number of productive tillers plant^{-1}	12.478	528.329**	84.022**	11.533**	0.932
Panicle length (cm)	63.631	509.149**	29.716**	6.694**	0.186
Number of spikelets panicle^{-1}	18.074	93.349**	14.116**	3.265**	0.343
Number of grains panicle^{-1}	5.130	3735.66**	778.35**	142.13**	2.25
1000 grain weight (g)	5.650	2783.38**	193.02**	27.18**	1.00
Grain yield plant^{-1}	5.650	459.73**	49.487**	9.265**	0.762
Harvest index (%)	0.003	0.004**	0.053**	0.012**	0.0015

**= significant at P<0.01probability level, *= Significant at P<0.05probability level and ns= Non-significant

Plant height (cm)

Under T2 = 6 dS m^{-1} NaCl salt stress, maximum harvest index was observed in HHZ- SAL-10 DT1 DT1 as 53.00% and 58% in the cross KSK-133 × HHZ-10-SAL. The relative decrease was observed to be more in HHZ- SAL-10 DT1 DT1 (15%) as compared to other parents. However, among hybrids KSK-133 × HHZ-10-SAL observed to have maximum harvest index as 58.00% among all hybrids. It shows that even in salt stress, found to have more harvest index. Relative decrease was found to be highest as 104.16 % in the cross KSK-133×FL-478 which showed that this hybrid was hardly affected and was more sensitive. Under treatment T3 = 8 dS m^{-1} NaCl salt stress, HHZ- SAL-10 DT1 DT1 and FL-478 obtained maximum harvest index under this stress as 54.00% and 55.00%. Among hybrids FL-478 × GML-498 and FL-478 × Kharaganjia (47.33% and 49.00%) observed to have maximum harvest index as compared to other genotypes. Relative decrease was observed greater in GML-498 as 63% decline and 83% in the cross KSK-133 × FL-478, emphasizing that they were highly affected under this salt stress and were sensitive to this stress (Table 2).

Table 2. Mean performance of plant height (cm) and number productive tillers plant^{-1} in F_1 hybrids and parents under salinity stress (hydroponic condition)

Parents	Plant height (cm)					Number productive tillers plant^{-1}				
	T_1= control	T_2= 6 ds $^{-1}$NaCl	R.D%	T_3= 8dsm^{-1}NaCl	R.D%	T_1= control	T_2= 6 ds m^{-1}NaCl	R.D%	T_3= 8dsm^{-1}NaCl	R.D%
KSK-133	106.33	101.97	-4.10	76.93	-27.650	16.000	14.230	-11.063	10.000	-37.500
RST-177	126.38	89.18	-29.43	99.34	-21.396	13.373	12.343	-11.063	10.110	-24.400
HHZ- SAL-10- DT1 DT1	104.71	88.80	-15.19	96.78	-7.573	26.077	23.163	-11.175	16.263	-37.635
FL-478	103.38	89.23	-13.68	103.38	0.000	11.113	11.343	2.070	7.960	-28.372
GML-498	120.30	91.00	-24.35	106.15	-11.762	12.300	12.337	0.301	8.410	-31.626
Kharaganjia	107.41	90.49	-15.75	96.67	-9.999	22.670	22.270	-1.764	8.227	-63.710
Average	**111.418**	**91.778**	**-17.08**	**96.542**	**-13.063**	**16.922**	**15.948**	**-4.889**	**10.162**	**-37.207**
F_1 hybrids										
KSK-133 x RST-177	111.97	88.23	-21.20	94.43	-15.665	19.377	20.310	4.815	9.350	-51.747
KSK-133 x HHZ-10-SAL-DT1 DT1	106.30	90.38	-14.97	91.26	-14.14	13.27	12.35	-6.98	8.38	-36.83
KSK-133 x FL-478	114.70	88.86	-22.52	87.32	-23.87	13.64	12.94	-5.13	9.38	-31.18
KSK-133 x GML-498	106.23	76.33	-28.14	92.35	-13.06	21.22	20.16	-5.02	10.25	-51.69
KSK-133 x Kharaganjia	99.30	89.30	-10.07	95.96	-3.36	19.26	18.19	-5.55	13.32	-30.83
RST-177 x HHZ-10-SAL	103.38	87.24	-15.61	81.49	-21.17	14.16	13.16	-7.06	9.32	-34.18
RST-177 x FL-478	93.08	85.52	-8.12	83.62	-10.16	13.38	12.25	-8.42	11.38	-14.92
RST-177 x GML-498	97.12	67.34	-30.66	86.69	-10.73	11.77	11.26	-4.33	9.31	-20.94
RST-177 x Kharagnjia	97.45	90.19	-7.45	83.48	-14.33	16.41	15.27	-6.96	11.32	-31.03
HHZ-10-SAL x FL-478	115.45	85.45	-25.98	90.15	-21.91	13.00	12.45	-4.23	9.47	-27.13
HHZ-10-SAL x GML-498	99.34	90.19	-9.21	85.36	-14.07	12.54	12.38	-1.33	10.19	-18.78
HHZ-10-SAL x Kharaganjia	112.04	90.15	-19.53	90.78	-18.97	11.41	11.64	1.95	10.18	-10.77
FL-478 x GML-498	103.19	75.23	-27.09	73.33	-28.93	12.49	13.34	6.82	9.17	-26.58
FL-478 x Kharaganjia	115.34	90.19	-21.80	91.74	-20.46	18.19	17.30	-4.89	11.56	-36.41
GML-498 x Kharaganjia	114.01	89.53	-21.47	92.68	-18.70	12.41	11.19	-9.80	8.79	-29.11
Average	105.92	85.60	-18.92	88.04	-16.64	14.83	14.28	-3.74	10.09	-30.14
Salinity (S)LSD 0.05%	0.575					0.340				
Genotype (G) LSD 0.05%	1.52					0.90				
S x G LSD 0.05%	2.63					1.559				

R. D = Relative difference between control and salt stress treatments

Number of tillers plant^{-1}

Variation was found in this trait among parents and hybrids. Maximum tillers per plant were observed in HHZ- SAL-10- DT1 DT1 (23.163) followed by Kharaganjia (22.270) under T2 = 6 dSm-^{1} salinity stress. However, among hybrids KSK-133 × RST-177 (20.310) and KSK-133 × FL-478 (20.160) observed to have maximum tillers plant^{-1} at this stress. Relative decrease was less declined in both parents and hybrids. Under T3 = 8 dS m-^{1} salinity stress, the parent HHZ- SAL-10- DT1 DT1 (16.263) and hybrids KSK-133 × Kharaganji (13.32), RST-177 × FL-478 (11.383) and RST-177 × Kharagnjia (11.320) observed to have maximum tillers plant^{-1}. Relative decrease was increased as 63% for the genotype Kharaganjia which showed that it was sensitive under this stress. Comparatively, the hybrids showed more relative decrease in the crosses as KSK-133 × RST-177 (51.72), KSK-133 × GML-498 (51.69) showing that these hybrids were more sensitive against salinity stress as shown (Table 2).

Panicle length (cm)

Maximum panicle length (cm) was observed in the genotype HHZ- SAL-10- DT1 DT1 (24.12) and KSK-133 (21.75) under 6 dS m-^{1}. RST-177 × HHZ-10-SAL DT1 DTI (24.230), RST-177 × FL-478 (24.130) and RST-177 × GML-498 (24.190) observed to have greater panicle length (cm). However relative decrease was found to be more in HHZ- SAL-10- DT1 DT1 (20.39%) and hybrid KSK-133 × FL-478 (27.06%). Among T3 = 8 dSm-^{1} HHZ- SAL-10- DT1 DT1 again showed a larger panicle length (cm). While KSK-133 × HHZ-10-SAL-DT1 DT1 observed to have maximum panicles. The relative decrease was found to be maximum in Kharagnaijia (22.60). Among the hybrids HHZ-10-SAL × Kharaganjia (40.85%) and KSK-133 × FL-478 (38.54%) showed a decline under this stress and were found to be more sensitive than other hybrids as shown in (Table 3).

Number of spikelets panicle^{-1}

Under 6 dS m-^{1} Kharagnjia observed to have greater number of spiklets panicle as compared to other genotypes (8.417) and among hybrids KSK-133 × Kharaganjia, RST-177 ×HHZ-10-SAL DT1 DT1, FL-478 × GML-498 and FL-478 × Kharaganjia observed to have a greater number of spikelets panicle (10.337, 10.487, 10.667). Relative decrease was found to be more in the parent KSK-133 as 40% decline and however among hybrids KSK-133 × FL-478 and HHZ-10-SAL × GML-498 observed to have a decline as 29% and 27%, revealing to be moderate tolerant.Treatment 8 dS m-^{1} showed to have maximum spikelets panicle^{-1} in KSK-133 × GML-498 and KSK-133 × Kharaganjia and RST-177 ×HHZ-10-SAL DT1 DT1 (8.840, 8.430 and 8.253). Relative decline was observed maximum in hybrids as 41% RST-177 × FL-478 (-41.230) (Table 3).

Number of grains panicle^{-1}

The greater the grains the more the yield.Under 6 dS m-^{1} KSK-133 and RST-177 (132) observed to have a greater number of grains panicle^{-1} as compared to control. Among the hybrids RST-177 × GML-498 (143.59) and HHZ-10-SAL × Kharaganjia (138.25) observed to have maximum number of grains panicle^{-1}. Relative decrease was found to be greater in Kharagnajia (23.97%) and KSK-133 × GML-498 (10.61%) under this stress. Under 8 dS m-^{1} GML-498 observed to have maximum grains panicle^{-1} under this salt stress. RST-177 × GML-498 and RST-177×Kharagnjia (138.00 and 132.00) exhibited maximum grains under this stress condition. The relative decline was found to be greater in Kharaganjia as 30.06 and maximum RD among hybrids was observed in KSK-133 × GML-498 12.65% and RST-177 × GML-498 as 11.09% (Table 4).

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Table 3. Mean performance panicle length (cm) and number of spikelets panicle^{-1} in F_1 hybrids and parents under salinity stress (hydroponic condition)

Parents	Panicle length (cm)					Number of spikelets panicle^{-1}				
	T_1= control	T_2= 6 ds m^{-1}NaCl	R.D %	T_3= 8dsm^{-1}NaCl	R.D%	T_1= control	T_2= 6 ds m^{-1}NaCl	R.D%	T_3= 8dsm^{-1}NaCl	R.D%
KSK-133	26.30	21.75	-17.30	23.18	-11.86	6.00	8.41	40.28	7.00	16.66
RST-177	21.82	18.11	-16.99	18.18	-16.67	8.00	7.84	-1.96	6.85	-14.33
HHZ- SAL-10- DT1 DT1	30.30	24.12	-20.38	24.08	-20.52	7.33	7.80	6.36	5.96	-19.68
FL-478	23.31	20.12	-13.69	18.18	-21.98	7.04	7.89	12.06	7.85	-11.45
GML-498	22.48	20.12	-10.49	19.15	-14.80	6.66	7.92	18.89	6.84	2.70
Kharaganjia	25.08	20.56	-18.02	19.41	-22.60	6.33	7.19	13.58	6.59	4.10
Average	**24.88**	**20.79**	**-16.15**	**20.36**	**-18.07**	**6.89**	**7.84**	**14.87**	**6.85**	**0.31**
F_1 hybrids										
KSK-133 x RST-177	23.39	20.37	-12.89	18.22	-22.11	11.11	9.15	-17.61	7.13	-35.82
KSK-133 x HHZ-10-SAL	26.33	23.41	-11.10	22.42	-14.87	11.44	9.21	-19.45	7.34	-35.85
KSK-133 x FL-478	26.49	19.32	-27.05	16.28	-38.51	12.00	8.41	-29.91	7.33	-38.91
KSK-133 x GML-498	22.30	18.14	-18.62	15.52	-30.39	11.00	9.43	-14.27	8.84	-19.63
KSK-133 x Kharaganjia	23.29	21.17	-9.10	18.42	-20.89	11.00	10.33	-6.02	8.43	-23.36
RST-177 x HHZ-10-SAL	22.15	24.23	9.37	19.39	-12.47	11.22	10.48	-6.55	8.25	-26.47
RST-177 x FL-478	25.41	24.13	-5.04	20.45	-19.51	12.29	9.19	-25.26	7.22	-41.23
RST-177 x GML-498	24.96	24.19	-3.09	20.35	-18.45	11.22	9.15	-18.50	8.39	-25.24
RST-177 x Kharagnjia	25.19	22.46	-10.83	18.39	-27.01	11.19	9.59	-14.27	8.19	-26.74
HHZ-10-SAL x FL-478	26.29	24.36	-7.33	20.28	-22.84	12.44	9.70	-21.98	7.72	-37.95
HHZ-10-SAL x GML-498	25.45	20.29	-20.25	17.42	-31.53	12.31	8.92	-27.49	7.88	-35.97
HHZ-10-SAL x Kharaganjia	26.19	18.19	-30.54	15.49	-40.82	11.63	9.70	-16.53	8.29	-28.71
FL-478 x GML-498	22.33	19.15	-14.26	18.46	-17.34	12.45	10.66	-14.32	9.66	-22.41
FL-478 x Kharaganjia	24.22	23.15	-4.41	20.46	-15.54	11.37	10.66	-6.24	8.59	-24.49
GML-498 x Kharaganjia	26.30	19.15	-27.18	17.53	-33.32	10.55	8.85	-16.10	9.15	-13.32
Average	**24.68**	**21.45**	**-12.82**	**18.60**	**-24.37**	**11.55**	**9.56**	**-16.97**	**8.16**	**-29.07**
Salinity (S)LSD 0.05%	0.15					0.206				
Genotype (G) LSD 0.05%	0.40					0.546				
S x G LSD 0.05%	0.69					0.54				

R. D = Relative difference between control and salt stress treatments

Seed yield plant^{-1}

The seed yield in crop plants is an important trait which relates with production. Under salt stress as 6 dS m^{-1} NaCl, GML-498 and RST-177 showed to have maximum seed yield as compared to other parents in this salt stress 19.180 and 18.230. However, among hybrids RST-177 × GML-498 and HHZ-10-SAL × Kharaganjia (25.357 and 25.423) observed to have more grain yield in 6 dS m^{-1} NaCl salt stress. The relative decrline exhibited maximum in the cross KSK-133 × HHZ-10-SAL (40.26%), KSK-133 × Kharaganjia (44.39%), FL-478 × GML-498 (45.36%) and GML-498 ×Kharaganjia (45.51%). These hybrids were affected greater in salt stress and can be considered as salt sensitive. While, at 8 dS m^{-1} NaCl salt stress maximum yield was observed in RST-177 and GML-498 (17.303g and 17.250g). Among hybrids RST-177 × GML-498 (25.320g), HHZ-10-SAL × Kharaganjia (26.723g), KSK-133 × FL-478 (23.570g) and RST-177 × Kharagnjia (23.090g) observed to have more yield as compared to control and showed that they can tolerate stress under this stress condition. The relative decrease was observed to be greater as in GML-498 and Kharaganjia (49.76% and 47.61%). However, the cross KSK-133 × Kharaganjia (49.35%), FL-478 × GML-498 (45.36%) and GML-498 × Kharaganjia (45.51%) showed greater decline among hybrids and can be considered as salt sensitive hybrids as shown in (Table 4).

Table 4. Mean performance of number of grains panicle^{-1} and seed yield plant^{-1} in F_1 hybrids and parents under salinity stress (hydroponic condition)

Parents	Number of grains panicle^{-1}					Seed yield plant^{-1}				
	T_1= control	T_2= 6 ds m^{-1}NaCl	R.D%	T_3= 8ds m^{-1}NaCl	R.D%	T_1= control	T_2= 6 ds m^{-1}NaCl	R.D%	T_3= 8dsm^{-1}NaCl	R.D%
KSK-133	140.38	132.00	-5.97	107.02	-23.76	22.21	12.55	-43.47	12.28	-79.10
RST-177	142.48	132.00	-7.35	111.27	-21.90	21.36	18.23	-14.66	17.30	-22.27
HHZ- SAL-10 DT1 DT1	135.59	120.00	-11.49	131.23	-3.21	11.44	15.26	33.41	15.39	25.89
FL-478	150.26	130.33	-13.26	120.26	-19.96	18.95	14.23	-24.92	14.22	-33.23
GML-498	134.27	131.00	-2.43	140.15	4.37	34.34	19.18	-44.15	17.25	-89.14
Kharaganjia	160.48	122.00	-23.97	112.23	-30.06	29.17	16.24	-44.32	15.28	-85.53
Avereage	**143.91**	**127.88**	**-10.75**	**120.36**	**-16.36**	**22.91**	**15.95**	**-23.02**	**15.29**	**-47.23**
F_1 hybrids										
KSK-133 x RST-177	129.38	122.33	-5.44	118.00	2.58	27.25	17.32	-36.44	17.393	-36.17
KSK-133 x HHZ-10-SAL	140.33	130.26	-7.17	125.00	2.67	30.52	18.22	-40.30	18.287	-40.08
KSK-133 x FL-478	132.30	130.55	-1.32	122.00	4.88	34.47	23.42	-32.04	23.570	-31.62
KSK-133 x GML-498	117.15	104.71	-10.61	102.33	1.74	37.33	22.72	-39.14	22.493	-39.75
KSK-133 x Kharaganjia	132.45	125.29	-5.40	118.00	4.15	40.34	22.43	-44.40	20.430	-49.35
RST-177 x HHZ-10-SAL DT1 DT1	108.41	107.81	-0.55	103.33	3.11	27.49	19.41	-29.38	19.193	-30.18
RST-177 x FL-478	140.26	131.27	-6.41	128.67	1.32	30.31	18.32	-39.54	18.653	-38.46
RST-177 x GML-498	155.23	143.59	-7.49	138.00	2.31	37.18	25.35	-31.81	25.320	-31.91
RST-177 x Kharagnjia	141.60	138.26	-2.35	132.00	3.12	36.30	22.42	-38.22	23.090	-36.39
HHZ-10-SAL x FL-478	118.38	119.37	0.83	109.00	5.98	29.28	19.35	-33.90	19.320	-34.03
HHZ-10-SAL x GML-498	132.38	125.27	-5.37	119.00	3.57	37.33	22.35	-40.10	21.723	-41.80
HHZ-10-SAL x Kharaganjia	141.38	138.45	-2.07	127.04	5.70	40.59	25.42	-37.37	26.723	-34.17
FL-478 x GML-498	132.42	136.30	2.93	130.41	-1.07	37.32	20.39	-45.36	20.390	-45.36
FL-478 x Kharaganjia	143.08	135.24	-5.47	123.42	5.78	34.227	21.027	-38.56	21.093	-38.37
GML-498 x Kharaganjia	140.22	133.12	-5.06	127.3	2.96	35.117	19.193	-37.61	19.193	-37.69
Average	133.66	128.12	-4.06	121.56	3.30	34.33	21.159	82.88	21.125	25.76
Salinity (S)LSD 0.05%	0.529					0.307				
Genotype (G) LSD 0.05%	1.400					0.814				
S x G LSD 0.05%	2.426					1.411				

R. D = Relative difference between control and salt stress treatments

1000 grain weight (g)

This character showed variation in different salt stress. FL-478 and Kharaganjia showed maximum grain weight among parents (21.463 and 21.99g) at 6 dS m^{-1} NaCl salt stress and the hybrids RST-177 × FL-478 (22.323g), KSK-133 × RST-177 (21.153g) and HHZ-10-SAL × Kharaganjia (20.187g) observed to have maximum 1000 grain weight. The relative decrease was found to be more in GML-498 and HHZ- SAL-10 DT1 DT1 (21.42% and 18.56%). The hybrids also showed a decline of KSK-133 × HHZ-10-SAL (33.00%), KSK-133 × FL-478 (26.84%), RST-177 ×HHZ-10-SAL DT1 DT1 (29.74%), RST-177 × Kharagnjia (23.10%) and RST-177 × Kharagnjia (23.48%). Similarly, RST-177 and GML-498 observed to have maximum grain yield (19.287g and 20.430g) under 8 dS m^{-1} NaCl salt stress.Whereas, among hybrids RST-177×FL-478, HHZ-10-SAL × Kharaganjia and GML-498 × Kharaganjia (18.393, 17.387 and 17.230g) exhibited maximum grain weight. The relative decrease was found to be more as 42% in Kharagnjia and 38% in GML-498 which found to be sensitive in this stress. However, among hybrids KSK-133 × HHZ-10-SAL (47.15%) and RST-177 × HHZ-10-SAL DT1 DT1 (51.28%) revealed maximum decline among hybrids as compared to control and can be considered as salt sensitive as shown in (Table 5).

Table 5. Mean performance of number of 1000 grain weight (g) and harvest index% in F_1 hybrids and parents under salinity stress (hydroponic condition)

Parents	1000 grain weight (g)					Harvest index%				
	T_1= control	T_2= 6 dS m-1NaCl	R.D%	T_3= 8dS/m-1NaCl	R.D%	T_1= control	T_2= 6 dS m-1NaCl	R.D%	T_3= 8dSm-1NaCl	R.D%
KSK-133	16.47	14.20	-13.77	13.50	-18.06	50.33	40.33	-19.86	38.00	-32.44
RST-177	22.17	20.26	-8.61	19.28	-13.01	51.33	47.00	-8.43	47.00	-76.29
HHZ- SAL-10 DT1 DT1	21.28	17.33	-18.58	16.33	-23.28	46.33	53.33	-15.10	54.00	-77.57
FL-478	25.43	21.46	-15.60	20.43	-19.66	48.00	47.00	-2.08	55.00	-67.54
GML-498	21.28	16.72	-21.44	13.05	-38.66	30.00	36.33	21.10	49.00	90.00
Kharaganjia	24.39	21.99	-9.85	17.25	-29.28	41.00	40.00	-2.43	32.00	-49.97
Avereage	**133.66**	**128.12**	**-14.64**	**121.56**	**-23.66**	**34.33**	**21.159**	**0.55**	**21.12**	**-35.63**
F_1 hybrids										
KSK-133 x RST-177	20.44	21.15	3.47	14.29	47.14	45.00	39.00	-13.33	40.00	-11.11
KSK-133 x HHZ-10-SAL	21.42	14.35	-32.99	11.32	96.77	52.67	58.00	10.12	42.00	-18.36
KSK-133 x FL-478	18.25	13.33	-26.97	11.42	83.09	24.00	49.00	104.16	44.00	83.33
KSK-133 x GML-498	13.22	14.45	9.33	12.42	-54.24	18.00	26.00	44.44	21.00	16.66
KSK-133 x Kharaganjia	20.43	17.65	-13.62	14.12	51.09	38.00	22.00	-42.10	21.00	-44.73
RST-177 x HHZ-10-SAL DT1 DT1	23.30	16.37	-29.72	11.35	120.05	34.00	42.00	23.52	40.00	17.64
RST-177 x FL-478	20.33	22.32	9.80	18.39	-53.07	29.00	34.00	17.24	38.67	33.34
RST-177 x GML-498	22.24	17.48	-21.41	13.99	66.74	42.67	38.00	-10.94	36.33	-14.85
RST-177 x Kharagnjia	19.17	14.74	-23.10	11.35	91.84	29.00	42.00	44.82	40.00	37.93
HHZ-10-SAL x FL-478	16.42	16.29	-0.74	14.45	-26.97	34.00	33.00	-2.94	31.00	-8.82
HHZ-10-SAL x GML-498	18.36	19.43	5.81	16.42	-42.49	40.00	31.00	-22.50	30.00	-25.00
HHZ-10-SAL x Kharaganjia	20.33	22.32	9.80	18.39	-53.07	29.00	34.00	17.24	38.67	33.34
FL-478 x GML-498	22.24	17.48	-21.41	13.99	66.74	42.67	38.00	-10.94	36.33	-14.85
FL-478 x Kharaganjia	19.35	18.32	-5.32	15.09	13.72	38.00	46.00	21.05	49.00	28.94
GML-498 x Kharaganjia	20.22	18.26	-9.71	17.23	-26.92	43.00	40.00	-6.97	39.00	-9.30
Average	19.66	17.38	-10.65	14.18	27.47	37.55	39.60	10.82	37.31	4.41
Salinity (S)LSD 0.05%	0.352					4.24				
Genotype (G) LSD 0.05%	0.933					0.011				
S x G LSD 0.05%	1.617					0.019				

R. D = Relative difference between control and salt stress treatments

Harvest index (%)

Under T2 = 6 dS m^{-1} NaCl salt stress, maximum harvest index was observed in HHZ- SAL-10 DT1 DT1 as 53.00% and 58% in the cross KSK-133 × HHZ-10-SAL. The relative decrease was observed to be more in HHZ- SAL-10 DT1 DT1 (15%) as compared to other parents. However, among hybrids KSK-133 × HHZ-10-SAL observed to have maximum harvest index as 58.00% among all hybrids. It shows that even in salt stress, found to have more harvest index. Relative decrease was found to be highest as 104.16 % in the cross KSK-133×FL-478 which showed that this hybrid was hardly affected and was more sensitive. Under treatment T3 = 8 dS m^{-1} NaCl salt stress, HHZ- SAL-10 DT1 DT1 and FL-478 obtained maximum harvest index under this stress as 54.00% and 55.00%. Among hybrids FL-478 × GML-498 and FL-

478 × Kharaganjia (47.33% and 49.00%) observed to have maximum harvest index as compared to other genotypes. Relative decrease was observed greater in GML-498 as 63% decline and 83% in the cross KSK-133 × FL-478, emphasizing that they were highly affected under this salt stress and were sensitive to this stress (Table 5)

Conclusions and Recommedations

The above research has concluded that fifteen F_1 hybrids for various morphological traits were evaluated under various salt stress treatments, such as T1 = 0.0 dS m^{-1} (control), T2 = 6 dS m^{-1} and T3 = 8 dS m^{-1} of NaCl at hydroponic condition. The result revealed that GML-498 and Kharanganjia exhibited short stature height, however more tillers $plant^{-1}$ and panicle length in HHZ- SAL-10-DT1 DT1 (23.163;24.12) followed by Kharaganjia were observed under T2 = 6 dSm-^{1} salinity stress. Kharagnajia showed greater number of spikelets $panicle^{-1}$ at T2 = 6 dS m^{-1} salt stress. The hybrids as KSK-133 x HHZ-10-SAL-DT1 DT1 (90.38 cm), RST-177 x Kharagnjia, HHZ-10-SAL x GML-498, HHZ-10-SAL DT1 DT1 x Kharaganjia and FL-478 x Kharangania observed short stature height, more number of grains $panicle^{-1}$, seed yield $plant^{-1}$under T2 = 6 and T3 = 8 dS m-^{1} of NaCl.

Authors' contributions

Conceived and designed the experiments: A Shereen & S Memon, Performed the experiments: AA Kaleri, Analyzed the data: S Memon & ZA Soomro, Contributed materials/ analysis/ tools: S Memon, T Majeedano & R Sahar, Wrote the paper: AA Kaleri & NY Sial.

References

1. Kanawapee N, Sanitchon J, Srihaban P &Theerakulpisut P (2011). Genetic diversity analysis of rice cultivars (Oryza sativa L.) differing in salinity tolerance based on RAPD and SSR markers. *Electro J of Biotechnol* 14(6): 2-2.
2. SahiC, Singh A, Kumar K, Blumwald E & Grover A (2006). Salt stress response in rice: genetics, molecular biology, and comparative genomics. *Functional &IntegrGeno* 6: 263-284.
3. Singh RK, Singh US, Khush GS&Rohilla R (2000). Genetics and biotechnology of quality traits in aromatic rices. *Aromatic Rices* 47-70.
4. Shi H, Quintero FJ, Pardo JM& Zhu JK (2002). The putative plasma membrane Na+/H+ antiporter SOS1 controls long-distance Na+ transport in plants. *The Plant Cell* 14(2): 465-477.
5. Singh RK, Mishra B &Jetly V (2001). Segregations for alkalinity tolerance in three rice crosses. *Sabrao J of Breed and Gene* 33: 31-34.
6. Arzani A & Ashraf M (2016). Smart engineering of genetic resources for enhanced salinity tolerance in crop plants. *Crit Rev in Plant Sci* 35(3): 146-189.
7. Rao PS, Mishra B & Gupta SR (2013). Effects of soil salinity and alkalinity on grain quality of tolerant, semi-tolerant and sensitive rice genotypes. *Rice Sci* 20(4): 284-291.
8. Parida AK & Das AB (2005). Salt tolerance and salinity effects on plants: a review. *Ecotoxicol and Environ Safety* 60(3): 324-349.
9. Li N, Chen S, Zhou X, Li C, Shao J, Wang R & Polle A (2008). Effect of NaCl on photosynthesis, salt accumulation and ion compartmentation in two mangrove species, *Kandelia candel* and *Bruguiera gymnorhiza*. *Aquatic Bot* 88(4): 303-310.
10. Chinnusamy V, Jagendorf A & Zhu JK (2005). Understanding and improving salt tolerance in plants. *Crop Sci* 45(2): 437-448.
11. Bhowmik SK, TitovS, Islam MM, Siddika A, Sultana S & Haque MS (2009). Phenotypic and genotypic screening of rice genotypes at seedling

stage for salt tolerance. *Afr J of Biotechnol* 8(23).
12. Haq TU, Akhtar J, Nawaz S & Ahmad R (2009). Morpho-physiological response of rice (*Oryza sativa* L.) varieties to salinity stress. *Pak J Bot* 41(6): 2943-2956.
13. Demiral T & Türkan I (2005). Comparative lipid peroxidation, antioxidant defense systems and proline content in roots of two rice cultivars differing in salt tolerance. *Environ and Exper Bot* 53(3): 247-257.
14. Theerakulpisut P, Bunnag S & Kong-Ngern K (2005). Genetic diversity, salinity tolerance and physiological responses to NaCl of six rice (*Oryza sativa* L.) cultivars. *Asian J Plant Sci* 4(6): 562-573.
15. Abbas G, Saqib M, Rafique Q, Rahman AU, Akhtar J, Haq MA & Nasim M. (2013). Effect of salinity on grain yield and grain quality of wheat (*Triticum aestivum* L.). *Pak J Bot* 50: 185-189.
16. Chang J, Cheong BE, Natera S & Roessner U (2019). Morphological and metabolic responses to salt stress of rice (*Oryza sativa* L.) cultivars which differ in salinity tolerance. *Plant Physiol and Biochem* 144(8): 427-435.
17. Yang YandGuo Y (2018). Elucidating the molecular mechanisms mediating plant salt-stress responses. *New Phytol* 217(2): 523-539.
18. Rengasamy P (2006) World Salinization with Emphasis on Australia. *J of Exper Bot* 57(8): 1017-1023.
19. Munns R (2005). Genes and salt tolerance: bringing them together. *New Phytol* 167(3): 645-663.
20. Shereen A, Asma MUS, Khan MA, Ali M & Arif M (2022). physio-biochemical analysis of salinity tolerance in sodium contrasting rice (*oryza sativa* L.) genotype. *Pak J Bot* 54(3): 787-794.
21. Ali A, Maggio A, Bressan RA & Yun DJ (2019). Role and functional differences of HKT1-type transporters in plants under salt stress. *Inter J of Mol Sci* 20(5): 1059.
22. Zelm VE, Zhang Y & Testerink C (2020). Salt tolerance mechanisms of plants. *Ann Rev of Plant Biol* 71(12): 403-433.
23. Munns R & Tester M (2008). Mechanisms of salinity tolerance. *Annu. Rev. Plant Biol.*, *59*, 651-681.
24. Roy SJ, Negrão S & Tester M (2014). Salt resistant crop plants. *Current Opin in Biotechnol 26*: 115-124.
25. Ahmad I, Iqbal N, Iqbal M, Aslam Z & Rasul E (2000). Germination and seedling growth of rice (*Oryza sativa* L.) under saline conditions. *Pak J of Biol Sci.*
26. Hussain N, Ali A, Sarwar G, Mujeeb F & Tahir M (2003). Mechanism of Salt Tolerance in Rice. *Pedosphere* 13(3): 233-238.