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EFFECT OF SALINITY STRESS ON GROWTH AND YIELD POTENTIAL OF BORO RICE

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ABSTRACT

Salinity in the most critical abiotic stress particularly in the coastal area of Ganges Delta. The cropping in the coastal regions of southwestern (SW) Bangladesh during *Boro* season mainly constraint by the soil and water salinity. Therefore, responses of the rice to different degree of salinity is important. So, a pot experiment was conducted at Dr. Purnendu Gain Field Laboratory of Agrotechnology Discipline, Khulna University, Khulna to screen the response of 8 different boro rice varieties (Noyanmoni, Abdulhai, Kaliboro, BRRI dhan55, Noyantara, Kajollota, Bareyratna, BINA dhan8) at different levels of salinity (0, 4, 8, 12, 16 and 20 dS m^{-1}). The experiment was conducted in a factorial completely randomized deign and replicated thrice. All the growth, yield attributes and yield were significantly declined with the increased levels of salinity compared to control (no salt solution added). All the plants were died with the imposed salinity levels at 12, 16 and 20 dS m^{-1}. Therefore, the collected parameters of rice varieties at 0-8 dS m^{-1} salinity levels were analyzed. Rice varieties respond well up to 4 dS m^{-1} and afterwards poor response noticed. Noyanmoni showed best performance in terms of growth, yield attributes and yield compared to other varieties in salinity conditions. From the findings of this study, it is concluded that under medium saline condition Noyanmoni is the suitable rice variety and can be fitted in the coastal saline soil of southwestern Bangladesh during *Boro* season.

Keywords: Salinity, Rice variety, Yield potential, Coastal region

INTRODUCTION

Bangladesh is an agricultural country and rice is the most important cereal crop where 80% of cultivable land is used for its cultivation. It is estimated that rice is grown in about 11.71 million hectares area of Bangladesh with a production of 37.91 million metric tons and the average yield is 3.24 t ha^{-1} (BBS, 2021). Rice is cultivated in three seasons as *Boro*, *Aus* and *Aman* in Bangladesh; and the yield potential is higher in the *Boro* season compared to other seasons. During *Boro* season, 4.79

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million hectares' area was used for rice cultivation and the production was 19.89 million metric tons with the average yield of 4.15 tons per hectare in 2020-21(BBS, 2021).

The coastal area covers >30% cultivable land in Bangladesh and are affected by salinity during the dry season (Haque, 2006). Out of 2.86 million hectares of coastal and offshore land in Bangladesh ~1.06 million hectares are affected by varying degrees of salinity (SRDI, 2012). These coastal saline soils cover portions of 8 agroecological zones of the country and are distributed unevenly in 64 upazilas of 13 coastal districts. The saline area is increasing with time: from 0.83 m ha to 1.09 m ha in the past 36 years (SRDI, 2010) due to increasing sea water level with increased global temperature.

Salinity is one of the most adverse environmental factors that limit the crop productivity because most of the crops are sensitive to high concentrations of salts in the soil (Hakim et al., 2013). In the coastal area the salinity level increase in the dry season due to the increased temperature and limited rainfall that adversely affect the crop production (Michael et al., 2004). Excess salt level affects several physiological pathways like photosynthesis, respiration, nitrogen fixation and carbohydrate metabolism. Variations in sensitivity due to salt during the life cycle increase the complexity of tolerance evaluation. Salinity can limit growth and plant yield in three ways including reducing osmotic potential, creating ion toxicity, causing disarrangement and imbalance of ion uptake causing disorders in enzyme activities and membrane and metabolic activities in the plant (Darwish et al., 2009; Akter and Oue, 2018). In rice, it has long been reported that grain yield is much more depressed by salt stress than vegetative growth. Salinity affects rice during transplanting, after transplanting and flowering stages, however it logarithmically endures salinity stress until ripening (Zeng and Shannon, 2003). The effects of salt stress on rice are highly dependent on plant phenology where young seedlings and plants at the flowering stage appear to be the most sensitive while tillering plants are less sensitive. Salinity applied at the seedling stage frequently induces premature senescence of leaves. Plant height, total number of tillers, panicle length, grain weight panicle^{-1}, 1000-grain weight and quality and quantity of grains decrease progressively with increase in salinity levels (Joseph, 2010; Dramalis et al., 2021).

In the coastal region of Bangladesh, farmers usually cultivate low yielding, local T. aman rice varieties in the monsoon season. During the winter and following *Boro* season (January –May) most of the land remains fallow due to the salinity problem, lack of fresh irrigation water and poor drainage condition (SRDI, 2010). This fallow area could be included under boro rice cultivation using salt tolerant varieties. Bangladesh Rice Research Institute (BRRI) and Bangladesh Institute of Nuclear Agriculture (BINA) has developed few salts tolerant varieties. Farmers in the coastal region usually concentrated on the cultivation of local rice varieties and it has some noble characteristics including salt tolerance. This study aims to screen the salt tolerant traditional boro rice varieties for cultivation in coastal areas of the country.

MATERIALS AND METHODS

Experimental site

The experiments were carried out at Dr. Purnendu Gain Field Laboratory of Agrotechnology Discipline, Khulna University during the *Boro* season (February-June). The area was located under the agro-ecological zone of Ganges Tidal Floodplain (AEZ-13). The experimental site during the *Boro* was characterized by low temperature in the early season and high temperature with limited rainfall during the late growing season.

Experimental design and treatments

The experiment was arranged in a factorial completely randomized design with three replications. The experimental treatments comprised of eight rice varieties (Noyanmoni, Abdulhai, Kaliboro, BRRI dhan55, Noyantara, Kajollota, Bareyratna, BINA dhan8) and eight levels of irrigation water salinity (0, 4, 8, 12, 16 and 20 dS m^{-1}). The pots were prepared with the fine dry soil (12.5% soil water content and slight acidic). Each pot contained 8.5 kg soil.

Preparation of salt solution

Different concentration of NaCl (0, 4, 8, 12, 16 and 20 dS m^{-1}) solution was used in the study. For the preparation of 4 dS m^{-1} salt solution, 40 g NaCl salt was taken in a 1000 ml flask and filled up to the mark with distilled water. Others level of salt solution were prepared following the same procedure.

Crop management

Urea, TSP, MoP, gypsum and zinc sulphate were used as the source of N, P, K, S and Zn. All the fertilizers except urea were mixed with the pot soil. Four seedlings of thirty days old were transplanted in each pot. Urea were topdressed in three equal splits at 10 days after transplanting (DAT), next at 30 DAT (active tillering) and 45 DAT (panicle initiation). Different concentration of salt solution (as per the treatment) was imposed in two time at tillering and flower initiation stage. All the plants at higher salinity levels (12, 16 and 20 dS m^{-1}) were died after the imposition of salt solution at tillering stages. Other intercultural operations (irrigation, weeding, plant protection etc.) were kept similar to all the pots. The crops were harvested at full maturity (95 DAT)

Data collection and analysis

Data on germination percentage, growth and yield attributes (effective tillers, panicle length, filled grain, unfilled grain and 1000-grain weight) and yield (grain and straw) were measured and recorded. The grain and straw were sun-dried and measured at 14% moisture content. The collected data were analyzed following analysis of variance technique (two-way ANOVA) using MSTAT-C computer package. The comparison among the means were separated by Duncan's New Multiple Range Test (DMRT) (Gomez and Gomez, 1984).

$$\text{Germination (\%)} = \frac{No.of\ germinated\ seed}{No\ of\ seed\ set}\ x\ 100$$

RESULTS AND DISCUSSION

As all the plants were died due to the imposition of salt solution at 12, 16 and 20 dS m^{-1}, therefore, only the results of the salinity level of 0, 4 and 8 dS m^{-1} have been presented. The higher salt accumulation in the older leaves cause to death (Munns et al. 2006) and this may lead to the death of the whole plant at 12 to 20 dS m^{-1} salinity level. The seeds of all varieties were treated with $HgCl_2$ and placed on separate petri dishes for germination test. First germination occurred at 3 days and the germination were completed within 6 days. The full germination of Noyantara and Kajollota were completed within 3 days. The full germination of Noyanmoni and Kaliboro were completed within 4 days. The germination percentages of all the varieties are presented in Table 1.

Table 1. Seed germination percentage of rice varieties

Variety	Germination (%)
Noyanmoni	100
Abdulhai	95
Kaliboro	100
BRRI dhan55	90
Noyantara	100
Kajollota	100
Bareyratna	85
BINAdhan8	80
Mean	*84.21*
SD (%)	*7.90*
CV (%)	*9.38*

Plant height (cm)

Different salinity levels had significant influence on plant height yet no significant (*$p<0.01$*) influence among the varieties and the interaction effect of variety and salinity (Table 2). Among the salinity level control treatment (no salt solution added) resulted the highest plant heigh then steadily decreased with the increased level of salinity. The gradual declined of plant height might be the inhibition of cell division and cell enlargement due to the salinity stress. The salinity stress may damage the cell membrane, cause nutritional imbalance, modify the growth regulator, limit the enzymatic and metabolic functions, reduced the rate of photosynthesis resulting poor plant growth and leads to total crop damage (Munns and Tester, 2008; Hasanuzzaman et al., 2012). Similar findings also reported by Jamil et al. (2012) and Islam et al. (2007) that the differences in plant height of rice varieties with different salinity levels and plants were died at higher salinity level. Numerically BINA dhan-8 showed the highest plant height. This might be the genetic makeup of the variety. Similar finding of variation in plant height was noticed by Puvanitha and Mahendra, (2018).

Table 2. Growth and yield attributes of rice varieties with the salinity level and the interaction of variety and salinity level

Treatment	Plant height (cm)	No. of tiller hill^{-1}	No of Functional panicle	Panicle length (cm)	Filled grains panicle^{-1}	1000-grain weight (g)	Straw weight hill^{-1} (g)
Salinity level							
0 dS m^{-1}	40.33a	13.92a	9.08a	6.54a	104.33a	27.32a	23.79
4 dS m^{-1}	31.58b	12.29a	7.92a	5.81a	66.83a	23.11a	22.92
8 dS m^{-1}	14.88c	6.13b	3.38b	2.17b	13.33b	8.8b	14.88
LS	**	**	*	**	**	**	**
SE (±)	2.95	1.36	*1.45*	0.82	*15.64*	*3.53*	0.43
Variety							
Noyanmoni	34.33	16.00a	15.22a	6.22ab	173.00 a	29.32	22.78b
Abdulhai	25.78	9.22ab	7.67b	3.39bc	61.22bc	14.12	21.78b
Kaliboro	22.67	12.44ab	10.11ab	5.39ab	48.67bc	23.47	15.78d
BRRI dhan55	28.89	7.11b	4.56bc	5.78ab	29.11bc	17.83	14.22d
Noyantara	22.44	6.67b	4.31bc	5.82ab	33.22bc	16.38	15.67d
Kajollota	28.44	10.22ab	8.00b	7.00ab	99.44b	32.27	17.78c
Bareyratna	30.22	10.11ab	7.89b	7.94a	39.33bc	31.24	19.56c
BINA dhan8	38.67	14.44a	4.89bc	3.00bc	41.22bc	9.69	36.67a
LS	*ns*	*	**	**	**	*ns*	**
SE (±)	*4.82*	*2.21*	2.37	*1.34*	*25.55*	*5.76*	*0.70*
Interaction of variety x salinity level							
LS	*ns*	*ns*	*ns*	*ns*	*ns*	*ns*	**
SE (±)	*6.36*	*3.84*	*2.32*	*4.11*	*44.25*	*9.98*	*1.21*

Here, LS and SE indicate level of significance and standard error, respectively

**, * and ns indicate significant at 1%, 5% level and non-significant, respectively Figures in a column having similar letter(s) do no differ significantly

Number of tillers hill^{-1}

The variation of tiller no. hill^{-1} may be the genetic chrematistics and salt tolerant capacity of the variety. Tiller no. hill^{-1} significantly (*p<0.01*) decreased with the higher level of salinity and the highest no. of tiller hill^{-1} achieved from control treatment (no salt added) which was on parity with 4 dS m^{-1} (Table 2). The decreasing trend of tiller hill^{-1} with the increased salinity levels were reported by WeonYoung et al. (2003) and Kakar et al. (2019). Among the varieties used in this experiment significantly (*p<0.05*) higher no. of tiller hill^{-1} was obtained from the variety Noyanmoni which was statistically at par to other variety except BRRI dhan55 and Noyantara (Table 2). The average tiller hill^{-1} was medium due to the tillering potentiality of the varieties under salt stress. The interaction of variety and salinity level had no significant response (Table 2). Similar findings also reported by Zeng and Shannon (2000) that in BR11, >30% reduction of effective tillers was observed with 150 mM NaCl treatment compared to control (no salinity).

No. of functional panicle hill^{-1}

No. of functional panicle hill^{-1} substantially (*p<0.05*) decreased with the increased level of salinity where control treatment (no salt added) produced the maximum no. of functional panicle hill^{-1} which was on similarity with 4 dS m^{-1} salinity level (Table 2). The results are in agreement with the findings of Khatun et al. (1995) and Grattan et al. (2002) that the number of functional panicles hill^{-1} reduced with the increased level of salinity. Excessive salt affect inhibits the fertility due to the imbalance supply of carbohydrates between vegetative growth and limits the distribution to the developing panicles (Murty and Murty, 1982) which reduce the pollen viability resulting letdown of seed set (Abdullah et al., 2001). Among the varieties, Noyanmoni significantly (*p<0.01*) produced the maximum functional panicle hill^{-1} which was statistically similar to Kaliboro (Table 2). Salinity level and variety had no significant interaction (Table 2). The number of functional panicles reduced due pollen shade and no grain formation with the increase level of salinity. The functional panicle among the variety depends on the genetic make-up of the variety and level of salt tolerant capacity.

Panicle length (cm)

Panicle length among the salinity levels and varieties were different significantly (*p<0.01*) however, their interaction was non-significant (Table 2). The highest panicle length was found at control (no salt added) then declined with the increased of salinity from 4 to 8 dS m^{-1} yet 4 dS m^{-1} provided statistically similar result to control. The reduced panicle length with the increased level of salinity reported by Islam et al. (2007). Aslam reported that both saline and saline sodic soils adversely affect the panicle length of rice. Grattan et al. (2002) stated that salinity had a negative impact on yield components (stand establishment, tiller no., floret sterility panicle length, grain panicle^{-1} and grain size was finally reduced yield. The highest panicle length was found in Bareyratna while the lowest was in BINA dhan8. This variation of panicle length may be the genetic make-up of the variety and their resistance to different level of salinity.

Number of filled grain

Salinity level had significant (*p<0.01*) influence on number of filled grain (Table 2). The highest number of filled grain panicle^{-1} was found at control treatment which was statistically at par with 4 dS m^{-1} salinity level. number of filled grain gradually decreased with the higher level of salinity. The reduced number of filled grain The lower no. of filled grain panicle^{-1} may be the pollen sterility with the increased level of salinity (Rad et al., 2011; Dramalis et al., 2021). The results of this are in accordance with the finding of Farshid and Hassan, (2012) and Khanam et al. (2018). Among the varieties significantly (*p<0.01*) highest number of filled grain panicle^{-1} was obtained from Noyanmoni while the lowest number of filled grain was found in BRRI dhan55. The variation of number filled grain panicle^{-1} might be the varietal characters and salt tolerance capacity of the varieties. The interaction of salinity and variety had no significant response on filled grain panicle^{-1}.

1000-grain weight (g)

1000-grain weight varied significantly (*p<0.01*) with the variation of salinity level (Table 2). Among the salinity level, control treatment (no salt added) resulted the higher 1000-grains weight which was statistically identical to 4 dS m^{-1} salinity level (Table 2). Grain size reduce with the enhance of salinity level might be the lower limited supply of photosynthates from vegetative part to reproductive part. The decreased of 1000-grain weight with the increased of salinity level was reported by Zeng and Shannon (2000) and Saadat et al. (2005). There was no significant difference observed among the varieties and the interaction of salinity level and varieties (Table 2).

Grain weight hill^{-1} (g)

Grain weight hill^{-1} was varied significantly (*p<0.05*) with the variation of salinity level and among the varieties separately but their interaction had no significant effect (Fig. 1A). The highest grain weight hill^{-1} was achieved from control treatment (no salt added) which was on uniformity with 4 dS m^{-1} salinity level. Rice cell division and cell elongation are seriously affected by salt stress, which lead to reduction of root, leaf growth, and yield (Munns, 2002). The results of this study are in agreement with the findings of Joseph et al. (2010), Zeng et al. (2003) they reported that grain weight was declined with the higher level of salinity. The lower grain weight was attributed due to the lower yield attributes. Among the varieties, Noyanmoni resulted the highest grain weight hill^{-1} which was statistically equal to Kajollota (Fig. 1B). The yield different among the varieties might be the varietal characteristics and ability to tolerate salinity.

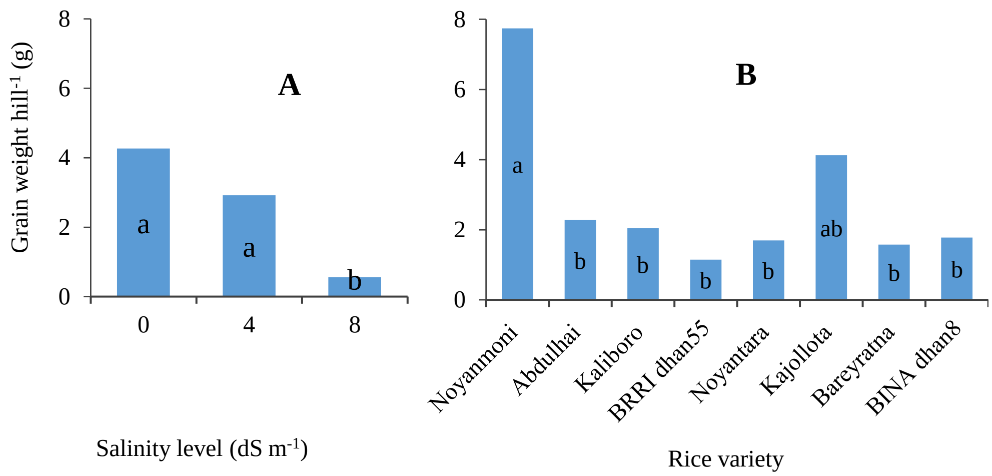

Figure 1. Grain weight hill^{-1} at different level of salinity (A) and of different rice varieties (B)

Straw weight hill^{-1} (g)

Straw weight was significantly ($p<0.01$) higher in control treatment (no salt added) which was statistically on parity with 4 dS m^{-1} salinity level (Table 2). Straw weight steadily declined with the increased level of salinity. The reduced straw weight in the higher salinity shows limited nutrient uptake and nutritional imbalance. The rate of photosynthesis decreased under salinity stress which led to shorter plant with lower biomass accumulation. The results of this study are in accordance with the findings of Rad et al. (2011). Among the varieties BINA dhan-8 significantly ($p<0.01$) resulted the highest straw yield (Table 2). This variation of straw yield among the varieties could be the genetic chrematistics of the variety and the level of saline tolerant. The interaction of salinity and varieties in relation to straw weight had significant ($p<0.01$) influence. The highest straw weight was obtained from BINA dhan8 with 4 dS m^{-1} level of salinity while the lowest was found at 8 dS m^{-1} level of salinity in BRRI dhan55 (Table 2).

Relationship of salinity with yield attributes and grain yield

The effect of salinity on panicle length, no. of grain panicle, 1000-grain weight and grain weight hill^{-1} was significant and negatively correlated (Fig. 2A-D). There was decreasing trend of yield attributes and yield of rice with the increased level of salinity. The linear regression of salinity with panicle length, no. of grain panicle, 1000-grain weight and grain weight hill^{-1} could be explained at 87%, 99%, 91% and 98%, respectively.

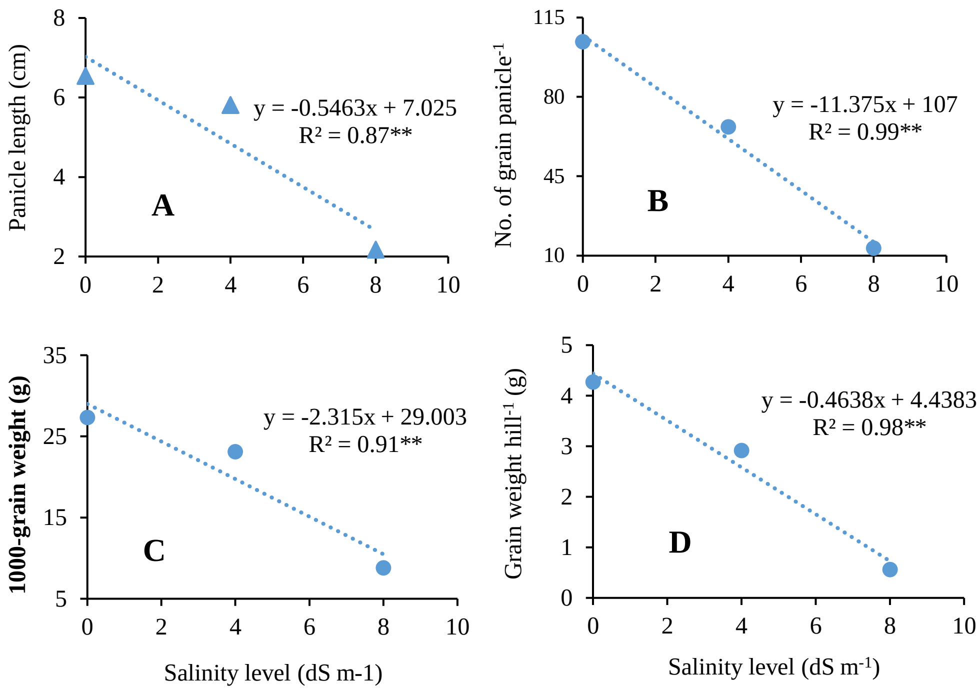

Figure 2. Functional relationship of salinity with panicle length (A), no. of grain panicle^{-1} (B), 1000-grain weight (C) and grain weight hill^{-1} (D)

CONCLUSION

Growth, yield attributes and yield of rice substantially influenced among the varieties with the imposed of different level of salinity. The higher the level of salinity the lower the growth, yield attributes and yield. From 12-20 dS m^{-1} level of salinity all the experimental plants were died due to salt stress. Among the variety used in this experiment BINA dhan8 produced the tallest plant height and straw weight hill^{-1}. The local variety Nayanmoni provided the higher tiller number hill^{-1}, 1000-grain weight, number of filled grain hill^{-1} and filled grain weight. The variety Bareyratna showed the highest panicle length, functional panicle. From the findings of this study, it can be concluded that Noyanmoni is the best salt tolerant variety (up to 8 dS m^{-1}) and can be suitable for the cultivation in coastal saline soils of southwestern Bangladesh.

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