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*Article*

# Improvement of salinity tolerance in rice by efficient management of potassium and zinc fertilizers

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**Abstract:** Appropriate nutrient management could increase crop productivity in saline areas by reducing the harmful effects of soil salinity. A field experiment was carried out at farmer's field of Botiaghata, Khulna to investigate the mitigation of soil salinity by efficient management of potassium and zinc fertilizers in rice. BRRI dhan53, a salt-tolerant rice cultivar during aman season, was used as a test crop. The experiment was laid out in a randomized complete block design with three replications where sixteen treatment combinations were used in a factorial arrangement. Potassium and zinc nutrients were supplied from potassium sulphate and zinc sulphate, respectively and they were applied in two splits, first split during final land preparation and second split at maximum tillering stage. Recommended doses of N, P and S fertilizers were applied to all the experimental plots. Results revealed that plant height, panicle length, number of effective tillers and grains per panicle increased significantly due to application of K and Zn fertilizers. All the yield contributing parameters showed higher values in $T_{15}$ ($K_{200}Zn_{200}$) treatment compared to other treatments. Grain and straw yields of BRRI dhan53 responded significantly to the different treatment combinations. The highest grain yield (4.46 t/ha) was obtained in $T_{15}$ ($K_{200}Zn_{200}$) treatment and the highest straw yield (6.27 t/ha) was also obtained in the same treatment. Higher doses of potassium and zinc also increased nutrient uptake (N, P, S and Zn) by BRRI dhan53. The $K^+/Na^+$ ratio was also found higher in grain (0.319) and straw (0.301) in $T_{15}$ treatment. Therefore, result of the experiment indicated that application of higher doses of K and Zn fertilizers could alleviate the adverse effects of salinity in rice production by increasing nutrient uptake and maintaining higher $K^+/Na^+$ ratio.

**Keywords:** nutrient uptake; potassium; rice; salinity tolerance; zinc

## 1. Introduction

Soil salinity is a major concern to agriculture all over the world because it affects almost all plant functions. Agricultural productivity is severely affected by soil salinity, and the damaging effect of salt accumulation in agricultural soils has become an important environmental concern (Jaleel *et al.*, 2007). In addition, increased salinity of arable land is expected to have devastating global effects, resulting in up to 50% land losses by the middle of the twenty first century (Mahajan and Tuteja, 2005). Approximately 7% of the world's land area, 20% of the world's cultivated land and nearly half of the irrigated land are affected by soil salinity (FAO, 2008; Mali *et al.*, 2012). An advance study shows that soil salinity has affected more than 100 million hectares of agricultural land world-wide (Athar and Ashraf, 2009). Although agro-climatic condition in Bangladesh is favorable for rice cultivation, rice production is being hampered in some areas of the country due to adverse situation such as salinity problem in coastal areas. The coastal areas of Bangladesh cover about 30% of the cultivable lands of the country. Out of 2.86 million hectares of coastal and offshore lands, about 1.06 million hectares are affected by varying degrees of salinity (SRDI, 2010). There is a report that coastal regions of

Bangladesh are quite lower in soil fertility (Haque, 2006). Increased soil salinity due to climate change would significantly reduce food grain production.

Salinity imposes both ionic toxicity and osmotic stress to plants (Zhu, 2003). Salt stress disturbs cytoplasmic $K^+/Na^+$ homeostasis, causing an increase in $Na^+$ to $K^+$ ratio in the cytosol (Zhu, 2003). In most of the cases, the negative effects of salinity have been attributed to increase in $Na^+$ and $Cl^-$ ions in different plants hence these ions produce the critical conditions for plant survival by intercepting different plant mechanisms. Although both $Na^+$ and $Cl^-$ are the major ions which produce many physiological disorders in plants, $Cl^-$ is the most dangerous (Tavakkoli *et al.*, 2010). The outcome of these effects may cause membrane damage, nutrient imbalance, altered levels of growth regulators, enzymatic inhibition and metabolic dysfunction, including photosynthesis which ultimately leads to plant death (Mahajan and Tuteja, 2005; Hasanuzzaman *et al.*, 2011).

Chemical amendments are found to be effective in the amelioration of saline soils. Mineral nutrients play critical roles in plant stress resistance (Cakmak, 2005; Marschner, 2012). Salt tolerance is directly associated with K contents because of its involvement in osmotic regulation and competition with Na. Plant salt tolerance requires not only adaptation to $Na^+$ toxicity but also the acquisition of abundant $K^+$ whose uptake by the plant cell is affected by high external $Na^+$ concentrations (Zhang *et al.*, 2010). Zinc plays an important role in many biochemical functions within plants. Zinc has been shown to improve salinity tolerance in tomato (El-Sherif *et al.*, 1990). Removal of exchangeable Na necessitates application of K and Zn to remove Na from the soil's exchange sites. Therefore, it can be possible to improve crop productivity in saline soils by proper fertilizer management particularly efficient management of K and Zn fertilizers with suitable high yielding crop varieties.

## 2. Materials and Methods

The field experiment was carried out at the farmer's field of Botiaghata, Khulna which belongs to the Agro-ecological Zone of the Ganges Tidal Floodplain (AEZ 13). The land was prepared by repeated ploughing and cross ploughing followed by laddering. A salt-tolerant rice variety of Aman season, BRRI dhan53 was used as a test crop. Thirty-day-old rice seedlings were transplanted in the experimental fields at a spacing of 25 cm ×20 cm.

The experiment was arranged in a factorial manner with three replications in RCBD. Treatments were the combination of four levels of K (0, 100, 150 and 200% of recommended fertilizer dose- RFD) and four levels of Zn (0, 100, 150 and 200% of RFD). There were sixteen treatment combinations *viz.* $T_0$= $K_0Zn_0$, $T_1$= $K_0Zn_{100}$, $T_2$= $K_0Zn_{150}$, $T_3$= $K_0Zn_{200}$, $T_4$= $K_{100}Zn_0$, $T_5$= $K_{100}Zn_{100}$, $T_6$= $K_{100}Zn_{150}$, $T_7$= $K_{100}Zn_{200}$, $T_8$ = $K_{150}Zn_0$, $T_9$ = $K_{150}Zn_{100}$, $T_{10}$ = $K_{150}Zn_{150}$, $T_{11}$ = $K_{150}Zn_{200}$, $T_{12}$ = $K_{200}Zn_0$, $T_{13}$ = $K_{200}Zn_{100}$, $T_{14}$ = $K_{200}Zn_{150}$ and $T_{15}$ = $K_{200}Zn_{200}$.

Potassium and zinc nutrients were supplied from potassium sulphate and zinc sulphate, respectively. K and Zn fertilizers were applied in two split doses, first dose at final land preparation and second dose at maximum tillering stage. Recommended doses of N, P and S fertilizers were applied to all experimental plots. The salinity levels of water and soil were monitored from the transplanting to the harvest stage. The crops were harvested at full maturity. Different plant parameters including grain and straw yields were recorded after harvesting.

Plant samples were analyzed for N, P, S, Na, K and Zn contents following standard methods in the Department of Soil Science of BAU and BINA. Data were analyzed statistically by ANOVA. The significance of differences between mean values was evaluated by Duncan's Multiple Range Test (DMRT). The software package, MStatC was followed for statistical analysis.

## 3. Results and Discussion

### 3.1. Effects of potassium and zinc on growth and yield components of rice (BRRI dhan53)

Soil salinity caused a significant decrease in growth and yield components of BRRI dhan53 (Table 1). All of the K and Zn treatments resulted in significantly higher plant height, panicle length, number of effective tillers and number of grains per panicle over the control treatment ($T_0$= $K_0Zn_0$). The maximum plant height (128.7 cm) was obtained in treatment $T_{15}$ ($K_{200}Zn_{200}$), which was statistically similar with treatments $T_7$, $T_{10}$, $T_{11}$, $T_{12}$ $T_{13}$ and $T_{14}$. The lowest plant height (121.4 cm) was observed in $T_0$ ($K_0Zn_0$) treatment (Table 1). The highest panicle length was found in treatment $T_{15}$ ($K_{200}Zn_{200}$) and the lowest panicle length was 23.67 cm found in control ($T_0$= $K_0Zn_0$) where no K and Zn was applied (Table 1). Application of potassium and zinc also significantly increased number of effective tillers per hill. The lowest effective tillers per hill was found in control $T_0$ ($K_0Zn_0$) and the highest effective tillers per hill was found in treatment $T_{15}$ ($K_{200}Zn_{200}$). Plants exposed to salinity drastically decreased filled grains of BRRI dhan53 rice. Results revealed that application of K and Zn fertilizers significantly increased the number of grains per panicle of BRRI dhan53 under saline conditions. The lowest number of grains per panicle was 106.9 found in control $T_0$ ($K_0Zn_0$) and the highest number of grains per panicle was 140.3 found in treatment $T_{15}$ ($K_{200}Zn_{200}$). It was observed that application of K and Zn fertilizers did not significantly influence 1000-grain weight of BRRI dhan53 under salt stress conditions (Table 1). Similar to the results, Kibria *et al.* (2015a) showed that application of potassium and zinc increased different yield components in salt tolerant rice variety BINA dhan-10. These results were also in agreement with Zafar *et al.* (2016) who conducted an experiment on wheat and found that application of potassium and zinc through soil and foliar means significantly improved the plant height, productive tillers per plant, fertile spikelets and spike and spike length under saline condition.

### 3.2. Effects of potassium and zinc on the grain and straw yields of rice (BRRI dhan53)

#### 3.2.1. Grain yield

A significant variation in grain yield of BRRI dhan53 was observed due to application of K and Zn fertilizers under saline conditions (Figure 1). Application of higher doses of K and Zn ($T_{15}$-$K_{200}Zn_{200}$) produced the highest grain yield (4.46 t/ha) which was statistically different from other treatments. The second highest grain yield was recorded in the treatment $T_{14}$ ($K_{200}Zn_{150}$). On the other hand, control treatment $T_0$ ($K_0Zn_0$) showed the lowest grain yield (3.30 t/ha) (Figure 1). Zafar *et al.* (2017) also found that potassium and zinc treatments in salt-stress conditions significantly increased grain yield of wheat. Increased biomass production was also observed in an experiment conducted by Singh *et al.* (2015) where salt-susceptible variety of wheat was treated with zinc under saline condition.

#### 3.2.2. Straw yield

Straw yield of rice responded significantly due to application of K and Zn fertilizers under saline condition (Figure 1). All the K and Zn treatments gave significantly higher straw yield over control $T_0$ ($K_0Zn_0$) treatment. The highest straw yield (6.27 t/ha) was obtained from treatment $T_{15}$ ($K_{200}Zn_{200}$) which was significantly different from other treatments. Control treatment $T_0$ ($K_0Zn_0$) produced the lowest straw yield (4.91 t/ha) which was identical with $T_1$ ($K_0Zn_{100}$) treatment (Figure 1). In agreement with our results, Kausar *et al.* (2016); Kamrani *et al.* (2013); Heidari and Jamshid (2010) found that grain and straw yields of wheat increased due to application of potassium and zinc fertilizers at higher doses in salt-stress conditions.

### 3.3. Nutrient uptake by rice plant (BRRI dhan53)

#### 3.3.1. Nitrogen uptake

Results shown in Table 2 indicate that nitrogen uptake by BRRI dhan53 influenced significantly due to application of K and Zn fertilization under saline conditions. The highest N uptake (52.81 kg/ha) by grain was obtained in treatment $T_{15}$ ($K_{200}Zn_{200}$), which was statistically different from other treatments. The lowest N uptake (34.06 kg/ha) by grain was observed in $T_0$ ($K_0Zn_0$) treatment (Table 2). Nitrogen uptake by straw also showed a significant variation due to different treatments. The highest N uptake by straw was obtained from treatment $T_{15}$ ($K_{200}Zn_{200}$), which was statistically higher than all other treatments. The lowest N uptake by straw was found in treatment $T_0$ ($K_0Zn_0$) (Table 2). Total N uptake was also influenced due to application of K and Zn fertilizers to saline soils (Table 2). The highest total N uptake (71.87 kg/ha) was recorded in treatment $T_{15}$ ($K_{200}Zn_{200}$) which was statistically different from other treatments. The lowest total N uptake (47.81 kg/ha) was found in control treatment $T_0$ ($K_0Zn_0$). The current results are in a good accordance with those reported by Zafar *et al.* (2017), Kibria *et al.* (2015a) and Rahman *et al*. (2005) who also concluded that application of zinc increased the nutrient uptake by plant in salt-stress conditions.

#### 3.3.2. Phosphorus uptake

A significant variation in phosphorus uptake by grain and straw was observed due to application of K and Zn fertilizers under saline condition (Table 2). The highest P uptake (8.55 kg/ha) by grain was recorded in treatment $T_{15}$ ($K_{200}Zn_{200}$), which was statistically similar to treatments $T_{13}$ and $T_{14}$. The highest P uptake by straw was also recorded in treatment $T_{15}$ ($K_{200}Zn_{200}$), which was statistically higher than all other treatments. The highest total P uptake (16.72 kg/ha) was obtained in treatment $T_{15}$ ($K_{200}Zn_{200}$) which was statistically identical to $T_{13}$ and $T_{14}$ treatments. The lowest total P uptake was observed in $T_1$ which was statistically identical with control treatment $T_0$ ($K_0Zn_0$). Similar to the results, Kausar *et al.* (2016) also reported that the uptake and accumulation of nutrients like phosphorus increased in plants subjected with K fertilizer application under saline environments. Kibria *et al.* (2015b) also found an increased phosphorus uptake in rice due to application of potassium fertilizers in salt-stress conditions.

### 3.3.3. Sulphur uptake

Results in Table 3 demonstrate that sulphur uptake by grain and straw differed significantly due to different treatments of potassium and zinc. The highest S uptake by grain was recorded in treatment $T_{15}$ ($K_{200}Zn_{200}$), which was statistically similar to treatments $T_{13}$ and $T_{14}$. The lowest S uptake was recorded in $T_0$ ($K_0Zn_0$) treatment which was statistically identical to $T_1$ and $T_2$ treatments. The highest amount of S uptake by straw was recorded in treatment $T_{15}$ ($K_{200}Zn_{200}$), which was statistically higher than all other treatments. The lowest S uptake by straw was found in treatment control treatment $T_0$ ($K_0Zn_0$). The highest amount of total S uptake (19.68 kg/ha) was recorded in treatment $T_{15}$ ($K_{200}Zn_{200}$) which was statistically identical with $T_{14}$. On the other hand, the lowest total S uptake (12.9 kg/ha) was observed in $T_0$ ($K_0Zn_0$) treatment which was statistically similar to $T_1$ and $T_2$ treatments (Table 3). In agreement with this result, Kibria *et al.* (2015b) found that the nutrient (NPS) uptake in rice increased by application of potassium fertilizer under saline conditions. Similar results were also reported by Wakeel (2013) and Maqsood *et al.* (2008) who found that application of higher doses of potassium helped plant to increase the uptake of nutrients by interacting with sodium.

### 3.3.4. Zinc uptake

Though uptake of Zn in grain did not increased significantly under saline conditions, Zn uptake by straw of BRRI dhan53 was significantly influenced due to application of K and Zn fertilizers (Table 3). The highest Zn uptake by grain was observed in $T_{15}$ ($K_{200}Zn_{200}$) treatment while the lowest Zn uptake was recorded in treatment $T_0$ ($K_0Zn_0$). The highest Zn uptake by straw was recorded in treatment $T_{15}$ ($K_{200}Zn_{200}$) which was statistically identical with $T_{11}$ and $T_{14}$ treatments. The lowest Zn uptake by straw was observed in control treatment ($K_0Zn_0$) which was statistically similar with $T_4$ treatment (Table 3). The highest total Zn uptake (0.351 kg/ha) was obtained in treatment $T_{15}$ which was statistically different from other treatments. The lowest total Zn uptake (0.231 kg/ha) was observed in $T_0$ ($K_0Zn_0$) treatment which was statistically identical with $T_4$ treatment (Table 3). The results are in a good conformity with the results obtained from an experiment conducted by Singh *et al.* (2015) where salt-susceptible variety of wheat was treated with zinc under saline condition. Shahriaripour *et al.* (2010) also found that Zn uptake increased in plant when Zn fertilizer was applied at higher doses.

## 3.4. Effects of potassium and zinc on $K^+/Na^+$ ratio of rice (BRRI dhan53)

Under saline conditions, $K^+/Na^+$ ratio in rice grain was significantly influenced due to application of K and Zn fertilizers (Figure 2). All the K and Zn treatments gave significantly higher $K^+/Na^+$ ratio over the control $T_0$ ($K_0Zn_0$) treatment (Figure 2). Among the treatments, $T_{15}$ ($K_{200}Zn_{200}$) and $T_{10}$ ($K_{150}Zn_{150}$) treatments demonstrated higher amount of $K^+/Na^+$ ratio (0.319) which was identical with $T_7$, $T_9$, $T_{11}$, $T_{12}$ and $T_{13}$ treatments whereas control treatment $T_0$ ($K_0Zn_0$) showed the lowest $K^+/Na^+$ ratio (0.208). $K^+/Na^+$ ratio in rice straw also responded significantly due to application of K and Zn fertilizers under saline condition (Figure 2). Maximum $K^+/Na^+$ ratio (0.301) was obtained from treatment $T_{15}$ ($K_{200}Zn_{200}$) which was identical with $T_{13}$ ($K_{200}Zn_{100}$) treatment whereas control treatment $T_0$ ($K_0Zn_0$) showed the lowest $K^+/Na^+$ ratio (0.203). Similar to the results, Kibria *et al.* (2015a) found an increased $K^+/Na^+$ ratio in salt-tolerant rice variety BINA dhan-10 through addition of potassium and zinc fertilizers at higher doses. Abbasi *et al.* (2015) also found that addition of potassium significantly alleviates harmful effect of salinity in maize by enhancing $K^+/Na^+$ ratio. Wakeel (2013) and Zhang *et al.* (2010) also found that higher doses of potassium increased K uptake and decreased Na uptake in saline condition.

**Table 1. Effects of potassium and zinc on growth and yield components of rice (BRRI dhan53).**

| Treatments | Plant height (cm) | Panicle length (cm) | Number of effective tillers per hill | Number of grains per panicle | 1000-grain weight (g) |
|---|---|---|---|---|---|
| $T_0 = K_0Zn_0$ | 121.4f | 23.67h | 10.27f | 106.9h | 23.2 |
| $T_1 = K_0Zn_{100}$ | 124.4e | 23.93gh | 11.40e | 116.2g | 23.3 |
| $T_2 = K_0Zn_{150}$ | 126.0bcde | 24.13fgh | 11.53e | 122.0f | 23.4 |
| $T_3 = K_0Zn_{200}$ | 126.5bcd | 24.40fgh | 12.60d | 128.4e | 23.7 |
| $T_4 = K_{100}Zn_0$ | 124.4e | 24.20fgh | 11.60e | 129.6de | 23.8 |
| $T_5 = K_{100}Zn_{100}$ | 125.5cde | 25.87bcd | 11.80e | 132.0cde | 23.8 |
| $T_6 = K_{100}Zn_{150}$ | 126.8bc | 26.47abc | 12.73cd | 134.1bcd | 23.8 |
| $T_7 = K_{100}Zn_{200}$ | 127.0abc | 26.73ab | 12.93bcd | 137.7abc | 23.9 |
| $T_8 = K_{150}Zn_0$ | 125.0de | 25.00def | 11.67e | 127.6e | 23.5 |
| $T_9 = K_{150}Zn_{100}$ | 126.0bcde | 25.60cde | 11.87e | 135.1abcd | 23.8 |
| $T_{10} = K_{150}Zn_{150}$ | 127.3ab | 26.53abc | 13.07abcd | 135.3abcd | 23.9 |
| $T_{11} = K_{150}Zn_{200}$ | 127.2abc | 27.00a | 13.20abcd | 138.3ab | 23.9 |
| $T_{12} = K_{200}Zn_0$ | 127.1abc | 24.40efg | 13.33abcd | 127.4e | 23.5 |
| $T_{13} = K_{200}Zn_{100}$ | 127.2abc | 26.80ab | 13.47abc | 138.4ab | 23.8 |
| $T_{14} = K_{200}Zn_{150}$ | 127.4ab | 27.20a | 13.53ab | 138.7ab | 23.9 |
| $T_{15} = K_{200}Zn_{200}$ | 128.7a | 27.33a | 13.80a | 140.3a | 24.1 |
| SE (±) | 0.529 | 0.304 | 0.231 | 1.81 | NS |

Same letter in a column represents insignificant difference at $p < 0.05$,
SE = Standard errors of means,
NS = Not significant

**Table 2. Effects of different level of potassium and zinc on N and P uptake by BRRI dhan53.**

| Treatments | N uptake (kg/ha) | | | P uptake (kg/ha) | | |
|---|---|---|---|---|---|---|
| | Grain | Straw | Total | Grain | Straw | Total |
| $T_0 = K_0Zn_0$ | 34.06h | 13.76ef | 47.81j | 4.430f | 6.46gh | 10.89fg |
| $T_1 = K_0Zn_{100}$ | 39.98def | 13.36f | 53.35fghi | 4.590f | 6.06i | 10.65g |
| $T_2 = K_0Zn_{150}$ | 38.23fg | 14.58de | 52.80ghi | 5.430e | 6.31hi | 11.74f |
| $T_3 = K_0Zn_{200}$ | 40.61de | 15.02d | 55.63efg | 5.330e | 6.43gh | 11.76f |
| $T_4 = K_{100}Zn_0$ | 38.84efg | 11.33h | 50.17ij | 6.810c | 6.70fg | 13.50cde |
| $T_5 = K_{100}Zn_{100}$ | 41.25cd | 15.15d | 56.40def | 6.220d | 6.85ef | 13.06e |
| $T_6 = K_{100}Zn_{150}$ | 38.20fg | 12.43g | 50.64hij | 6.190d | 6.98def | 13.17de |
| $T_7 = K_{100}Zn_{200}$ | 41.92cd | 17.26b | 59.19bcd | 7.150bc | 7.09de | 14.24bc |
| $T_8 = K_{150}Zn_0$ | 36.65g | 15.26d | 51.91hi | 7.630b | 7.28cd | 14.90b |
| $T_9 = K_{150}Zn_{100}$ | 37.60g | 16.12c | 53.78fgh | 6.940c | 7.10de | 14.04bcd |
| $T_{10} = K_{150}Zn_{150}$ | 38.94efg | 14.49de | 53.43fghi | 6.780c | 7.47bc | 14.25bc |
| $T_{11} = K_{150}Zn_{200}$ | 41.63cd | 16.83bc | 58.46bcde | 7.090bc | 7.65b | 14.75b |
| $T_{12} = K_{200}Zn_0$ | 41.78cd | 16.22c | 58.00cde | 7.530b | 7.11de | 14.65b |
| $T_{13} = K_{200}Zn_{100}$ | 44.48b | 17.04bc | 61.52b | 8.480a | 7.50bc | 15.98a |
| $T_{14} = K_{200}Zn_{150}$ | 43.04bc | 17.25b | 60.29bc | 8.920a | 7.67b | 16.58a |
| $T_{15} = K_{200}Zn_{200}$ | 52.81a | 19.06a | 71.87a | 8.550a | 8.17a | 16.72a |
| SE (±) | 0.718 | 0.294 | 1.02 | 0.178 | 0.103 | 0.287 |

Same letter in a column represents insignificant difference at $p < 0.05$

**Table 3. Effects of potassium and zinc on S and Zn uptake by BRRI dhan53.**

| Treatments | S uptake (kg/ha) | | | Zn uptake (kg/ha) | | |
|---|---|---|---|---|---|---|
| | Grain | Straw | Total | Grain | Straw | Total |
| $T_0$= $K_0Zn_0$ | 4.83h | 8.07f | 12.90h | 0.081 | 0.149h | 0.231i |
| $T_1$= $K_0Zn_{100}$ | 5.14gh | 8.29f | 13.43gh | 0.098 | 0.160g | 0.258h |
| $T_2$= $K_0Zn_{150}$ | 5.36fgh | 8.71e | 14.07fgh | 0.101 | 0.188ef | 0.289fg |
| $T_3$= $K_0Zn_{200}$ | 5.85ef | 8.46ef | 14.31fg | 0.105 | 0.205bc | 0.310cd |
| $T_4$= $K_{100}Zn_0$ | 6.05def | 8.47ef | 14.52fg | 0.091 | 0.147h | 0.239i |
| $T_5$= $K_{100}Zn_{100}$ | 5.61efg | 9.20d | 14.81f | 0.101 | 0.179f | 0.283g |
| $T_6$= $K_{100}Zn_{150}$ | 6.58cd | 8.47ef | 15.06ef | 0.108 | 0.193de | 0.301de |
| $T_7$= $K_{100}Zn_{200}$ | 7.38b | 10.1c | 17.50bcd | 0.118 | 0.206bc | 0.320c |
| $T_8$ = $K_{150}Zn_0$ | 6.12de | 10.1c | 16.27de | 0.096 | 0.159g | 0.253h |
| $T_9$ = $K_{150}Zn_{100}$ | 7.650ab | 10.6b | 18.33bc | 0.111 | 0.185ef | 0.296ef |
| $T_{10}$ = $K_{150}Zn_{150}$ | 7.660ab | 11.0b | 18.74ab | 0.116 | 0.198cd | 0.311cd |
| $T_{11}$ = $K_{150}Zn_{200}$ | 7.020bc | 10.2c | 17.27cd | 0.120 | 0.213ab | 0.331b |
| $T_{12}$ = $K_{200}Zn_0$ | 7.160bc | 10.6b | 17.83bc | 0.101 | 0.153gh | 0.254h |
| $T_{13}$ = $K_{200}Zn_{100}$ | 7.570ab | 9.99c | 17.56bcd | 0.117 | 0.194de | 0.310cd |
| $T_{14}$ = $K_{200}Zn_{150}$ | 7.750ab | 11.0b | 18.78ab | 0.122 | 0.216a | 0.339b |
| $T_{15}$ = $K_{200}Zn_{200}$ | 8.190a | 11.4a | 19.68a | 0.130 | 0.220a | 0.351a |
| SE (±) | 0.223 | 0.131 | 0.428 | NS | 0.0032 | 0.0035 |

Same letter in a column represents insignificant difference at $p< 0.05$
NS = Not significant

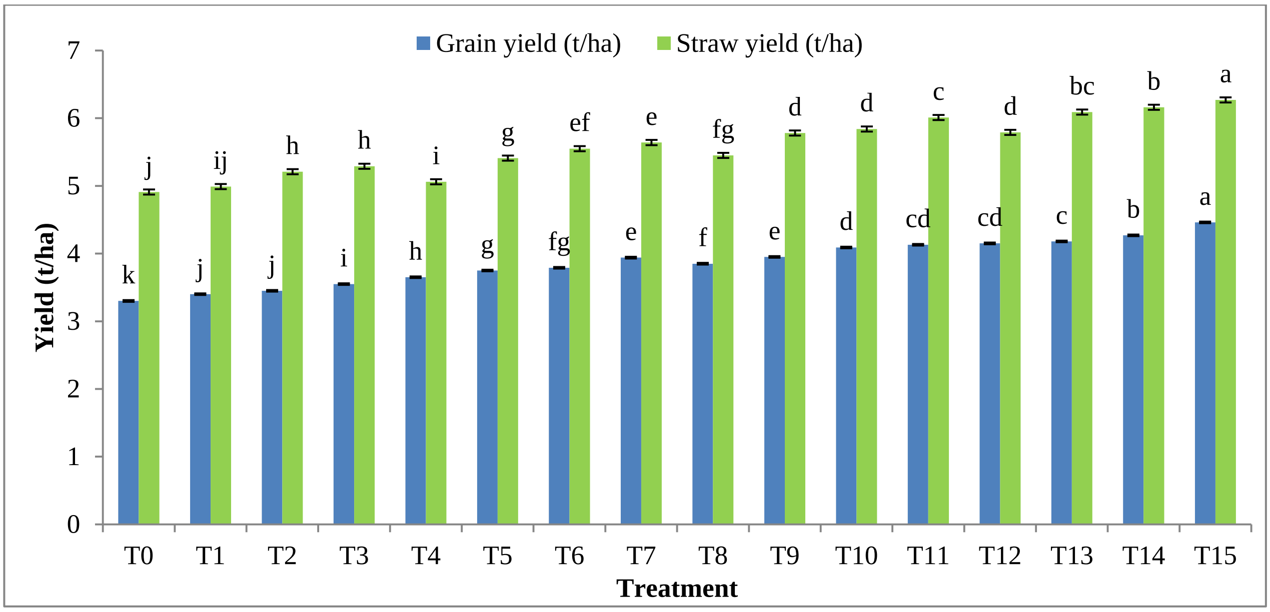


**Figure 1. Effects of potassium and zinc on grain and straw yield of rice (BRRI dhan53). Values represent the mean±SE of three replications. For the same parameter, bars with the same letters are not significantly different at $p< 0.05$.**

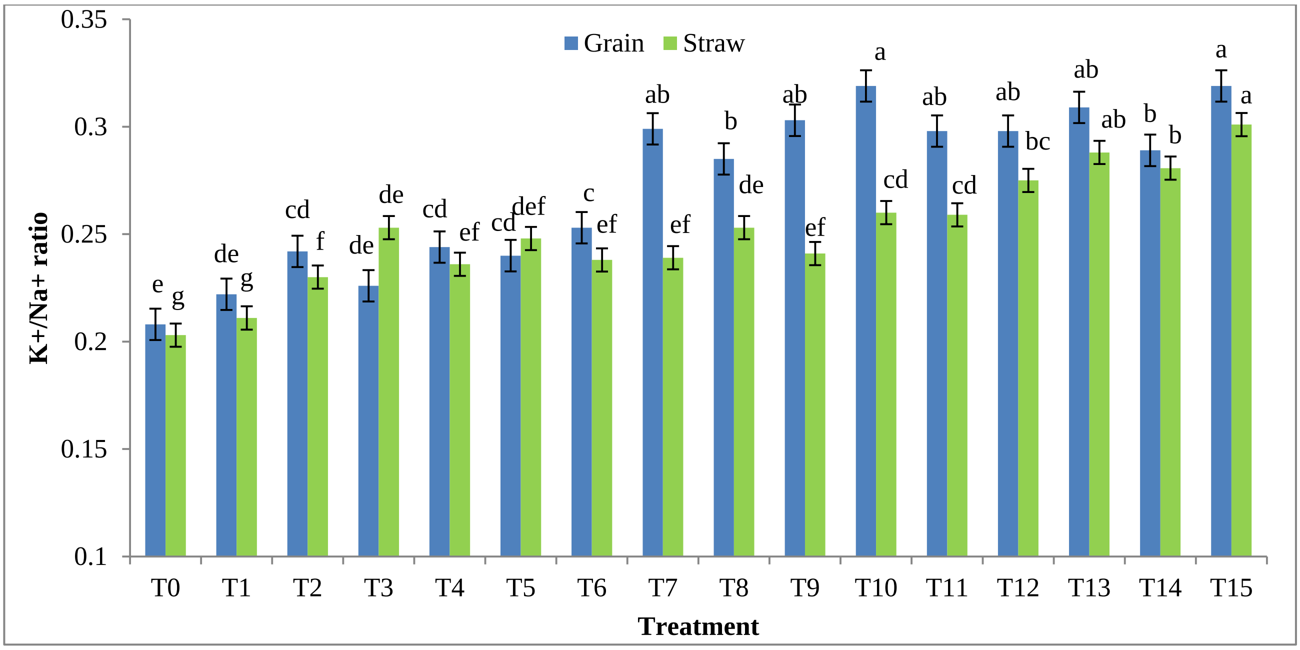


**Figure 2. Effects of potassium and zinc on $K^+/Na^+$ ratio in rice (BRRI dhan53). Values represent the mean±SE of three replications. For the same parameter, bars with the same letters are not significantly different at $p< 0.05$.**

## 4. Conclusions

Soil salinity caused a significant reduction in growth and yield of rice as it affected nutrient uptake and $K^+/Na^+$ ratio. Improved growth and yield of rice by application of K and Zn fertilizers were accompanied with increased $K^+/Na^+$ ratio and nutrient uptake under salinity conditions. From this study it can be concluded that higher doses of K and Zn fertilization are suitable for rice cultivation in saline areas. However, efficient management of K and Zn fertilizers at 200% of recommended fertilizer dose in two splits with salt-tolerant high yielding rice cultivar could be practiced to improve crop productivity in saline areas.

**Conflict of interest**

None to declare.

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