Journal of Agroforestry and Environment

Volume 16, Issue 2, 2023

Journal DOI: https://doi.org/10.55706/jae
Journal homepage: www.jagroforenviron.com

Evaluation of Newly Developed Advanced Rice Genotypes at Reproductive Stage Under Salinity Conditions

M. F. Ikbal[1,2]*, M. Y. Rafii[3], S. I. Ramlee[3], M. N. Yaapar[3], M. M. Islam[2], M. M. Rahman[2], S. M. A. Alim[2], M. E. Hossain[2], Md. Mohimenul Islam[2] and Md. Shahed Hossain[2]

[1*]Institute of Tropical Agriculture and Food Security, Universiti Putra Malaysia, Serdang 43400, Selangor, Malaysia
[2]Bangladesh Institute of Nuclear Agriculture, BAU Campus, Mymensingh-2202, Bangladesh
[3]Department of Crop Science, Faculty of Agriculture, Universiti Putra Malaysia, Serdang 43400, Selangor, Malaysia;

[*]Correspondence: binaikbal@gmail.com; Phone: +8801717840065

Received: 05/09/2023

Accepted: 26/12/2023

Available online: 31/12/2023

Abstract: Rice (*Oryza sativa* L.) is a staple food for more than half of the world's population, its growth and productivity are continually threatened by several biotic and abiotic stresses among which salinity is one of the major hindrances. Hence, cultivating salt-tolerant rice varieties is the most effective approach to reducing the salinity problem. The rice plants were challenged against salinity at BC_2F_2 populations and the selected lines proved to be tolerant to salinity up to 8 and 10 dSm^{-1}, at reproductive screening. Salt stress reduced plant height, panicle length, tiller and panicle number per plant, filled grains, 1000 seeds weight, and ultimately the yield per hill. From the reproductive screening against salinity, 12 and four progenies of BC_2F_2-Binadhan-17 were tolerant up to 10 dSm^{-1}, and 8 dSm^{-1}, respectively. From this study, finally 14 Binadhan-17-*Saltol* advanced lines with high-yielding and salt tolerance were selected for further evaluation in the salinity-affected field. Furthermore, the developed lines are recommended for commercial cultivation in Malaysia and other rice-growing regions, especially for salt-affected rice fields.

Keywords: Rice; Salinity; Reproductive; Salt-tolerant; Varieties; Cultivation.

INTRODUCTION

Rice (*Oryza sativa* L.) is considered as a significant food for the people, and in Malaysia, the self-sufficiency level is only around 75% with an average yield of 4.5 t/ha per season. To counter the ever-increasing demand, rice production needs to be increased by approximately 7 t/ha per season (Tan et al., 2015). However, it is often endangered by abiotic and biotic factors that diminish rice yield. Soil salinity is one of the predominant abiotic stresses that impede crop growth, development, and subsequently yield (Chen et al., 2021). Approximately one-third of cultivable land worldwide is impacted by salt, and by 2050, half of all arable land might be salinized; thus, salinity is becoming an increasing challenge to sustainable agriculture (Shrivastava & Kumar, 2015).Rice is typically sensitive to salinity (Moradi & Ismail, 2007) yet rice types vary considerably in their salinity tolerance (Kamyab-Talesh et al., 2014). Additionally, it disrupts the physical and chemical qualities of soil and has a greater impact on crop development (Singh, 2016). For the forecast of rice production, the panicle weight, tiller number per plant, and harvest index are vital agronomic characteristics. These yield elements are significantly impacted by salt (Mojakkir et al., 2015).There are many reports on research for the salinity tolerance at the seedling stage in rice (Sabouri & Sabouri, 2008) but very little attention has been given to the reproductive stage salinity tolerance in terms of both technical feasibility and time consumed for screening (Sabouri & Biabani, 2009). These screened salt tolerant advanced lines will be cultivated in the coastal area in Malaysia which will helpful in food safety in Malaysia.

So, the objectives of the present investigation were to find out and established suitable selection criteria for the screening of newly developed advanced rice genotypes under salinized and nonsalinized condition at reproductive stage with the agronomic performances.

MATERIALS AND METHODS

Experimental Location and required materials

At the glass house of field 15, and that's 55 meters above sea level and located at latitude 2°59' north and longitude 101°43' east, the Faculty of Agriculture, Universiti Putra

Malaysia, Malaysia, screened advanced rice lines for salt tolerance.

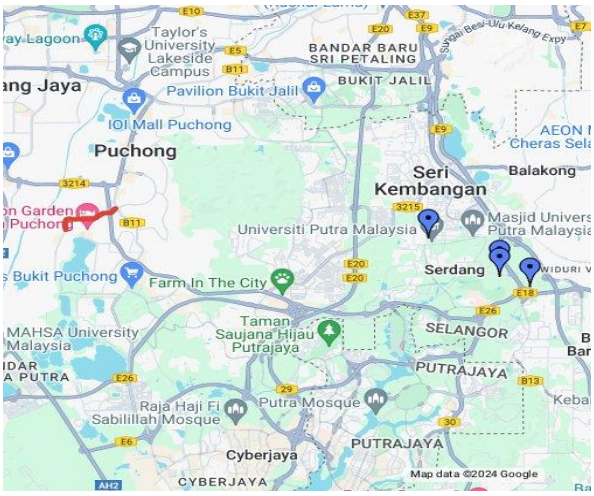

Figure. 1. Study area map of the experiment

Three replications and a randomized complete block design were used to set up the studies. Four salinity treatments were used in the two-factor experiment: control (non-salinized water solution, 0.3 dSm-1), 6 dSm-1, 8 dSm-1, and 10 dSm-1. In plastic pots with perforations, plants are grown. The pots were put in a bucket that was functioning as a water bath. One seedling was allowed to grow per pot (experimental unit). Binadhan-10, FL479 were used as tolerant checks and IR29, Binadhan-17, MR297 were used as susceptible checks (Islam et al., 2008). 14 developed NILs of Binadhan-17 were used in this experiment. EC meter, pH meter, NaOH and HCL, NaCl (analytical grade), perforated plastic bags, plastic trays (85 × 65 × 28 cm), Cylindrical plastic containers for mixing (50 L and 100 L capacity), N, P, and K fertilizers, Beaker (1000 ml), Volumetric flasks (100 and 200 ml capacity) were required for establishing the screening procedure at the vegetative and reproductive stages.

Seedling raising, pot preparations and salinization

Two setups were maintained: normal and salinized. The pots were placed in a plastic tray which serves as a water bath. Perforated plastic pots were filled with paddy filled fertile soil. 50 N, 25 P, 25 K mg/kg were added into the plastic pots. The initial soil level should be about 1 cm higher than the uppermost circle of holes. Place pots with levelled soil in a plastic tray loaded with tap water. This is the water bath. During this soil settling procedure, pregerminated seeds of rice genotypes were sowed on the soil surface of perforated plastic pots (three or four seeds pot^{-1}). Thinning was done after 2 weeks to maintain one seedling per pot and water level of the tray was raised up to 1 cm above the soil surface.

When the seedlings are 28 d old, siphon out all water from the water bath. Allow a 12-h break after siphoning out water that drains out from pots. The pots were salinized at EC 6 dSm^{-1}, 8 dSm^{-1}, and 10 dSm^{-1} by dissolving analytical grade sodium chloride after 4 weeks of seed sowing. The EC of the solution was monitored every week until maturity, and if necessary, additional salt or tap water was added to adjust the EC. Approximately 5-6 weeks after seeding, roots may be seen growing into the water bath via the holes in the plastic container. Therefore, the pots should not be moved, since any damages to the roots would interfere with the salt tolerance mechanism of the plant.

Data recorded

Data of plant height, panicle length, panicle number hill^{-1}, number of tiller hill^{-1}, days of flowering, filled grain hill^{-1}, unfilled grain hill^{-1}, 1000 seed weight, yield plant^{-1}, dry weight plant^{-1}, and biological yield were recorded. From each replication five plants/genotypes were collected. The plant height was measured from the ground to leaf tips, panicle length (cm) from the neck node to the tip of the panicle. To calculate filled and unfilled grains/panicle, panicles were then threshed, then the panicles were oven dried to reduce moisture content (14%) for the measurement of grain yield/plant. Individual plant shoots were oven dried at 70 °C for 70 hours to determine shoot dry weight/plant.

The reduction (%) of plant character was calculated with the following equation,

$$\text{Reduction (\%)} = \frac{\text{Plant character at control} - \text{Plant character at saline condition}}{\text{Plant character at control condition}}$$

Statistical analysis

The collected data were analysed for each parameter using SAS software (version 9.4). Means were separated by least significant difference (LSD).

RESULTS AND DISCUSSION

Plant height reduction

The most essential factor of morpho-physiology, which also serves as a determinant of shoot yield and total biomass production, is plant height. Plant height decreased when salt levels rose for all of the advanced lines and check types.

The NILs-BC_2F_2-Binadhan-17, the lowest and maximum plant height reductions were reported in Binadhan-10 and IR29, respectively, at salinity levels of 8 and 10 dSm-1. The highest plant height across all treatments was discovered in Binadhan-10 (114.37 cm) from the control, while the lowest plant height was observed in IR29 (75.34 cm) from 10 dSm^{-1}.(Table 1).

According to reports, plants' height gradually reduced as saline levels increased (Falah, 2010). Salinity stress may hinder cell growth or division, which would restrict plant height. The plant height and root length of crop plants under saline conditions decrease due to salt accumulation in cell walls; this phenomenon limits cell wall growth, springiness, and elongation (Taghipour & Salehi, 2008). The results are also supported by the past findings of Zhao et al. (2009), and Bagues et al. (2018), who observed similar observations in M_1 rice populations treated with different salinity levels.

Table 1. Decreased plant height of advanced rice lines at different levels of salinity

Advanced lines	Plant height (cm) of BC_2F_2-Binadhan-17 *Saltol* lines						
	Control (0.3 dSm^{-1})	6 dSm^{-1}	% R	8 dSm^{-1}	% R	10 dSm^{-1}	% R
BC_2F_2-106	104.91 b^A	97.45 b-e^B	7.11	94.17 c-f^C	10.24	91.49 bcd^D	12.80
BC_2F_2-23	102.16 cd^A	95.55 d-g^B	6.47	93.56 d-g^C	8.42	90.34 de^D	11.57
BC_2F_2-78	99.44 e^A	95.52 d-g^B	3.94	92.72 fgh^C	6.76	89.30 ef^D	10.20
BC_2F_2-69	103.03bcd^A	97.29 cde^B	5.57	95.25 bcd^C	7.55	92.46 b^D	10.26
BC_2F_2-140	104.34 b^A	100.25 b^{AB}	3.92	94.63 b-e^{BC}	9.31	92.21 bc^C	11.62
BC_2F_2-98	98.84 fg^A	93.72 f-I^B	5.17	92.19 ghi^B	6.73	89.32 ef^C	9.63
BC_2F_2-11	101.74 cd^A	94.71 e-h^B	6.91	91.46 hij^C	10.11	88.37 fg^D	13.14
BC_2F_2-172	98.22 fg^A	91.79 i^B	6.55	89.16 kl^C	9.22	84.29 i^D	14.19
BC_2F_2-84	104.26 b^A	94.65 e-i^B	9.22	92.18 ghi^C	11.59	90.68 cde^C	13.02
BC_2F_2-117	103.43 bc^A	97.75 bcd^B	5.49	95.65 bc^C	7.52	91.33 bcd^D	11.69
BC_2F_2-60	97.74 fg^A	93.55 ghi^B	4.28	90.33 jkl^C	7.58	87.22 gh^D	10.76
BC_2F_2-81	97.23 g^A	92.60 hi^B	4.76	88.68 l^C	8.79	85.64 hi^D	11.92
BC_2F_2-163	104.60 b^A	98.64 bc^B	5.70	96.46 b^C	7.78	92.35 b^D	11.71
BC_2F_2-45	101.34 e^A	95.20 d-h^B	6.06	90.80 ijk^C	10.41	91.39 bcd^C	9.82
Binadhan-10	114.37 a^A	110.35 a^B	3.52	108.49 a^C	5.14	105.98 a^D	7.34
Binadhan-17	101.75 cd^A	94.56 e-i^B	7.06	89.31 kl^C	12.22	85.76 hi^D	15.71
FL478	98.67 fg^A	96.56 c-f^A	2.14	93.41 gef^B	5.33	91.35 bcd^B	7.41
IR29	94.48 h^A	82.88 j^B	12.28	78.36 m^C	17.06	75.34 j^D	20.26
CV (%)	1.19	1.84		1.20		1.09	
LSD (0.05)	2.01	2.92		1.84		1.63	

At the 5% level of significance, the means with the same small letter(s) in the same column and superscript capital letter(s) in the same row are not statistically different.

Panicle length and panicle length reduction

Varying salt levels had a considerable impact on the duration of different rice genotypes' panicles, however the amount of reduction varied by genotype (Table 2). As longer panicles could result in more grains, it is also a significant yield-contributing characteristic. The control condition had the longest panicles of all genotypes, whereas the salinity level of 10 dSm^{-1} had the shortest panicles. These results showed that a decrease in salt shortens rice panicle length. In the situation of NILs- BC_2F_2-Binadhan-17, the longest panicle measured 25.62 cm (BC_2F_2-172) under control conditions, while with 10 dSm-1 salinity, the lowest panicle measured 17.38 cm (BC_2F_2-163), a drop of 25.32% from control treatment. Other than the check variety, BC_2F_2-45 had the lowest panicle length reduction (10.06%) and BC_2F_2-84 had the largest (27.69) at 10 dSm-1 salinity. In accordance with our observations about the length of the panicle of rice under salt stress, Sultana et al. (2014), Aslam et al. (2003) and Alam et al. (2001) found that salinity significantly affects the panicle length, seed setting percentage, and panicle weight, thereby reducing the grain yield. Several researchers have observed that salt has a major impact on the length of the rice panicle (Ali et al., 2004).

DOI: https://doi.org/10.55706/jae1641

Table 2. Decreased panicle length of advanced rice lines at different levels of salinity

Advanced lines	Panicle length (cm) of BC_2F_2-Binadhan-17 *Saltol* lines						
	Control (0.3 dSm^{-1})	6 dSm^{-1}	% R	8 dSm^{-1}	% R	10 dSm^{-1}	% R
BC_2F_2-106	24.25 dc^{A}	22.54 d-g^{B}	7.03	21.07 cde^{C}	13.09	19.54 de^{D}	19.40
BC_2F_2-23	24.17 dc^{A}	21.77 ghi^{B}	9.93	20.24 ef^{C}	16.27	18.81 d-g^{D}	22.19
BC_2F_2-78	23.11 e^{A}	21.58 hij^{B}	6.61	19.47 fg^{C}	15.77	17.73 hi^{D}	23.29
BC_2F_2-69	25.31 ab^{A}	24.21 a^{A}	4.35	22.85 a^{B}	9.73	19.65 cd^{C}	22.36
BC_2F_2-140	24.59 bc^{A}	22.86 ed^{B}	7.04	20.79 de^{C}	15.45	18.56 fgh^{D}	24.51
BC_2F_2-98	23.21 e^{A}	21.15 ij^{B}	8.88	19.27 gh^{C}	16.96	18.22 f-i^{C}	21.47
BC_2F_2-11	23.68 de^{A}	22.01 fgh^{B}	7.04	20.33 e^{C}	14.13	19.15 def^{D}	19.13
BC_2F_2-172	25.62 a^{A}	24.46 a^{B}	4.52	18.54 h^{C}	27.64	0.00 j^{D}	100.00
BC_2F_2-84	24.66 bc^{A}	23.17 cde^{B}	6.04	20.58 de^{C}	16.54	17.83 ghi^{D}	27.69
BC_2F_2-117	23.24 e^{A}	20.76 jk^{B}	10.70	19.28 gh^{C}	17.07	18.60 e-h^{C}	19.99
BC_2F_2-60	25.18 ab^{A}	24.09 ab^{B}	4.32	23.25 a^{C}	7.65	21.68 a^{C}	13.90
BC_2F_2-81	24.16 dc^{A}	22.70 def^{B}	6.03	20.29 ef^{C}	16.02	0.00 j^{D}	100.00
BC_2F_2-163	23.28 e^{A}	20.23 k^{B}	13.09	18.50 h^{C}	20.54	17.38 i^{D}	25.32
BC_2F_2-45	24.25 dc^{A}	23.71 abc^{AB}	2.21	22.59 ab^{BC}	6.85	21.81 a^{C}	10.06
Binadhan-10	25.20 ab^{A}	23.35 bcd^{B}	7.34	21.39 cd^{C}	15.12	20.53 bc^{C}	18.53
Binadhan-17	23.29 e^{A}	0.00 l^{B}	100.00	0.00 i^{B}	100.00	0.00 j^{B}	100.00
FL478	23.24 e^{A}	22.40 e-h^{AB}	3.63	21.75 bc^{B}	6.40	21.30 ab^{B}	8.36
IR29	21.33 f^{A}	0.00 l^{B}	100.00	0.00 i^{B}	100.00	0.00 j^{B}	100.00
CV (%)	2.17	2.52		2.77		3.91	
LSD (0.05)	0.86	0.84		0.84		0.98	

At the 5% level of significance, the means with the same small letter(s) in the same column and superscript capital letter(s) in the same row are not statistically different.

Number of panicle/hill

That is seen from the fact that rice plants' number of panicles per hill diminishes as saline levels rise (Table 3). The amount of panicles per hill varied significantly according on salinity levels. The control condition had the most spikelets per hill of all genotypes, while the salinity level with the fewest panicles per hill was 10 dSm-1. The highest number of panicles per hill was 14.79, 11.01, 9.99, and 8.30 in IR29, BC_2F_2-106, BC_2F_2-45, and BC_2F_2-78, respectively, at control, 6, 8, and 10 dSm-1 salinity levels. Panicle number reduction ranged from 10.03 to 100% in these tested lines. All advanced lines with the exception of BC_2F_2-172 and BC_2F_2-81 had the lowest panicle number decrease percent at all salinity levels. All stages of the growth and development of the rice plant are impacted by salinity, and the crop's reactions to salinity vary depending on the stage of growth, the concentration, and the length of exposure to salt (Joseph et al., 2010a). Grattan et al. (2002), and Hasanuzzaman et al. (2009) also reported that salinity stress reduces the number of panicles in rice that support our results. The lower panicle yield in high salinity can be due to lower accumulation of photosynthate to the reproductive parts. When the plants are continuously exposed to saline media, salinity affects the panicle initiation (Islam & Hossain, 2020).

Number of tiller per hill and total tiller reduction

The total number of tillers per hill was significantly affected by varying saline levels. Due to the higher saline level, fewer tillers were used overall per hill across all genotypes (Table 4). In control conditions, there were the most total tillers per hill of all genotypes, while at 10 dSm-1 salinity levels, there were the fewest. The maximum number of total tiller per hill were 17.07 (IR29), 14.51 (BC_2F_2-84), 11.90 (BC_2F_2-45), and 10.12 (BC_2F_2-45) at control, 6 dSm^{-1}, 8 dSm^{-1}, and 10 dSm^{-1} respectively. Due to salinity stress total tiller reduction was varied from 0.57 to 70.49%. Other than check variety, the minimum total tiller reduction were 0.57% (BC_2F_2-84), 13.74% (BC_2F_2-163) and 17.77% (BC_2F_2-140) and the maximum were 23.79% (BC_2F_2-81), 45.04% (BC_2F_2-172), and 52.93% (BC_2F_2-81) found at 6, 8 and 10 dSm^{-1} respectively.

According to (Munns, 2002) salinity reduces the growth of plant through osmotic effects, reduces the ability of plants to take up water and this causes reduction in growth. In addition, if excessive amount of salt enters the plant, the concentration of salt eventually rises to a toxic level which hampers the photosynthesis of a plant to a level that cannot sustain growth. Our results agree with the findings of other researchers (Mahmood et al., 2009; Zeng & Shannon, 2005) who stated decreasing trend of tillers number $plant^{-1}$ in rice with increasing salinity level.

DOI: https://doi.org/10.55706/jae1641

Table 3. Decreased panicle/hill of advanced rice lines at different levels of salinity

Advanced lines	Panicle/hill of BC$_2$F$_2$-Binadhan-17 ***Saltol*** lines						
	Control (0.3 dSm^{-1})	6 dSm^{-1}	% R	8 dSm^{-1}	% R	10 dSm^{-1}	% R
BC$_2$F$_2$-106	13.12 ef^{A}	11.01 a^{B}	16.06	8.43 fg^{C}	35.77	6.67 bc^{D}	49.19
BC$_2$F$_2$-23	12.12 k^{A}	9.94 b^{B}	17.98	8.18 fg^{C}	32.55	6.41 bcd^{D}	47.15
BC$_2$F$_2$-78	14.29 b^{A}	10.92 a^{B}	23.54	9.40 bc^{C}	34.23	8.30 a^{D}	41.93
BC$_2$F$_2$-69	12.48 hi^{A}	9.01 c^{B}	27.78	7.72 hi^{C}	38.17	5.79 de^{D}	53.58
BC$_2$F$_2$-140	11.21 m^{A}	9.05 c^{B}	19.24	8.91 de^{B}	20.52	7.70 a^{C}	31.28
BC$_2$F$_2$-98	13.86 c^{A}	10.10 b^{B}	27.12	7.51 i^{C}	45.83	5.04 ef^{D}	63.62
BC$_2$F$_2$-11	12.94 fg^{A}	9.05 c^{B}	30.02	8.60 ef^{B}	33.52	5.92 cd^{C}	54.24
BC$_2$F$_2$-172	11.77 l^{A}	8.16 d^{B}	30.68	5.83 k^{C}	50.45	0.00 g^{D}	100.00
BC$_2$F$_2$-84	13.48 dA	10.09 b^{B}	25.15	8.11 gh^{C}	39.85	6.83 b^{D}	49.34
BC$_2$F$_2$-117	13.21def^{A}	9.69 bc^{B}	26.63	7.08 j^{C}	46.42	5.94 cd^{D}	55.05
BC$_2$F$_2$-60	12.71 gh^{A}	9.75 bc^{B}	23.24	9.75 ab^{B}	23.27	8.07 a^{C}	36.49
BC$_2$F$_2$-81	10.50 n^{A}	6.46 e^{B}	38.49	5.94 k^{B}	43.41	0.00 g^{C}	100.00
BC$_2$F$_2$-163	12.23 ijk^{A}	11.00 a^{B}	10.03	9.31 cd^{C}	23.85	6.82 b^{D}	44.26
BC$_2$F$_2$-45	14.40 b^{A}	10.05 b^{B}	30.22	9.99 a^{B}	30.61	7.83 a^{C}	45.59
Binadhan-10	12.20 jk^{A}	10.02 b^{B}	17.89	9.38 bc^{C}	23.14	7.91 a^{D}	35.15
Binadhan-17	13.39 de^{A}	0.00 f^{B}	100.00	0.00 l^{B}	100.00	0.00 g^{B}	100.00
FL478	12.43 ij^{A}	9.62 bc^{B}	22.56	8.57 ef^{C}	31.04	6.72 bc^{D}	45.92
IR29	14.79 a^{A}	0.00 f^{B}	100.00	0.00 l^{B}	100.00	0.00 g^{B}	100.00
CV (%)	1.29	5.29		3.51		8.39	
LSD (0.05)	0.27	0.75		0.43		0.82	

At the 5% level of significance, the means with the same small letter(s) in the same column and superscript capital letter(s) in the same row are not statistically different.

Table 4. Decreased Tiller/hill of advanced rice lines at different levels of salinity

Advanced lines	**Tiller/hill of BC$_2$F$_2$-Binadhan-17 *Saltol* lines**						
	Control (0.3 dSm^{-1})	**6 dSm^{-1}**	**% R**	**8 dSm^{-1}**	**% R**	**10 dSm^{-1}**	**% R**
BC$_2$F$_2$-106	14.12 de^{A}	12.12 de^{B}	14.21	10.40 d^{C}	26.39	7.97 c^{D}	43.55
BC$_2$F$_2$-23	13.13 fgh^{A}	11.14 fg^{B}	15.18	10.18 de^{C}	22.49	9.02 b^{D}	31.32
BC$_2$F$_2$-78	15.36 b^{A}	13.35 b^{B}	13.11	11.40 b^{C}	25.80	10.00 a^{D}	34.92
BC$_2$F$_2$-69	14.49 cd^{A}	12.49 cd^{B}	13.76	8.71 gh^{C}	39.90	7.01 de^{D}	51.61
BC$_2$F$_2$-140	12.18 i^{A}	10.22 i^{B}	16.10	9.90 e^{B}	18.72	10.01 a^{B}	17.77
BC$_2$F$_2$-98	14.84 bc^{A}	13.83 b^{B}	6.83	8.29 h^{C}	44.13	6.99 de^{D}	52.89
BC$_2$F$_2$-11	13.95 de^{A}	12.77 c^{B}	8.48	11.12 bc^{C}	20.31	9.03 b^{D}	35.28
BC$_2$F$_2$-172	12.76 ghi^{A}	10.79 gh^{B}	15.44	7.01 i^{C}	45.04	6.01 fg^{D}	52.90
BC$_2$F$_2$-84	14.59 cd^{A}	14.51 a^{A}	0.57	8.54 h^{B}	41.47	6.91 ef^{C}	52.66
BC$_2$F$_2$-117	14.49 cd^{A}	11.60 ef^{B}	19.95	9.24 f^{C}	36.22	7.96 c^{D}	45.08
BC$_2$F$_2$-60	13.55 ef^{A}	11.31 fg^{B}	16.51	10.88 c^{B}	19.69	8.92 b^{C}	34.18
BC$_2$F$_2$-81	12.51 hi^{A}	9.54 j^{B}	23.79	7.02 i^{C}	43.90	5.89 gh^{D}	52.93
BC$_2$F$_2$-163	13.25 fg^{A}	12.70 c^{A}	4.15	11.43 ab^{B}	13.74	7.97 c^{C}	39.85
BC$_2$F$_2$-45	15.52 b^{A}	13.58 b^{B}	12.52	11.90 a^{C}	23.30	10.12 a^{D}	34.77
Binadhan-10	13.05 fgh^{A}	11.24 fg^{B}	13.89	10.03 de^{C}	23.19	8.99 b^{D}	31.15
Binadhan-17	14.07 de^{A}	11.94 e^{B}	15.18	9.23 f^{C}	34.44	6.97 e^{D}	50.50
FL478	13.24 fg^{A}	10.94 gh^{B}	17.40	9.02 fg^{C}	31.85	7.91 cd^{C}	40.26
IR29	17.07 a^{A}	10.44 hi^{B}	38.83	6.86 i^{C}	59.82	5.04 h^{D}	70.49
CV (%)	3.03	2.66		3.02		7.13	
LSD (0.05)	0.70	0.53		0.48		0.94	

At the 5% level of significance, the means with the same small letter(s) in the same column and superscript capital letter(s) in the same row are not statistically different.

DOI: https://doi.org/10.55706/jae1641

Days to 50% flowering

Being an important character to assess early maturity, days to flowering was taken to an account for the genotypes. The genotypes' varying days to 50% flowering varied from 73.94 to 86.76 days. If treatment is effective, it is hoped that the control treatment will provide the most days for 50% flowering. The control treatment, followed by treatments 6 dSm-1, 8 dSm-1, and 10 dSm-1, had the maximum number of days to 50% flowering (Table 5). Tiwari et al. (2011) also observed significant variation among genotypes for days to 50% flowering.

Table 5. Effect on 50% flowering of advanced rice lines under different salinity level

Advanced lines	50% flowering of BC_2F_2-Binadhan-17 *Saltol* lines						
	Control (0.3 dSm^{-1})	**6 dSm^{-1}**	**% R**	**8 dSm^{-1}**	**% R**	**10 dSm^{-1}**	**% R**
BC_2F_2-106	79.09 i^{A}	78.05 f^{B}	1.32	77.08 e^{C}	2.55	76.76 ef^{C}	2.95
BC_2F_2-23	81.15 g^{A}	79.08 e^{B}	2.55	77.10 e^{C}	4.99	75.99 g^{D}	6.37
BC_2F_2-78	78.08 j^{A}	77.00 g^{B}	1.37	75.23 g^{C}	3.65	74.90 h^{C}	4.07
BC_2F_2-69	82.08 f^{A}	81.14 c^{B}	1.15	79.49 c^{C}	3.16	79.03 c^{C}	3.72
BC_2F_2-140	79.06 i^{A}	77.32 g^{B}	2.19	76.08 f^{C}	3.77	74.15 ij^{D}	6.21
BC_2F_2-98	83.13 e^{A}	81.25 c^{B}	2.26	80.21 b^{C}	3.51	78.15 d^{D}	5.99
BC_2F_2-11	77.01 k^{A}	75.95 h^{B}	1.38	74.46 h^{C}	3.32	73.94 j^{C}	3.99
BC_2F_2-172	80.02 h^{A}	79.07 e^{B}	1.19	78.16 d^{C}	2.32	0.00 k^{D}	100.00
BC_2F_2-84	82.10 f^{A}	80.20 d^{B}	2.32	79.15 c^{C}	3.59	77.17 e^{D}	6.00
BC_2F_2-117	79.99 h^{A}	79.37 e^{B}	0.78	77.31 e^{C}	3.35	76.15 g^{D}	4.80
BC_2F_2-60	77.75 j^{A}	76.93 g^{B}	1.05	76.03 f^{C}	2.21	74.54 hi^{D}	4.12
BC_2F_2-81	83.98 d^{A}	82.29 b^{B}	2.01	80.22 b^{C}	4.48	0.00 k^{D}	100.00
BC_2F_2-163	78.98 i^{A}	78.05 f^{B}	1.18	77.11 e^{C}	2.37	76.23 fg^{D}	3.48
BC_2F_2-45	80.03 h^{A}	79.25 e^{B}	0.97	78.12 d^{C}	2.38	75.70 g^{D}	5.41
Binadhan-10	86.76 a^{A}	84.50 a^{B}	2.60	83.07 a^{C}	4.25	83.39 a^{C}	3.89
Binadhan-17	84.79 c^{A}	0.00 i^{B}	100.00	0.00 i^{B}	100.00	0.00 k^{B}	100.00
FL478	82.54 f^{A}	81.04 c^{B}	1.82	80.05 b^{C}	3.02	80.14 b^{C}	2.91
IR29	85.37 b^{A}	0.00 i^{B}	100.00	0.00 i^{B}	100.00	0.00 k^{B}	100.00
CV (%)	0.41	0.36		0.35		0.58	
LSD (0.05)	0.56	0.42		0.41		0.58	

At the 5% level of significance, the means with the same small letter(s) in the same column and superscript capital letter(s) in the same row are not statistically different.

No of filled grain/panicle and filled grain reduction

The quantity of filled grains per panicle determines the plant's yield, which varied dramatically amongst the lines. The most important aspect of yield is the amount of filled grain per panicle, which is also most closely connected to seed output. Statistics regarding rice grain packed per panicle as influenced by various salt levels are displayed in (Table 6). NILs-BC_2F_2-Binadhan-17 results showed that the lowest number of filled grains per panicle (55.66) was discovered in BC_2F_2-84 at 10 dSm-1 salinity, which has a 63.89% decrease in comparison to control treatment, and the maximum number (164.77) was found in BC_2F_2-98 at control. At 10 dSm-1 salinity, FL478 had the lowest filled grain reduction (11.48%) and BC_2F_2-84 had the highest filled grain reduction (63.89%) when compared to the check variety. These findings suggest that high salinity reduced the number of filled rice grains per panicle. These numbers show that greater salt levels decreased the amount of loaded grains in each rice panicle. Hence, as salt increased, there were more empty grains overall each panicle, which decreased yield. The main causes of sterility and decreased seed set in growing rice grains were impaired translocation of soluble carbohydrates to primary and secondary spikelets, accumulation of more salt and less potassium in all floral areas, and reduction of the specific activity of starch synthetase (Aref & Rad, 2012).

Thousand seeds weight reduction

Salinity stress had significant negative effect on 1000 grain weight of different rice genotypes depending on the size and shape of grains (Table 7). Seed weight is an important quality attribute of crop. On the other hand, in case of NILs-BC_2F_2-Binadhan-17, 1000 seed weight ranged from 15.46 g to 25.66 g and the highest 1000 seed weight was recorded in Binadhan-10 and lowest one was recorded in BC_2F_2-140. At 10 dSm^{-1}, the highest 1000 seeds weight reduction (29.90%) was found in BC_2F_2-163 and the lowest (13.37%) was found in FL478.

DOI: https://doi.org/10.55706/jae1641

Table 6. Effect on filled grain of advanced rice lines under different salinity level

Advanced lines	Filled grain of BC_2F_2-Binadhan-17 *Saltol* lines					
	Control (0.3 dSm^{-1})	6 dSm^{-1}	% R	8 dSm^{-1}	% R	10 dSm^{-1}	% R
BC_2F_2-106	161.65 cde^{A}	135.59 b^{B}	16.12	116.78 bc^{C}	27.76	102.08 b^{D}	36.85
BC_2F_2-23	157.99 e^{A}	128.57 d^{B}	18.62	115.21 c^{C}	27.08	104.54 a^{D}	33.83
BC_2F_2-78	163.24 abc^{A}	142.15 a^{B}	12.92	124.83 a^{C}	23.53	101.60 b^{D}	37.76
BC_2F_2-69	160.48 d^{A}	124.49 ef^{B}	22.42	106.76 d^{C}	33.47	97.07 d^{D}	39.51
BC_2F_2-140	157.69 e^{A}	123.35 fg^{B}	21.78	101.51 f^{C}	35.63	93.17 e^{D}	40.92
BC_2F_2-98	164.77 a^{A}	130.28 cd^{B}	20.93	114.15 c^{C}	30.72	100.21 bc^{D}	39.18
BC_2F_2-11	163.30 abc^{A}	134.03 bc^{B}	17.92	118.80 b^{C}	27.25	97.78 d^{D}	40.12
BC_2F_2-172	161.05 dc^{A}	108.63 i^{B}	32.55	60.45 i^{C}	62.46	0.00 g^{D}	100.00
BC_2F_2-84	154.12 gh^{A}	110.14 gh^{B}	28.54	73.55 h^{C}	52.28	55.66 g^{D}	63.89
BC_2F_2-117	160.73 d^{A}	128.20 de^{B}	20.24	114.03 c^{C}	29.06	104.95 a^{D}	34.70
BC_2F_2-60	156.49 ef^{A}	118.60 h^{B}	24.21	106.28 de^{C}	32.09	97.13 d^{D}	37.93
BC_2F_2-81	154.00 h^{A}	103.60 j^{B}	32.73	57.63 i^{C}	62.58	0.00 h^{D}	100.00
BC_2F_2-163	155.06 fgh^{A}	128.47 d^{B}	17.15	115.56 c^{C}	25.47	101.56 b^{D}	34.50
BC_2F_2-45	163.83 ab^{A}	134.70 b^{B}	17.78	119.55 b^{C}	27.03	106.51 a^{D}	34.99
Binadhan-10	128.46 i^{A}	117.30 h^{B}	8.69	103.59 ef^{C}	19.36	98.25 cd^{C}	23.52
Binadhan-17	156.43efg^{A}	0.00 i^{B}	100.00	0.00 j^{B}	100.00	0.00 h^{B}	100.00
FL478	98.65 j^{A}	94.42 k^{B}	4.29	91.48 g^{C}	7.27	87.33 f^{D}	11.48
IR29	84.14 k^{A}	0.00 i^{B}	100.00	0.00 j^{B}	100.00	0.00 h^{B}	100.00
CV (%)	0.95	2.09		2.03		1.76	
LSD (0.05)	2.36	3.80		3.13		2.25	

At the 5% level of significance, the means with the same small letter(s) in the same column and superscript capital letter(s) in the same row are not statistically different.

Table 7. Effect on 1000 grain weight of advanced rice lines under different salinity level

Advanced lines	1000 grain weight/panicle of BC_2F_2-Binadhan-17 *Saltol* lines					
	Control (0.3 dSm^{-1})	6 dSm^{-1}	% R	8 dSm^{-1}	% R	10 dSm^{-1}	% R
BC_2F_2-106	22.70 c^{A}	19.41 cd^{B}	14.51	18.56 ef^{BC}	18.26	17.40 d^{C}	23.36
BC_2F_2-23	22.64 c^{A}	19.55 cd^{B}	13.66	19.47 de^{B}	14.00	18.54 c^{B}	18.11
BC_2F_2-78	21.67 de^{A}	18.43 d^{B}	14.95	18.26 fg^{B}	15.75	16.52 ef^{C}	23.77
BC_2F_2-69	20.67 fgh^{A}	19.26 cd^{B}	6.84	18.11 fg^{C}	12.37	16.49 ef^{D}	20.22
BC_2F_2-140	21.31 efg^{A}	18.43 d^{B}	13.49	16.34 h^{C}	23.33	15.46 g^{C}	27.43
BC_2F_2-98	22.32 dc^{A}	20.06 bc^{B}	10.13	18.47 efg^{C}	17.24	17.10 de^{C}	23.39
BC_2F_2-11	23.03 c^{A}	19.27 cd^{B}	16.34	19.55 de^{B}	15.11	16.98 de^{C}	26.27
BC_2F_2-172	20.63 gh^{A}	14.72 e^{B}	28.65	7.36 i^{C}	64.32	0.00 h^{D}	100.00
BC_2F_2-84	21.53 def^{A}	19.73 cd^{A}	8.35	16.33 h^{B}	24.13	15.65 g^{B}	27.28
BC_2F_2-117	21.08 efg^{A}	20.16 bc^{B}	4.36	17.98 fg^{C}	14.70	16.77 de^{D}	20.44
BC_2F_2-60	21.38 efg^{A}	19.50 cd^{B}	8.79	19.75 cd^{B}	7.61	15.76 fg^{C}	26.26
BC_2F_2-81	20.93 efg^{A}	14.25 e^{B}	31.90	8.26 i^{C}	60.55	0.00 h^{D}	100.00
BC_2F_2-163	22.67 c^{A}	19.49 cd^{B}	14.05	17.41 gh^{C}	23.23	15.89 fg^{C}	29.90
BC_2F_2-45	22.72 c^{A}	21.33 b^{B}	6.10	20.70 bc^{B}	8.89	19.42 b^{C}	14.54
Binadhan-10	25.66 a^{A}	24.25 a^{B}	5.51	22.57 a^{C}	12.03	21.08 a^{D}	17.85
Binadhan-17	21.23 efg^{A}	0.00 f^{B}	100.00	0.00 j^{B}	100.00	0.00 h^{B}	100.00
FL478	24.61 b^{A}	23.06 a^{B}	6.30	21.80 ab^{C}	11.42	21.32 a^{C}	13.37
IR29	19.98 h^{A}	0.00 f^{B}	100.00	0.00 j^{B}	100.00	0.00 h^{B}	100.00
CV (%)	2.43	5.05		4.24		3.49	
LSD (0.05)	0.89	1.44		1.10		0.79	

At the 5% level of significance, the means with the same small letter(s) in the same column and superscript capital letter(s) in the same row are not statistically different.

DOI: https://doi.org/10.55706/jae1641

Table 8. Effect on yield/panicle of advanced rice lines under different salinity level

Advanced lines	Yield/Panicle of BC$_2$F$_2$-Binadhan-17 *Saltol* lines						
	Control (0.3 dSm^{-1})	6 dSm^{-1}	% R	8 dSm^{-1}	% R	10 dSm^{-1}	% R
BC$_2$F$_2$-106	30.21 ab^{A}	21.70 d^{B}	28.18	18.14 bc^{C}	39.96	15.14 b^{D}	49.87
BC$_2$F$_2$-23	29.26 dc^{A}	19.73 fg^{B}	32.55	14.26 fg^{C}	51.27	9.30 g^{D}	68.21
BC$_2$F$_2$-78	30.68 a^{A}	25.54 a^{B}	16.76	17.55 c^{C}	42.78	10.15 f^{D}	66.90
BC$_2$F$_2$-69	26.21 e^{A}	19.18 g^{B}	26.83	13.83 g^{C}	47.23	9.12 g^{D}	65.21
BC$_2$F$_2$-140	30.72 a^{A}	22.18 d^{B}	27.82	16.34 de^{C}	46.83	10.16 f^{D}	66.94
BC$_2$F$_2$-98	30.14 ab^{A}	20.73 e^{B}	31.23	14.53 fg^{C}	51.78	8.03 h^{D}	73.36
BC$_2$F$_2$-11	28.97 dc^{A}	20.31 ef^{B}	29.88	14.25 fg^{C}	50.81	9.05 g^{D}	68.76
BC$_2$F$_2$-172	30.11 ab^{A}	16.28 i^{B}	45.92	8.21 i^{C}	72.74	0.00 i^{D}	100.00
BC$_2$F$_2$-84	28.96 dc^{A}	21.70 d^{B}	25.06	15.77 e^{C}	45.55	11.22 e^{D}	61.27
BC$_2$F$_2$-117	30.68 a^{A}	24.57 b^{B}	19.91	16.66 d^{C}	45.69	12.25 d^{D}	60.08
BC$_2$F$_2$-60	29.73 bc^{A}	23.35 c^{B}	21.44	14.80 f^{C}	50.20	8.75 gh^{D}	70.58
BC$_2$F$_2$-81	30.95 a^{A}	17.30 h^{B}	44.11	9.07 h^{C}	70.68	0.00 i^{D}	100.00
BC$_2$F$_2$-163	28.83 d^{A}	23.62 c^{B}	18.06	17.67 c^{C}	38.70	12.04 d^{D}	58.24
BC$_2$F$_2$-45	30.77 a^{A}	25.23 ab^{B}	18.02	19.22 a^{C}	37.53	13.43 c^{D}	56.36
Binadhan-10	26.94 e^{A}	23.43 c^{B}	13.04	18.70 ab^{C}	30.60	17.53 a^{D}	34.94
Binadhan-17	25.06 f^{A}	0.00 j^{B}	100.00	0.00 j^{B}	100.00	0.00 i^{B}	100.00
FL478	19.42 g^{A}	16.61 hi^{B}	14.47	13.76 g^{C}	29.12	11.08 e^{D}	42.92
IR29	26.67 e^{A}	0.00 j^{B}	100.00	0.00 j^{B}	100.00	0.00 i^{B}	100.00
CV (%)	1.78	2.89		3.71		5.04	
LSD (0.05)	0.84	0.91		0.83		0.73	

At the 5% level of significance, the means with the same small letter(s) in the same column and superscript capital letter(s) in the same row are not statistically different.

Seed yield and seed yield reduction

Salinity stress reduced the grain weight in all rice varieties but the degree of reduction was not similar for all varieties as well as for salinity levels (Table 8). The results indicated that seed yield of rice was significantly influenced by different salinity level. The maximum seed yields of all genotypes were found in control and the minimum were at 10 dSm^{-1} salinity. At control, the maximum seed yield (30.95 g/pot) was found in BC$_2$F$_2$-81 followed by BC$_2$F$_2$-45 (30.77 g/pot) while at 10 dSm^{-1} salinity, the maximum seed yield (17.53 g/pot) was found in Binadhan-10 followed by BC$_2$F$_2$-106 (15.14 g/pot). All advanced lines accept BC$_2$F$_2$-172, and BC$_2$F$_2$-81 were also showed better seed yield at 10 dSm^{-1} salinity. The minimum seed yield reduction (34.94%) was found in Binadhan-10 and the maximum (73.36%) was found in BC$_2$F$_2$-98 at 10 dSm^{-1} salinity level. It has long been recognized that a crop's sensitivity to salinity varies from one developmental growth stage to the next (Läuchli & Grattan (2007). Rice has been reported as being salt-sensitive in both its vegetative and reproductive stages (Moradi & Ismail, 2007), leading to a reduction in productivity of more than 50% when exposed to 6.65 dSm^{-1} salinity (Cha-um & Kirdmanee, 2010). Yaqoob et al. (2012) and Tiwari et al. (2011) also observed that there is a significant variation among genotypes for yield plant^{-1}. The loss of grain yield hill^{-1} may result from a combination of reduction in tillering capacity, lower panicle initiation, reduced panicle length and reduction in grain formation as well as in grain size due to salinity stress. Grain yield reduction of rice varieties due to salt stress is also reported by Purnendu (2004). A significant effect of salinity on the weight of one thousand seeds was observed by (Rad et al., 2011). Consequently, salinity depletes the ovaries of photosynthetic pigments and soluble proteins.This alteration might lead to a reduction in ovarian photosynthesis, resulting in inadequate sugar generation in the ovaries.

The decrease in 1000-grain weight may be attributable to a decrease in grain size caused by a decrease in the deposition of carbohydrates and other food elements into grain as a consequence of salt stress. Zubaer et al. (2007) observed that salinity reduced the 1000-grain weight in rice and degree of reduction was different in different genotypes which supports the results of our study.

CONCLUSION

In brief, our study revealed that, maximum advanced lines showed a significant degree of tolerances against salinity. Salt stress reduced plant height, panicle length, tiller and panicle number/plant, filled grains, 1000 seeds weight, and ultimately the yield/hill. In this experiment, the result provided clear evidence that the tolerant genotypes displayed least reduction of growth related parameters. The

DOI: https://doi.org/10.55706/jae1641

performance of all the genotypes with respect to yield and yield contributing traits differed from each other under different salinity level. According to the experiment, NILs-BC_2F_2-Binadhan-17 rice genotypes, BC_2F_2-106, BC_2F_2-23, BC_2F_2-78, BC_2F_2-69, BC_2F_2-140, BC_2F_2-98, BC_2F_2-11, BC_2F_2-84, BC_2F_2-117, BC_2F_2-60, BC_2F_2-163, BC_2F_2-45 were able to tolerate salt levels up to 10 dSm^{-1} and BC_2F_2-172, BC_2F_2-81 were able to tolerate salt levels up to 8 dSm^{-1}. These selected screened genotypes could also be used in marker-assisted backcrossing for the development of salt-tolerant high-yielding rice genotypes and these methods can be further used for a reliable and efficient reproductive screening of salt-tolerant rice. Finally, we recommend further detailed study on the field of these identified salt-tolerant rice genotypes.

Conflict of Interest

There are no conflicts of interest declared by the authors.

REFERENCES

Alam, S. M., Ansari, R., Mujtaba, S. M., & Shereen, A. (2001). Salinization of millions of hectares of land continues to reduce crop productivity severely worldwide. *Saline Lands and Rice: Industry & Economy. Pakistan Economist*, *17*, 60–71.

Ali, Y., Aslam, Z., Ashraf, M. Y., & Tahir, G. R. (2004). Effect of salinity on chlorophyll concentration, leaf area, yield and yield components of rice genotypes grown under saline environment. *International Journal of Environmental Science & Technology*, *1*(3), 221–225.

Aref, F., & Rad, H. E. (2012). Physiological characterization of rice under salinity stress during vegetative and reproductive stages. *Indian Journal of Science and Technology*, *5*(4), 2578–2586.

Aslam, M., Muhammad, N., Qureshi, R. H., Ahmad, Z., Nawaz, S., & Akhtar, J. (2003). Calcium and salt-tolerance of rice. *Communications in Soil Science and Plant Analysis*, *34*(19–20), 3013–3031.

Bagues, M., Sarabi, B., Ghashghaie, J., Souli, I., & Nagaz, K. (2018). The validity of carbon isotope discrimination as a screening criterion for grain yield in two barley landraces under deficit irrigation with saline water in southern Tunisia. *Plant Biotechnology*, 18–502.

Chaudhry, U. K., Ahmed, N., Junaid, M. D., Ali, M. A., Saboor, A., Danish, S., Hussain, S., & Ahmad, S. (2022). Salinity Tolerance in Rice. In *Modern Techniques of Rice Crop Production* (pp. 275–293). Springer Singapore. https://doi.org/10.1007/978-981-16-4955-4_16

Chaum, S., & Kirdmanee, C. (2010). Effect of glycinebetaine on proline, water use, and photosynthetic efficiencies, and growth of rice seedlings under salt stress. *Turkish Journal of Agriculture and Forestry*, *34*(6), 517–527.

Chen, T., Shabala, S., Niu, Y., Chen, Z. H., Shabala, L., Meinke, H., Venkataraman, G., Pareek, A., Xu, J., & Zhou, M. (2021). Molecular mechanisms of salinity tolerance in rice. *Crop Journal*, *9*(3), 506–520. https://doi.org/10.1016/j.cj.2021.03.005

Colla, E., Coune, P., Liu, Y., Pletnikova, O., Troncoso, J. C., Iwatsubo, T., Schneider, B. L., & Lee, M. K. (2012). Endoplasmic reticulum stress is important for the manifestations of α-synucleinopathy in vivo. *Journal of Neuroscience*, *32*(10), 3306–3320.

Falah, A. (2010). The effects of salinity at different growth stage on rice. *Proceeding of 11th National Congress Opn Agronomy*.

Grattan, S., Zeng, L., Shannon, M., & Roberts, S. (2002). Rice is more sensitive to salinity than previously thought. *California Agriculture*, *56*(6), 189–198.

Hasanuzzaman, M., Fujita, M., Islam, M. N., Ahamed, K. U., & Nahar, K. (2009). Performance of four irrigated rice varieties under different levels of salinity stress. *International Journal of Integrative Biology*, *6*(2), 85–90.

Islam, M. R., Salam, M. A., Bhuiyan, M. A. R., Rahman, M. A., Yasmeen, R., Rahman, M. S., Uddin, M. K., Gregorio, G. B., & Ismail, A. M. (2008). BRRI Dhan 47: A salt tolerant rice variety for Boro season isolated through participatory variety selection. *International Journal of Biological Research*.

Islam, M. Z., Baset Mia, M. A., Islam, M. R., & Akter, A. (2007). Effect of different saline levels on growth and yield attributes of mutant rice. *J Soil Nat*, *1*(2), 18–22.

Islam, S. S., & Hossain, M. (2020). Morphological and yield performance of rice varieties grown in moderately and strongly saline soils of Khulna, Bangladesh. *GSJ*, *8*(3).

Joseph, B., Jini, D., & Sujatha, S. (2010). Biological and physiological perspectives of specificity in abiotic salt stress response from various rice plants. *Asian J. Agric. Sci*, *2*(3), 99–105.

Kamyab-Talesh, F., Mousavi, S. F., Asadi, R., Rezaei, M., & Khaledian, M. R. (2014). Evaluation of some rice cultivars' response to salinity stress using resistance indices. *Archives of Agronomy and Soil Science*, *60*(9), 1303–1314.

Kumar, V., Singh, A., Mithra, S. V. A., Krishnamurthy, S. L., Parida, S. K., Jain, S., Tiwari, K. K., Kumar, P., Rao, A. R., Sharma, S. K., Khurana, J. P., Singh, N. K., & Mohapatra, T. (2015). *Genome-wide association mapping of salinity tolerance in rice (Oryza sativa)*. *22*, 1–13. https://doi.org/10.1093/dnares/dsu046

Läuchli, A., & Grattan, S. R. (2007). Plant growth and development under salinity stress. In *Advances in molecular breeding toward drought and salt tolerant crops* (pp. 1–32). Springer.

Mahmood, A., Latif, T., & Khan, M. A. (2009). Effect of salinity on growth, yield and yield components in basmati rice germplasm. *Pak. J. Bot*, *41*(6), 3035–3045.

Mojakkir, A. M., Tareq, M. Z., Mottalib, M. A., Hoque, A., & Hossain, M. A. (2015). Effect of salinity at reproductive stage in rice. *Int J Bus Social Sci*, *3*, 7–12.

Moradi, F., & Ismail, A. M. (2007). Responses of photosynthesis, chlorophyll fluorescence and ROS-scavenging systems to salt stress during seedling and reproductive stages in rice. *Annals of Botany*, *99*(6), 1161–1173.

Munns, R. (2002). Comparative physiology of salt and water stress. *Plant, Cell & Environment*, *25*(2), 239–250.

Pathan, M. S., Subudhi, P. K., Courtois, B., & Nguyen, H. T. (2004). Molecular dissection of abiotic stress tolerance in sorghum and rice. In *Physiology and biotechnology integration for plant breeding* (pp. 449–488). CRC Press.

Purnendu, G. (2004). Effect of salinity on some yield attributes of rice. *Pak J Biol Sci*, *7*(5), 760–762.

Rad, H. E., Aref, F., Khaledian, M., Rezaei, M., Amiri, E., & Falakdehy, O. Y. (2011). The effects of salinity at different growth stage on rice yield. *Ecology, Environment and Conservation*, *17*(3), 111–117.

Rad, H. E., Aref, F., & Rezaei, M. (2012). Rice growth and yield components respond to changes in water salinity stress. *World Applied Sciences Journal*, *20*(7), 997–1007.

Sabouri, HOSSEIN, & Biabani, A. (2009). Toward the mapping of agronomic characters on a rice genetic map: quantitative trait loci analysis under saline condition. *Biotechnology*, *8*(1), 144–149.

Sabouri, Hossein, & Sabouri, A. (2008). New evidence of QTLs attributed to salinity tolerance in rice. *African Journal of Biotechnology*, *7*(24).

Shahid, S. A., Zaman, M., & Heng, L. (2018). Soil Salinity: Historical Perspectives and a World Overview of the Problem. In *In Guideline for Salinity Assessment, Mitigation and Adaptation Using Nuclear and Related Techniques; Springer International Publishing: Cham, Switzerland*. https://doi.org/10.1007/978-3-319-96190-3

Shrivastava, P., & Kumar, R. (2015). *Soil salinity: a serious environmental issue and plant growth promoting bacteria as one of the tools for its alleviation. Saudi J Biol Sci 22: 123–131*.

Singh, K. (2016). Microbial and enzyme activities of saline and sodic soils. *Land Degradation & Development*, *27*(3), 706–718.

Sultana, T., Islam, R., Chowdhury, M. S. N., Islam, M. S., Hossain, M. E., & Islam, M. M. (2014). Performance evaluation of two rice varieties under different levels of NaCl salinity stress. *Bangladesh Research Publication Journals*, *10*(2), 186–195.

Tabassum, R., Tahjib-Ul-Arif, M., Hasanuzzaman, M., Sohag, A. A. M., Islam, M. S., Shafi, S. M. S. H., Islam, M. M., & Hassan, L. (2021). Screening salt-tolerant rice at the seedling and reproductive stages: An effective and reliable approach. *Environmental and Experimental Botany*, *192*(August), 104629. https://doi.org/10.1016/j.envexpbot.2021.104629

Taghipour, F., & Salehi, M. (2008). The study of salt tolerance of Iranian barley Hordeum vulgare L. genotypes in seedling growth stages. *Biyolojik Çeşitlilik ve Koruma*, *1*(2), 53–58.

Tan, K. Z., Radziah, O., Halimi, M. S., Khairuddin, A. R., & Shamsuddin, Z. H. (2015). Assessment of plant growth-promoting rhizobacteria (PGPR) and rhizobia as multi-strain biofertilizer on growth and N2 fixation of rice plant. *Australian Journal of Crop Science*, *9*(12), 1257–1264.

Tiwari, D. K., Pandey, P., Tripathi, S., Giri, S. P., & Dwivedi, J. L. (2011). Studies on genetic variability for yield components in rice (Oryza sativa L.). *Advances in Agriculture & Botanics*, *3*(1), 76–81.

Yaqoob, M., Hussain, N., & Rashid, A. (2012). Assessment of genetic variability in rice (Oryza sativa L.) genotypes under rainfed conditions. *Journal of Agricultural Research (03681157)*, *50*(3).

Zeng, L., & Shannon, M. C. (2005). Salinity effects on seedling growth and yield components of Rice. *Pakistan Journal of Botany*, *37*(1), 131–139.

Zhao, N., Guan, J., Forouhar, F., Tschaplinski, T. J., Cheng, Z.-M., Tong, L., & Chen, F. (2009). Two poplar methyl salicylate esterases display comparable biochemical properties but divergent expression patterns. *Phytochemistry*, *70*(1), 32–39.

Zubaer, M. A., Chowdhury, A., Islam, M. Z., Ahmed, T., & Hasan, M. A. (2007). Effects of water stress on growth and yield attributes of Aman rice genotypes. *International Journal of Sustainable Crop Production*, *2*(6), 25–30.

DOI: https://doi.org/10.55706/jae1641