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The Effect of Salinity on Morphological Characteristics of Seven Rice (*Oryza sativa*) Genotypes Differing in Salt Tolerance

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Abstract: The effect of salinity on morphological characters of salt tolerant genotypes PVSB9, PVSB19, PNR381, PNR519, Iratom24 and salt sensitive genotype NS15 along with one standard check salt tolerant rice cultivar Pokkali were assessed in two factors Completely Randomized Design with four replications. Seven rice genotypes in combination with six levels of salinity (0, 3, 6, 9, 12 and 15 dS m^{-1}) were randomly assigned in 168 experimental plastic pots. The different morphological characters studied include plant height, total number of tillers, Root Dry Weight (RDW), Shoot Dry Weight (SDW) and Total Dry Matter (TDM) content of the selected rice genotypes in view to evaluate their response at different salinity levels. The results on the effect of morphological characters indicated that plant height, total tillers, root, shoot and total dry matter were significantly decreased by the application of salinity. The genotypes Pokkali, PVSB9, PVSB19 showed significantly higher values and the lowest value of all these characters were recorded in NS15. A sharp decrease in percent relative- plant height, RDW, SDW, TDM, total tillers were found in susceptible genotype NS15 after 3 dS m^{-1} level of salinity, but these characters were found to decrease slowly in tolerant genotypes.

Key words: Relative growth, susceptible, osmotic shock, electrical conductivity, photosynthetic pigment, dry matter accumulation

INTRODUCTION

Salinity is a major threat to crop productivity in the southern and south-western part of Bangladesh, where it is developed due to frequent flood by sea water of the Bay of Bengal and on the other hand introduction of irrigation with saline waters (Gain *et al.*, 2004). Plant growth was seriously affected due to salinity, which reduced of turgor in expanding tissues and osmo-regulation (Steponkus, 1984; Heidari-Sharifabad and Mirzaie-Nodoushan, 2006). Rice breeders have used genetic variability to produce cultivars that have high yield potential and that resist disease and insect damage and that tolerate cold, drought and even floods. But apart from some sporadic work in Sri Lanka and India, little has been done until recently to identify any breed/cultivars adaptable to adverse soil conditions such as salinity. In Bangladesh, there are approximately 2.85 million hectares (ha) of coastal soils (Ponnamperuma, 1977) which occur in the southern and southwestern parts of the country. There is a general lacking of suitable salt tolerant Modern Variety (MV) of rice to suit at different agroecological zones in the coastal areas of Bangladesh (Gain *et al.*, 2004). The alarming growth of population in Bangladesh and loss of arable land of the country due to urbanization are main causes of concern for finding ways and means for augmenting food production particularly rice. The possibility of increasing food production by increasing land area is quite out of question in Bangladesh. The only feasible alternative is to increase the cultivable land areas by bringing salt affected soils under cultivation with high yielding salt tolerant rice cultivars. The lack of an effective evaluation method for salt tolerance in the screening of genotypes is one of the reasons for the limited success in conventional salt tolerant breeding. Typical agronomic selection parameters for salinity tolerance are yield, biomass, plant surviving, plant height, leaf area and injury, relative growth rate and relative growth reduction. Aim of this study is to search the possibility of developing some salt tolerant rice cultivars for producing rice successfully in salt affected soils.

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MATERIALS AND METHODS

The experiment was conducted in plastic pots of 30 cm in diameter at the glasshouse of Bangladesh Institute of Nuclear Agriculture (BINA), Mymensingh during the period from December, 2003 to June, 2004. The experiment was laid out in two factorials CRD (Completely Randomized Design) with four replications. Factor one is seven rice (*Oryza sativa*) genotypes (five of them are advanced lines/mutants namely, PVSB19, PVSB9, PNR519, PNR381, NS15 and two of them are salt-tolerant mutant genotypes (namely, Pokkali and Iratom24) and factor second is salinity levels (namely, 0, 3, 6, 9, 12 and 15 dS m^{-1}). Soil for this pot experiment was taken from the field of BINA Farm, which was non-calcareous. The soil was dried under the sun followed by crushing, mixed thoroughly and 8 kg soil was put in each pot (Mathew *et al*., 2002). The pot soil was fertilized with urea, Triple Supper Phosphate (TSP), Muriate of Potash (MOP) and gypsum as sources of N, P, K and S at the rate of 100 kg N, 60 kg P_2O_5, 75 kg K_2O and 20 kg S ha^{-1}, respectively (BARC, 1989). The whole amount of TSP, MOP, gypsum and 1/3rd of urea was applied prior to final preparation of the pots. Thereafter, the soil in pots was moistened with water and commercial NaCl salt was added to develop salinity upto the level of 3 dS m^{-1}. Six weeks-old single seedling of selected rice genotypes per hill and three hills per pot were transplanted in the respective pot. Two weeks after transplanting the remaining salt solutions were applied in each pot according to the treatments. To avoid osmotic shock (dehydration in plant tissue caused by sudden addition of salt in higher concentration), salt solutions were added in three equal installments on alternate days until the expected conductivity was reached. Salt solutions were collected every 24 h from each pot and Electric Conductivity (EC) was measured with a conductivity meter and necessary adjustments were made. The remaining 2/3rd urea was top dressed in two equal installments at 25 and 50 days after transplanting. Weeds grown in the pots were removed by hands. Watering was done in each pot to hold the soil water level and salt concentration constant when needed.

Collection of morphological data: Plant samples were collected from pots at maturity stage of the crop (Alam, 1990). After harvesting, the plant samples were separated into root, stem, leaf and panicle. The plant height (cm) was measured from the surface level of the growth media to the tip of the longest leaf before harvesting. Total tillers number $hill^{-1}$ was counted at flowering and maturity stages. Roots were carefully cleaned with running tap water and finally washed with distilled water (Samonte *et al*., 2001). Then the root samples were oven-dried to a constant weight at 70°C. The mean root dry weight $hill^{-1}$ was calculated for each treatment. After separation of roots, the samples of stem, leaf and panicle were oven-dried to a constant weight at 70°C. Then the shoot dry weight was calculated from the summation of leaf, stem and panicle. The Total Dry Matter (TDM) was calculated from the summation of root and shoot $hill^{-1}$ (Samonte *et al*., 2001).

Relative growth data: The relative growth performance of the rice genotypes was calculated to evaluate the salt tolerance for each genotype by the following formula proposed by Ashraf and Waheed (1990):

$$\text{Relative growth data (\%)} \frac{\text{The growth data of salt treated plant of a rice genotype}}{\text{The growth data of control treated plant of that genotype}} \times 100$$

Statistical analysis: The collected data were analyzed statistically following Completely Randomized Design by MSTAT-C statistical software programme (Gomez and Gomez, 1984). The mean grouping were done by Duncan's Multiple Range Test (DMRT) and line graphs were developed as and when required (Gomez and Gomez, 1984).

RESULTS AND DISCUSSION

The previously selected four salt tolerant genotypes (PVSB9, PVSB19, PNR519, PNR381), one moderately tolerant genotype Iratom24, one susceptible genotype NS15 and a standard check salt tolerant cultivar Pokkali were used in this study. These genotypes have been selected for this study in order to study the mechanism of salinity tolerance in rice plant. To evaluate the genotypic performance, the absolute (Dewey, 1960) and relative (Maas *et al*., 1988) values of the following morphological characters have been taken into consideration:

Plant height: Obtained results show that the plant height of different rice genotypes was significantly influenced from the different salinity levels (Table 1). The tallest (96.11 cm) was produced in control condition followed by the salinity level of 3 dS m^{-1} and the shortest (32.36 cm) was observed at highest salinity level (15 dS m^{-1}) used. In addition, it was observed that the plant height reduced when the salinity level increased. Similar phenomena were also found in respect to relative plant height due to different levels of salinity applied. The percent relative plant height of different genotypes differed significantly due to the mean effect of different salinity levels (Table 2).

Table 1: The effect of different salinity levels on different morphological characters in 7 selected rice genotypes

Salinity levels ($dS\ m^{-1}$)	Plant height (cm)	Relative plant height (%)	Total tiller $hill^{-1}$ (No.)	Relative total tiller $hill^{-1}$ (%)	Root dry wt. $hill^{-1}$ (g)	Relative root dry wt. $hill^{-1}$ (%)	Shoot dry wt. $hill^{-1}$ (g)	Relative shoot dry wt. $hill^{-1}$ (%)	Root/ shoot ratio	TDM $hill^{-1}$ (g)	Relative TDM $hill^{-1}$ (%)
0	96.11a	100.00a	20.45a	100.00a	4.50a	100.00a	42.09a	100.00a	0.11b	46.59a	100.00a
3	94.75a	98.22a	14.93b	76.08b	2.82b	66.37b	28.66b	68.87b	0.10bc	31.48b	68.33b
6	91.46b	94.58b	12.46c	64.01c	2.00c	49.11c	22.85c	55.99c	0.08d	24.85c	54.96c
9	80.39c	81.70c	9.15d	49.44d	1.17d	29.79d	15.96d	38.84d	0.09cd	17.12d	37.79d
12	54.74d	53.46d	4.92e	27.35e	0.26e	5.91e	4.07e	7.99e	0.14a	4.33e	7.85e
15	32.36e	33.87e	3.37f	18.35f	0.05e	1.13e	0.33f	0.79f	0.15a	0.38f	0.82f
S_x	0.748	0.844	0.361	1.796	0.126	2.703	0.772	1.643	0.006	0.817	1.646
CV (%)	5.280	5.800	17.540	17.010	37.250	34.010	21.530	19.140	28.910	20.800	19.370

S_x: Standard deviation, CV: Coefficient of variation, TDM: Total dry matter. Values having same letter(s) in a column do not different significantly at 5% level of probability

Table 2: Genotypic effect on different morphological characters in 7 selected rice genotypes

Genotypes	Plant height (cm)	Relative plant height (%)	Total tiller $hill^{-1}$ (No.)	Relative total tiller $hill^{-1}$ (%)	Root dry wt. $hill^{-1}$ (g)	Relative root dry wt. $hill^{-1}$ (%)	Shoot dry wt. $hill^{-1}$ (g)	Relative shoot dry wt. $hill^{-1}$ (%)	Root/ shoot ratio	TDM $hill^{-1}$ (g)	Relative TDM $hill^{-1}$ (%)
Pokkali (V1)	137.90a	86.63a	7.40d	64.30a	2.28a	50.63a	32.36a	55.08a	0.07c	34.63a	54.75a
PVSB19 (V10)	68.95c	77.60b	10.63c	60.75ab	1.57c	47.41a-c	15.51c	47.95bc	0.14a	17.08c	47.56bc
PVSB9 (V11)	74.53b	87.65a	10.66c	62.04a	1.99ab	48.24ab	18.30b	50.91ab	0.12ab	20.29b	50.59ab
PNR519 (V23)	63.51d	76.71b	11.88b	55.84bc	1.49c	40.88bc	15.11c	44.45c	0.11b	16.59c	44.03c
PNR381 (V25)	68.58c	72.66c	10.72c	52.74c	1.74bc	41.43bc	17.88b	44.64c	0.11b	19.63b	43.95c
NS15 (V26)	52.44f	63.75d	13.75a	39.87d	1.38c	26.82d	14.84c	29.43d	0.11b	16.22c	29.21d
Iratom 24 (V30)	58.84e	73.80c	11.13bc	55.57bc	2.14ab	38.95c	18.95b	45.44c	0.12ab	21.09b	44.63c
S_x	0.808	0.911	0.389	1.939	0.136	2.919	0.835	1.775	0.007	0.883	1.778
CV (%)	5.280	5.800	17.540	17.010	37.250	34.010	21.530	19.140	28.910	20.800	19.370

S_x: Standard deviation, CV: Coefficient of variation, TDM: Total dry matter. Values having same letter(s) in a column do not different significantly at 5% level of probability

The percent relative plant height of tolerant genotypes PVSB9, Pokkali, PVSB19 and PNR519 showed significantly higher values compared to susceptible NS15. The genotype PVSB9 produced the highest % relative plant height (87.65%) and the lowest value (63.75%) was recorded in NS15. The results presented in Fig. 1a indicate that the % relative plant height started decreasing in all the selected genotypes except Pokkali and PVSB9 and this effect was apparent at 3 dS m^{-1} salinity and it was most pronounced in genotype NS15 while it decreased slowly in Pokkali and PVSB9 upto 12 dS m^{-1} salinity level. The percent relative plant height in PVSB19, PNR519, PNR381 and Iratom24 decreased slowly upto 9 dS m^{-1} level of salinity and at further higher salinity it drastically reduced. Choi *et al.* (2003) observed that the plant height decreased in the 0.5% saline water in the soil. Khan *et al.* (1997) conducting a pot experiment with three rice cultivars reported that plant height was seriously decreased by salinity. Pushpam and Rangasamy (2002) observed that salinity induced general reduction in shoot and root length in susceptible cultivars (IR-20, IR-50) as compared to the tolerant ones (Pokkali).

Number of total tillers: The effect of different levels of salinity on total number of tillers $hill^{-1}$ of the seven selected rice genotypes was found significant at 1% level of probability (Table 1). The maximum number of tillers $hill^{-1}$ (20.45) was recorded in control treatment and it was minimum (3.37) at highest level of salinity (15 dS m^{-1}). It was further noted that the number of tillers $hill^{-1}$ decreased with the increase in salinity levels and this effect was severe at higher salinity levels (12 and 15 dS m^{-1}). Similar phenomenon was also found in % relative tillers $hill^{-1}$. It appears from the results (Table 2) that the number of tillers $hill^{-1}$ and percent relative tillers $hill^{-1}$ of seven selected rice genotypes were significantly influenced by the mean effect of salinity levels. The total number of tillers $hill^{-1}$ was highest (13.75) in NS15 and it was lowest (7.40) in Pokkali. The percent relative tillers $hill^{-1}$ was also highest (64.30%) in Pokkali and the lowest (39.87%) was in NS15. The effect of different salinity levels on % relative tillers $hill^{-1}$ of different rice genotypes varied significantly (Fig. 1b). Except control treatments the maximum number of relative tillers $hill^{-1}$ (84.38%) was recorded in Iratom24 at 3 dS m^{-1} level of salinity followed by PVSB9 (83.70%) at same salinity and it was minimum (8.33%) in NS15 at 15 dS m^{-1} level of salinity. Figure 1b showed a gradual reduction in total number of tillers $hill^{-1}$, which started from the salinity level of 3 dS m^{-1} and it was prominent in genotype NS15. Choi *et al.* (2003) observed that tiller number of rice decreased in 0.5% saline water in the soil with low salinity level. Zeng *et al.* (2001) observed that reduction in tiller number per plant was significant only when plants were salinized for 20 days duration before Panicle Initiation (PI) of rice. The tiller number decreased significantly at 15.62 dS m^{-1} salinity level in BR11 rice (Gain *et al.*, 2004).

Root dry weight: It was evident from the results that the different levels of salinity significantly influenced the Root Dry Weight (RDW) hill^{-1} of 7 selected rice genotypes (Table 1). The highest RDW (4.50 g) was obtained at control treatment and the lowest RDW (0.05 g) was recorded in 15 dS m^{-1} level of salinity. It was further observed that the RDW of seven selected rice genotypes decreased with the increase in salinity level and at higher level the decrease was severe. Similar results were also found in % relative RDW of rice genotypes due to salinity. The results presented in Table 2 show that the % relative RDW of the selected rice genotypes varied significantly due to the mean effect of salinity levels. The highest relative RDW (50.63%) was found in Pokkali and the lowest (26.82%) value was observed in susceptible genotype NS15, which was statistically different from other genotypes. It can be seen from the Fig. 1c that the % relative RDW hill^{-1} of seven selected rice genotypes varied significantly due to the application of different levels of salinity. The highest relative RDW (77.28%) was recorded in genotypes PVSB9 and Pokkali at 3 dS m^{-1} level and it was lowest in genotype NS15 at all the salinity. At control treatment, the seven selected genotypes showed the same results (100%). The percentage relative RDW in genotype NS15 decreased very sharply from 3 to 6 dS m^{-1} salinity levels (Fig. 1c). Pushpam and Rangasamy (2002) observed that salinity induced general reduction in shoot and root length in susceptible cultivars (IR-20, IR-50) as compared to the tolerant ones (Pokkali) which corroborate our results. Increasing concentrations of NaCl from 50-150 mM progressively decreased root growth (Lin and Kao 2001).

Shoot dry weight: It can be shown in Table 1 that the Shoot Dry Weight (SDW) hill^{-1} of rice genotypes was significantly affected by salinity levels and SDW hill^{-1} decreased as the salinity level was increased. The highest SDW (42.09 g) hill^{-1} was obtained at control and the lowest SDW (0.33 g) hill^{-1} was found at 15 dS m^{-1} level of salinity. Similar pattern of results was found in percent relative SDW also due to the application of salinity (Table 1). A significant variation was obtained in percent relative SDW of seven selected rice genotypes due to the mean effect of different salinity levels (Table 2). The highest relative SDW (55.08%) was found in Pokkali and the lowest value (29.43%) was in susceptible genotype NS15. The percent relative SDW hill^{-1} of different rice genotypes was significantly influenced by different salinity levels (Fig. 1d). Except control treatment, the highest relative SDW (77.45%) was recorded in PVSB9 at 3 dS m^{-1} level of salinity. The percent relative SDW hill^{-1} of NS15 was lowest at all the salinity levels as compared to other genotypes. The percent relative SDW hill^{-1} of PVSB9 and Pokkali reduced gradually and reached to the minimum at 15 dS m^{-1} level of salinity while that of other genotypes reached to minimum at 12 dS m^{-1} (Fig. 1d). These results indicated that PVSB9 and Pokkali were more resistant than other rice genotypes under this study. Here, we found that the % relative SDW decreased due to salinity even at 3 dS m^{-1} level and a greater reduction was found from 6 dS m^{-1} salinity level and it was prominent in NS15 as compared to other genotypes. Salinity caused a substantial reduction in shoot and root dry weight, but the effect on root growth was proportionately less than that on shoot growth (Welfare *et al*., 1996). But the results indicate that both root and shoot yield was equally affected by the increase in salinity levels. Zeng *et al*. (2001) observed that reduction in shoot dry weight of plants harvested at seed maturity was significant only when plants were salinized for 20 days duration before booting, but not after booting. Pushpam and Rangasamy (2002) observed that salinity induced general reduction in shoot and root length in susceptible cultivars (IR-20, IR-50) when compared to the tolerant cultivar (Pokkali). It was evident that tolerant rice genotypes maintained higher photosynthetic pigments, which caused more photosynthetic efficiency and dry matter accumulation in shoot and roots under salt stress (Lin and Kao, 2001).

Total dry matter content: The results presented in Table 1 show that the Total Dry Matter (TDM) content hill^{-1} of the different rice genotypes was significantly affected by different salinity levels. The highest TDM (46.59 g) was produced under control treatment and the lowest TDM (0.38 g) was in the highest salinity level (15 dS m^{-1}). Similar pattern of results was also recorded in relative TDM content hill^{-1} of seven selected rice genotypes due to different salinity levels (Table 1). A significant variation in relative TDM yield of selected rice genotypes was obtained when the mean effect of different salinity levels was considered. The highest relative TDM (54.75%) was recorded in Pokkali, which was statistically identical with PVSB9 and it was lowest (29.21%) in susceptible genotype NS15, which statistically differed from other genotypes (Table 2). There was a significant variation in the effect of different salinity levels on % relative TDM hill^{-1} of seven selected genotypes of rice under study (Fig. 1e). The highest relative TDM (77.30%) was recorded in PVS B9 at 3 dS m^{-1} level of salinity and it was least (0.30%) in NS 15 at 15 dS m^{-1}

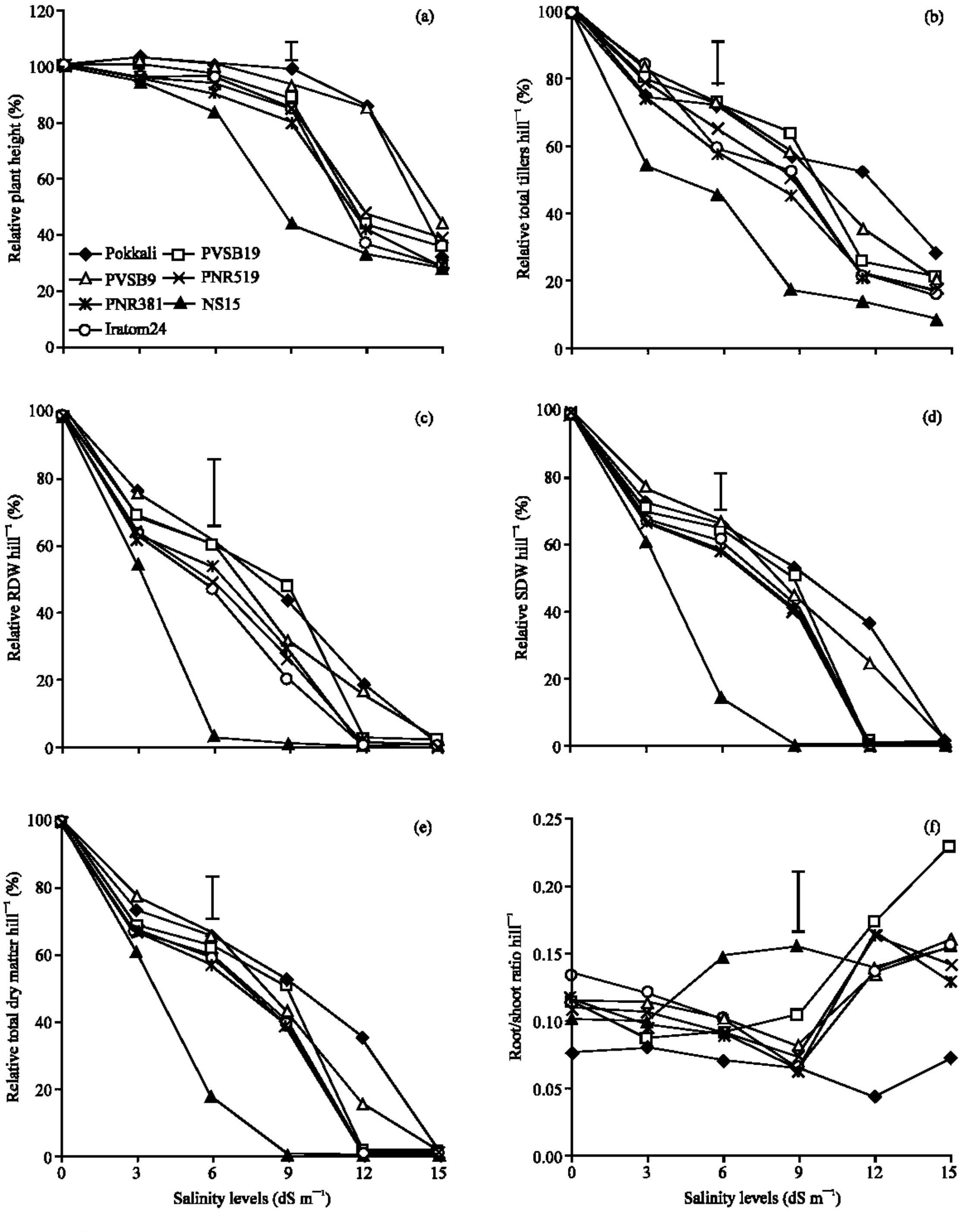

Fig. 1: The effect of different salinity levels on relative (a) plant height, (b) total tillers, (c) root dry weight (RDW) (d) Shoot Dry Weight (SDW) (e) total dry matter and (f) root/shoot ratio of seven selected rice genotypes (vertical bars represent LSD at 0.05 level of significance)

level which was statistically identical with PVSB19, PNR519, PNR381 at 12 dS m^{-1} level of salinity and with Iratom24 at 12 and 15 dS m^{-1} levels and with PVSB9, Pokkali at 15 dS m^{-1} level of salinity.

From the results presented in Fig. 1e it appeared that the salinity decreased the total dry matter content of all the selected rice genotypes. The results further show that under salinity stress the least reduction in total dry matter was obtained in Pokkali, PVSB9, PVSB19, Iratom24, PNR519 and PNR381 and very sharp reduction was in NS15. Asch *et al*. (2000) reported that the salt tolerant genotype had the smallest reduction in dry matter and the susceptible genotype had the greatest reduction in dry matter, which corroborate the results. These researchers further stated that the growth reductions were attributed to unknown mechanisms of assimilate loss that must have occurred after export from the sites of assimilation. The apparent losses might be due to several factors, such as root decomposition and exudation and energy consuming processes, such as general osmoregulation and interception of Na and K from the transpiration stream and subsequent storage in leaf sheaths. Lin and Kao (2001) stated that tolerant rice genotypes maintained higher photosynthetic pigments which caused more photosynthetic efficiency and dry matter accumulation in shoot and root under salt stress. Pushpam and Rangasamy (2002) observed a general reduction in shoot and root length in susceptible cultivars due to salinity effect as compared to the tolerant cultivar. Gain *et al*. (2004) stated that the biomass of the rice plant decreased significantly from 7.81 dS m^{-1} level of salinity.

Root/shoot ratio: The effect of salinity on root/shoot ratio $hill^{-1}$ of seven selected rice genotypes differed significantly from each other. It ranged from 0.08 to 0.15 (Table 1). The highest (0.15) value was obtained at 15 dS m^{-1} and the lowest value (0.08) was recorded at 6 dS m^{-1} level of salinity. These differences did not maintain any sequence with the levels of salinity. The root/shoot ratio $hill^{-1}$ of the genotypes under study differed due to the mean effect of different salinity levels. The highest value (0.14) was found in genotype PVSB19 and the lowest value (0.07) was found in Pokkali (Table 2). The effect of different salinity levels on root/shoot ratio $hill^{-1}$ of seven selected rice genotypes differed significantly (Fig. 1f). The highest value (0.23) was found in PVSB19 at 15 dS m^{-1} level of salinity and the lowest value (0.04) was obtained in Pokkali at 12 dS m^{-1} level of salinity. But it did not maintain any regular pattern. The highest root/shoot ratio was found in PVSB19 followed by Iratom24 and PVSB9 and the lowest value was recorded in Pokkali. Welfare *et al*. (1996) observed that salinity caused a substantial reduction in shoot and root dry weight in all varieties, but the effect on root growth was proportionately less than on shoot growth and increased the root/shoot ratio, although this effect was more pronounced in some varieties than the others.

CONCLUSIONS

The results showed that the salt tolerant rice genotypes had better expression of morphological characters than the salt susceptible under the saline soils. Increasing salinity level above 3 dS m^{-1} sharply reduced all growth characters such as percent relative plant height, RDW, SDW, TDM, total tillers were found in susceptible genotype NS15 but these characters were found to decrease slowly in tolerant genotypes.

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