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Screening of Rice Genotypes Based on Root Growth for Salt Tolerance at Germination Stage

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Abstract

Salinity induced changes in root length and weight under salt tolerant condition. To examine the effect of different degrees of salinity on the root growth of rice, a total of 127 rice genotypes including mostly traditional, cultivated in the coastal regions of Bangladesh and some improved genotypes were used in the study. The study was conducted in petri dish providing 0, 6, 9, 12 and 15 dS m^{-1} (deci Siemens) salinity. Based on the performances, genotypes were scored and grouped as highly tolerant (score 1), tolerant (score 3), moderately tolerant (score 5), susceptible (score 7) and highly susceptible (score 9). Salinity stress reduced the root length and weight of rice genotypes. But the extent of root length and weight, varied with genotypes and levels of salinity. Generally in control condition root length and weight was found higher and it gradually decreased with increasing salt concentration. Based on decrease of root dry weight at 15 dS m^{-1} salinity, 8 genotypes scored 1, 28 scored 3, 40 scored 5, 35 scored 7, and 16 scored 9. Regarding root length, 14 genotypes were found highly tolerant, 18 were tolerant, 27 moderately tolerant, 38 susceptible and 30 were highly susceptible. Based on the score, the relationship between salinity level and tolerances of the different rice genotypes can be understood.

Key words: Genotypes, Germination, Rice (*Oryza sativa*), Root growth and Salt tolerance

Introduction

Salt stress is a major abiotic stress that leads to a series of changes including plant morphological, physiological, biochemical and molecular changes. Salinity limits the plant growth and profitable crop production worldwide (Kumar *et al.*, 2010; Tavakkoli, 2011). FAO studies reported that 7% of the arable land affected by salinity (Goldani and Latifi, 2006). It was found that 0.83 Mha of land at coastal Bangladesh were affected by soil salinity at different degrees (CCC, 2007) which reaches up to 1.06 Mha in 2009 (SRDI, 2010). Rice (*Oryza sativa* L.) is the most important cereal food crop in the world (Ma *et al.*, 2007; Melissa *et al.*, 2009). About one billion people of rural areas in Bangladesh, India and Southeast Asia are depends on rice cultivation. High salt concentration in soil is the major constraint to rice production in Bangladesh and India (Mohammadi-Nejad *et al.*, 2010). It is estimated that a net reduction of 0.5 million metric tons of rice production would take place due to a 0.3 m sea level rise in coastal areas of Bangladesh (World Bank, 2000).

Salt stress affects many growth parameters i.e., germination percentage, root and shoot length, root and shoot dry matter, root /shoot ratio etc. The detrimental effect of salinity occurs because of osmotic stress and specific ion toxicity (Shrivastava and Kumar, 2015; Zhang *et al.*, 2010; Sosa *et al.*, 2005). Rice is rated as an especially salt-sensitive crop (Mahmud *et al.*, 2017; Gholizadeh and Navabpour, 2011; Zeng and Shannon, 2000). But the response of rice to salinity varies with growth stage. In the most commonly cultivated rice cultivars, young seedlings are very sensitive to salinity (Rad *et al.*, 2012; Ferdose *et al.*, 2009; Shereen *et al.*, 2005; Flowers and Yeo, 1981). According to the classification of crop tolerance to salinity, the rice crop is within the sensitive division from 0 to 8 dS m^{-1} (Hakim *et al.*, 2010). Inhibition of seed germination and shoot and root was noticed as a result of sodium chloride treatments in rice and cabbage (Jamil *et al.*, 2007; Sheng *et al.*, 2011). It is considered that salinity has adverse effect of salt on plant height, root, shoot and dry matter of rice and these parameters are decreased with increasing in salt concentration (Kazemi and Eskandari, 2013; Rajakumar, 2013; Ologundudu *et al.*, 2014). Though dissimilarity is also found where root length was increased with salt stress (Hussain *et al.*, 2013).

Development of salt tolerant varieties has been considered as one of the strategies to increase rice production in saline prone coastal areas. Selection of salt tolerant genotypes has been carried out for over 3 decades (Flowers, 2004) and various screening methodologies used (Kuchanur *et al.*, 2006) to screen out tolerant varieties. The present study was therefore designed to understand the mechanisms of salt tolerance in rice plant and to screen out a wide range of rice genotypes based on their tolerance though root growth parameters at different levels of salinity.

Materials and Methods

The experiment was conducted at the laboratory of the Department of Biochemistry and Molecular Biology, Bangladesh Agricultural University, Mymensingh.

Study materials

There were 127 rice genotypes comprising 120 traditional genotypes cultivated in the coastal region of Bangladesh and 7 improved varieties were used as check varieties for selection of salt tolerance. Among the genotypes 6 were previously released as moderately salt tolerant rice variety (Binadhan 8, BR23, BRRI dhan40, BRRI dhan41, BRRI dhan47 and BRRI dhan53) and 1 was salt susceptible rice variety (Binadhan 7).

Salinity treatments

Four salinity levels such as 0, 6, 9, 12 and 15 dS m^{-1} were maintained in the experiment. The different salinity levels were obtained by dissolving crude salt (collected from seashore) in distilled water. During dissolving salt with distilled water, the EC value was frequently measured with EC meter so that pre-fixed salinity level could be maintained. The control (0 dS m^{-1}) was maintained using distilled water only.

Germination test

The study was carried out in petri dishes having 15 cm diameter using two layers of filter paper. Twenty five seeds were placed on filter paper and 10ml of treatment solutions of different salinity levels were poured in each petri dish to immerse the seeds partially for ensuring proper aeration. The petri dishes were placed on a table in the laboratory. The seeds were allowed to germinate at room temperature (25±2°C). Distilled water was added to each Petri dish every day as required. The young seedlings were up-rooted 8 days after sowing (DAS). Ten randomly selected plants of each genotype from each treatment were used for data recording.

Data collection

Root length was measured from the base to top of the radical. Roots were separated from the seedlings and oven-dried at 65^0C for a period until a constant weight was obtained. Dry weight (mg) of root of each seedling was recorded.

Percent decrease of root length and root weight, due to salinity stress was calculated using the following formula**:**

$$\%\, decrease = \frac{Traits\ of\ control\ treatment - Traits\ of\ salinized\ treatment}{Traits\ of\ control\ treatment} \times 100$$

The range of percent decrease was determined and divided into five equal groups in ascending order. The groups were chronologically scored as 1, 3, 5, 7 and 9 which represent highly tolerant, tolerant, moderately tolerant, susceptible and highly susceptible genotypes to salt stress, respectively. The grouping of rice genotypes into five distinct categories were done according to IRRI (1996).

Statistical analysis

The experiment was arranged in a completely randomized design with three replications and the data collected and calculated were analyzed using MSTAT – C computer programs and comparison of means were tested for significance using least significant difference (LSD) test, at 0.01 level of probability.

Results

Root dry weight

Salt stress significantly reduced the root dry weight of rice genotypes (Table 1.1), but the rate of reduction was not similar across the genotypes. At salinity levels 6, 9, 12 and 15 dS m^{-1} the ranges of root dry weight were 1.2-5.0, 0.8-4.2, 0.6-3.2 and 0.2-2.4 mg $plant^{-1}$, respectively. Percent decrease of root dry weight under different levels of salinity (6, 9, 12 and 15 dS m^{-1}) were -5.0 - 54.5%, 0 - 73.7%, 16.7 - 80% and 27.8 - 93.3%, respectively (Table 1.2). Based on the percent reduction of root dry weight at 15 dS m^{-1} salinity, the rice genotypes were grouped into five categories and relative score values were assigned. Based on the degree of reduction of root dry weight, 8 genotypes had scored 1, 28 genotypes had 3, 40 genotypes had 5, 35 genotypes had 7 and 16 genotypes scored 9. The genotypes possessing score 1 were Machranga, Hogla, Pengek, Beki Balam, Bashful Balam, Tikaram, Talmugur and Rati Sail which had ability to retain root dry weight under high salinity condition. Genotypes ERI, Sada Mota Bashpai, Patnai (SW), Swarna dhan, Lal Gotal, Lambo, Tilek Kuchi, Bouari, Gota, Sadamota, Khejure Chori, Ghocca, Mondeshor, Kesa, Mohime and Kalihytra were highly susceptible to salinity and thus had least ability to sustain their root weight in saline condition.

Root length

Salt stress reduced the root length of rice significantly (Table 2). With the increasing salt concentration, the root length gradually decreased. Across the genotypes ranges of root length were 2.5-13.9, 2.0-10.6, 2.1-9.6, 1.2-8.5 and 0.4-6.7 cm at 0, 6, 9, 12 and 15 dS m^{-1} salinity respectively (Table 2.2). Under control condition the mean of root length was 7.4 cm which was reduced by 17.1, 27.9, 44.1 and 61.9 % at 6, 9, 12 and 15 dS m^{-1} salinity respectively. To categorize the rice genotypes on the basis of their capability to minimize the decreasing effect (on root length), tolerance index table was constructed (18-33% decrease- score 1, highly tolerant; 34-48% decrease-3, tolerant; 49-63% decrease-5, moderately tolerant; 64-78 % decrease-7, susceptible; 79-93 % decrease- 9, highly susceptible). Based on the score value it was found that, 14 genotypes were highly tolerant, 18 genotypes were tolerant, 27 genotypes were moderately tolerant, 38 genotypes were susceptible, and 30 genotypes were highly susceptible. Genotypes Ranga Hogla, Pengek, BRRI dhan47, Jota Balam, PBRC-30, Bashful Balam, Rajshahi Balam, Arman Sardar, Khok Shail, Lal Tupi, BR23, Talmuri, BRRI dhan41 and Pokkali were classified as highly tolerant.

Table 1. ANOVA table of root dry weight in germination stage

Source	Degrees of freedom	Sum of squares	Mean square	F value	Prob
Salinity (S)	1	647.897	647.897	63238.6294	0.0000
Genotype (G)	126	229.047	1.818	177.4318	0.0000
S × G	126	94.447	0.750	73.1632	0.0000
Error	254	2.602	0.010		
Total	507	973.993			
%CV	4.24				
±SE(salinity): 0.0064		±SE(genotype): 0.0506		±SE(interaction): 0.0716	

Table 2. Effects of salinity on root dry weight of rice genotypes at germination stage

Sl. no.	Rice genotypes	Root dry weight (mg plant^{-1})					%Decrease over control				[a]Score at 15 dS m^{-1}
		0 dS m^{-1}	6 dS m^{-1}	9 dS m^{-1}	12 dS m^{-1}	15 dS m^{-1}	6 dS m^{-1}	9 dS m^{-1}	12 dS m^{-1}	15 dS m^{-1}	
1	Binadhan 7	2.0	1.8	1.2	1.0	0.4	10.0	40.0	50.0	80.0	7
2	Ledra binni	3.0	2.6	1.4	1.2	1.0	13.3	53.3	60.0	66.7	5
3	Machranga	2.6	2.2	2.2	1.6	1.6	15.4	15.4	38.5	38.5	1
4	Vushiara	3.6	3.2	2.8	2.8	2.0	11.1	22.2	22.2	44.4	3
5	Dud sail	2.0	1.8	0.8	0.8	0.4	10.0	60.0	60.0	80.0	7
6	Ghunshi-1	4.2	2.6	2.2	1.2	1.2	38.1	47.6	71.4	71.4	7
7	Ranga Hogla	3.8	3.6	3.2	2.4	1.8	5.3	15.8	36.8	52.6	3
8	ShornaMushuri	3.8	3.0	2.8	2.4	2.2	21.1	26.3	36.8	42.1	3
9	Lal 40	3.6	2.6	2.4	2.0	1.8	27.8	33.3	44.4	50.0	3
10	Gotamala	5.0	4.0	3.0	1.4	1.2	20.0	40.0	72.0	76.0	7
11	Hogla	4.2	3.6	3.2	3.0	3.0	14.3	23.8	28.6	28.6	1
12	Bola Balam	3.2	2.4	1.8	1.6	1.2	25.0	43.8	50.0	62.5	5
13	Pengek	4.2	3.6	3.2	2.8	2.6	14.3	23.8	33.3	38.1	1
14	ERI	2.4	1.4	1.4	0.8	0.4	41.7	41.7	66.7	83.3	9
15	BRRI dhan40	2.9	2.4	1.8	1.4	0.8	17.2	37.9	51.7	72.4	7
16	BRRI dhan47	3.4	2.8	2.8	1.8	1.4	17.6	17.6	47.1	58.8	5
17	Jota Balam	3.4	3.2	2.2	1.8	1.5	5.9	35.3	47.1	55.9	5
18	Jiradhan	2.0	1.4	1.4	0.4	0.4	30.0	30.0	80.0	80.0	7
19	Patnai (FW)	4.2	3.2	2.4	1.8	1.2	23.8	42.9	57.1	71.4	7
20	Sada Mota Bashpai	4.4	4.2	2.4	1.8	0.6	4.5	45.5	59.1	86.4	9
21	Patnai (SW)	3.6	2.4	2.2	0.8	0.6	33.3	38.9	77.8	83.3	9
22	Swarna Pajam	3.4	2.6	1.4	1.2	1.1	23.5	58.8	64.7	67.6	5
23	Sada Gotal	3.6	3.2	2.2	1.6	1.0	11.1	38.9	55.6	72.2	7
24	Swarna dhan	3.6	1.8	1.4	1.0	0.6	50.0	61.1	72.2	83.3	9
25	Shaheb Kachi	5.2	4.6	2.4	2.0	2.0	11.5	53.8	61.5	61.5	5
26	PBRC-30	2.6	2.4	2.4	1.6	1.2	7.7	7.7	38.5	53.8	3
27	Kongaj	4.0	4.0	3.0	2.0	1.6	0.0	25.0	50.0	60.0	5
28	Lal Gotal	3.2	2.2	1.2	0.8	0.4	31.3	62.5	75.0	87.5	9
29	Kathi Goccha	4.4	3.4	3.0	2.4	2.2	22.7	31.8	45.5	50.0	3
30	Mala goti	3.0	2.4	2.2	1.6	1.4	20.0	26.7	46.7	53.3	3
31	Lutori	3.6	3.2	3.0	2.4	1.4	11.1	16.7	33.3	61.1	5
32	Mait Chal	3.6	3.2	3.0	2.6	1.0	11.1	16.7	27.8	72.2	7
33	Durga Bhog	3.0	2.2	2.0	1.6	1.4	26.7	33.3	46.7	53.3	3
34	Lambo	2.8	1.6	1.6	1.0	0.4	42.9	42.9	64.3	85.7	9
35	Chap Shail	3.8	3.4	3.2	1.4	1.2	10.5	15.8	63.2	68.4	5
36	44 dhan	4.2	2.4	2.6	1.0	0.8	42.9	38.1	76.2	81.0	7
37	Swarnalata	3.6	3.2	2.0	1.6	1.0	11.1	44.4	55.6	72.2	7
38	Tilek Kuchi	3.0	3.0	2.0	1.0	0.4	0.0	33.3	66.7	86.7	9
39	Dakh Shail	2.2	2.0	1.4	1.2	1.0	9.1	36.4	45.5	54.5	5
40	Beki Balam	3.2	3.1	3.2	2.6	2.2	3.1	0.0	18.8	31.3	1
41	Kalmilata	4.2	3.2	2.2	1.6	1.2	23.8	47.6	61.9	71.4	7
42	Basmati	4.4	4.1	2.2	1.6	1.4	6.8	50.0	63.6	68.2	5
43	Bouari	4.4	2.0	2.0	1.4	0.6	54.5	54.5	68.2	86.4	9

Sl. no.	Rice genotypes	Root dry weight (mg plant^{-1})					%Decrease over control				[a]Score at 15 dS m^{-1}
		0 dS m^{-1}	6 dS m^{-1}	9 dS m^{-1}	12 dS m^{-1}	15 dS m^{-1}	6 dS m^{-1}	9 dS m^{-1}	12 dS m^{-1}	15 dS m^{-1}	
44	Bashful Balam	3.0	2.6	3.0	1.8	2.0	13.3	0.0	40.0	33.3	1
45	Patnai	4.6	3.4	3.0	2.6	2.2	26.1	34.8	43.5	52.2	3
46	Rajshahi Balam	2.8	2.2	2.0	1.8	1.2	21.4	28.6	35.7	57.1	5
47	Arman Sardar	3.5	2.8	1.8	1.7	1.5	20.0	48.6	51.4	57.1	5
48	Orgoja	4.2	2.5	2.1	1.4	1.4	40.5	50.0	66.7	66.7	5
49	Hamai	3.4	2.8	2.6	2.4	1.2	17.6	23.5	29.4	64.7	5
50	Gota	4.8	3.2	2.8	2.0	0.8	33.3	41.7	58.3	83.3	9
51	Joisri Ghunshi	4.4	4.2	3.4	2.8	2.2	4.5	22.7	36.4	50.0	3
52	Kumra Ghor	4.0	4.2	3.5	3.0	1.8	-5.0	12.5	25.0	56.3	5
53	Sada Balam	3.6	3.4	2.4	2.4	2.0	5.6	33.3	33.3	44.4	3
54	Ashful	4.2	4.0	2.0	1.6	1.4	4.8	52.4	61.9	66.7	5
55	Chini Kanai	1.4	1.4	0.8	0.6	0.6	0.0	42.9	57.1	57.1	5
56	Raja Shail	3.4	3.2	2.8	2.0	2.0	5.9	17.6	41.2	41.2	3
57	Tikaram	3.2	3.0	2.6	2.2	2.0	6.3	18.8	31.3	37.5	1
58	Mota aman	4.6	2.4	1.8	1.6	1.8	47.8	60.9	65.2	60.9	5
59	Sadamota	4.0	2.4	1.8	1.2	0.6	40.0	55.0	70.0	85.0	9
60	Bazra Muri	5.0	3.6	3.2	2.6	1.4	28.0	36.0	48.0	72.0	7
61	Swarna	3.8	3.2	1.6	1.2	0.8	15.8	57.9	68.4	78.9	7
62	Asami Hajir	2.6	2.6	2.2	1.6	1.2	0.0	15.4	38.5	53.8	3
63	IRRI-1010	2.8	2.8	1.8	1.2	1.0	0.0	35.7	57.1	64.3	5
64	Jol Paira	4.2	4.1	4.2	2.0	1.6	2.4	0.0	52.4	61.9	5
65	Hugla Pata	8.8	4.8	2.0	2.4	2.4	45.5	77.3	72.7	72.7	7
66	Dudh Kalam	3.6	3.4	2.2	1.6	1.4	5.6	38.9	55.6	61.1	5
67	Rani Shalot	4.6	4.2	3.4	3.2	1.8	8.7	26.1	30.4	60.9	5
68	Moghai Balam	4.7	2.5	2.1	1.7	1.4	46.8	55.3	63.8	70.2	7
69	Khejure Chori	3.2	3.2	2.2	2.2	0.4	0.0	31.3	31.3	87.5	9
70	Kuchra	3.8	3.2	2.0	2.0	2.0	15.8	47.4	47.4	47.4	3
71	Depa Kolom	3.4	2.4	2.4	1.4	1.0	29.4	29.4	58.8	70.6	7
72	Khok Shail	2.7	2.6	1.4	1.2	1.1	3.7	48.1	55.6	59.3	5
73	Ashfuli	3.0	2.6	1.4	1.2	1.1	13.3	53.3	60.0	63.3	5
74	Anda	2.8	2.7	2.6	1.8	1.5	3.6	7.1	35.7	46.4	3
75	Ghocca	3.4	2.6	1.8	0.2	0.2	23.5	47.1	94.1	94.1	9
76	Mondeshor	3.0	2.0	1.4	1.4	0.4	33.3	53.3	53.3	86.7	9
77	Lalbanamuri	2.8	2.4	2.8	1.2	0.8	14.3	0.0	57.1	71.4	7
78	Chenga	3.8	3.0	1.0	0.8	0.8	21.1	73.7	78.9	78.9	7
79	Dhar Shail	2.0	1.6	1.2	0.4	0.4	20.0	40.0	80.0	80.0	7
80	Khainol	3.6	3.2	2.4	2.2	1.4	11.1	33.3	38.9	61.1	5
81	Rupessore	3.4	3.2	3.0	1.6	1.2	5.9	11.8	52.9	64.7	5
82	Bhute Shalot	3.0	2.6	2.4	2.0	1.4	13.3	20.0	33.3	53.3	3
83	Kute Patnai	3.4	2.0	1.8	1.4	1.2	41.2	47.1	58.8	64.7	5
84	Hati Bajore	2.8	2.6	2.0	1.8	1.2	7.1	28.6	35.7	57.1	5
85	Jamai Naru	4.8	3.4	2.2	2.0	1.8	29.2	54.2	58.3	62.5	5
86	Holde Gotal	3.6	3.2	1.8	1.6	1.2	11.1	50.0	55.6	66.7	5
87	Kesa	4.4	3.2	1.4	2.0	0.2	27.3	68.2	54.5	95.5	9
88	Ghunshi-2	4.8	2.6	2.0	1.4	1.1	45.8	58.3	70.8	77.1	7
89	Mohime	3.0	2.2	2.0	1.6	0.2	26.7	33.3	46.7	93.3	9
90	Lal Tupi	4.6	3.6	2.6	2.6	2.2	21.7	43.5	43.5	52.2	3
91	Tor Balam	2.6	1.8	1.2	1.2	1.2	30.8	53.8	53.8	53.8	3
92	Nona Kochi	5.4	5.0	2.2	1.2	1.0	7.4	59.3	77.8	81.5	7
93	Pairjat	2.0	1.4	1.4	0.8	0.4	30.0	30.0	60.0	80.0	7
94	Lal Biroi	2.6	2.2	2.0	1.6	1.2	15.4	23.1	38.5	53.8	3
95	Koicha Binni	2.8	1.6	1.2	1.2	0.8	42.9	57.1	57.1	71.4	7
96	Fulkandi	3.8	3.2	2.2	1.6	1.0	15.8	42.1	57.9	73.7	7
97	Talmugur	3.6	3.4	3.0	3.0	2.6	5.6	16.7	16.7	27.8	1
98	Kali boro	3.2	2.8	2.8	2.4	1.8	12.5	12.5	25.0	43.8	3
99	Kakua binni	2.0	1.8	1.2	0.8	0.8	10.0	40.0	60.0	60.0	5

Sl. no.	Rice genotypes	Root dry weight (mg plant^{-1})					%Decrease over control				[a]Score at 15 dS m^{-1}
		0 dS m^{-1}	6 dS m^{-1}	9 dS m^{-1}	12 dS m^{-1}	15 dS m^{-1}	6 dS m^{-1}	9 dS m^{-1}	12 dS m^{-1}	15 dS m^{-1}	
100	Pajam	3.4	2.0	1.6	1.3	1.0	41.2	52.9	61.8	70.6	7
101	Nonabokra	4.4	3.4	3.0	2.8	2.4	22.7	31.8	36.4	45.5	3
102	Jolkumri	5.2	4.0	3.0	1.4	1.2	23.1	42.3	73.1	76.9	7
103	Kasia binni	3.2	2.8	2.6	2.4	1.0	12.5	18.8	25.0	68.8	7
104	Gigoj	3.6	3.0	2.4	1.8	1.4	16.7	33.3	50.0	61.1	5
105	Rati Sail	3.0	2.0	2.0	2.0	1.8	33.3	33.3	33.3	40.0	1
106	Sakal Mukhi	4.5	3.2	2.4	1.8	1.2	28.9	46.7	60.0	73.3	7
107	Golapi	3.9	3.2	2.8	2.6	2.0	17.9	28.2	33.3	48.7	3
108	Malshira	3.4	3.2	2.2	1.8	1.1	5.9	35.3	47.1	67.6	5
109	Pankhiraj	3.4	2.8	2.4	1.6	1.4	17.6	29.4	52.9	58.8	5
110	Jongliboro	2.0	1.8	1.2	1.2	0.8	10.0	40.0	40.0	60.0	5
111	Nunia	1.2	1.2	1.0	1.0	0.6	0.0	16.7	16.7	50.0	3
112	Nunia-1	1.6	1.0	0.8	0.8	0.4	37.5	50.0	50.0	75.0	7
113	Minikit	3.2	2.0	1.8	1.6	0.8	37.5	43.8	50.0	75.0	7
114	BR23	3.0	3.0	2.3	1.9	1.4	0.0	23.3	36.7	53.3	3
115	Kalihytra	3.0	1.4	2.4	1.4	0.2	53.3	20.0	53.3	93.3	9
116	Khato Komro	3.2	2.4	2.2	0.8	0.6	25.0	31.3	75.0	81.3	7
117	Talmuri	5.0	4.0	3.4	2.6	2.2	20.0	32.0	48.0	56.0	5
118	Bekas	3.2	2.2	1.8	1.4	0.8	31.3	43.8	56.3	75.0	7
119	Patnai Balam	4.0	2.4	2.2	2.0	1.8	40.0	45.0	50.0	55.0	5
120	Khesrail	3.4	3.3	3.0	2.2	1.8	2.9	11.8	35.3	47.1	3
121	Kajal Sail	4.0	4.0	3.8	2.6	1.6	0.0	5.0	35.0	60.0	5
122	Binadhan 8	4.2	3.4	2.6	2.2	1.8	19.0	38.1	47.6	57.1	5
123	BRRI dhan41	2.5	2.2	2.1	1.7	1.2	12.0	16.0	32.0	52.0	3
124	Kuti Patnai	2.6	2.4	2.4	1.6	1.2	7.7	7.7	38.5	53.8	3
125	Dorkumur	3.4	1.6	1.4	1.2	1.0	52.9	58.8	64.7	70.6	7
126	BRRI dhan53	2.4	2.2	2.0	0.8	0.7	8.3	16.7	66.7	70.8	7
127	Pokkali	3.4	3.4	2.6	2.2	2.0	0.0	23.5	35.3	41.2	3
	Mean	**3.5**	**2.8**	**2.2**	**1.7**	**1.3**	**20.0**	**36.8**	**51.8**	**64.3**	

[a]**Score:** 27-40%: 1; 41-54%: 3; 55-68%: 5; 69-82%: 7, 83-96%: 9

Table 3. ANOVA table of root length in germination stage

Source	Degrees of freedom	Sum of squares	Mean square	F value	Prob
Salinity (S)	1	2819.830	2819.830	70736.6497	0.0000
Genotype (G)	126	966.203	7.668	192.3620	0.0000
S × G	126	684.439	5.432	136.2654	0.0000
Error	254	10.125	0.040		
Total	507	4480.598			
%CV	3.99				
±SE(salinity): 0.0125		±SE(genotype): 0.0998		±SE(interaction): 0.1412	

Table 4. Effects of salinity on the root length of rice genotypes at germination stage

Sl. no.	Rice genotypes	Root length (cm plant$^{-1)}$					%Decrease over control				[a]Score at 15 dS m^{-1}
		0 dS m^{-1}	6 dS m^{-1}	9 dS m^{-1}	12 dS m^{-1}	15 dS m^{-1}	6 dS m^{-1}	9 dS m^{-1}	12 dS m^{-1}	15 dS m^{-1}	
1	Binadhan 7	3.5	3.4	3.1	2.8	1.8	2.9	11.4	20.0	48.6	5
2	Ledra binni	5.0	4.0	4.2	3.2	1.6	20.0	16.0	36.0	68.0	7
3	Machranga	6.8	4.7	3.2	2.2	1.5	30.9	52.9	67.6	77.9	7
4	Vushiara	6.5	6.4	6.3	4.9	3.0	1.5	3.1	24.6	53.8	5
5	Dud sail	9.0	8.0	5.5	5.0	2.3	11.1	38.9	44.4	74.4	7
6	Ghunshi-1	5.5	4.8	4.1	3.8	1.9	12.7	25.5	30.9	65.5	7
7	Ranga Hogla	5.2	4.8	4.8	4.6	4.0	7.7	7.7	11.5	23.1	1
8	ShornaMushuri	10.1	6.5	5.2	3.2	1.7	35.6	48.5	68.3	83.2	9
9	Lal 40	7.8	7.5	7.2	6.6	4.1	3.8	7.7	15.4	47.4	3

Sl. no.	Rice genotypes	Root length (cm plant$^{-1)}$					%Decrease over control				[a]Score at 15 dS m^{-1}
		0 dS m^{-1}	6 dS m^{-1}	9 dS m^{-1}	12 dS m^{-1}	15 dS m^{-1}	6 dS m^{-1}	9 dS m^{-1}	12 dS m^{-1}	15 dS m^{-1}	
10	Gotamala	6.5	5.2	3.8	3.4	3.0	20.0	42.3	48.5	54.6	5
11	Hogla	4.1	3.6	3.2	2.8	2.6	12.2	22.0	31.7	36.6	3
12	Bola Balam	5.4	4.3	3.1	1.5	1.8	20.4	42.6	72.2	66.7	7
13	Pengek	8.1	7.4	7.0	6.6	5.7	8.6	13.6	18.5	29.6	1
14	ERI	2.5	2.0	2.4	2.3	1.1	20.0	5.0	8.0	55.0	5
15	BRRI dhan40	5.9	5.4	4.3	3.7	3.6	8.5	27.1	38.1	39.0	3
16	BRRI dhan47	5.9	5.8	5.2	4.9	4.8	1.7	12.5	17.6	19.0	1
17	Jota Balam	5.2	4.7	4.7	4.4	3.8	9.6	9.6	15.4	26.9	1
18	Jiradhan	7.9	6.9	4.6	5.8	3.9	13.2	41.8	26.6	50.6	5
19	Patnai (FW)	13.9	9.8	4.3	4.2	2.7	29.5	69.1	69.8	80.6	9
20	Sada Mota Bashpai	6.4	6.0	4.2	3.8	3.5	6.3	34.1	41.1	45.3	3
21	Patnai (SW)	8.0	6.8	6.0	5.8	3.1	15.0	25.0	27.5	61.3	5
22	Swarna Pajam	6.2	3.5	3.6	2.6	0.8	43.5	41.9	58.1	87.1	9
23	Sada Gotal	7.9	6.1	5.8	4.9	2.6	22.8	26.6	38.0	66.7	7
24	Swarna dhan	8.2	7.4	5.1	2.9	3.3	9.5	37.8	64.6	60.4	5
25	Shaheb Kachi	7.3	6.2	4.9	5.0	3.1	15.1	32.9	31.5	57.5	5
26	PBRC-30	8.2	7.4	6.6	6.0	5.8	9.8	19.5	26.8	29.3	1
27	Kongaj	8.8	6.0	6.2	4.2	4.1	31.8	29.5	52.3	53.4	5
28	Lal Gotal	6.6	6.3	5.3	4.0	1.8	4.5	19.7	39.4	72.7	7
29	Kathi Goccha	6.6	6.5	5.7	3.5	2.9	1.5	13.6	47.0	56.1	5
30	Mala goti	6.5	4.7	4.6	3.4	3.3	27.7	29.2	47.7	49.2	5
31	Lutori	9.6	8.0	6.4	4.7	2.2	16.7	33.3	51.0	77.3	7
32	Mait Chal	5.6	5.5	5.4	4.5	2.6	1.8	3.6	19.6	53.6	5
33	Durga Bhog	7.4	5.5	5.1	3.4	1.1	25.7	31.1	54.1	85.1	9
34	Lambo	6.8	5.0	4.0	3.4	1.4	26.5	41.2	50.0	79.4	9
35	Chap Shail	7.8	6.3	5.5	3.3	1.7	19.4	29.7	57.5	77.7	7
36	44 dhan	7.2	4.8	4.7	4.6	2.0	33.3	34.7	36.1	72.2	7
37	Swarnalata	9.8	8.9	7.8	6.0	3.3	9.2	20.4	38.8	66.3	7
38	Tilek Kuchi	11.3	6.5	5.7	6.1	1.5	42.5	49.6	46.0	86.7	9
39	Dakh Shail	7.0	6.6	6.0	5.8	3.3	5.7	14.3	17.1	52.9	5
40	Beki Balam	5.2	5.1	4.8	3.6	3.0	1.9	7.7	30.8	42.3	3
41	Kalmilata	8.7	7.8	6.8	2.8	2.0	10.3	21.8	67.8	77.0	7
42	Basmati	4.5	3.0	2.9	2.0	0.8	33.3	35.6	55.6	82.2	9
43	Bouari	9.3	8.8	5.3	3.8	1.6	5.4	43.4	59.1	82.8	9
44	Bashful Balam	6.5	6.0	5.0	5.2	4.8	7.7	23.1	20.0	26.2	1
45	Patnai	6.0	5.8	4.1	3.6	3.4	3.3	31.7	40.0	43.3	3
46	Rajshahi Balam	5.1	5.0	4.9	4.1	3.7	2.0	3.9	19.6	27.5	1
47	Arman Sardar	6.0	5.7	5.6	4.5	4.0	5.0	6.7	25.0	33.3	1
48	Orgoja	6.8	6.2	5.3	4.0	2.3	8.8	22.1	40.6	66.2	7
49	Hamai	9.4	9.2	3.8	4.4	3.8	2.1	59.6	53.2	59.6	5
50	Gota	6.5	4.6	6.0	3.7	2.3	29.2	7.7	43.1	64.6	7
51	Joisri Ghunshi	8.0	4.8	3.8	3.3	2.8	39.9	52.5	58.8	65.0	7
52	Kumra Ghor	6.8	5.8	4.6	3.1	1.9	14.7	32.1	54.4	72.1	7
53	Sada Balam	10.8	7.6	6.1	6.1	1.0	29.6	43.5	43.5	90.7	9
54	Ashful	7.6	6.0	5.1	4.0	3.1	21.1	32.9	47.4	59.2	5
55	Chini Kanai	7.3	6.4	4.8	3.0	1.8	12.3	34.2	58.9	75.3	7
56	Raja Shail	7.7	7.6	6.8	4.6	1.9	0.5	11.5	40.5	74.7	7
57	Tikaram	9.6	7.8	8.1	4.4	2.5	19.2	15.8	54.4	74.0	7
58	Mota Aman	4.7	4.5	4.5	2.3	1.2	4.3	4.3	51.1	74.5	7
59	Sadamota	6.1	4.2	3.7	2.0	1.9	31.1	39.3	67.2	68.9	7
60	Bazra Muri	5.6	5.1	4.6	2.6	1.2	8.9	17.9	53.6	78.6	9
61	Swarna	6.6	4.7	3.2	2.2	1.5	28.8	51.5	66.7	77.3	7
62	Asami Hajir	10.5	9.0	5.3	4.0	5.0	13.9	49.2	61.9	52.4	5
63	IRRI-1010	10.5	5.1	5.2	3.4	3.7	51.4	50.5	67.9	64.8	7
64	Jol Paira	7.2	6.2	7.0	6.6	3.8	13.9	2.8	8.3	47.8	3

Sl. no.	Rice genotypes	Root length (cm plant$^{-1)}$					%Decrease over control				[a]Score at 15 dS m^{-1}
		0 dS m^{-1}	6 dS m^{-1}	9 dS m^{-1}	12 dS m^{-1}	15 dS m^{-1}	6 dS m^{-1}	9 dS m^{-1}	12 dS m^{-1}	15 dS m^{-1}	
65	Hugla Pata	7.2	6.9	4.6	5.8	3.9	4.7	36.1	19.4	45.8	3
66	Dudh Kalam	9.8	7.3	6.2	2.9	2.5	25.8	37.0	70.5	74.2	7
67	Rani Shalot	9.9	8.4	7.2	6.2	5.8	15.2	27.3	37.4	41.4	3
68	Moghai Balam	6.8	5.8	4.6	3.1	1.9	14.7	32.1	54.4	72.1	7
69	Khejure Chori	9.2	8.2	6.4	4.7	2.2	10.9	30.4	48.9	76.3	7
70	Kuchra	7.9	6.0	6.8	4.8	3.1	24.1	13.9	39.2	60.8	5
71	Depa Kolom	9.4	8.8	8.5	6.9	4.8	6.4	9.6	26.6	48.9	5
72	Khok Shail	7.0	6.7	6.0	5.8	5.0	4.3	14.3	17.1	28.6	1
73	Ashfuli	9.0	8.0	5.5	5.0	2.3	11.1	38.9	44.4	74.4	7
74	Anda	12.8	6.8	5.0	3.2	2.4	46.9	61.1	74.7	81.1	9
75	Ghocca	10.2	6.8	6.1	4.2	2.0	33.3	40.2	58.8	80.4	9
76	Mondeshor	8.0	6.2	4.8	3.6	1.6	22.5	40.0	55.0	80.0	9
77	Lalbanamuri	10.0	4.5	6.0	2.8	1.0	54.5	40.1	71.9	90.0	9
78	Chenga	6.7	5.2	6.3	1.6	0.8	21.8	6.0	76.1	88.1	9
79	Dhar Shail	4.1	3.1	2.4	1.7	0.4	24.4	41.5	58.5	90.2	9
80	Khainol	7.4	6.5	5.2	4.4	2.0	12.2	29.7	40.5	73.0	7
81	Rupessore	8.3	6.3	5.5	3.3	1.7	24.1	33.7	60.0	79.0	9
82	Bhute Shalot	6.5	6.4	5.8	4.3	3.9	1.5	10.8	33.8	40.0	3
83	Kute Patnai	9.2	5.1	7.0	4.9	3.3	44.6	24.3	46.7	64.1	7
84	Hati Bajore	7.0	7.0	6.0	1.8	1.5	0.0	14.3	74.3	78.6	9
85	Jamai Naru	5.8	5.4	5.8	4.4	3.1	6.9	0.9	24.1	46.6	3
86	Holde Gotal	7.0	7.0	5.2	1.2	1.2	0.0	25.7	82.9	82.9	9
87	Kesa	10.3	8.3	8.2	5.3	1.6	19.4	20.4	48.5	84.5	9
88	Ghunshi-2	5.7	4.6	4.3	3.2	1.5	19.3	24.6	43.9	73.7	7
89	Mohime	10.6	9.6	7.4	5.6	1.9	9.8	30.5	47.4	82.1	9
90	Lal Tupi	2.7	2.6	2.3	2.5	1.8	3.7	14.8	7.4	33.3	1
91	Tor Balam	8.6	6.2	6.9	4.1	2.4	27.9	19.8	52.3	72.1	7
92	Nona Kochi	10.4	8.3	5.3	2.5	1.8	20.5	48.9	76.1	82.8	9
93	Pairjat	7.2	6.2	5.6	5.2	3.0	13.3	22.2	27.8	58.3	5
94	Lal Biroi	5.4	3.5	3.6	2.6	0.8	35.2	33.3	51.9	85.2	9
95	Koicha Binni	5.1	5.0	4.3	1.9	0.8	2.0	15.7	62.7	84.3	9
96	Fulkandi	6.9	5.4	4.3	3.7	2.6	21.7	37.7	47.1	62.3	5
97	Talmugur	5.0	4.2	3.6	3.3	2.9	16.0	28.0	34.0	42.0	3
98	Kali boro	10.8	8.4	5.0	4.0	2.5	22.2	53.7	63.0	76.9	7
99	Kakua binni	4.0	3.0	2.9	2.0	0.8	25.0	27.5	50.0	80.0	9
100	Pajam	8.6	7.7	7.1	7.0	4.1	10.5	17.4	18.6	52.3	5
101	Nonabokra	3.8	3.4	2.8	2.9	2.5	10.5	26.3	23.7	34.2	3
102	Jolkumri	6.3	4.3	4.9	3.9	1.7	31.7	22.2	38.1	73.0	7
103	Kasia binni	7.1	5.4	4.0	3.3	1.2	23.9	43.7	53.5	83.1	9
104	Gigoj	11.1	5.4	3.5	2.6	1.4	51.4	68.5	76.6	87.4	9
105	Rati Sail	10.8	10.6	9.6	7.8	4.3	1.9	11.5	27.8	60.6	5
106	Sakal Mukhi	8.3	7.5	7.2	6.6	3.1	9.6	13.3	20.5	62.7	5
107	Golapi	8.9	7.4	5.1	2.9	3.1	16.6	42.7	67.4	65.2	7
108	Malshira	8.0	6.2	4.8	3.6	1.8	22.5	40.0	55.0	77.5	7
109	Pankhiraj	10.5	8.8	8.6	8.5	6.7	16.2	18.1	19.0	36.2	3
110	Jongliboro	8.4	7.5	6.5	4.3	4.1	10.7	22.6	48.8	51.2	5
111	Nunia	4.7	3.6	2.4	1.9	1.0	21.9	47.6	59.2	78.5	9
112	Nunia-1	5.2	4.6	3.3	2.4	1.5	11.5	36.5	53.8	71.2	7
113	Minikit	3.1	2.1	2.1	2.0	1.3	32.3	32.3	35.5	58.1	5
114	BR23	7.3	7.3	7.2	7.1	6.0	0.0	2.1	2.7	18.5	1
115	Kalihytra	11.1	8.6	8.0	4.3	1.3	22.1	27.3	61.1	88.7	9
116	Khato Komro	7.4	6.5	5.7	1.5	2.8	12.2	23.0	79.7	62.2	5
117	Talmuri	3.4	3.4	2.9	3.1	2.5	0.0	14.7	8.8	26.5	1
118	Bekas	6.4	4.2	3.7	2.0	1.9	34.4	42.2	68.8	70.3	7
119	Patnai Balam	6.5	4.9	4.7	3.8	3.1	24.6	27.7	41.5	52.3	5
120	Khesrail	6.2	5.7	5.4	4.0	3.9	8.1	12.9	35.5	37.1	3

Sl. no.	Rice genotypes	Root length (cm plant$^{-1)}$					%Decrease over control				[a]Score at 15 dS m^{-1}
		0 dS m^{-1}	6 dS m^{-1}	9 dS m^{-1}	12 dS m^{-1}	15 dS m^{-1}	6 dS m^{-1}	9 dS m^{-1}	12 dS m^{-1}	15 dS m^{-1}	
121	Kajal Sail	4.5	3.8	3.6	3.1	2.7	15.6	20.0	31.1	40.0	3
122	Binadhan 8	3.8	3.5	2.8	2.3	2.0	7.9	26.3	39.5	47.4	3
123	BRRI dhan41	7.5	6.1	6.4	6.0	5.9	18.1	14.1	19.5	21.5	1
124	Kuti Patnai	7.2	6.1	2.8	2.8	2.0	15.3	61.1	61.1	72.2	7
125	Dorkumur	13.3	7.6	8.6	4.5	2.7	42.6	35.1	66.0	79.6	9
126	BRRI dhan53	5.5	5.2	3.8	3.4	3.0	5.5	31.8	39.1	46.4	3
127	Pokkali	7.6	7.0	6.4	5.6	5.4	7.9	15.8	26.3	28.9	1
	Mean	**7.4**	**6.0**	**5.2**	**4.0**	**2.7**	**17.1**	**27.9**	**44.1**	**61.9**	

[a] **Score:** 27-40%: 1; 41-54%: 3; 55-68%: 5; 69-82%: 7, 83-96%: 9

Discussion

Salinity stress reduced the root length and root weight of the rice genotypes. But the extent of reduction varied with genotypes and levels of salinity. Root length was reduced by 18 to 93% with the average of 61.9% and root dry weight was reduced by 27 to 96% with an average of 64.3%. Rajakumar (2013) reported that increasing salt stress resulted in gradual decrease in root length. The higher rate of reduction of root length under salinity might be due to elevated inhibitory effect of NaCl salt to root growth compared with shoot growth (Jamil *et al.*, 2007; Hakim *et al.*, 2010; Anbumalarmathi and Mehta, 2013).

Conclusions

Salinity stress reduced the root growth of the rice genotypes. The extent of root weight and root length reduction varied with genotypes and levels of salinity.

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