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Effect of salinity on morpho-physiological traits at reproductive stages of *Oryza sativa*

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Abstract

Soil salinity is one of the most adverse environmental problems which restricts crop yield. Salinity affects rice plants very badly from germination to its maturity. Therefore, a pot experiment was conducted to study the salinity tolerance of rice genotypes viz. SAL655, STL15, PBRC37, Binadhan-8 and BRRI dhan28. The plants were grown under four salinity levels (0, 6, 9 and 12 dSm^{-1}). Plant height, total number of green leaves $hill^{-1}$, root dry weight, stem dry weight, total dry weight per hill, root shoot ratio was found to be decreased gradually with gradual increase in salinity levels as compared to the control. The genotype Binadhan-8 and PBRC37 showed the better performance in respect of all the parameters than other genotypes. Therefore, Binadhan-8 and PBRC37 were found more tolerant than other genotypes to salt stress.

Introduction

Salinity is considered as one of the important physical factors influencing rice production. At the present, salinity is the most widespread soil problem in different countries (Roy et al., 2018; Sagar et al., 2019) and is considered as a serious constraint to increased rice production worldwide (Flowers and Yeo, 1981; Chen et al., 2021). There exists tremendous variation for different abiotic stresses such as salt stress within species in rice (Thomson et al., 2010; Khaton et al., 2016; Roy et al., 2018; Rauf et al., 2020; Sagar et al., 2020), providing opportunities to improve crop salt-stress tolerance through genetic means. Rice (*Oryza sativa* L.) is one of the most important world food crops, serving as the staple food for over one-third of the world's population (Sen et al., 2020). However, rice is very sensitive to salt stress (Lee et al., 2011) and

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salinity problem of rice received very little attention in the past, but due to increased demand for growing more food to feed the booming population of the country, it has become imperative to explore the potentials of these lands. The effective reclamation of the saline soils is difficult and complex due to frequent inundation and tidal flooding (Li et al., 2015). Rice is moderately salt sensitive crop species (Lee et al., 2011; Rauf et al., 2020). It has been reported that rice at critical level (4 dSm^{-1}) might give normal straw yield (Bal and Dutt, 1986; Singh et al., 2018). Salinity affects the growth of rice plants by decreasing the rate of water uptake due to osmotic effect, or through ion-specific toxic effects or through nutritional imbalance caused by ion antagonism (Nemati et al., 2011; Yan et al., 2020). Study on the response of rice to salinity stress may be helpful in breeding salt tolerant cultivars by identifying physiological features potential to salinity tolerance. Salt tolerant cultivars had lower Na^+ and higher K^+ content (Munns and Tester, 2008; Jamil et al., 2012; Ueda et al., 2013). The effect of soil salinity varies from genotype to genotype (Flowers and Yeo, 1981; Shereen et al., 2020). Salinity also reduces the yield up to 30−80% (Zeng and Shannon, 2000; Hakim et al., 2014). Most of the workers reported that salt tolerant genotype showed less accumulation of Na^+ and Cl^- and maintained its specificity for K^+ (Yeo and Flowers, 1982; Flowers, 2004; Huqe et al., 2021). However, little information regarding the salt tolerance limits of different cultivars of rice cultivated during T. aman season. Therefore, the present piece of research work was undertaken to assess the effect of salinity stress on growth and physiological characters of some rice genotypes and to identify relative salt tolerant genotype (s).

Materials and Methods

A pot experiment was carried out at the pot yard of Bangladesh Institute of Nuclear Agriculture (BINA), Mymensingh, during the period from 8 February to 8 May 2018. Geographically the experimental area is located at 24˚75' N latitude and 90˚50' E longitudes at the elevation of 18 m above the sea level. The soil of the experiment was collected from BINA farm, Mymensingh under the agro-ecological zone of Old Brahmaputra Floodplain (AEZ-9). The experimental site falls under the sub-tropical climate, which is characterized, by high temperature, high humidity and heavy rainfall with occasional gusty winds in the Kharif season (April−September) and less rainfall associated with moderately low temperature during the rabi season (October−March). Inner wall of each perforated plastic pot is covered by a piece of cloth so that soil cannot easily washout. Soils were collected from BINA farm, Mymensingh. The collected soil was well pulverized and dried in the sun. Plant propagules and inert materials were removed from the soil. The dry soil was thoroughly mixed with well rotten cow dung. Then the necessary fertilizers were applied such as urea, triple super phosphate, muriate of potash and gypsum at the rate of 1.35, 1.55, 0.82 and 0.75 g pot^{-1} corresponding to 125, 150, 80 and 50 kg ha^{-1}, respectively. Plastic pots of 13 cm diameter and 18 cm height were used for the experiment.

The pots of the experiment were filled with 2 kg of soils. The pots were placed in 150 Liters tray type water reservoir for nutrient solution and maintenance of salinity. The water depth of the reservoir was 18 cm and it was always maintained by addition of water at weekly basis. The two−factor experiment was laid out in a Completely Randomized Design (CRD) method with four replications. The one factor was salinity level which was placed in the tray type water reservoir and another was genotypes that were placed in the pot. The seeds of five rice genotypes were collected from Plant Breeding Division, BINA, Mymensingh. The studied genotypes were SAL655, STL15, PBRC37, Binadhan-8 and BRRI dhan28. Binadhan-8 was used as check variety. The salt treatments of the experiment were four levels of salinity viz., 0, 6, 9 and 12 dSm^{-1}. The twenty-five (25) days old seedlings were transplanted in the pot and maintained next 25 days for adequate growth. Each pot contained one hill and denoted a replication. The total number of pots used in this study was 80 (5×4×4). The required quantities of salts (commercial salt) were applied to water reservoir at 25 days after transplanting to impose salinity. The salinity levels were monitored by EC meter. The salinity levels of the water reservoir were monitored weekly by EC meter and saline solution was added (when necessary) to maintained required salinity level in the reservoir. Different intercultural operations were done as and when necessary. Water was supplied to water reservoir to maintain a specific water height to ensure sufficient moisture for the normal growth of the crops. All the plants of the given cultivars were harvested at a time grain maturity (about 95−100% grains were matured).

Different morphological and physiological traits were recorded to study the salinity tolerance of rice genotypes. Plant height was measured with a ruler considering the length between the bases of the plant to the tip of the panicle. The number of green and affected leaves per hill was counted at harvest. For root length, the roots were uprooted from soil, then separated from plant followed by rinse with water and then dried in oven at 72˚C for 3 days. The dry weight of root and shoot was recorded by weighing with an electric balance. Total dry weight was obtained by the summation of the dry weight of root and shoot. Root-shoot ratio was calculated by following formula:-

$$Root\ Shoot\ Ratio = \frac{Root\ dry\ weight}{Shoot\ dry\ weight}$$

The collected data were analyzed statistically following the analysis of variance (ANOVA) technique and the mean differences were adjudged by Duncan's Multiple Range Test (DMRT) using the statistical computer package program, MINITAB. Graphs were developed using Sigma Plot software.

Results and Discussion

***Plant height*:** The variation in plant height among the studied genotypes was statistically significant (Table 1). The highest plant height was recorded in Binadhan-8 (89.75 cm) followed by SAL655 (88.75 cm). In contrast, BRRI dhan28 had shortest plant height (74.38 cm). Genotypic variations in plant height were also observed by Karim (Karim, 2007) in rice which supported the present experimental result. The effect of salinity on plant height was found statistically significant (Table 1).

Table 1. Variation in morphological characters of five rice genotypes and four salinity stress.

Genotypes	Plant height (cm)	Total no. of green leaves/hill	No. of affected leaves
SAL655 (V_1)	88.75 a	33.00 b	23.72 c
STL15 (V_2)	84.88 b	32.75 b	21.78 d
PBRC37 (V_3)	82.81 c	33.00 b	26.81 a
Binadhan-8 (V_4)	89.75 a	36.13 a	18.69 e
BRRI dhan28 (V_5)	74.38 d	30.13 c	26.13 b
Level of sign.	**	**	**
Salinity			
0 dS m^{-1} (S_0)	89.05 a	42.90 a	12.20 d
6 dS m^{-1} (S_1)	85.10 b	36.15 b	22.20 c
9 dS m^{-1} (S_2)	82.80 c	29.70 c	28.05 b
12 dS m^{-1} (S_3)	79.50 d	23.25 d	31.25 a
Level of sign.	**	**	**

** = Significant at 1% level of probability; * = Significant at 5% level of probability, Different letters on treatment means represent the significant difference at 5% levels of significance.

Result revealed that plant height was decreased with increasing salinity levels but the decrement was insignificant till 6 dS m^{-1}. The tallest plant was recorded in control (89.05 cm) and the lowest was recorded in 12 dS m^{-1} (79.50 cm). Similar result was also reported by Sen (2002) in rice and they found that plant height was decreased with increasing salinity level. The interaction between salinity levels and genotypes at harvest had significant effect on plant height (Figure 1).

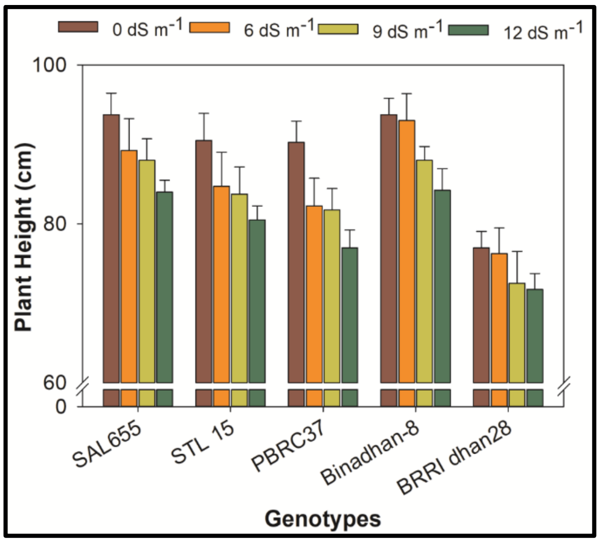

Figure 1. Effect of salinity on plant height of five rice genotypes. The vertical bars represent the standard error of means (n=3).

Result revealed that the decrement of plant height due to salinity was lesser in SAL655 and Binadhan-8 than the other three genotypes. It indicates that these two genotypes had salinity tolerance in growth and development than the others. The highest plant height was observed in Binadhan-8 with control (93.75 cm) which was statistically similar to that of SAL655 at 0 dS m^{-1} (93.75 cm). The lowest plant height was observed in BRRIdhan28 at 12 dS m^{-1} (71.75 cm). Similar result was also reported by Hossain (Hossain, 2002) in rice who observed the tallest plant height in control irrespective of the genotypes and the shortest in 12 dS m^{-1} which also supported the present experimental result.

***Total number of green leaves per hill*:** The number of green leaves hill^{-1} varied significantly among the studied genotypes (Table 1). The highest green leaves hill^{-1} was observed in Binadhan-8 (36.13). The lowest number of green leaves hill^{-1} was recorded in BRRI dhan28 (30.13) due to production of fewer tillers hill^{-1}. Similar results in genotypic variation in leaves hill^{-1} was also reported by different researchers (Lutts et al., 1996; Maiti et al., 2008) in rice. The effect of salinity on green leaf number was statistically significant (Table 1). Result revealed that green leaf number hill^{-1} decreased with increased salinity level. The highest number of green leaves hill^{-1}, was noticed in control plants (42.90) and the lowest was recorded in 12 dSm^{-1} (23.25). The interaction between salinity levels and genotypes had significant effect on green leaf number hill^{-1} (Figure 2). The highest green leaf number hill^{-1} was observed in PBRC37 with control (48.25). The lowest green leaf number was observed in BRRIdha28 with 12 dSm^{-1} (21.25). Similar result was also reported by researcher (Yeo et al., 1991) in rice who observed that the highest number of green leaves hill^{-1} in control treatment irrespective of the cultivars and the lowest in 12 dSm^{-1} which also supported the present experimental result.

***Number of affected leaves per hill*:** In case of genotypes, number of affected leaves varied significantly (Table 1). The highest number of affected leaves was recorded in PBRC37 (26.81). In contrast, Binadhan-8 showed the lowest number of affected leaves hill^{-1} (18.69). The effect of salinity on number of affected leaves was significant (Table 1). Result revealed that number of affected leaves decreased with increase in salinity levels. The highest number of affected leaves was observed in 12 dSm^{-1} (31.25). In contrast, the lowest number of affected leaves was recorded at control (12.20). Similar result was also reported by different researchers (Lutts et al., 1996; Maiti et al., 2008) in rice. The interaction between salinity levels and genotypes had significant effect on number of affected leaves (Figure 2). The highest number of affected leaves was observed in PBRC37 with 12 dSm^{-1} (33.75). The lowest number of affected leaves was observed in Binadhan-8 with 0 dSm^{-1} (10.50). Similar result was also reported by the researcher (Yeo et al., 1991) in rice who observed that the highest number of affected leaves.

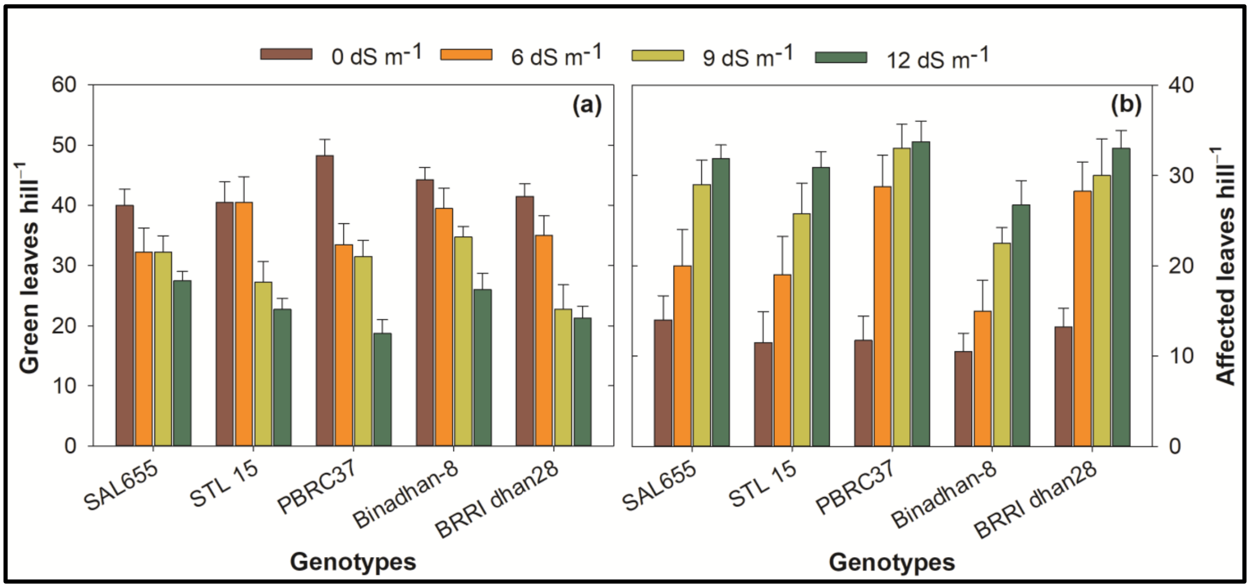

Figure 2. Effect of salinity on a) green leaves per hill and b) affected leaves per hill of five rice genotypes. The vertical bars represent the standard error of means (n=3).

***Root dry weight per hill*:** The root dry weight $hill^{-1}$ varied significantly among the studied genotypes (Table 2). The highest root dry weight $hill^{-1}$ was observed in Binadhan-8 (7.807 g $plant^{-1}$). In contrast, BRRIdhan28 produced the lowest root dry weight (5.304 g $hill^{-1}$) which was statistically similar in PBRC37 (5.401 g $hill^{-1}$). Variation in root dry weight among the cultivars grown under salinity was also observed by different researchers (Power and Mehta, 1997; Uddin et al., 2005; Sagar et al., 2019). The effect of salinity on root dry weight was statistically significant (Table 2). Result showed that root dry weight $hill^{-1}$ decreased with increased salinity level. The highest root dry weight $hill^{-1}$, was observed in control (0 dSm^{-1}) plant (8.267 g $hill^{-1}$) and the lowest was recorded at 12 dSm^{-1} (5.059 g $hill^{-1}$) (Table 2). Reduced root weight under saline condition might be due to inhibition of root growth (Babu and Thirmurugan, 2001). Similar result was also reported by researcher (Huqe et al., 2021) and they observed that root weight decreased with increased salinity levels. The interaction effect of salinity levels and genotypes in relation to root dry weight was significant (Figure 3). The highest root dry weight $hill^{-1}$ was observed in SAL655 under control (10.39 g $hill^{-1}$) and the lowest was observed in PBRC37 at 12 dSm^{-1} salinity level (4.42 g $hill^{-1}$).

***Stem dry weight per hill*:** The stem dry weight $hill^{-1}$ varied significantly among the studied genotypes (Table 2). The highest stem dry weight $hill^{-1}$ was observed in PBRC37 (19.35 g $plant^{-1}$) which was statistically similar in Binadhan-8 (19.84 g $hill^{-1}$). In contrast, STL15 produced the lowest stem dry weight (17.16 g $hill^{-1}$) which was statistically similar in SAL655 (17.41 g $hill^{-1}$) and BRRIdhan28 (17.68 g $hill^{-1}$). The effect of salinity on stem dry weight was statistically significant (Table 2). Result showed that root dry weight $hill^{-1}$ decreased with increased salinity level. The highest stem dry weight hill^{-1} was observed in control (0 dSm^{-1}) plant (19.94 g hill^{-1}) and the lowest was recorded at 12 dSm^{-1} (16.49 g hill^{-1}). The interaction effect of salinity levels and genotypes in relation to stem dry weight was significant (Figure 3). The highest stem dry weight hill^{-1} was observed in Binadhan-8 under control (21.04 g hill^{-1}) and the lowest was observed in STL15 at 12 dSm^{-1} salinity level (15.36 g hill^{-1}) which was statistically similar in BRRIdhan28 at 12 dSm^{-1} salinity level (15.60 g hill^{-1}).

Table 2. Variation in dry matter production and distribution of five rice genotypes under four different salinity stress levels.

Genotypes	Root dry wt. hill^{-1} (g)	Stem dry wt. hill^{-1} (g)	Total dry wt. hill^{-1} (g)	Root shoot ratio
SAL655 (V_1)	7.207 b	17.41 b	24.62 b	0.41 a
STL15 (V_2)	6.810 c	17.16 b	23.97 b	0.39 b
PBRC37 (V_3)	5.401 d	19.35 a	24.75 b	0.28 d
Binadhan-8 (V_4)	7.807 a	19.84 a	27.65 a	0.39 b
BRRI dhan28 (V_5)	5.304 d	17.68 b	22.98 c	0.30 c
Level of sig.	**	**	*	**
Salinity				
0 dsm^{-1} (S_0)	8.267 a	19.94 a	28.21 a	0.42 a
6 dsm^{-1} (S_1)	6.642 b	18.72 b	25.36 b	0.36 b
9 dsm^{-1} (S_2)	6.056 c	18.00 c	24.06 c	0.34 c
12 dsm^{-1} (S_3)	5.059 d	16.49 d	21.55 d	0.31 d
Level of sig.	**	**	**	***

* = Significant at 5% level of probability; ** = Significant at 1% level of probability; *** = Significant at 0.1% level of probability, Different letters on treatment means represent the significant difference at 5% levels of significance.

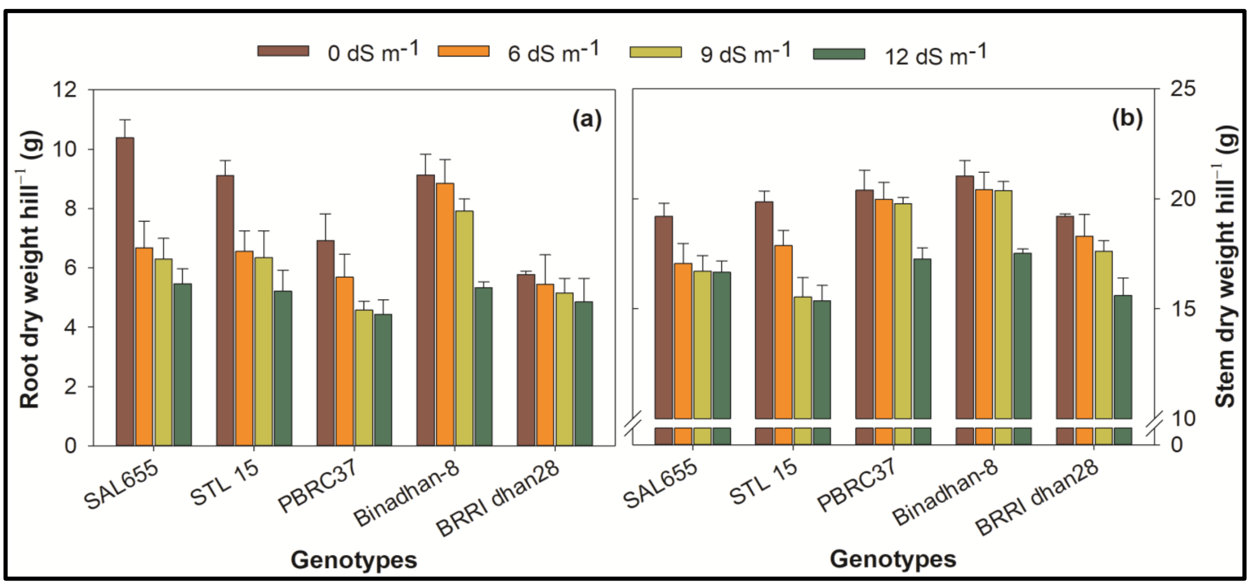

Figure 3. Effect of salinity on a) root dry weight per hill and b) stem dry weight per hill of five rice genotypes. The vertical bars represent the standard error of means (n=3).

***Total dry weight per hill*: The total dry weight varied significantly among the studied genotypes (Table 2). The highest total dry weight was observed in Binadhan-8 (27.65 g plant^{-1}). In contrast, BRRIdhan28 produced the lowest total dry matter (22.98 g hill^{-1}). The effect of salinity on total dry weight was statistically significant (Table 2). Result showed that total dry weight decreased with increased salinity level. The highest total dry matter was observed in control (0 dSm^{-1}) plant (28.21 g hill^{-1}) and the lowest was recorded at 12 dSm^{-1} (21.55 g hill^{-1}). The interaction effect of salinity levels and genotypes in relation to total dry weight was significant. The highest total dry weight was observed in Binadhan-8 under control (31.00 g hill^{-1}) and the lowest was observed in BRRI dhan28 at 12 dSm^{-1} salinity level (20.00 g hill^{-1}) (Figure 4).

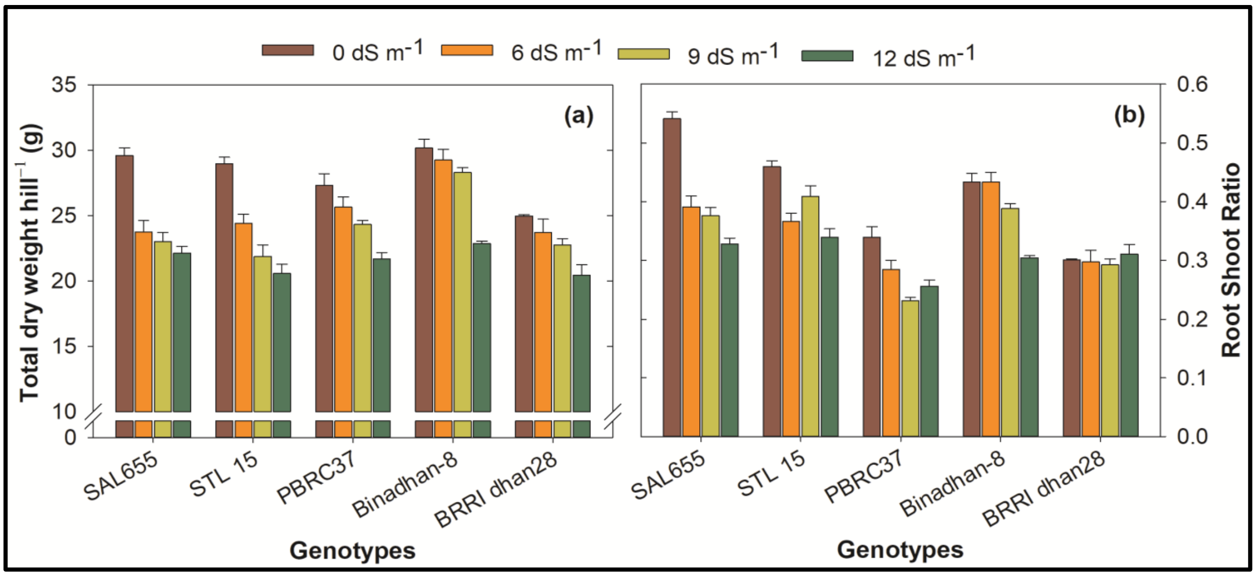

Figure 4. Effect of salinity on a) total dry weight per hill and b) root shoot ratio of five rice genotypes. The vertical bars represent the standard error of means (n=3).

***Root Shoot Ratio*: The variation in root shoot ratio among the studied genotypes was statistically significant (Table 2). The highest root shoot ratio was recorded in SAL655 (0.41 g plant^{-1}) and the lowest was recorded in PBRC37 (0.28 g plant^{-1}). The effect of salinity on root shoot ratio was statistically significant (Table 2). Root shoot ratio decreased with increased salinity level. The highest root shoot ratio was recorded in 0 dSm^{-1} (0.42 g plant^{-1}) and the lowest was recorded at 12 dSm^{-1} (0.31 g plant^{-1}). Similar result was also reported by Sen (2002) in rice. The interaction between salinity levels and cultivars had significant effect on root shoot ratio (Figure 4). The highest root shoot ratio was observed in SAL655 under control (0.52 g plant^{-1}). The lowest root shoot ratio was observed in PBRC37 at 12 dSm^{-1} (0.23 g plant^{-1}).

Conclusion

The effect of different levels of salinity was significant on plant height, total number of green leaves hill^{-1}, number of affected leaves hill^{-1}, root dry weight, stem dry weight, total dry weight, and root shoot ratio. Results indicated that all the parameters decreased with increased salinity levels. The highest plant height, total numbers of green leaves/hill, root dry weight, stems dry weight, total dry weight, root shoot ratio were observed in control plant. The lowest values of the above parameters were observed at 12 dSm^{-1} salinities.

The highest number of affected leaves hill^{-1} was observed in 12 dSm^{-1} and the lowest was found in 0 dSm^{-1} salinity level. The highest plant height, total number of green leaves hill^{-1}, root dry weight, stem dry weight, total dry weight was recorded in Binadhan-8 while the highest number of affected leaves hill^{-1} was recorded in PBRC37. The highest root shoot ratio was recorded in SAL655 and the lowest root shoot ration was found in PBRC37.In contrast, the lowest plant height, total number of green leaves hill^{-1}, root dry weight, were recorded in BRRI dhan28 while the lowest number of affected leaves/hill was recorded in Binadhan-8, lowest stem dry weight was recorded in STL15. Interaction between salinity and genotypes had significant effect on all the studied morphological parameters. Among the genotypes, the decrement of the morphological parameters like plant height, total number of green leaves hill^{-1}, total dry weight, root shoot ratio was less due to salinity in SAL655, PBRC37 and Binadhan-8 than those in the others. On the other hand, the decrement of the above studied parameters due to salinity was the highest in BRRI dhan28. All the studied rice genotypes were variably affected in growth, among the genotypes; Binadhan-8 and PBRC37 were found comparatively more tolerant in 12 dSm^{-1} saline condition than the other genotypes with less reduction in growth parameters.

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