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Performances of *Boro* Rice as Affected by Different Concentrations of Marine Water

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Abstract

Salinity is one of the most devastating abiotic stresses limiting crop production. Considering this issue, a pot experiment was conducted at Sher-e-Bangla Agricultural University, Dhaka, Bangladesh during the *boro* season (2017-2018) using two rice (*Oryza sativa* L.) varieties, namely BRRI dhan28 (salt sensitive) and BRRI dhan47 (salt tolerant), to assess the effects of varied salinity levels on the growth and the performance of the rice varieties under salt stress conditions. Four salinity treatments were used in this experiment, *viz.* control S_0 (only freshwater), quarter-strength marine water S_1 (three-parts freshwater and one-part marine water; 7.5 ds m^{-1}), half-strength marine water S_2 (half freshwater and half marine water; 15 ds m^{-1}), and full-strength marine water S_3 (only marine water; 30 ds m^{-1}). These mixtures were used for irrigation purposes throughout the life cycle of the plants. Salt stress significantly decreased the plant height, relative water content (RWC) of leaves, number of effective tillers $hill^{-1}$, number of filled grains $panicle^{-1}$, 1000-grain weight, grain yield, straw yield, and biological yield of the rice. In both rice types, plant growth and yield were reduced as the salinity level increased. Grain yields decreased by 50, 90, and 100% in BRRI dhan28 when irrigated with quarter strength, half strength, and full-strength seawater, respectively, but decreased by 27, 50, and 72%, respectively, in BRRI dhan47. Similarly, other yield attributes had higher reductions in BRRI dhan28 under salt stress conditions than BRRI dhan47. However, irrigation with marine water in rice might lead to some straw yield but produced little to no grain.

Keywords

Salinity, salt-tolerant, sweater, plant growth, grain yield

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Introduction

Salinization of soil is one of the serious environmental factors that limit crop productivity worldwide. Salinization of agricultural land is becoming a more serious concern daily. It is estimated that over 50% of the world's arable land will be salt-affected by the year 2050 (Munns & Tester, 2008). Because of this adverse environmental factor, most agricultural crops are now considered salt-sensitive due to the high concentration of salts in the soil. The increased salinity in the soil creates an unfavorable environment and hydrological situation that restrict normal crop production. Salinity in the soil creates osmotic, ionic, and oxidative stress in plants (Munns & Tester, 2008; Hussain *et al.*, 2020). Depending on the duration and severity of the contamination, it impairs a variety of physiological and metabolic processes in plants. Salinity-related harm to plants begins during germination and extends until the plant dies (Mishra *et al.*, 2013). In the seedling stage, salt stress affects plant growth by osmotic and ionic stresses (Mahajan & Tuteja, 2005). Plants exposed to saline conditions experienced both hyperionic and hyperosmotic stresses, which cause membrane damage, nutrient imbalance, enzymatic inhibition, metabolic dysfunction, photosynthesis inhibition, oxidative stress, growth inhibition, and death (Isayenkov & Maathuis, 2019). The negative impacts of salinity on most crop plants makes them salt sensitive, except for some halophytes. Based on the growth and yield reductions under salt stress conditions, rice (*Oryza sativa* L.) is considered one of the most salt-sensitive crops. Rice yield reductions due to salt are a significant challenge to the food security of an ever-growing rice-loving population, particularly in Asia (Khush, 2005; Mishra *et al.*, 2013; Rahman *et al.*, 2017).

The coastal belt of Bangladesh is one of the closest locations to the Bay of Bengal. Salinity intrusion has steadily spread into inland water and soil as a result of tropical cyclones. This remarkable salinity intrusion into the cropping areas has tremendously reduced crop production across the coastal belt in Bangladesh (Mahmuduzzaman *et al.*, 2014).

Although rice is the staple food of Bangladesh, the rice production level still remains low in the coastal region of this country due to the extent of high salinity in croplands (Miah *et al.*, 2004). The coastal areas are potentially suited for rice production but have been left idle due to salinity problems (Kana *et al*., 2011). Because of the rising trend of salinity intrusion in the coastal belt of Bangladesh, farmers are losing the willingness to cultivate various crops including rice in that region. Considering the issues presented above, the present study was conducted to assess the effects of varying salinity levels on rice and the performance of rice varieties under salt stress conditions.

Materials and Methods

Experimental location and soil

The experiment was conducted at the Sher-e-Bangla Agricultural University (SAU) farm, Dhaka, under the agro-ecological zone of Modhupur Tract, AEZ-28. The plastic pots used in the experiment were 35.56cm (14 inches) in diameter and 45.72cm (18 inches) in depth. The experimental pots were filled with 10 kg soil (soil pH - 5.5, EC-0.25 ds m^{-1}) collected from the SAU farm.

Materials and cultivation methods

Seeds of the salt-sensitive variety BRRI dhan28 (Rashid & Nasrin, 2014; Islam *et al*., 2018) and salt-tolerant variety BRRI dhan47 (Rashid & Nasrin, 2014) were collected from the Bangladesh Rice Research Institute (BRRI). After growing in a seedbed, thirty-day-old seedlings were transplanted into the plastic pots at the rate of a single seedling $hill^{-1}$. Three hills were set in each pot. Twenty days after transplanting, the seedlings were treated with freshwater and different strengths of marine water. Saline water was collected from Patenga Sea beach, Chattogram, Bangladesh. Irrigation with the different strengths of marine water and freshwater continued until the last irrigation as per the requirements of the plants. Fertilizers were applied as per the recommendations of BRRI (urea, TSP, MOP, and gypsum were applied at the rates of 260, 90, 150, and 110 kg ha^{-1}, respectively) and other intercultural operations were done as per the requirements of the crop.

Experimental design and treatments

The experiment was done in a completely randomized design (CRD) with two factors and three replications using 24 plastic pots. The treatment combinations were as follows:

(i) Factor A: 2 Rice varieties

BRRI dhan28 (V_1)

BRRI dhan47 (V_2)

(ii) Factor B: 4 Salinity levels

Control (S_0)

Quarter strength marine water (S_1; 7.5 ds m^{-1})

Half strength marine water (S_2; 15 ds m^{-1})

Full strength marine water (S_3; 30 ds m^{-1})

Data collection and analysis

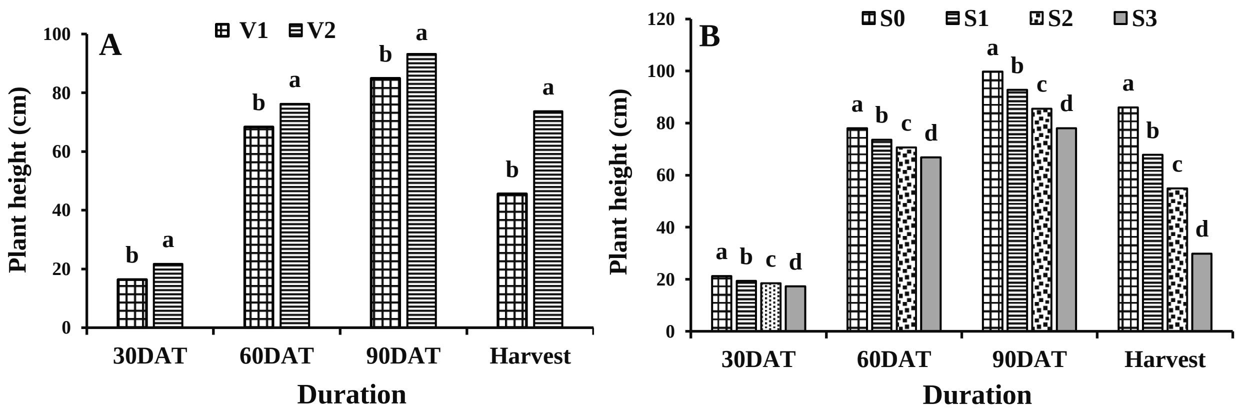
Different growth and yield contributing parameters, namely plant height, number of tillers $hill^{-1}$, number of grains $panicle^{-1}$, 1000-grain weight, grain yield, straw yield, and biological yield, were observed throughout the experimental period following standard methods to understand the experimental objectives. Relative water content (RWC) was measured at 90 DAT according to the methods of Barrs & Weatherley (1962). Statistical analysis was done following two way ANOVA model using Statistix10 computer program and mean separation was done by least significant difference (LSD) test at the 5% level of significance.

Results and Discussion

Effect on plant height

Varietal variation showed a significant effect on the plant height of *boro* rice. BRRI dhan47 produced taller plants throughout the growing period of rice compared with BRRI dhan28 (**Figure 1A**).

Significant variation was also observed in the plant height of rice under different levels of salinity (**Figure IB**). Exposure to saline water decreased the plant height of *boro* rice and the magnitude of decreases increased with the advancement of the growth period and increment of the salinity level. These results are in agreement with Rahman *et al.* (2016a) who showed that plant height decreased with increased salinity levels. Under salt stress conditions, Na^+ enters into the shoots of rice through the apoplastic pathway and subsequently affects cell division and cell elongation, and ultimately reduces growth (Hussain *et al.,* 2017). In our study, we noticed that plant height reduced by 21, 36, and 65%, respectively, when rice seedlings were irrigated with quarter-strength, half-strength, or full-strength seawater. Our results are corroborated by Islam *et al.* (2007) who noted that stunted plant growth is the most common symptom of salinity at different growth stages of rice.



Note: V_1 = BRRI dhan28, V_2 = BRRI dhan47, S_0 = Control, S_1 = Quarter strength marine water, S_2 = Half strength marine water, S_3 = Full strength marine water

Figure 1. Effects of variety (A) and salinity (B) on plant height at different growth periods of *boro* rice [LSD $_{(0.05)}$= 0.51, 3.83, 2.84, and 1.66 for variety, and 0.73, 5.42, 4.01, and 2.35 for salinity at 30, 60, and 90 DAT, and at harvest, respectively)

However, the combined effects of variety and salinity had a significant effect on plant height at 90 DAT and at harvest (**Table 1**). The plant height reductions at harvesting time in BRRI dhan28 were 31, 53, and 100% for the exposures to quarter-strength, half-strength, and full-strength marine water, respectively, where they were 11, 20, and 32%, respectively, in BRRI dhan47. The plant height decrease was 100% in BRRI dhan28 at harvesting time due to exposure to full-strength seawater, as all the plants died during that period. In addition, under salt stress conditions, throughout the entire life cycle of rice, the plant height reductions were higher in BRRI dhan28 compared with BRRI dhan47. This indicates that BRRI dhan28 is more vulnerable to salt compared with BRRI dhan47.

Effect on RWC of leaves

A significant variation in the relative water content (RWC) of leaves was observed with varietal variation (**Figure 2**). At 90 DAT, BRRI dhan47 showed a 39% higher RWC of leaves compared with BRRI dhan28.

Exposure to different strengths of saline water also significantly influenced the RWC of leaves (**Figure 2**). Salinity induces osmotic stress in plants which limits water availability for cellular extension and causes physiological drought (Shabani *et al.*, 2013; Rahman *et al.*, 2016b). Salt-induced osmotic stress reduced RWC by interrupting the water uptake capacity of rice (Rahman *et al.*, 2016a,b). In our study, we found that the applications of quarter-strength, half-strength, and full-strength marine water as irrigation water decreased the RWC of leaves by 14, 24, and 44%, respectively, compared with the control. These results are in agreement with Rahman *et al.* (2016a) who reported that salinity reduces the RWC of rice leaves and different levels of salinity showed different levels of RWC in rice.

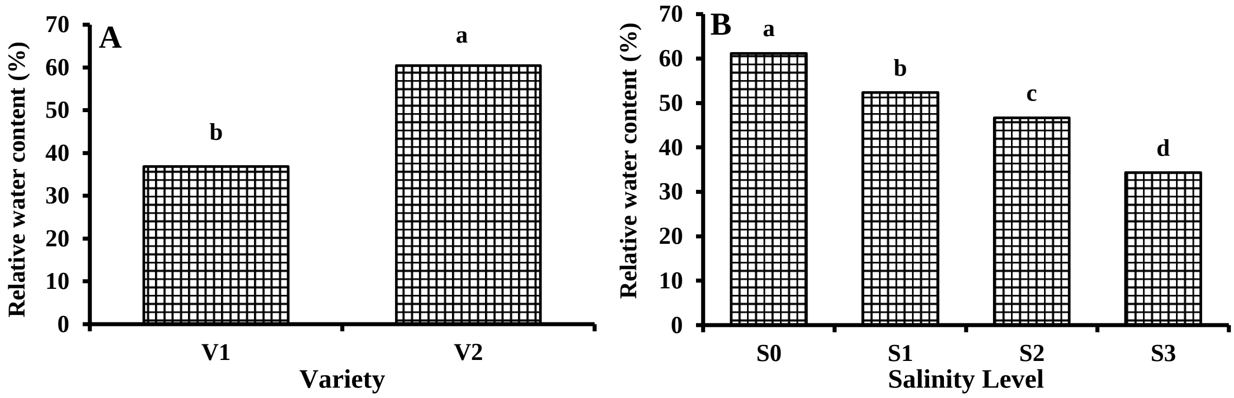
The combination of variety and different levels of salinity had a negative impact on the leaf RWC of *boro* rice (**Figure 3**). Compared with the control, the RWCs of leaves decreased by 16, 33, and 64% in BRRI dhan28 for the applications of quarter-strength, half-strength, and full-strength seawater, respectively, where as they decreased by 12, 16, and 28%, respectively, in BRRI dhan47. In all the levels of salt stress, the RWC reductions were higher in BRRI dhan28 compared with BRRI dhan47. This indicates that the salt-induced damage was lower in BRRI dhan47 than BRRI dhan28.

Table 1. Combined effects of variety and salinity on plant height at different growth periods of *boro* rice

Treatments	Plant height (cm)			
	30 DAT	60 DAT	90 DAT	Harvest
V_1S_0	18.56	72.00	99.17[a]	84.46[a]
V_1S_1	16.73	68.66	90.17[bc]	57.93[d]
V_1S_2	15.66	68.00	80.67[d]	39.83[e]
V_1S_3	14.66	64.66	69.67[e]	0.00[f]
V_2S_0	23.83	84.00	100.33[a]	87.50[a]
V_2S_1	22.10	78.66	95.33[ab]	77.66[b]
V_2S_2	21.26	73.33	90.50[bc]	69.90[c]
V_2S_3	19.80	69.00	86.50[c]	59.73[d]
$LSD_{(0.05)}$	NS	NS	5.67	3.33
CV (%)	3.07	6.05	3.64	3.18

Note: Values with different letters are significantly different at the 5% level of probability.

Here: V_1 *= BRRI dhan28,* V_2 *= BRRI dhan47,* S_0 *= Control,* S_1 *= Quarter strength marine water,* S_2 *= Half strength marine water,* S_3 *= Full strength marine water*



Note: V_1 = BRRI dhan28, V_2 = BRRI dhan47, S_0 = Control, S_1 = Quarter strength marine water, S_2 = Half strength marine water, S_3 = Full strength marine water

Figure 2. Effects of variety (A) and salinity (B) on leaf relative water content of *boro* rice at 90 DAT [LSD $_{(0.05)}$= 2.56 for variety and 3.63 for salinity at 90 DAT]

Effect of yield attributes

Effect on the number of tillers hill^{-1}

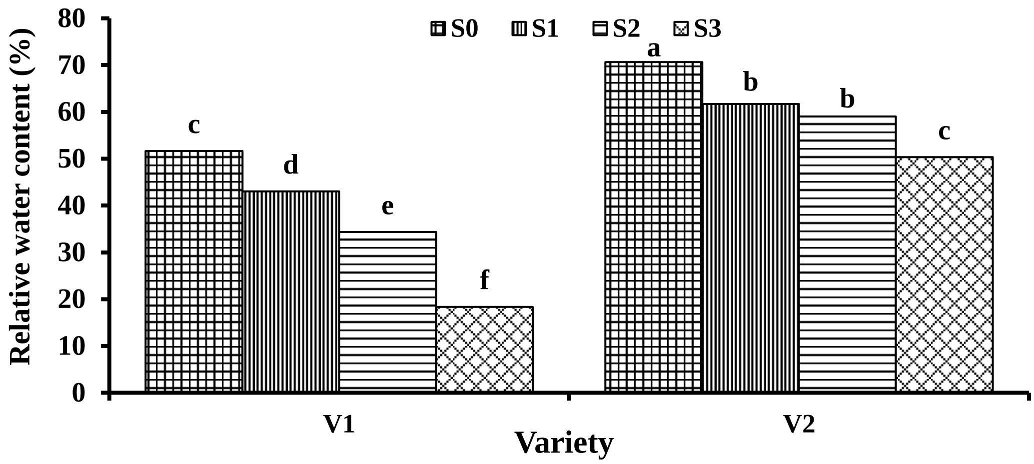
In *boro* rice, varietal variation had a major effect on the number of tillers hill^{-1} (**Table 2**). BRRI dhan47 produced an 81% higher number of effective tillers than BRRI dhan28. This result is in agreement with Roy *et al.* (2019) who stated that different rice varieties show different numbers of effective tillers.

On the other hand, salt stress showed a great negative impact on tiller production in rice. Increases in salinity strength proportionally decreased the number of effective tillers hill^{-1} in rice (**Table 2**). Applications of quarter-strength, half-strength, and full-strength marine water decreased the number of effective tillers hill^{-1} by 36, 58, and 86%, respectively, compared with the control. Similar findings were reported by Zeng *et al.* (2002) who reported that salinity (4.4 and 8.2 ds m^{-1}) reduced yield attributes including the number of effective tillers hill^{-1}. The production of non-effective tillers hill^{-1} increased by 55, 116, and 183% in rice for the applications of quarter-strength, half-strength, and full-strength marine water, respectively, compared with the control. Production of non-effective tillers increased under saline conditions due to higher panicle sterility. Hussain *et al*. (2017) noted that salinity causes sterility of panicles and even sometimes arrests panicle initiation by decreasing nutrient uptake and photosynthesis, and increasing leaf senescence.

The number of tillers hill^{-1} in rice was also greatly reduced by the combined effects of variety and salinity (**Table 2**). Compared with the control, exposure to quarter-strength, half-strength, and full-strength marine water decreased the number of effective tillers hill^{-1} by 41, 72, and 100%, respectively, in BRRI dhan28, and 32, 47, and 71 %, respectively, in BRRI dhan47. Between the two varieties, the reduction rate of effective tiller production was higher in BRRI dhan28 under all levels of salinity. This indicates that tiller production was higher in BRRI dhan47 compared with BRRI dhan28 under salt stress conditions. The number of non-effective tillers hill^{-1} was increased by the intrusion of saline water in both varieties of rice. The number of non-effective tillers hill^{-1} was higher in BRRI dhan28 compared to BRRI dhan47 at every level of salinity. This also indicates the susceptibility of BRRI dhan28 to salinity. These results agree with Sultana *et al.* (2014) who noted that salt-tolerant varieties showed decreased potentiality in tiller production under salt stress conditions.

Effect on the number of grains panicle^{-1}

Varietal variation showed a significant influence on the number of filled grains panicle^{-1} and unfilled grains panicle^{-1} of rice (**Table 2**). BRRI dhan47 produced 29% higher filled grains panicle^{-1} and 28% lower unfilled grains panicle^{-1} compared with BRRI dhan28. These results corroborate the findings of Roy *et al.* (2019) who



Note: V_1 = BRRI dhan28, V_2 = BRRI dhan47, S_0 = Control, S_1 = Quarter strength marine water, S_2 = Half strength marine water, S_3 = Full strength marine water]

Figure 3. Combined effects of variety and different levels of salinity on leaf RWC of *boro* rice leaves at 90 DAT. [LSD $_{(0.05)}$= 5.13]

Table 2. Effects of variety, salinity, and their combination on the number of tillers, number of grains, and 1000-grain weight at different growth periods of *boro* rice

Treatments	Effective tillers hill^{-1} (No.)	Non-effective tillers hill^{-1} (No.)	Filled grains panicle^{-1} (No.)	Unfilled grains panicle^{-1} (No.)	1000-grain wt (g)
			Variety		
V_1	6.75^b	6.58^a	58.91^b	22.25^a	13.92^b
V_2	12.25^a	4.75^b	83.75^a	16.00^b	16.80^a
LSD $_{(0.05)}$	0.57	0.27	1.56	1.15	0.48
			Salinity		
S_0	17.16^a	3.00^d	124.33^a	6.50^c	22.97^a
S_1	10.83^b	4.66^c	90.33^b	17.00^d	19.74^b
S_2	7.16^c	6.50^b	46.33^c	36.50^a	14.54^c
S_3	2.38^d	8.50^a	24.33^d	16.50^b	4.19^d
LSD $_{(0.05)}$	0.81	0.38	2.21	1.62	0.67
			Combined effect of variety and salinity		
V_1S_0	14.66^b	3.66^d	132.33^a	8.00^e	22.28^{ab}
V_1S_1	8.33^c	5.66^e	85.33^d	26.00^c	18.98^c
V_1S_2	4.00^d	7.66^b	18.00^g	55.00^a	14.42^d
V_1S_3	0^e	9.33^a	0^h	0^f	0^f
V_2S_0	19.66^a	2.33^c	116.33^b	5.00^e	23.66^a
V_2S_1	13.33^b	3.66^d	95.33^c	8.00^e	20.5^{bc}
V_2S_2	10.33^c	5.33^c	74.66^e	18.00^d	14.66^d
V_2S_3	5.66^d	7.66^b	48.66^f	33.00^b	8.38^e
LSD $_{(0.05)}$	1.14	0.54	3.12	2.3	0.96
CV (%)	2.46	1.17	6.71	4.93	2.05

Note: Values with different letters are significantly different at the 5% level of probability

Here: V_1 = BRRI dhan28, V_2 = BRRI dhan47, S_0 = Control, S_1 = Quarter strength marine water, S_2 = Half strength marine water, S_3 = Full strength marine water

reported that different varieties produce different numbers of grains panicle^{-1}.

Salinity decreased the production of filled grains and increased sterile spikelets by disturbing the processes of pollination and fertilization (Hussain *et al.*, 2017). Our results suggested that exposure to salinity decreased the production of filled grains panicle^{-1} and increased the production of unfilled grains panicle^{-1}. However, intrusion of quarter-strength, half-strength, and full-strength marine water decreased the number of filled grains panicle^{-1} by 27, 62, and 80% respectively, compared with the control. The sterile spikelets increased by 161, 461, and 153% when rice plants were exposed to quarter, half, and full-strength marine water, respectively. These results were in line with Choi *et al.* (2003) who stated that increases in salinity decreased the number of filled grains panicle^{-1}.

The combination of variety and salinity also influenced the number of grains panicle$^{–1}$ (**Table 2**). Compared with the control, external applications of quarter-strength, half-strength, and full-strength marine water decreased the number of filled grains panicle$^{–1}$ by 35, 86 and 100%, respectively, in BRRI dhan28, and by 18, 35, and 58%, respectively, in BRRI dhan47. Under salt stress conditions, the reduction rate of the production of filled grains was higher in BRRI dhan28 than BRRI dhan47. Under full-strength saline water, the number of filled grains panicle$^{–1}$ was zero as there were no effective tillers under this treatment. Similar results were also reported by Gerona *et al.* (2019) who noted that when rice plants were exposed to salt stress at the latter part of their life cycle, the reproductive growth of rice was seriously hampered, even resulting in very little grain yield.

Effect on 1000-grain weight

The 1000-grain weight of rice significantly varied depending on the variety, and BRRI dhan47 showed an 18% higher 1000-grain weight than BRRI dhan28 (**Table 2**).

Salt exposure decreased the 1000-grain weight of rice, and the rate of reduction increased as the salinity level increased (**Table 2**). Abdullah *et al*. (2001) stated that salinity reduces the translocation of soluble sugars and inhibits starch synthesis in grain, and consequently, reduces the 1000-grain weight of rice. In our study, we found that applications of quarter-strength, half-strength, and full-strength marine water decreased the 1000-grain weight by 14, 36, and 81%, respectively, compared with the control. Salinity-induced 1000-grain weight reduction was also reported by Salam *et al*. (2007).

The interaction of variety and salinity greatly influenced the 1000-grain weight of rice (**Table 2**). Compared with the control, the 1000-grain weights of rice decreased by 14, 35, and 100% in BRRI dhan28 for the applications of quarter-strength, half-strength, and full-strength marine water, respectively, where as they decreased by 13, 38, and 64 %, respectively, in BRRI dhan47. In BRRI dhan28, the 1000-grain weight reduction was 100% in full-strength seawater exposure, as this treatment produced no grain. These results are in agreement with Gerona *et al*. (2019) who reported that salinity exposure at the reproductive stage increased the number of sterile spikelets and decreased the 1000-grain weight. Similar results were also reported by Salam *et al*. (2007) who noted that BRRI dhan47 showed a higher 1000-grain weight compared to BRRI dhan28 under salt stress.

Effect on yield of rice

Effect on grain yield

Significant variation was observed in the grain yield of rice due to varietal variation (**Table 3**). BRRI dhan28 showed a 53% lower yield than BRRI dhan47. BRRI dhan47 showed a higher yield because it also showed higher numbers of effective tillers hill$^{–1}$ and filled grains panicle$^{–1}$, and a higher 1000-grain weight than BRRI dhan28.

Exposure to salinity showed a negative impact on the grain yield of rice (**Table 3**). Compared with the control, the grain yield pot$^{–1}$ decreased by 36, 66, and 83% for the intrusion of quarter-strength, half-strength and full-strength marine water, respectively. It was revealed that grain yield decreased gradually with increased levels of salinity. Salinity reduced grain yield by decreasing the numbers of effective tillers hill$^{–1}$ and filled grains panicle$^{–1}$, and the 1000-grain weight, which is in line with Zeng *et al.* (2002.

The combined effect of variety and salinity also showed a significant variation on grain yield of rice (**Table 3**). Compared with the control, intrusion of quarter-strength, half-strength, and full-strength marine water decreased the grain yields pot^{-1} by 50, 89, and 100%, respectively, in BRRI dhan28, and 26, 49, and 72%, respectively, in BRRI dhan47. The grain yield reduction was 100% in BRRI dhan28 under full-strength marine water as there were no effective tillers in this treatment. These results are in agreement with Gerona *et al*. (2019) who noted that exposure to salinity at both the growth and reproductive stages might give a normal or reduced straw yield of rice but the plants produced very little grain. However, under all levels of salinity, the grain yield reduction was higher in BRRI dhan28 than BRRI dhan47 because the damage to the yield attributes (reductions of the number of effective tillers hill^{-1}, number of filled grains panicle^{-1}, and 1000-grain weight) of BRRI dhan28 were higher in all levels of salinity. Similar results were reported by Salam *et al*. (2007) who showed that grain yield reductions were higher in a salt-sensitive variety than in a tolerant variety under salt stress conditions.

Salinity drastically reduced the straw yield of rice, and straw yield reductions increased with increased levels of salinity (**Table 3**). Exposure to quarter-strength, half-strength, and full-strength marine water decreased the straw yields pot^{-1} by 26, 40, and 67%, respectively, compared with the control. Straw yield decreased under salt stress conditions as salinity decreased the number of tillers in rice. These results are corroborated by Siddique *et al*. (2015) who noted that salinity reduces the straw yield of rice due to photosynthesis reduction and a lower uptake of nutrients.

Table 3. Effects of variety, salinity, and their combination on yield at different growth periods of *boro* rice

Treatments	Grain yield pot^{-1} (g)	Straw yield pot^{-1} (g)	Biological yield (g)
Variety			
V_1	41.83^b	192.33^b	234.17^b
V_2	90.00^a	239.92^a	329.92^a
LSD (0.05)	2.81	8.26	8.21
Salinity			
S_0	123.83^a	325.50^a	449.33^a
S_1	78.50^b	240.50^b	319.00b
S_2	41.33^c	193.00^c	234.33^c
S_3	20.00^d	105.50^d	125.50^d
LSD (0.05)	3.97	11.68	11.61
Combined effect of variety and salinity			
V_1S_0	104.67^b	299.33^b	404.00^b
V_1S_1	52.00^c	217.67^d	269.67^d
V_1S_2	10.66^e	180.33^e	191.00^e
V_1S_3	0^e	72.00^g	72.00^f
V_2S_0	143.00^a	351.67^a	494.67^a
V_2S_1	105.00^b	263.33^c	368.33^c
V_2S_2	72.00^c	205.67^{de}	277.67^d
V_2S_3	40.00^d	139.00^f	179.00^e
LSD $_{(0.05)}$	5.62	16.53	16.42
CV (%)	12.07	35.45	35.23

Note: Values with different letters are significantly different at the 5% level of probability

Here: V_1 = BRRI dhan28, V_2 = BRRI dhan47, S_0 = Control, S_1 = Quarter strength marine water, S_2 = Half strength marine water, S_3 = Full strength marine water]

The combination of variety and salinity influenced the straw yield of rice (**Table 3**). Compared with the control, the straw yields of rice decreased by 27, 39 and 75% in BRRI dhan28 for the exposures to quarter-strength, half-strength, and full-strength marine water, respectively, where they decreased by 25, 41 and 60%, respectively, in BRRI dhan47. A similar trend was observed by Salam *et al*. (2007) who noted that yield reductions were higher in a salt-sensitive variety than in a tolerant variety under salt stress conditions.

Effect on biological yield

The biological yield of rice was significantly influenced by varietal variation (**Table 3**). BRRI dhan28 produced a 28% lower biological yield than BRRI dhan47. Biological yield was lower in BRRI dhan28 as the number of effective tillers hill^{-1}, number of filled grains panicle^{-1}, grain yield, and straw yield were lower than BRRI dhan47.

Salt stress decreased the biological yield of rice, and the biological yield decreased with increased levels of salinity (**Table 3**). Compared with the control, the biological yields decreased by 29, 47, and 72%, respectively, for the external applications of quarter-strength, half-strength, and full-strength marine water in rice. It was revealed that salinity decreased the biological yield as salt stress damages the yield attributes, and decreased the grain and straw yields. These results are in agreement with Siddique *et al*. (2015) who noted that salinity decreased the biological yield of rice by decreasing the straw yield and other yield attributes.

The interaction of variety and salinity greatly affected the biological yield of *boro* rice (**Table 3**). Compared with the control, exposure to quarter-strength, half-strength, and full-strength marine water decreased the biological yields pot^{-1} of *boro* rice by 33, 52, and 82%, respectively, in BRRI dhan28, where as they were decreased by 22, 43, and 63%, respectively, in BRRI dhan47. The biological yield reduction was higher in all levels of salinity in BRRI dahn28 than BRRI dhan47 as the other yield reductions and damage of the yield attributes showed a similar trend under salt stress conditions.

Conclusions

Our results suggested that exposure to salinity reduced the growth and yield of *boro* rice, and yield reductions increased with increased levels of salinity. Application of full-strength marine water resulted in grain yield reductions of 72 and 100% in BRRI dhan47 and BRRI dhan28, respectively. Exposure to salt throughout the life cycle of rice may result in some straw yield but little to no grain. The performance of salt-tolerant variety (BRRI dhan47) was better in all levels of salinity than in the sensitive variety (BRRI dhan28). The tolerant variety produced satisfactory grain and straw when irrigated with quarter and half-strength marine water. However, the present study was conducted by irrigating with high strength (0-30 ds m^{-1}) marine water without measuring the salinity of the soil. Further research, in which the soil salinity is measured, might be conducted to clearly understand the marine water-induced salinity effects on rice.

Acknowledgments

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