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Article

Comparative studies on tolerance of two rice genotypes differing in their salinity tolerance

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Abstract: Salinity is a serious problem affecting one third of the irrigation land and limiting the yield potential of modern rice (*Oryza sativa* L.) varieties. To increase our understanding of salt tolerance mechanisms in rice for better production, knowledge of salinity effects on rice seedling growth and yield components is inevitable. Despite of large number of studies on salinity tolerance of rice, we have very limited knowledge on the overall effect of salinity on rice seedlings growth. The experiment was carried out to assess the responses of salinity on the growth, nutrient accumulation and yield of rice genotypes BRRI dhan29 (salt-sensitive) and BINA dhan-10 (salt-tolerant). The pot experiment was conveyed at the net house to evaluate the response of two rice genotypes at five levels of salt stresses (0, 25, 50, 75, 100 mM NaCl) at the vegetative stage. After harvesting of rice, electrical conductivity of soil was analyzed. Growth, yield components, grain and straw yields were evaluated. Binadhan-10 showed a higher salt tolerance in physiological parameters of rice than BRRI dhan29. A significant reduction of growth, yield components, grain and straw yields of both rice genotypes was found in response to salt stress. At different salt stress conditions nutrient uptake (NPS) and K^+/Na^+ ratio was significantly decreased in both rice genotypes. Yet, K^+/Na^+ ratio was more in salt-tolerant variety than salt-sensitive variety.

Keywords: salinity; yield component; nutrient uptake; K^+/Na^+ ratio; rice

1. Introduction

Oryza sativa L., also known as rice, is the grain that has influenced the economics, cuisines, and cultures of billions of Asians (Hakim *et al.,* 2014). It is the most important cereal crop and major staple food for majority of human population worldwide (Krishnamurty *et al.,* 2016). Tania *et al.* (2014) reported that around one third population of the world consumed rice. According to reports, Bangladesh produced 37608000 M tons of rice on 28912000 acres of land, and at the same time, the country was cultivating amon, boro, and aus at rates of 48%, 41%, and 11%, respectively (BBS, 2021). Rice production is affected by rising sea level in two ways, one is salinity intrusion which degrades soil quality, turned into reduced rice production and another is the rice fields are converted into shrimp ponds and total rice production decreases accordingly (Sarwar and Khan, 2007). Due to the increasing trend of population, food requirements are increasing rapidly, and it is necessary to increase crop production and that’s why adoption of salt tolerant rice is crucial to maintain sustainability of national rice production. Several promising salt-tolerant rice verities have been developed and showed adaptability to salt-affected areas in the lowland coastal region (Subekti *et al.,* 2020 and Singha *et al.,* 2021). Salinity is one of the major obstacles to increasing in rice growing areas worldwide (Islam *et al.,* 2019). Salinity affected approximately 7% of the world's total land area, 20% of the world's cultivated land area and nearly 50% of the world's irrigated land area (Zhu, 2001). According to SRDI (2012), 1.056 million hectares of arable land are damaged by salt to varied degrees out of 2.86 million hectares of coastal and off-shore fields. Rice fields are disappearing at an alarming rate as a result of rising sea levels, salinization, erosion, and human settlements (Maclean *et al.,* 2003). Because rice is a salt-sensitive crop, soil salinity is a significant issue limiting output across significant portions of Africa and south and southeast Asia (Flowers *et al.,* 1981; Ponnamperuma *et al.,* 1984). Salinity and drought stress are among the most serious challenges to crop production in the world today, particularly in developing countries (Zhou *et al.,* 2007; Rahman *et al.,* 2021). Salinity affects almost every aspect of the physiology and biochemistry of plants and thus significantly reduces yield. Seed germination, water deficit, cause ion imbalance of the cellular ions resulting in ion toxicity and osmotic stress are caused by high exogenous salt concentrations (Khan *et al.,* 2002; Khan and Panda, 2002; Panda and Khan, 2003; Demiral and Turkan, 2005; Mandhania *et al.,* 2006). Plant metabolism affected by salt stress, especially on leaf senescence which have been occurred due to the accumulation of toxic Na^+ and Cl^- ions or depletion of K^+ and Ca^{2+} ions (Al-Karaki, 2000). Salinity increases the production of ROS (reactive oxygen species) in plant cells which causes toxicity and oxidative damage (Hasegawa *et al.,* 2000; Banu *et al.,* 2009; Banu *et al.,* 2010). The viability of pollen, the amount of chlorophyll, and the amount of carbohydrates have all been significantly inhibited as a result of an increased Na^+ concentration in floral parts also the buildup of photosynthates (sugars) in panicle branches and a decline in starch synthase activity were both demonstrated to cause lower grain production (Abdullah *et al.,* 2002; Aref and Rad, 2012). According to Zeng and Shannon (2000), salinity hinders the transformation and translocation of certain carbohydrates, which reduces grain production when exposed to salt stress. Increasing global warming increases the average temperatures which might cause the 'melting' of polar ice caps and resulting from the rise-up of the sea-water level gains (2.8 – 3.1 mm/year), and thus causing salty water intrusion into the coastal areas (Hakim *et al.,* 2014). Selamat and Ismail (2009), reported that fifty per cent yield is being lost of the salt-sensitive rice genotypes due to salinity. About 30-50% of net cropped area of Bangladesh remains fallow in Rabi and Kharif-1 season, mainly due to soil and water salinity (Hossen *et al.,* 2020). Therefore, researchers and policy makers must invent ways for the efficient utilization of the salinity prone areas. The ideal method for bringing the salinity-vulnerable areas under rice cultivation may be the selection of a salt-tolerant rice variety (Shereen *et al.,* 2005; Ali *et al.,* 2004). The main goals of this study are to investigate the effects of salt stress on the root and plant growth, yield component, and grain and straw yields of salt-sensitive and salt-tolerant rice genotypes as well as to study the effects of salinity on nutrient uptake and K^+/Na^+ ratio of salt-sensitive and salt-tolerant rice genotypes. This study is intended to provide a better understanding of the pathways attributed to tolerance to salinity and the selection of better plant types.

2. Materials and Methods

2.1. Pot preparation and experimental site

A pot experiment was carried out at the net-house, Department of Soil Science, BAU, Mymensingh (Old Brahmaputra Floodplain, AEZ 9) to investigate the effects of salt stress on the growth, yield components and grain and straw yield as well as nutrient uptake by salt-sensitive and salt-tolerant rice cultivars i.e. BRRIdhan29 (salt-sensitive) and Binadhan-10 (salt-resistant). Total 30 (5×2×3) pots were used in this experiment. Equal size plastic pots (15 cm deep with 17 cm diameter at the top) having a surface area of 0.023 m^2 at the opening ware used in the experiment. The soil was collected at 15 cm depth from the Soil Science Field Laboratory, BAU, Mymensingh.

2.2. Treatments and design of the experiment

Five NaCl concentrations *viz.* control (T_0 = no NaCl), (T_{25} = 25 mM NaCl), (T_{50} =50 mM NaCl), (T_{75} =75 mM NaCl), and (T_{100} =100 mM NaCl) were used as treatments in the experiment. The experiment was laid out in a randomized complete block design (RCBD) with three replications.

2.3. Crop cultivation and collection of data

The plastic pots were filled with 8 kg soil so that enough space was kept to maintain flooded condition. Full doses of chemical fertilizers were added to soils during pot preparation. Urea fertilizer was applied in three split doses. Thirty-days-old seedlings of two rice varieties were collected from the Soil Science Field Laboratory, Bangladesh Agricultural University and Bangladesh Institute of Nuclear Agriculture (BINA), Mymensingh. Then three seedlings of each variety were transplanted in each pot. To create salinity, pure salt (NaCl) was utilized. No NaCl was applied to the soils during the control treatment. 19.05 g, 38.09 g, 57.14 g, and 76.18 g of NaCl, respectively, were applied to the pots at the active tillering stage for the 25 mM, 50 mM, 75 mM, and 100 mM NaCl treatments. Intercultural operations were conducted when necessary. When about 90% grains became golden yellow in color, crops were harvested and harvested crop of each pot was separately collected and properly tagged. Sampling, threshing and processing were done properly.

2.4. Soil sample analysis

Mechanical analysis of soil was done by hydrometer method and the textural class was determined by Marshall's triangular co-ordinate following USDA system. Soil pH was measured with the help of a glass electrode pH meter. Soil EC was measured with the help of EC meter. Changed chemical properties of post-harvest soil including electrical conductivity (EC) under different salt stress conditions was determined following the standard method.

2.5. Plant sample analysis

Data on the plant's height, root length, dry weight, number of active tillers, panicle length, number of filled grains per panicle, plant dry weight, and grain weight were gathered. After that, plant samples were dried in an oven, ground in a grinding machine and stored in small paper bags and placed in desiccators. After that plant samples were digested for determination of N, P, K, Na and S contents.

2.6. Statistical analysis

Data were analyzed statistically using analysis of variance (ANOVA) to examine the treatment effects, and the mean differences were adjudged by Duncan's Multiple Range Test (DMRT) (Gomez and Gomez, 1984) and ranking was indicated by letters.

3. Results

This experiment was carried out to determine the effects of salt stress on morphological viz. root and shoot growth of rice plants as well as nutrient uptake by grain and straw, $K^{+/}Na^{+}$ ratio in grain and straw of rice varieties exhibiting differences in salinity tolerance. Results obtained on different morphological and physiological parameters of salt-sensitive (BRRI dhan29) and salt-tolerant (Binadhan-10) rice cultivars have been presented here.

3.1. Effects of salt stress on physiological parameters of rice cultivars

Soil salinity caused a significant decrease in plant height, root length, root dry weight, number of effective tillers per hill, panicle length, number of filled grains of rice cultivars (salt-sensitive and salt-tolerant) used in the experiment (Table 1). The highest plant height for the salt-sensitive BRRI dhan29 was 102.3 cm under control conditions, and the lowest plant height was 67.30 cm with the 100 mM NaCl treatment. At 50 mM, 75 mM, and 100 mM NaCl treatments, the change in plant height was not statistically significant. The Binadhan-10 plant reached a height of 113.0 cm at the control treatment and 78.33 cm at the 100 mM NaCl treatment. Plant height did not differ statistically significantly between the control and 25 mM NaCl treatments, but it did at 50 mM NaCl treatments. For the salt-sensitive BRRI dhan29 strain, the largest root length was 22.0 cm under control conditions, and the lowest root length was 11.0 cm under 100 mM NaCl. The maximum root length for Binadhan-10 was 22.33 cm under control treatment, whereas the minimum root length was 14.0 cm with 100 mM NaCl treatment. In every treatment, Binadhan-10's roots were longer than BRRI dhan29's. The highest root dry weight for BRRI dhan29 was 5.99 g under control treatment, whereas the lowest root dry weight was 2.08 g with 100 mM NaCl treatment. The difference in root dry weight between the 25 mM NaCl treatment and the control group was not statistically significant. The highest root dry weight for Binadhan-10 was 8.99 g under control treatment, whereas the lowest root dry weight was 3.47 g with 100 mM NaCl treatment. In every treatment, Binadhan-10 had a heavier root dry weight than BRRI dhan29.As the saline levels increased, the number of efficient tillers per hill drastically reduced. The number of effective tillers per hill varied significantly between the salt-sensitive variety (BRRI dhan29) and the salt-tolerant variety (Binadhan-10). With regard to both cultivars, the control treatment produced the greatest number of productive tillers per hill. At treatments with 75 mM and 100 mM NaCl for BRRI dhan29, there was no tiller that was functional. When exposed to 100 mM NaCl, Binadhan-10 failed to generate a useful tiller. Furthermore, it was found that both rice cultivars' effective tillers drastically decreased at 50 mM NaCl. Salt-sensitive and salt-tolerant rice cultivars both experienced a decrease in panicle length as salinity levels rose. Both the 75 mM and 100 mM NaCl treatments for BRRI dhan29 and the 100 mM NaCl treatment for Binadhan-10 did not result in panicles. In BRRI dhan29, the highest number of filled grains (86.7) was at control treatment whereas the lowest number (9.2) was at 50 mM NaCl treatment. In case of Binadhan-10, the highest number of filled grain was produced at control treatment and the lowest number was at 75 mM NaCl treatment. It was observed that at 50 mM NaCl caused a significant decrease of number of filled grains of both rice cultivars. Both rice varieties failed to produce filled grain at 100 mM NaCl treatment. Again, soil salinity also causes a great decrease in plant dry weight and grain weight per pot which is shown in Figure 1. The highest plant dry weight for BRRI dhan29 was 36.0 g under control treatment, whereas the lowest plant dry weight was 6.9 g with 100 mM NaCl treatment. The highest plant dry weight for Binadhan-10 was 36.36 g under control treatment, whereas the lowest plant dry weight was 11.43 g with 100 mM NaCl treatment. The dry weight of the plants varied greatly between the two rice cultivars treated with 100 mM NaCl and the control. For BRRI dhan29, the highest grain weight was 19.50 g at control treatment, whereas the lowest grain weight was 3.01 g with 50 mM NaCl treatment. The highest grain weight for Binadhan-10 was 27.53 g under control treatment, whereas the lowest grain weight was 4.01 g with 75 mM NaCl treatment. In every treatment, Binadhan-10's grain weight was greater than BRRI dhan29's.

3.2. Effects of salt stress on nutrient uptake by rice cultivars

A significant variation in nitrogen, phosphorus and sulfur uptake by grain and straw was observed in BRRI dhan29 and Binadhan-10 due to salt stress (Table 2). With rising salinity levels, the nitrogen uptake by grain and straw considerably decreased. In case of the BRRI dhan29, no nitrogen uptake by grain was observed at the 75 mM and 100 mM NaCl treatments, but Binadhan-10 did not exhibit any grain production at the 75 mM and 100 mM NaCl treatments. In the case of straw, there was no discernible difference in the amounts of nitrogen absorbed by BRRI dhan29 at 75 mM and 100 mM NaCl treatments, and by Binadhan-10 at 50 mM to 100 mM NaCl treatments. In contrast to BRRI dhan29, Binadhan-10 had increased grain and straw nitrogen uptake at all treatment levels. Due to plant death, in case of BRRI dhan29, there was no phosphorus uptake by grains at 75 mM and 100 mM NaCl treatments. Again, there is no phosphorus uptake by grains of Binadhan-10 at 100 mM NaCl treatment. In case of BRRI dhan29, there was no sulfur uptake by grain at 75 mM and 100 mM NaCl treatments while in case of Binadhan-10, there was no sulfur uptake by grain under 100 mM NaCl because of plant death. The highest sulfur uptake by grain in the instance of BRRI dhan29 was 0.028 g at control treatment, while the lowest was 0.004 g. The highest sulfur uptake by grain in the case of Binadhan-10 was 0.041 g at control treatment, while the lowest was 0.006 g. At treatments ranging from 50 mM to 100 mM NaCl, there was no substantial difference in sulfur uptake for straw of either kind. Moreover, it was shown that both rice cultivars' uptake of sulfur was reduced significantly by 50 mM NaCl.

3.3. Effects of salt stress on potassium and sodium ratio (K^+/Na^+) in rice straw and grain

The K^+/Na^+ ratio in rice straw and grain of both salt-sensitive (BRRI dhan29) and salt-tolerant (Binadhan-10) rice varieties significantly decreased due to salt stress. At control treatment, the K^+/Na^+ ratio was higher in Binadhan-10 than BRRI dhan29 (Figure 2). In case of BRRI dhan29, the highest K^+/Na^+ ratio was 0.21 at control treatment and the lowest was 0.10. In case of Binadhan-10, the highest K^+/Na^+ ratio was 0.23 at control treatment and the lowest was 0.15. But K^+/Na^+ ratio was higher in Binadhan-10 at every level of treatment compared to BRRI dhan29. Again, in case of BRRI dhan29, no K^+/Na^+ ratio was detected at 75 mM and 100 mM NaCl treatments and in case of Binadhan-10, no K^+/Na^+ ratio was detected at 100 mM NaCl treatment because plants could not produce grain at those treatments. However, salt-sensitive rice variety (BRRI dhan29) showed lower K^+/Na^+ ratio compared to the salt-tolerant rice variety (Binadhan-10) in grains.

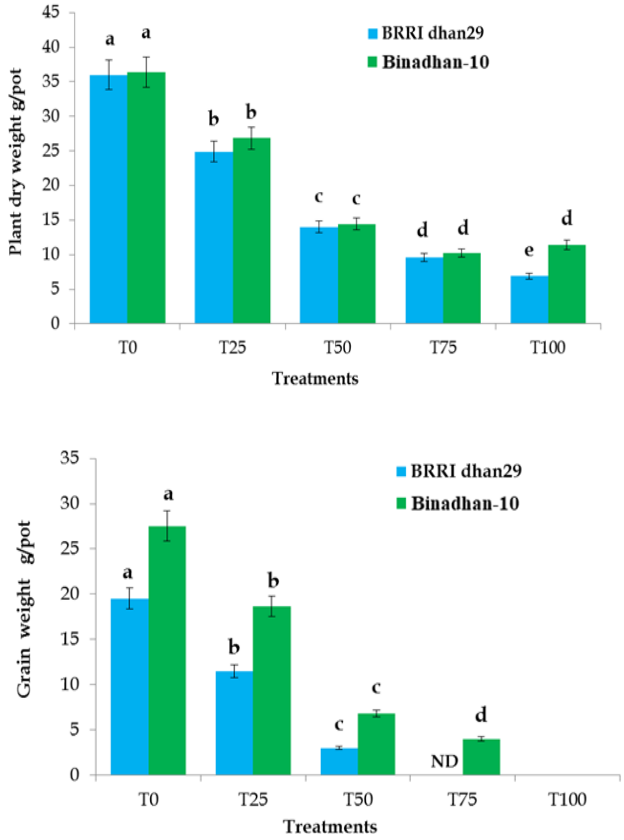

Figure 1. Salinity's effects on the plant dry weight and grain weight per pot of various rice genotypes.

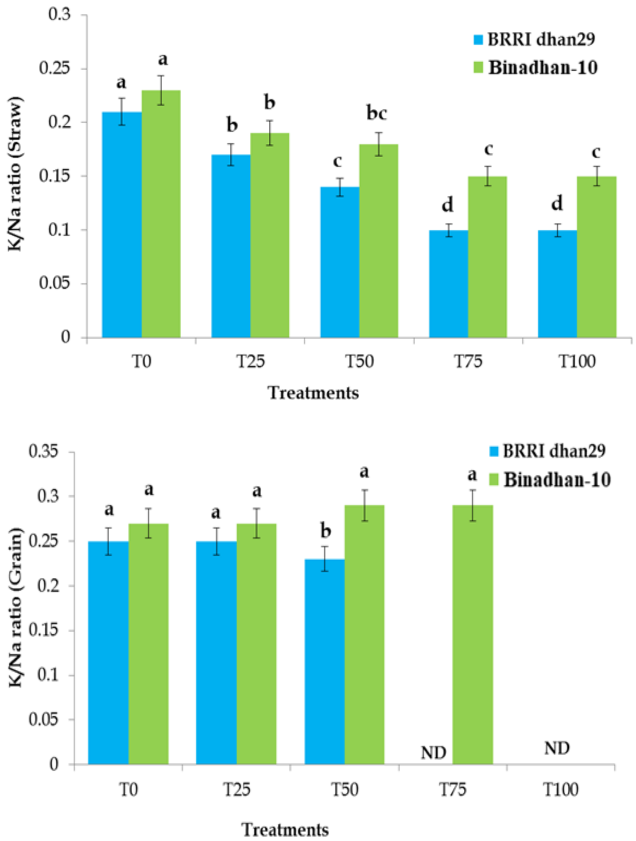

Figure 2. Salinity's effects on K^+ /Na^+ ratio in straw and grain of various rice genotypes.

Where, T_0= Control, T_{25}= 25 Mm NaCl, T_{50}= 50 Mm NaCl, T_{75}= 75 Mm NaCl, T_{100}= 100 Mm NaCl

Table 1. Salinity's impact on various rice species' development and yield components (BRRI dhan29 and Binadhan-10).

Treatments	**Plant height (cm)**		**Root length (cm)**		**Root dry weight per pot (g)**		**No. of effective tillers hill^{-1}**		**Panicle length (cm)**		**Filled Grain per panicle (no.)**	
	BRRI dhan29	**Binadhan -10**	**BRRI dhan29**	**Binadhan -10**	**BRRI dhan29**	**Binadhan -10**	**BRRI dhan29**	**Binadhan -10**	**BRRI dhan29**	**Binadhan -10**	**BRRI dhan29**	**Binadhan -10**
T_0	102.3a	113.0a	22.00a	22.33a	5.993a	8.990a	13.00a	14.00a	26.70a	26.53a	86.70a	85.02a
T_{25}	87.30b	107.0a	16.70b	19.33b	5.540a	6.970b	11.00b	12.00b	23.20b	24.20b	65.80b	78.52b
T_{50}	74.00c	82.67b	14.30c	17.67c	3.100b	4.180c	2.000c	5.00c	14.90c	18.40c	9.200c	18.22c
T_{75}	71.00c	80.00b	12.70cd	15.67d	2.240bc	3.750cd	ND	1.00d	ND	10.33d	ND	12.03d
T_{100}	67.30c	78.33b	11.00d	14.00e	2.080c	3.470d	ND	ND	ND	ND	ND	ND
SE (±)	2.02	3.30	0.571	0.339	0.278	0.198	0.258	0.316	0.509	0.699	1.38	0.702
CV (%)	**4.35**	**6.20**	**6.46**	**3.29**	**12.73**	**6.27**	**8.60**	**8.56**	**6.81**	**7.63**	**7.36**	**3.13**

ND indicates no plants survived during the data recording; In a column, same letter (s) do not differ significantly at 5% level of significance; SE= Standard errors of means, CV= Co-efficient of variation. Where, T_0= Control, T_{25}= 25 mM NaCl, T_{50}= 50 mM NaCl, T_{75}= 75 mM NaCl, T_{100}= 100 mM NaCl

Table 2. Salinity's impact on various rice species' development and yield components (BRRI dhan29 and Binadhan-10).

Treatments	**N uptake (g/pot)**				**P uptake (g/pot)**				**S uptake (g/pot)**			
	BRRI dhan29		**Binadhan-10**		**BRRI dhan29**		**Binadhan-10**		**BRRI dhan29**		**Binadhan-10**	
	Grain	**Straw**	**Grain**	**Straw**	**Grain**	**Straw**	**Grain**	**Straw**	**Grain**	**Straw**	**Grain**	**Straw**
T_0	0.218a	0.114a	0.416a	0.129a	0.035a	0.045a	0.034a	0.047a	0.028a	0.057a	0.041a	0.056a
T_{25}	0.109b	0.075b	0.292b	0.091b	0.021b	0.028b	0.023b	0.032b	0.017b	0.036b	0.027a	0.039b
T_{50}	0.028c	0.041c	0.110c	0.047c	0.005c	0.016bc	0.008c	0.017bc	0.004c	0.020c	0.01b	0.021c
T_{75}	ND	0.025d	0.066cd	0.034c	ND	0.012c	0.005c	0.012c	ND	0.014c	0.006b	0.013c
T_{100}	ND	0.017d	ND	0.037c	ND	0.009c	ND	0.013c	ND	0.009c	ND	0.015c
SE (±)	0.0068	0.0046	0.029	0.0069	0.0027	0.0038	0.0033	0.0044	0.0026	0.0037	0.0035	0.0049
CV (%)	**16.39**	14.64	**28.12**	**17.59**	**36.18**	**28.12**	**44.21**	**31.11**	**44.72**	**22.58**	**35.46**	**28.77**

ND indicates no plants survived during the data recording; In a column, same letter (s) do not differ significantly at 5% level of significance; SE= Standard errors of means, CV= Co-efficient of variation. Where, T_0= Control, T_{25}= 25 mM NaCl, T_{50}= 50 mM NaCl, T_{75}= 75 mM NaCl, T_{100}= 100 mM NaCl

4. Discussion

With the increase of salinity level in both rice varieties, plant height and root growth are decreased drastically. This is because, salinity alter physiological activities of the varieties. When thirteen rice genotypes and two control kinds were used for the study, Safitri *et al.* (2017) discovered that plant height and root length dramatically reduced with increased salt. On four rice types, Kibria *et al.* (2017) found comparable findings. Islam *et al.* (2011) conducted research on hybrid rice and showed how salt stress causes plants to grow shorter. Similar to the outcome, Miah *et al.* (1992) discovered that plant height dropped as salt level increased. In research using two wheat cultivars (Seher and Lasani) and 100 mM salt stress, Talat *et al.* (2013) found that salt stress dramatically decreased plant height of both wheat cultivars. As roots come into close touch with the salt of the surrounding solution, they are the first to do so and may also be the initial site of injury. Momayezi *et al.* (2010) and Dadkhah *et al.* (2001) found root length reduction in rice as well as in other crops due to salinity. In an experiment, Moghbeli *et al.* (2012) discovered that Aloe vera roots were considerably shorter under salt stress (Aloe vera). This is because salt may impact root length by affecting final cell size and cell production rate (Azaizeh *et al.*, 1992). The data clearly demonstrated that the root dry weight of the rice cultivars showed marked decrease as the salinity level was increased. Chunthaburee *et al.* (2016) studied on twelve rice cultivars, including four white rice and eight black glutinous rice cultivars found significant decrease in root dry weight for all rice cultivars at the seedling stage. Reduced rates of new cell production may cause the inhibition of growth as reported by Shabala *et al.* (2000). Hakim *et al.* (2014) on twelve rice varieties found that dry shoot and root weight decreased significantly as the levels of salinity increased. Similar result was also observed by Talat *et al.* (2013) on two wheat cultivars. The reduction in dry weight accumulation can be attributed to increasing stiffness of the cell wall due to altered cell wall structure induced by salinity as reported by Sweet *et al.* (1990). With the increase in salinity levels, plant dry weight decreased in salt-sensitive and salt-tolerant rice genotypes. Sexcion *et al.* (2009) revealed that plant weight significantly decreased with the increasing salinity levels in all varieties. Safitri *et al.* (2017) found that plant dry weights of tolerant genotype Pokkali and sensitive variety IR29 were significantly different. Both salt-sensitive and salt-tolerant rice cultivars experience a considerable reduction in panicle length and the overall number of productive tillers per hill when exposed to salinity.

This outcome is consistent with the research on rice cultivars by Islam *et al.* (2011) and Ali *et al.* (2004). In addition, Zeng and Shannon (2000) noted a decrease in the number of rice tillers per hill and came to the conclusion that this could be the main factor causing yield loss in rice when exposed to salt stress. Here, as the saline level increased, grain weight and the number of filled grains likewise reduced. Additionally, Rad *et al.* (2012) demonstrated that raising salinity level up to $8dSm^{-1}$ decreased the number of filled grains per panicle. Islam *et al.* (2011) studied on hybrid rice and reported that grain yields decreased with increased salinity of 6 and $10dSm^{-1}$. Again Ali *et al.* (2004) and Miah *et al.* (1992) found significant reduction in grain yield due to salinity.

Plant metabolism depends heavily on inorganic elements including N, P, K, and S. Rice cultivars' ability to absorb N was hampered by soil salinity. In the shoots, nitrogen and iron contents drastically dropped as salinity increased, according to Turan *et al.* (2010). As previously stated, Cordovilla *et al.* (1995) observed that NaCl lowered N concentration in the shoot tissues with decreased plant absorption of phosphorus and sulfur. P content in plant components also fell as salinity rose (Gulmezoglu and Daghan, 2017). Potassium and sodium are the most important elements for the plant to survive during salt stress. Higher uptake of Na^+ competes with the uptake of other nutrient ions, especially K^+, and causes K^+ deficiency leading to lower K^+/Na^+ ratio in rice under salt stress. Similarly, Dhar *et al*. (2015) reported that application of both proline and organic manures significantly increased K^+/Na^+ ratio of rice under saline condition. The experiment's findings suggested that increased K and Zn fertilizer applications might reduce the negative impacts of salt on rice production by boosting nutrient absorption and maintaining a higher K^+/Na^+ ratio (Pal *et al.*, 2019). Elevated NaCl levels resulted in significant decreases in K^+ in all the genotypes besides increasing Na^+. The K^+/Na^+ ratio was significantly higher in the salt-tolerant genotype than the salt-sensitive genotype both in straw and grain samples of rice.

The findings of the current study revealed that Binadhan-10 had improved salt tolerance due to maintaining the ideal K^+/Na^+ ratio in both straw and grain. Rice's $K^{+/}Na^+$ ratio decreased with rising salt level, according to research by Islam *et al.* (2011), Miah *et al.* (1992), and Haq *et al.* (2009). Additionally, Sakil *et al.* (2017) discovered that salt-sensitive rice genotypes saw a greater decrease in the K^+/Na^+ ratio than salt-tolerant genotypes. This is due to the fact that salt causes ionic toxicity in plants, which disrupts their ability to absorb nutrients.

5. Conclusions

One of the most important issues with planting regions is soil salinity, which has a negative effect on crop growth and productivity globally. Many experts are interested in developing salt-tolerant cultivars to get around this barrier. In this study, a salt-sensitive (BRRI dhan29) and a salt-tolerant (Binadhan-10) rice cultivars have been used under different levels of salinity. The findings of this investigation demonstrated that the responses of salt-sensitive and salt-tolerant rice varieties to salt stress varied significantly. At various salt levels, both rice cultivars saw a considerable decrease in growth and yield components. While Binadhan-10 produced grain up to 75 mM NaCl treatment, BRRI dhan29 produced grain up to 50 mM NaCl. Both rice genotypes dramatically reduced their nutrient absorption (NPS) and K^+/Na^+ ratio under various salt stress situations. The K^+/Na^+ ratio, on the other hand, was higher in the salt-tolerant variety than the salt-sensitive variety. Therefore, Binadhan-10 is excellent for growing in the salty soils of Bangladesh especially coastal regions.

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Data availability

The tables, figures and texts in this article contain the data that support the findings of this study.

Conflict of interest

None to declare.

Author contributions

Planning of experiment: Prof. Dr. Md. Anamul Hoque and Prof. Dr. Md. Abul Hashem; Conduction of experiment: Yeasmin Akter; Data collection and analysis: Yeasmin Akter and Jotirmoy Chakrobortty; Manuscript writing: Jotirmoy Chakrobortty and Yeasmin Akter; Reviewing and editing: Prof. Dr. Md. Anamul Hoque. All authors have read and approved the final manuscript.

References

Al-Karaki GN, 2000. Growth, water use efficiency, and sodium and potassium acquisition by tomato cultivars grown under salt stress. J. Plant Nutr., 23: 1-8.

Ali Y, Z Aslam, MY Ashraf and GR Tahir, 2004. Effect of salinity on chlorophyll concentration, leaf area, yield and yield components of rice genotypes grown under saline environment. Int. J. Environ. Sci. Technol.,1: 221-225.

Abdullah Z, MA Khan and TJ Flowers, 2002. Causes of sterility in rice under salinity stress. In R. Ahmad and K. A. Malik (Eds.), Prospects for saline agriculture, Vol. 37, pp. 177–187. Dordrecht: Springer.

Aref F and HE Rad, 2012. Physiological characterization of rice under salinity stress during vegetative and reproductive stages. Indian J. Sci. Technol., 5: 2578–2586.

Azaizeh H, B Gunes and E Steudle, 1992. Effects of NaCl and $CaCl_2$ on water transport across root cells of maize *Zea mays* L. seedlings. Plant Physiol., 99: 886-894.

Banu MNA, MA Hoque, M Watanabe-Sugimoto, K Matsuoka, Y Nakamura, Y Shimoishi, and Y Murata, 2009. Proline and glycinebetaine induce antioxidant defense gene expression and suppress cell death in cultured tobacco cells under salt stress. J. Plant Physiol., 166: 146-156.

Banu MNA, MA Hoque, M Watanabe-Sugimoto, MM Islam, M Uraji, K Matsuoka and Y Murata, 2010. Proline and glycinebetaine ameliorated NaCl stress via scavenging of hydrogen peroxide and methylglyoxal but not superoxide or nitric oxide in tobacco cultured cells. Biosci. Biotechnol. Biochem., 74: 1–7.

BBS, 2021. Summary Crop Statistics. Bangladesh Bureau of Statistics, Statistical Division, Ministry of Planning, Government People's Republic of Bangladesh, Dhaka, Bangladesh, pp. 32-41.

Chunthaburee S, A Dongsansuk, J Sanitchon, W Pattanagul and P Theerakulpisut, 2016. Physiological and biochemical parameters for evaluation and clustering of rice cultivars differing in salt tolerance at seedling stage. Saudi J. Biol. Sci., 23: 467–477.

Cordovilla MP, A Ocana, F Ligero and C Lluch, 1995. Salinity effects on growth analysis and nutrient composition in four grain legumes rhizobium symbiosis. J. Plant Nutr., 18: 1595-1609.

Dhar S, MG Kibria, MM Rahman and MA Hoque, 2015. Mitigation of the adverse effects of soil salinity in rice using exogenous proline and organic manure. Asian J. Med. Biol. Res., 1: 478-486.

Dadkhah AR, WS Stewart and H Griffith, 2001. Effects of salinity on yield and root quality of sugarbeet *Beta vulgaris* L. J. Exp. Bot., 52: 31-31.

Demiral T and I Türkan, 2005. Comparative lipid peroxidation, antioxidant defense systems and proline content in roots of two rice cultivars differing in salt tolerance. Environ. Exp. Bot., 53: 247-257.

Flowers TJ and AR Yeo, 1981. Variability in the resistance of sodium chloride salinity within rice *Oryza sativa* L. varieties. New Phytol., 88: 363-373.

Gulmezoglu N and H Daghan, 2017. The interactive effects of phosphorus and salt on growth, water potential and phosphorus uptake in green beans. Appl. Ecol. Environ. Sci., 15: 1831-1842.

Hossen K, MIH Sohag, NJ Sunny, MR Sojib, T Ferdous, A Shila and R Ahmed, 2020. Interaction of variety and urea fertilizer and its impact on salt-tolerant Boro rice in the coastal area of Bangladesh. Asian Australas. J. Food Saf. Secur., 4: 1-7.

Hakim MA, AS Juraimi, MM Hanafi, MR Ismail, MY Rafii, MM Islam, and AJ Selamat, 2014. The effect of salinity on growth, ion accumulation and yield of rice varieties. J. Anim. Plant Sci., 24: 874-885.

Hasegawa PM, RA Bressan, JK Zhu and HJ Bohnert, 2000. Plant cellular and molecular responses to high salinity. *Annu. Rev. Plant Biol.*, 51: 463-499.

Haq TU, J Akhtar, S Nawaz and R Ahmad, 2009. Morpho-physiological response of rice (*Oryza sativa* L.) varieties in salinity stress. Pak. J. Bot., 41: 2943-2956.

Islam MM, R Gupta and MS Islam, 2019. Assessment of rice genotypes for salt stress at seedling and reproductive stage by using phenotypic and molecular markers. Asian Australas. J. Biosci. Biotechnol., 4: 176-183.

Islam MT, PC Sharma, RK Gautam, D Singh, S Singh, B Panesar and S Ali, 2011. Salt tolerance in parental lines of rice hybrids through physiological attributes molecular markers. J. Exp. Agric. Int., 2: 1-7.

Kibria MG, M Hossain, Y Murata and MA Hoque, 2017. Antioxidant defense mechanisms of salinity tolerance in rice genotypes. Rice Sci., 24: 155-162.

Khan MH, and SK Panda, 2002. Induction of oxidative stress in roots of Oryza sativa L. in response to salt stress. Biol. Plant., 45: 625-627.

Khan MH, KL Singha, and SK Panda, 2002. Changes in antioxidant levels in Oryza sativa L. roots subjected to NaCl-salinity stress. Acta Physiol. Plant., 24: 145-148.

Krishnamurthy SL, PC Sharma, SK Sharma, V Batra, V Kumar, and LVS Rao, 2016. Effect of salinity and use of stress indices of morphological and physiological traits at the seedling stage in rice. Indian J. Exp. Biol., 54: 843-850.

Maclean JL, DC Dawe, and GPEds Hettel, 2003. Rice almanac: Source book for the most important economic activity on earth. Int. Rice Res. Inst., 92: 739.

Mandhania S, S Madan, and V Sawhney, 2006. Antioxidant defense mechanism under salt stress in wheat seedlings. Biol. Plant., 50: 227-231.

Miah MMA, GM Panaullah, MS Rahman and M Ishaque, 1992. Effect of soil salinity and phosphorus on the growth yield and mineral nutrition of rice. Bangladesh Rice J., 3: 1-5.

Moghbeli E, S Fathollahi, H Salari, G Ahmadi, F Saliqehdar, A Safari and MSH Grouh, 2012. Effects of salinity stress on growth and yield of *Aloe vera* L. J. Med. Plant Res., 6: 3272-3277.

Momayezi MR, AR Zahara, MM Hanafi and MR Ismail, 2010. Effect of chloride and sulfate salinity on nutrient uptake in iranian rice *Oryza sativa* L. 19th World Congress of Soil Science, Soil solutions for a changing world, 1-6 August 2010, Brisbane, Australia, pp. 36-39.

Pal SC, Chakrobortty J, MA. Hashem and MA Hoque, 2019. Improvement of salinity tolerance in rice by efficient management of potassium and zinc fertilizers. Asian Australas. J. Biosci. Biotechnol., 4: 154-161.

Panda SK and MH Khan, 2003. Salt stress influences lipid peroxidation and antioxidants in the leaf of an indica rice *Oryza sativa* L. Physiol. Mol. Biol. Plants., 9: 273-278.

Ponnamperuma FN, 1984. Role of cultivar tolerance in increasing rice production on saline lands.

Rad HE, F Aref and M Rezaei, 2012. Evaluation of salinity stress affects rice growth and yield components in Northern Iran. Am. J. Sci. Res., 54: 40-51.

Rhaman MS., S Imran, M Karim, J Chakrobortty, M Mahamud, P Sarker, and M Hasanuzzaman, 2021. 5-aminolevulinic acid-mediated plant adaptive responses to abiotic stress. Plant Cell Rep., 40: 1451-1469.

Singha T, MA Mahamud, S Imran, NC Paul, MN Hoque, T Chakrobarty, MAA Galib and L Hassan, 2021. Genetic diversity analysis of advanced rice lines for salt tolerance using SSR markers. Asian J. Med. Biol. Res., 7: 214-221.

Safitri H, BS Purwokob, IS Dewic and SW Ardieb, 2017. Salinity tolerance of several rice genotypes at seedling stage. Indones. J. Agric. Sci., 18: 63–68.

Sakil M, S Sharmin, BL Das and MA Hossain, 2017. Effect of Salinity and Alleviating Role of Methyl Jasmonate in Some Rice Varieties. Asian J. Plant Sci., 16: 87-93.

Shabala S, O Babourina and I Newman, 2000. In specific mechanisms of osmoregulation in bean mesophyll cells. J. Exp. Bot., 51: 1243-1253.

Sarwar GM and MH Khan, 2007. Sea level rise. A threat to the coast of Bangladesh. Internationales Asien forum, pp. 375.

Selamat A and MR Ismail, 2009. Deterministic model approaches in identifying and quantifying technological challenges in rice production and research and in predicting population, rice production and consumption in Malaysia. Pertanika J. Trop. Agric. Sci., 32: 267-291.

Shereen A, S Mumtaz, S Raza, MA Khan, and S Solangi, 2005. Salinity effects on seedling growth and yield components of different inbred rice lines. Pak. J. Bot., 37: 131-139.

Subekti NA, H Sembiring, D Nugraha and B Priatmojo, 2020. Yield of different rice cultivars at two levels of soil salinity under seawater intrusion in West Java, Indonesia. Biodivers. J., 21: 14-20.

Sexcion PSH, JA Egdane, AM Ismail and MLD Sese, 2009. Morpho-physiological traits associated with tolerance of salinity during seedling stage in rice *Oryza sativa* L. Philipp. J. Crop Sci., 34: 27-37.

SRDI. 2012. Saline Soils of Bangladesh. Ministry of Agriculture, Bangladesh, pp. 50–79.

Sweet WJ, JC Morrison, JML abaritch and MA Matthews, 1990. Altered synthesis and composition of cell wall of grapevines *Vitis vinifera* L. during expression and growth inhibiting water deficits. Plant Cell Physiol., 31: 407-414.

Talat A, K Nawaz, K Hussian, KH Bhatti, EH Siddiqi, A Khalid, S Anwer and MU Sharif, 2013. Foliar application of proline for salt tolerance of two wheat *Triticum aestivum* L. cultivars. World Appl. Sci. J., 22: 547-554.

Tania M, MA Khan and J Fu, 2014. Epithelial to mesenchymal transition inducing transcription factors and metastatic cancer. Tumor Biol., 35: 7335–7342.

Turan UA, AHA Elkarim, N Taban and S Taban, 2010. Effect of salt stress on growth and ion distribution and accumulation in shoot and root of maize plant. Afr. J. Agric. Res., 5: 584-588.

Zhou J, X Wang, Y Jiao, Y Qin, X Liu, K He and XW Deng, 2007. Global genome expression analysis of rice in response to drought and high-salinity stresses in shoot, flag leaf, and panicle. Plant Mol. Biol., 63: 591-608.

Zhu JK, 2001. Plant salt tolerance. Trends in Plant Sci., 6: 66-71.

Zeng L and MC Shannon, 2000. Salinity effects on seedling growth and yield components of rice. Crop Sci., 40: 996-1003.