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Standardization of technique and screening for salinity tolerance in rice (*Oryza sativa* L.)

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ABSTRACT

Salt tolerance is an important constrain for rice, which is generally categorized as a typical glycophyte. The present study was carried out at departmental laboratory of Bidhan Chandra Krishi Viswavidyalaya, Mohanpur, Nadia, West Bengal, in three replication following CRD. In order to find a suitable dose for screening, initially the seeds of twenty genotypes were subjected to five different concentrations viz., 0 mM, 40 mM, 60 mM, 80 mM and 120 mM of NaCl following glass plate technique for 10 days. The observations were recorded from ten randomly selected seedlings on 12 seedling characters and on the basis of performance of the seedlings of these genotypes grown in all the five concentrations of salt, 60 mM of NaCl was found to be a suitable dose to screen all forty genotypes. All the forty genotypes were further evaluated at 60 mM of NaCl for 14 parameters and respective control in three replications to screen susceptible and tolerant genotypes. Differential growth performances were observed for all the parameters studied. Tolerance index and salinity susceptibility index were found to be reliable parameters in the identification of susceptible and tolerant genotypes. Considering, relative reduction of mean values of seedling characters in general and SSI and TI in particular, six genotypes viz., IR10206-29-2-1-1, PUSA NR 580-6, BRRI Dhan 53, CSR 22, Annada and Lalat were selected as susceptible and IR11T138, Lal Minikit (WGL20471), IR66946-3R-149-1-1, IR06M143, IRRI 147 and BRRI Dhan 47 as tolerant.

Key words: *Screening, salinity tolerance, susceptible, tolerance index, salinity susceptibility index*

INTRODUCTION

Rice is generally sensitive to salinity (Yeo et al., 1991) though rice varieties differ greatly in salt tolerance (Akbar et al., 1997; Amin et al., 1996; Yeo et al., 1991). According to Yoshida (1981) rice is more sensitive to salinity during early seedling growth and flowering than other growth stages. Under saline conditions germination ability of seeds differs from one crop to another and even amongst the cultivars of the same crop (Asana and Kale, 1965; Maliwal and Paliwal, 1967; Kumar and Bhardwaj, 1981).

According to Mock and McNeill (1979), Koscielniak and Dubert (1985) and Sarangi et al. (2015), vigorous seedling provides basis for good crop stand and productivity. Therefore, evaluation of the rice genotypes at seedling stage appeared to be a relevant and important initial step of breeding programme with an objective to evolve salt tolerant lines. Screening of germplasm at seedling stage is readily acceptable as it is based on the simple criterion of selection. By this method rapid screening can be done which is difficult at vegetative and reproductive stage (Gregorio et al., 1997). Further, screening under controlled condition reduces the environmental effects and the hydroponic system is free of difficulties associated with soil related

stress factors. The conventional methods of plant selection for salt tolerance are difficult due to large effects of the environment and low narrow sense heritability of salt tolerance (Gregorio, 1997). Such factor hinders the development of an accurate, rapid and reliable screening technique.

The response of plants to excess sodium chloride (NaCl) is complex and involves changes in their morphology, physiology and metabolism (Parida and Das, 2005). However, considering germination, active tillering and towards maturity rice is relatively tolerant to salt stress but is sensitive during the early seedling and reproductive stages (Pearson and Bernstein, 1959; Zheng et al., 2001). Therefore, there is good reason to screen the germplasm accessions and breeding material for salt tolerance when the plant is sensitive to salt stress during two particular growth stages. The main purpose of the study was to identify suitable dose of NaCl concentration for screening and to screen salt tolerant and salt susceptible genotypes in relation to biomass production at early vegetative growth stages.

MATERIALS AND METHODS

The materials in present experiment comprised 40 rice genotypes collected from ICAR-Central Soil Salinity Research Institute, Regional Research Station, Canning Town, South 24 Parganas, West Bengal. The experiment was carried out at departmental laboratory of Bidhan Chandra Krishi Viswavidyalaya, Mohanpur, Nadia, West Bengal, in three replication following CRD.

Standardization of technique

Preparation of salt solution

Salt solution of different salinity level was prepared by dissolving the appropriate amount of NaCl in one litre of water which were as follows:

The molecular weight of NaCl = 23+35.46=58.46 g

Therefore,

1. 40 mMNaCl = 2.338 g NaCl in 1 liter of water
2. 60 mMNaCl = 3.508 g NaCl in 1 liter of water
3. 80 mMNaCl = 4.677 g NaCl in 1 liter of water
4. 120 mMNaCl = 7.015 g NaCl in 1 liter of water

N. B. 1 dS/m EC = 10 mM of NaCl

Amount of salt (g)	Volume (ml)	Concentration
58.46	1000	1 M or 1000 mM
2.33	1000	40 mM
3.50	1000	60 mM
4.68	1000	80 mM
7.02	1000	120 mM

Identification of suitable dose of salt

In order to determine the suitable concentration of salt solution, initially the seeds of twenty genotypes were subjected to five different salt concentrations viz., 0 mM, 40 mM, 60 mM, 80 mM and 120 mM. On the basis of performance of the seedlings of these genotypes grown in all the five concentrations of salt, a suitable dose was identified for screening all forty genotypes. For the purpose of standardization of technique, data were recorded from ten randomly selected seedlings on 12 morphological characters *viz.,* final germination percentage (FGP), speed of germination (SG), germination energy (GE), shoot length (SL), root length (RL), total seedling length (TSL), shoot fresh weight (SFW), root fresh weight (RFW), total fresh weight (TFW), shoot dry weight (SDW), root dry weight (RDW) and total dry weight (TDW).

Method of screening

Forty five viable seeds of each rice genotype were surface sterilized with 0.1% $HgCl_2$ solution for 2 minutes followed by thorough washing in distilled water. Fifteen seeds of a genotype were arranged in a row over a glass plate (20 × 30 cm) lined with saline solution soaked blotting paper. The whole set was then placed in a transparent polythene bag and set in place holders in a slanted way. There were three such sets for each genotype representing three replications. Then the seeds were allowed to germinate in the plates containing saline solution absorbed filter paper in the laboratory in presence of sufficient light and aeration. In the treatment plates, salt solution of desired salinity was used as germinating medium whereas in controls, pure distilled water was used for the purpose. The seedlings were allowed to grow for 10 days under indoor laboratory condition under sufficient light, 70-80% relative humidity (RH) and at a temperature range of 25-30^{0}C. Three replications were maintained for all the treatments including the respective controls. The

number of seeds that sprouted and germinated was counted daily up to 9 days. Data were collected from ten randomly selected seedlings from each replication. On tenth day, the seedlings were harvested; adsorbed water was removed by placing them on blotting paper and weighted immediately for collecting data on fresh weight. Data on length of root and shoot were recorded after placing the seedlings on graph paper. Shoot and root dry weights (10 seedlings) were recorded after drying the seedlings at 70°C in hot air oven till they stopped losing weight. Data were recorded through destructive sampling. Due to treatment with saline solution, the seedling growth was ought to be affected. Therefore, the extent of effect of a particular salt concentration on seedling growth was reflected by the amount of reduction in growth with compared to controls. In the present study percent relative reduction (RR%) for different seedling characters of all the genotypes were calculated for statistical analysis. The data were recorded on final germination percentage (FGP), speed of germination (SG), germination energy (GE), shoot length (SL), root length (RL), total seedling length (TSL), shoot fresh weight (SFW), root fresh weight (RFW), total fresh weight (TFW), shoot dry weight (SDW), root dry weight (RDW) and total dry weight (TDW). Tolerance Index (TI) and Salinity Susceptibility Index (SSI) under each salinity level was calculated as per Garg and Singla (2004) and Fisher and Maurer (1978) respectively.

RESULTS AND DISCUSSION

Identification of optimum salt concentration for screening large number of rice genotypes from mean performance of seedling characters in 20 rice genotypes

For identification of optimum salt concentration, twenty genotypes of rice were tested in 40 mM, 60 mM, 80 mM and 120 mM of NaCl solution. At 80 mM of NaCl only 8 genotypes showed visual growth while remaining 12 did not even germinate whereas at 120 mM of NaCl none germinated. However, at 40 and 60 mM salinity levels a comparable growth of the seedlings could be noticed in the 20 genotypes. Therefore, the mean performances of these twenty genotypes at seedling stage were observed in 40 mM and 60 mM salinity levels. The results obtained so far for different seedling characters under study are presented in table 1, 2 and 3 respectively.

Considering the mean values for different morphological characters of the seedlings grown under the above concentrations of NaCl, it was observed that they were affected in all three levels of salinity in various ways. Earlier, Win et al. (2011) found that all the three salinity levels *i.e.,* 75, 150 and 250 mM of NaCl, markedly retarded plant height, leaf number, shoot length, root length, chlorophyll content, shoot fresh weight, root fresh weight, shoot dry weight, root dry weight and leaf area as well as the percentage of water. Misra et al. (1996), Maity et al. (2000), Yupsanis et al. (2001), Misra and Dwivedi (2004) also found a progressive and gradual decrease in seed germination, plant height, shoot and root length, dry matter biomass, root, stem and leaf weights with progressive increase in salinity stress in mungbean. Naseer et al. (2001) reported decrease in the germination percentage, root and shoot length and fresh and dry weight in barley varieties with increasing salinity level.

Comparing the results presented in the table 1 and 2 it was observed that there was a linear increasing effect of salinity on different morphological characters of the seedlings with increase in the dose. Davoud Akhzari et al. (2012) opined that increasing salinity level caused reduction in seedling height, shoot dry weight, root length, root weight and survival scores at seedling stage in three plant species *viz., Agropyron elongatum*, *Kochia prostrate* and *Puccinellia distans*. Root length exhibited statistically significant amount of reduction at all salinity levels in all the genotypes (Sharp, 1996 and Kirnak et al., 2001b). Such findings corroborate the results of the present work where it was observed that roots continue to grow at low soil salinity potential that completely inhibited shoot growth. This may be due to the reason that many traits like root size and depth that explain adaptation to water stress which induce osmotic stress similar to salt stress (Chaves et al., 2003) are associated with plant development and structure and are constitutive rather than stress inducible. According to Krishnamurthy et al. (2007) higher salinity level retard seed germination and root emergence due to osmotic effect which is deleterious and prevent the plants from maintaining their proper nutritional requirements necessary for their healthy growth. Similar causes might have reduced the root growth in rice in the present experiment.

Table 1. Final germination percentage, tolerance index (TI), salinity susceptibility index (SSI) and relative reduction (RR) in different seedling characters of 20 genotypes of rice at 40 mM of NaCl.

S.N.	Genotypes	FGP	SG	GE	RR-RL	RR-SL	RR-TSL	RR-RFW	RR-SFW	RR-TFW	RR-RDW	RR-SDW	RR-TDW	TI	SSI
1.	IR52280-117-1-1-3	97.22	6.15	91.66	15.34	18.24	21.72	19.34	12.07	16.12	22.84	14.43	22.38	80.19	0.86
2.	Canning-7	94.44	5.67	88.89	13.74	14.58	18.71	21.58	10.46	20.68	35.84	18.58	25.49	89.88	0.73
3.	CSR-4	92.16	5.91	92.16	12.57	15.64	23.87	17.41	12.57	12.72	13.71	25.72	35.75	83.02	0.83
4.	CSRC (S) 32-B-B-B-3-B	100.00	5.10	94.44	16.34	17.81	19.27	20.76	12.19	15.86	38.11	25.64	40.57	73.11	1.04
5.	CSRC (S) 36-B-B-2-B	100.00	6.16	96.58	11.96	12.63	12.72	15.44	11.28	14.92	14.11	28.56	38.42	82.37	0.83
6.	CSRC (S) 50-2-1-2-B	95.90	6.13	95.90	9.04	10.50	12.61	14.72	9.57	16.37	32.63	21.43	35.37	71.59	0.95
7.	PUSA NR 580-6	90.82	5.28	90.82	32.61	25.44	35.56	25.35	27.54	23.64	50.58	30.31	35.63	78.19	1.07
8.	CSRC (S) 50-2-1-1-4-B	97.33	5.79	97.33	8.31	12.76	9.69	11.15	11.68	15.69	25.32	19.80	27.52	79.97	0.94
9.	CSRC (S) 49-B-5-2-B-1	96.07	6.27	96.07	12.65	15.26	16.42	18.66	9.51	16.57	28.36	17.46	28.73	70.57	0.95
10.	CSRC (S) 53-1-B-1-B	96.07	6.16	96.07	11.52	15.60	19.56	18.58	11.44	17.70	38.81	25.41	32.49	74.91	1.12
11.	CSRC (S) 47-7-B-B-1-1	95.29	5.44	95.29	16.59	17.82	19.66	16.04	11.92	15.60	22.36	14.54	24.59	83.94	0.77
12.	IR 75395-2B-B-19-2-1-B	98.41	6.10	98.41	8.49	10.76	15.65	12.68	9.57	12.65	20.66	18.59	30.68	90.33	0.49
13.	CSR 12	100.00	6.32	100.00	12.57	18.52	11.59	9.57	11.28	15.54	35.75	25.72	20.82	89.50	0.53
14.	CSR 22	96.73	5.23	96.73	16.68	12.53	20.68	15.61	12.74	22.68	40.66	35.70	45.51	66.33	1.18
15.	CSR 34	96.87	6.15	96.87	13.94	16.49	15.96	14.53	11.45	16.53	25.08	18.51	25.29	77.43	1.01
16.	CSR36	98.74	5.86	98.74	14.50	12.92	10.42	12.39	9.53	12.55	28.54	16.43	30.93	75.28	0.89
17.	Bidhan-2	96.10	6.40	96.10	8.48	13.67	14.48	12.55	9.54	18.47	30.37	25.39	35.43	85.03	0.77
18.	IR11T142	98.08	6.19	98.08	9.52	15.45	12.53	17.61	8.55	14.48	32.61	14.68	30.52	83.73	0.80
19.	IR11T138	97.23	6.55	97.23	4.61	8.56	6.43	9.49	8.55	4.40	3.61	5.27	5.46	96.08	0.13
20.	IR66946-3R-116-1-1	96.41	7.15	96.41	12.36	16.44	10.43	15.55	10.54	17.80	25.42	18.61	30.53	69.08	1.00
Mean		96.69	6.00	91.72	13.09	15.08	16.40	15.95	11.60	16.05	28.27	21.04	30.11	80.03	0.84
C.V.		3.87	6.38	6.53	3.57	3.42	2.62	16.82	3.15	11.28	4.56	1.44	1.63	3.17	9.89
S.E.M		2.16	0.22	3.46	0.28	0.29	0.25	1.55	0.21	0.15	0.74	0.17	0.28	1.46	0.05
C.D at 5%		6.19	0.63	9.89	0.81	0.85	0.71	4.43	0.60	2.99	2.13	0.50	0.81	4.19	0.13
Range Lowest		90.82	5.10	88.89	4.61	8.56	6.43	9.49	8.55	4.40	3.61	5.27	5.46	66.33	0.13
Range Highest		100.00	7.15	100.00	32.61	25.44	35.56	25.35	27.54	23.64	50.58	35.70	45.51	96.08	1.18

Interestingly, in contrary to length, it was observed that in case of dry weight, the relative reduction was more in root than that of shoot. It may be mentioned that while length was measured, the longest root was considered and the number of seminal roots was not considered but dry weight was taken for all the roots which might have been the cause for such contrasting result. Generally, a genotype exhibiting significantly higher relative reduction for one character due to a particular treatment the other characters also followed the similar trend in the same treatment. Again, at a particular concentration of salinity, different genotypes responded differently for a particular character. Such differential response of different genotypes to a particular concentration of salinity has earlier been reported by Abida et al. (2012) in case of sorghum where the germination percentage was found to vary from 89.0% to 100.0% in seven different lines. It might be attributed to differential genetic makeup of different genotypes. Further, it was observed from Table 1 that the variety PUSA NR 580-6 showed highest relative reduction for all the morphological characters under study except for shoot dry weight and total dry weight whereas IR11T138 showed lowest reduction for all the morphological characters.

Relative reductions of different seedling characters studied were less and no discriminating effect could be noticed in different genotypes when treated with 40 mM of NaCl but it was more pronounced in case of treatment with 60 mM whereas 80 mM concentration produced largest effect so much so that some of the genotypes failed to germinate. Thus, treatment with 40 mM of salinity could not produce enough effect to screen the genotypes and application of 80 mM of salinity produced much drastic effect to obtain enough number of seedlings to study. The results thus indicate that 60 mM concentration of NaCl would be more suitable for screening genotypes for salt tolerance of the rice genotypes.

Perusal of the result presented in table 1, 2 and 3 indicated that the relative reductions for different seedling characters increased linearly with increasing dose of salinity from 40 mM to 80 mM. Generally, shoot length was more affected than root length in all the concentrations excepting a few *viz.,* PUSA NR 580-6, CSR 22 and CSR 36 at 40 mM (Table 1); PUSA NR 580-6 and CSR 12 at 60 mM (Table 2) and Canning-7, CSRC (S) 50-2-1-1-4-B, Bidhan 2, IR11T142 and IR66946-3R-116-1-1 at 80 mM (Table 3). According to Krishnamurthy et al. (2007) higher salinity level retard seed germination and root emergence due to osmotic effect which is deleterious and prevent the plants from maintaining their proper nutritional requirements necessary for their healthy growth.

Perusal of the results presented in Table 1, 2 and 3 indicated that two different parameters *viz.,* tolerance index (TI) and salinity susceptibility index (SSI) would be more indicative for identification of optimum dose that would help to identify/screen genotypes for tolerance and susceptibility to salinity. The performance of different genotypes with respect to TI and SSI in all the three concentrations of salinity (Table 4) revealed that the values for a particular parameter varied with the genotype and with the concentration of salt. But for a particular genotype the values for a parameter changed with the change of salt concentration. Considering the range for each parameter it was observed that the values obtained at 60 mM was medium *i.e.,* neither too low nor too severe. In case of other morphological characters also like relative reduction of shoot length (RR-SL), root length (RR-RL) and total seedling length (RR-TSL) similar trend was noticed. Win et al. (2011) opined that the growth parameters of twelve genotypes of *Vigna* exhibited differential responses to different levels of imposed salinity stress and found plant height, leaf number, shoot and root length, chlorophyll content, shoot and root fresh weight, shoot and root dry weight and leaf area decreased with increasing NaCl salinity.

From the comparative view, the salinity level of 60 mM seemed to be a stress neither too severe nor too mild. Therefore, it was felt rational to screen all the available 40 genotypes of rice imposing 60 mM salinity only to identify salinity susceptible and tolerant lines.

Mean performance of 40 rice genotypes under 60 mM salinity level

All the genotypes exhibited to be affected due to salinity treatment as revealed by relative reduction of different parameters (table 5). However, there was differential response of different genotypes due to treatment. The final germination percentage varied from 78.04 - 97.22%. Salinity may affect seed germination in two

Table 2. Final germination percentage, tolerance index (TI), salinity susceptibility index (SSI) and relative reduction (RR) in different seedling characters of 20 genotypes of rice at 60 mM of NaCl.

S.N.	Genotypes	FGP	SG	GE	RR-RL	RR-SL	RR-TSL	RR-RFW	RR-SFW	RR-TFW	RR-RDW	RR-SDW	RR-TDW	TI	SSI
1.	IR52280-117-1-1-3	89.56	5.37	89.56	22.22	25.79	28.35	25.16	17.14	24.23	36.94	22.73	37.34	61.78	0.94
2.	Canning-7	87.33	5.46	87.33	17.79	23.24	26.94	27.12	19.05	26.23	46.09	26.26	32.07	64.64	0.89
3.	CSR-4	87.47	5.69	87.47	15.69	19.65	29.74	28.24	17.41	22.57	51.11	32.30	43.76	53.61	1.17
4.	CSRC (S) 32-B-B-B-3-B	93.83	5.91	93.83	19.44	23.75	27.80	26.86	17.33	24.41	47.07	34.21	47.35	50.12	1.21
5.	CSRC (S) 36-B-B-2-B	96.10	5.59	96.10	18.22	23.39	22.56	26.54	18.22	23.32	46.44	33.99	47.20	61.85	0.97
6.	CSRC (S) 50-2-1-2-B	92.96	5.49	92.96	17.38	21.40	23.70	25.39	17.87	27.91	41.97	28.51	46.00	50.52	1.23
7.	PUSA NR 580-6	83.59	5.21	83.59	39.44	36.24	40.16	33.81	37.34	31.81	84.29	38.82	75.10	21.74	1.84
8.	CSRC (S) 50-2-1-1-4-B	93.88	5.48	93.88	18.18	21.56	21.63	24.13	17.12	27.19	46.36	28.38	36.65	63.33	0.96
9.	CSRC (S) 49-B-5-2-B-1	93.54	5.59	93.54	21.37	23.24	21.61	24.85	15.08	24.44	36.75	22.45	35.78	55.84	1.13
10.	CSRC (S) 53-1-B-1-B	89.66	5.11	89.66	19.04	22.60	29.06	27.53	19.40	25.14	46.89	34.46	46.64	55.26	1.14
11.	CSRC (S) 47-7-B-B-1-1	87.52	3.38	87.52	23.01	26.49	27.33	24.14	18.46	24.24	45.48	33.02	34.35	68.05	0.85
12.	IR 75395-2B-B-19-2-1-B	84.34	5.66	84.34	19.18	21.75	26.51	26.36	18.04	22.95	44.11	28.38	49.43	52.24	1.21
13.	CSR 12	92.51	5.23	92.51	24.76	23.55	22.85	21.70	16.82	24.09	42.09	33.86	34.76	64.56	0.83
14.	CSR 22	84.47	4.68	85.70	27.82	29.18	35.02	31.61	21.60	46.53	54.25	32.52	56.77	43.91	1.33
15.	CSR 34	93.17	5.75	93.17	24.44	21.14	21.51	25.47	18.85	27.23	41.30	29.30	54.20	48.99	1.20
16.	CSR36	95.26	5.27	95.26	23.47	24.20	23.65	27.42	17.26	28.40	47.56	31.48	52.24	64.71	0.94
17.	Bidhan-2	92.47	5.59	92.47	20.01	26.38	27.58	24.72	18.27	28.60	43.37	36.41	50.32	66.56	0.82
18.	IR11T142	93.41	5.98	93.41	18.62	26.56	31.32	28.55	18.61	28.91	42.15	28.63	42.09	57.58	1.05
19.	IR11T138	94.34	6.56	94.34	8.57	14.71	13.29	17.24	12.92	11.74	10.65	8.49	7.86	93.29	0.17
20.	IR66946-3R-116-1-1	92.17	5.70	92.17	22.85	24.83	21.24	27.50	17.56	25.94	43.96	26.20	41.87	56.12	1.07
Mean		**90.88**	**5.43**	**90.94**	**21.08**	**23.98**	**26.09**	**26.22**	**18.72**	**26.29**	**44.94**	**31.02**	**43.59**	**57.73**	**1.05**
CV		2.76	6.95	2.77	4.36	3.93	4.12	4.94	5.98	5.47	4.83	3.97	2.75	3.72	5.13
SEM		1.45	0.22	1.46	0.53	0.54	0.62	0.75	0.65	0.83	1.25	0.71	0.69	1.24	0.03
C.D at 5%		4.15	0.62	4.17	1.51	1.55	1.77	2.14	1.84	2.37	3.58	2.03	1.97	3.54	0.08
Range Lowest		83.59	3.38	83.59	8.57	14.71	13.29	17.24	12.92	11.74	10.65	8.49	7.86	21.74	0.17
Range Highest		96.10	6.56	96.10	39.44	36.24	40.16	33.81	37.34	46.53	84.29	38.82	75.10	93.29	1.84

Table 3. Final germination percentage, tolerance index (TI), salinity susceptibility index (SSI) and relative reduction (RR) in different seedling characters of 8 genotypes of rice at 80 mM of NaCl.

S.N.	Genotypes	FGP	SG	GE	RR-RL	RR-SL	RR-TSL	RR-RFW	RR-SFW	RR-TFW	RR-RDW	RR-SDW	RR-TDW	TI	SSI
1.	Canning-7	72.86	3.24	72.07	60.58	55.34	58.44	35.72	26.53	36.34	64.10	41.53	51.20	50.61	1.12
2.	CSRC (S) 32-B-B-B-3-B	81.67	2.18	80.29	41.69	65.38	50.20	44.63	63.46	55.51	67.55	58.49	64.54	45.53	1.18
3.	CSRC (S) 50-2-1-1-4-B	70.44	2.39	66.50	37.72	36.10	37.05	38.01	33.17	31.51	55.94	42.09	54.26	42.24	1.22
4.	CSRC (S) 53-1-B-1-B	66.61	3.22	60.71	32.56	35.67	35.46	52.89	30.45	32.79	74.95	49.61	62.20	37.80	1.29
5.	CSR 12	81.24	3.69	75.95	34.44	40.33	36.66	32.66	69.22	55.89	52.82	48.55	50.94	49.06	1.12
6.	Bidhan-2	78.41	2.25	78.41	55.96	43.53	50.62	77.71	59.21	68.36	83.36	77.89	80.56	19.44	1.57
7.	IR11T142	73.77	3.58	69.01	53.16	40.47	48.45	40.98	48.02	44.84	61.24	67.66	64.74	35.26	1.31
8.	IR66946-3R-116-1-1	67.57	3.60	61.66	42.60	34.84	39.88	52.83	28.57	40.86	59.15	47.14	54.36	45.64	1.21
Mean		74.07	3.02	70.57	44.84	43.96	44.59	46.93	44.83	45.76	64.89	54.12	60.35	40.70	1.25
C.V.		1.59	6.28	1.73	2.85	2.80	2.60	2.39	3.08	2.49	2.28	3.03	2.26	2.19	4.08
S.E.M		0.68	0.11	0.70	0.74	0.71	0.67	0.65	0.79	0.66	0.86	0.95	0.79	0.52	0.03
C.D at 5%		2.06	0.33	2.13	2.23	2.15	2.03	1.96	2.42	1.99	2.60	2.87	2.39	1.56	0.08
Range Lowest		66.61	2.18	60.71	32.56	34.84	35.46	32.66	26.53	31.51	52.82	41.53	50.94	19.44	1.12
Range Highest		81.67	3.69	80.29	60.58	65.38	58.44	77.71	69.22	68.36	83.36	77.89	80.56	50.61	1.57

ways: (a) osmotically, by decreasing the ease with which seeds may take up water; and (b) ionically, by facilitating the uptake of ions in excess amount to be toxic for the embryonic activity (Ayers, 1953). Salinity results in poor plant stand due to decrease in the rate of seed germination and seedling survival for most of the agricultural crops (Karim et al., 1992). In the present experiment the speed of germination ranged from 3.52 - 6.45 with a mean of 5.56. Speed of germination is a complex physiological process triggered by imbibition of water after possible dormancy mechanisms followed by the emergence of plumule and radicle. The speed of germination was decreased as the salinity levels increased. The reduction in speed of germination at high salt levels might be due to osmotic stress (Heenan et al., 1988). Mohammed et al. (1989) and Khan et al. (1997) also reported similar findings that there was reduction in speed of germination with increase in salinity level.

There was significant reduction in germination energy with an increase in salt concentration (Table 1 and 2). Though the values for FGP and GE% varied with the genotype but they were same for a particular genotype at a particular level of salinity. However, two out of the 40 genotypes under study, viz., RP2525-124-98-3 and IR77664-B-25-1-2-1-3-12-5-A5Y had high FGP but low GE%, which indicates that the seeds of these varieties might have continued to germinate even 4 days after collection of final data. In the present experiment RR-SL was more pronounced than RR-RL in all the genotypes except in case of IR10206-29-2-1-1, PUSA NR 580-6, CSR 28, CSR 34 and IR06M143. However, Rahman (2001), opined that root length of all the cultivars of rice in seedling stage were remarkably suppressed over shoot length in all concentrations with exception at 0.01% of NaCl. Such difference of response to salinity might be attributed to differential genetic makeup of the genotypes used. In this respect, Yeo et al. (1991) stated that the varieties differ greatly in salt tolerance. Table 5 revealed that there were 22 genotypes exhibiting significant relative reduction for root length, 37 for relative reduction of shoot length and 33 for relative reduction of total seedling length whereas 21 genotypes *viz.,* IR10206-29-2-1-1, CSR-4, CSRC (S) 50-2-1-2-B, PUSA NR 580-6, CSRC (S) 33-9-B-B-B, IR75395-2B-B-19-2-1-B, CSR 12, CSR 13, CSR 22, Bidhan-2, IR11T142,

Table 4. Tolerance index (TI) and salinity susceptibility index (SSI) of 20 genotypes of rice at 40 mM, 60mM and 80mM of NaCl.

		40 mM		60 mM		80 mM	
S.N.	Genotypes	TI	SSI	TI	SSI	TI	SSI
1.	IR52280-117-1-1-3	80.19	0.86	61.78	0.94	-	-
2.	Canning-7	89.88	0.73	64.64	0.89	50.61	1.12
3.	CSR-4	83.02	0.83	53.61	1.17	-	-
4.	CSRC (S) 32-B-B-B-3-B	73.11	1.04	50.12	1.21	45.53	1.18
5.	CSRC (S) 36-B-B-2-B	82.37	0.83	61.85	0.97	-	-
6.	CSRC (S) 50-2-1-2-B	71.59	0.95	50.52	1.23	-	-
7.	PUSA NR 580-6	78.19	1.07	21.74	1.84	-	-
8.	CSRC (S) 50-2-1-1-4-B	79.97	0.94	63.33	0.96	42.24	1.22
9.	CSRC (S) 49-B-5-2-B-1	70.57	0.95	55.84	1.13	-	-
10.	CSRC (S) 53-1-B-1-B	74.91	1.12	55.26	1.14	37.80	1.29
11.	CSRC (S) 47-7-B-B-1-1	83.94	0.77	68.05	0.85	-	-
12.	IR 75395-2B-B-19-2-1-B	90.33	0.49	52.24	1.21	-	-
13.	CSR 12	89.50	0.53	64.56	0.83	49.06	1.12
14.	CSR 22	66.33	1.18	43.91	1.33	-	-
15.	CSR 34	77.43	1.01	48.99	1.20	-	-
16.	CSR36	75.28	0.89	64.71	0.94	-	-
17.	Bidhan-2	85.03	0.77	66.56	0.82	19.44	1.57
18.	IR11T142	83.73	0.80	57.58	1.05	35.26	1.31
19.	IR11T138	96.08	0.13	93.29	0.17	-	-
20.	IR66946-3R-116-1-1	69.08	1.00	56.12	1.07	45.64	1.21
Mean		80.03	0.84	57.73	1.05	40.70	1.25
C.V.		3.17	9.89	3.72	5.13	2.19	4.08
S.E.M		1.46	0.05	1.24	0.03	0.52	0.03
C.D at 5%		4.19	0.13	3.54	0.08	1.56	0.08
Range Lowest		66.33	0.13	21.74	0.17	19.44	1.12
Range Highest		96.08	1.18	93.29	1.84	50.61	1.57

IR11T138, IR66946-3R-116-1-1, IRRI 147, Annada, Lal Minikit (WGL20471), IR66946-3R-149-1-1, Lalat, Sada Minikit (IET4786), Boby and BRRI Dhan 53 revealed relative reduction for all the three parameters i.e., for RR-RL, RR-SL and RR-TSL. The present findings corroborate the findings of Khan et al. (2003) who reported similar results. They studied response of 44 wheat accessions at seedling stage under NaCl salinity for shoot length, root length, shoot fresh weight and root fresh weight. Patel et al. (2010) reported the impact of salt stress in three Indian cowpea genotypes and observed that germination and total seedling length were affected due to imposition of 2, 4, 6, 8 and 10 dS/m NaCl salt stress. The reduction in shoot length under salt stress is due to excessive accumulation of salts in the cell wall that might have affected elasticity. Further, secondary cells appear sooner and wall becomes rigid as a consequence the turgor pressure efficiency in cell enlargement decreases. Such processes may cause the shoot remain short (Aslam et al., 1993). The low solute potential in the cell sap might pull more water to reach turgidity under saline condition. Two major factors might be involved in soil-water salinity which inhibits plant growth and development. Firstly, salt particle reduce the capacity of water potential in the cell sap and this might slower the growth and development. Secondly, salt concentration inside the plant cell may cause toxicity that retards plant growth. Plants initially adjust to saline condition by decreasing tissue water content through osmotic adjustment (Marschner, 1995). Therefore, water status is highly sensitive to salinity and is dominant in determining plant responses to stress (Stpein and Klobus, 2006). One or more of the above causes might have been responsible for reduced shoot length due to salinity in the present experiment. Considering relative reduction for fresh weight of the three different seedling characters (RR-RFW, RR-SFW and RR-TFW), there were 27, 24 and 26 genotypes exhibiting significant RR-RFW, RR-SFW and RR-TFW respectively. Generally the genotypes that exhibited significant relative reduction for length of different characters produced significant relative reduction for weight of respective character also. The present findings showed that under salt stress, fresh weights of shoots and roots decreased. This

Table 5. Final germination percentage, tolerance index (TI), salinity susceptibility index (SSI) and relative reduction (RR) in different seedling characters of 40 genotypes of rice at 60 mM of NaCl.

S.N.	Genotypes	FGP	SG	GE	RR-RL	RR-SL	RR-TSL	RR-RFW	RR-SFW	RR-TFW	RR-RDW	RR-SDW	RR-TDW	TI	**SSI**
1.	IR10206-29-2-1-1	78.04	4.21	78.04	75.13	63.01	71.53	38.24	24.06	39.07	87.53	53.09	72.52	27.52	1.83
2.	IR52280-117-1-1-3	86.78	5.33	86.78	21.82	26.13	29.15	24.49	16.17	23.08	39.87	20.22	37.56	62.44	0.95
3.	Canning-7	88.32	5.51	88.32	18.22	22.08	27.61	26.63	18.22	25.90	44.32	25.59	31.38	65.18	0.88
4.	CSR-4	88.17	5.78	88.17	16.14	20.19	30.91	27.86	16.67	23.05	50.78	33.06	44.67	54.08	1.18
5.	CSRC (S) 32-B-B-B-3-B	92.69	5.84	92.69	20.36	24.98	26.93	27.46	18.17	25.00	46.52	32.83	48.48	51.52	1.22
6.	CSRC (S) 36-B-B-2-B	95.43	5.46	95.43	17.05	22.65	21.80	25.71	17.14	24.69	48.18	35.04	47.76	63.01	0.95
7.	CSRC (S) 50-2-1-2-B	93.67	5.53	93.67	16.47	20.76	22.98	24.30	16.90	26.80	40.89	27.44	47.60	51.04	1.24
8.	PUSA NR 580-6	84.31	5.17	84.31	40.87	36.47	41.46	34.88	38.27	33.32	85.90	40.95	76.12	22.50	1.86
9.	CSRC (S) 33-9-B-B-B	91.77	5.32	91.77	21.10	26.04	28.64	24.95	18.13	27.77	49.10	32.40	32.41	67.59	0.82
10.	CSRC (S) 50-2-1-1-4-B	95.11	5.52	95.11	17.08	20.19	20.26	22.82	16.56	26.18	45.68	27.70	35.53	62.34	0.97
11.	CSRC (S) 49-B-5-2-B-1	94.66	5.67	94.66	22.20	23.76	22.36	25.96	15.83	24.74	38.23	23.45	36.59	57.36	1.11
12.	CSRC (S) 53-1-B-1-B	91.77	5.38	91.77	18.01	21.97	28.16	26.46	18.83	24.92	45.84	33.09	45.72	54.28	1.15
13.	CSRC (S) 47-7-B-B-1-1	89.10	3.52	89.10	22.13	25.46	26.20	22.34	17.83	23.81	41.57	32.00	33.10	66.90	0.84
14.	RP2525-124-98-3	83.44	5.82	80.55	19.47	24.87	24.89	22.86	16.97	26.03	38.38	35.24	51.77	50.06	1.23
15.	IR77664-B-25-1-2-1-3-12-5-A5Y	83.55	5.87	77.88	22.35	27.04	24.51	22.94	18.07	25.37	48.20	27.64	34.45	65.55	0.87
16.	IR75395-2B-B-19-2-1-B	88.89	5.70	88.89	17.72	22.01	25.94	25.87	17.04	22.18	43.38	27.72	48.51	51.49	1.22
17.	CSR 12	93.84	5.38	93.84	23.69	24.47	23.98	22.51	17.22	23.79	41.12	32.43	33.73	66.27	0.85
18.	CSR 13	94.66	5.32	94.66	17.43	25.89	20.71	24.14	17.32	24.49	36.26	34.36	37.45	62.55	0.95
19.	CSR 22	85.70	4.83	85.70	26.53	28.18	33.65	30.54	20.94	45.77	52.37	61.24	56.17	44.44	1.32
20.	CSR 28	88.89	6.03	88.89	24.94	23.63	23.67	23.80	16.60	25.26	45.99	27.37	47.56	57.92	1.14
21.	CSR 29	97.22	5.36	97.22	21.44	25.56	28.66	22.80	16.99	21.35	40.99	23.42	48.75	51.25	1.23
22.	CSR 34	94.04	5.81	94.04	23.49	20.39	20.51	24.70	18.10	26.52	40.26	27.14	52.72	50.01	1.18
23.	CSR36	97.22	5.47	97.22	22.04	23.56	22.72	25.72	16.17	26.69	46.46	30.81	51.46	63.88	0.93
24.	BRRI Dhan 47	90.67	6.13	90.67	14.46	15.01	17.87	20.93	14.45	20.94	35.71	12.82	28.34	69.03	0.78

Table 5. Cont.....

S.N.	Genotypes	FGP	SG	GE	RR-RL	RR-SL	RR-TSL	RR-RFW	RR-SFW	RR-TFW	RR-RDW	RR-SDW	RR-TDW	TI	SSI
25.	Bidhan-2	93.30	5.70	93.30	19.32	25.63	26.58	23.58	17.45	27.76	42.25	35.47	49.42	67.85	0.81
26.	IR06M143	90.61	6.14	90.61	13.49	11.90	14.15	18.10	10.74	13.17	22.60	11.25	18.14	83.53	0.42
27.	IR11T142	95.00	5.72	95.00	17.58	25.99	30.48	27.35	17.46	27.73	41.24	27.57	41.24	58.76	1.04
28.	IR11T138	93.48	6.45	93.48	9.24	15.76	12.82	16.91	13.50	12.97	11.14	9.14	8.34	92.14	0.18
29.	IR66946-3R-116-1-1	93.55	5.85	93.55	23.78	25.32	20.75	28.21	18.19	26.43	44.87	26.44	42.80	57.20	1.08
30.	IRRI 147	92.61	6.22	92.61	10.76	14.17	12.55	22.75	12.55	18.75	27.46	9.68	20.61	78.23	0.57
31.	Annada	83.94	4.59	83.99	30.27	32.72	43.22	30.48	28.46	30.59	60.57	37.46	54.42	48.58	1.30
32.	Lal Minikit (WGL20471)	94.38	6.44	94.38	11.60	13.05	15.14	17.32	12.15	10.30	13.55	10.97	12.72	88.08	0.28
33.	IR66946-3R-149-1-1	96.12	6.12	96.12	12.02	18.78	18.07	14.76	11.74	14.69	17.06	18.11	17.17	84.13	0.36
34.	Lalat	86.61	5.38	86.61	34.66	40.89	35.72	37.65	48.81	42.94	56.33	45.12	60.04	41.58	1.28
35.	Sada Minikit (IET4786)	87.60	5.98	87.60	22.57	24.64	27.32	26.49	17.73	23.69	45.53	28.97	36.85	63.15	0.93
36.	Boby	95.00	6.01	95.00	17.97	26.20	22.22	27.72	18.30	27.73	40.57	24.87	48.22	51.78	1.22
37.	BRRI Dhan 53	82.67	5.29	82.67	30.77	35.15	38.35	36.45	22.37	41.66	63.00	50.87	58.72	35.35	1.46
38.	Rashi (IET1441)	95.00	5.38	95.00	16.67	22.61	27.77	27.69	18.59	23.89	40.50	24.54	31.05	55.00	1.15
39.	BRRI Dhan 55	90.55	5.53	90.55	17.71	23.63	25.71	26.02	15.54	26.14	45.32	28.37	42.82	57.18	1.08
40.	Bina-8	95.00	5.47	95.00	19.00	20.62	28.34	23.12	18.43	24.11	40.08	31.44	39.60	60.40	1.00
Mean		**90.83**	**5.56**	**90.62**	**21.69**	**24.78**	**26.61**	**25.59**	**18.62**	**25.73**	**43.64**	**29.43**	**41.56**	**59.03**	**1.02**
C.V.		5.46	7.75	5.25	11.95	3.38	3.86	5.09	4.39	6.19	5.58	5.04	4.49	3.83	4.70
S.E.M		2.87	0.25	2.75	1.49	0.48	0.59	0.75	0.47	0.92	1.40	0.86	1.08	1.13	0.03
C.D at 5%		8.07	0.70	7.73	4.21	1.36	1.67	2.12	1.33	2.59	3.94	2.41	3.04	3.19	0.07
Range	Lowest	78.04	3.52	50.12	9.24	11.90	12.55	14.76	10.74	10.30	11.14	9.14	8.34	22.50	0.18
Range	Highest	97.22	6.45	97.22	75.13	63.01	71.53	38.24	48.81	45.77	87.53	61.24	76.12	92.14	1.86

reduction in weights with increasing salinity may be due to limited supply of metabolites to young growing tissues, because metabolic production is significantly perturbed at high salt stress either due to low water uptake or toxic effect of NaCl as advocated by Waisel (1972). In case of relative reduction for dry weight it was noticed that 32 genotypes for root, 34 genotypes each for shoot and for total dry weight revealed significant relative reduction. In case of rice seedling study, Rahaman (2001) found total dry matter accumulation was significantly suppressed by NaCl of 0.3% and by higher level in all the fourteen cultivars he studied. Generally, the genotypes that exhibited significant relative reduction for one character had produced similar result for the other character also. Verma (1981) found that germination, plant height, fresh and dry weights of shoot and roots decreased tremendously under salt stress. Poonia and Jhonsen (1976) found that increased concentration of solutes like Na+ decreased dry weight of shoots and roots in case of wheat. Therefore, it may be considered that similar effects might have caused reduction of dry weight of the treated seedlings in the present experiment. Interestingly, in the present experiment considering relative reduction data (Table 5), the shoot length was more affected compared to root while considering dry weight, the root part was more affected. It may be mentioned that for root length, the longest seminal root was considered and the number of roots was not taken into account while for measuring dry weight all the roots were harvested, dried and weighed for recording data this might have reversed the results. Also, salt concentration inside the root cell might have cause toxicity that retarded growth. Partitioning of photosynthate or translocation of photosynthate from shoot to the root was affected due to salinity might be the third reason. The genotype IR10206-29-2-1-1 showed highest relative reduction for root length, shoot length, total seedling length, root fresh weight and root dry weight. Similarly, Lalat for shoot fresh weight; CSR 22 for total fresh weight and shoot dry weight and PUSA NR 580-6 for total dry weight showed highest relative reduction. However, considering the lowest value for relative reduction, IR11T138 for root length, root dry weight, shoot dry weight and total dry weight; IR06M143 for shoot length and shoot fresh weight; 1RRI 147 for total seedling length; IR66946-3R-149-1-1 for root fresh weight; Lal Minikit (WGL20471) for

total fresh weight; IR11T138 for root dry weight, shoot dry weight and total dry weight were evident. Under salinity stress conditions, nutrient and water absorption by roots and shoots are reduced (Tehran Natural Resources Bureau, 2003) which might have resulted in general reduction of growth.

Tolerance index and salinity susceptibility index are the two most important parameters for evaluating genotypes for tolerance to salinity. Since TI is the ratio of dry weight under salinity and control condition and SSI is ratio of deduced mean dry weight (from one) of all the seedlings of all the genotypes under study in salinity stressed and non-stressed conditions respectively; the higher value for TI and lower for SSI will be desirable. Chauhan et al. (2012) stated that the lowest value of salinity susceptibility index (SSI) implies the greater tolerance against salinity. In the present experiment, the highest value for tolerance index and lowest value for the salinity susceptibility index had been recorded from the same genotype *i.e.,* IR11T138 and the vice versa from the genotype PUSA NR 580-6 (Table 5). Such differential response of different genotypes to salinity has earlier been reported by Win et al. (2011) in rice.

CONCLUSION

On the basis of performance of the seedlings of these genotypes grown in all the five concentrations of salt, 60 mM of NaCl was found to be a suitable dose to screen rice genotypes for salinity tolerance. Out of forty genotypes screened, six genotypes each exhibiting greater tolerance and susceptibility to salinity stress were selected on the basis of relative reduction of mean values of seedling characters in general and SSI and TI in particular. Such genotypes were IR10206-29-2-1-1, PUSA NR 580-6, BRRI Dhan 53, CSR 22, Annada and Lalat as susceptible and IR11T138, Lal Minikit (WGL20471), IR66946-3R-149-1-1, IR06M143, IRRI 147 and BRRI Dhan 47 as tolerant.

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