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ALLEVIATION OF SOIL SALINITY IN RICE BY POTASSIUM AND ZINC FERTILIZATION

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ABSTRACT

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The field experiment was conducted to investigate the mitigation of soil salinity in rice by application of potassium and zinc fertilizers. Salt-tolerant cultivar BINA dhan-10 was used as test crop. In this experiment sixteen treatment combinations were used and the experiment was laid out in a randomized complete block design (RCBD) in a factorial arrangement with three replications. Potassium sulphate and zinc sulphate were used to supply K and Zn nutrients, respectively, and they were applied in two split doses, first dose during final land preparation and second dose at maximum tillering stage. All experimental plots received recommended doses of N, P and S fertilizers. Plant height, panicle length, effective tillers, grains per panicle and 1000-grain weight was significantly increased due to application of K and Zn fertilizers. Most of the yield contributing parameters showed higher values in T_{14} and T_{15} treatments compared to other treatments. Grain and straw yields of BINA dhan-10 responded significantly with the different treatment combinations. The highest grain yield (4.33 t/ha) was obtained in T_{14} ($K_{200}Zn_{150}$) and T_{15} ($K_{200}Zn_{200}$) treatments whereas the highest straw yield (5.35 t/ha) was obtained in T_{14} treatment, which was higher than all other treatments. An increase in grain yield by 22% over control was observed in both T_{14} and T_{15} treatments and straw yield showed 22% and 14% increase over the control in T_{14} and T_{15} treatments, respectively. Nutrient (NPS and Zn) uptake was higher when K and Zn were applied at higher doses. The K^+/Na^+ ratio was also found higher in grain (0.42) and straw (0.44) in T_{15} treatment. Therefore, it may be concluded that application of higher doses of K and Zn fertilizers could alleviate the adverse effects of salinity in rice by increasing nutrient uptake and maintaining higher K^+/Na^+ ratio.

Key words: *K^+/Na^+ ratio, nutrient uptake, soil salinity, nutrient management*

INTRODUCTION

Soil salinity is a major concern to agriculture all over the world. More than 6% of the world’s land and one third of the world's irrigated land are affected by salinity (FAO 2008). Salinity imposes both ionic toxicity and osmotic stress to plants, leading to nutritional disorder and oxidative stress (Zhu 2003). Salt stress disturbs cytoplasmic K^+/Na^+ homeostasis, causing an increase in Na^+ to K^+ ratio in the cytosol (Zhu 2003). Salt stress causes increased uptake of Na^+ and Cl^-, and decreased uptake of essential cations particularly K^+ (Khan *et al.* 2003).

Agriculture is the single most important sector of Bangladesh’s economy. Climate change is widely recognized as the most serious environmental threat to agriculture. Climate change causes sea level rise, affecting coastal areas of Bangladesh. Coastal areas of Bangladesh cover more than 30% of the cultivable lands of the country. About 1.06 million hectares of arable lands are affected by salinity (SRDI 2010). Increased soil salinity due to climate change would significantly reduce food grain production. The dominant crop grown in saline areas is local transplanted Aman rice with low yields. Agricultural land use in these areas is very poor which is much lower than country’s average cropping intensity.

There is a report that coastal regions of Bangladesh are quite lower in soil fertility (Haque 2006). Appropriate management practices with suitable crop cultivars having higher yield potential could contribute to the improvement of crop production in saline soils. Plants have developed a wide range of mechanisms to resist a variety of stressed conditions. Mineral nutrients play critical roles in plant stress resistance (Cakmak 2005; Marschner 2012). Salt tolerance is directly associated with potassium contents because of its involvement in osmotic regulation and competition with Sodium. 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).

Chemical amendments are found to be effective in the amelioration of saline soils. Removal of exchangeable Na necessitates application of K and Zn to remove Na from the soil's exchange sites. There are increasing evidences that application of K and Zn fertilizers reduce the adverse effects of salinity in a variety of crops including rice (Idrees *et al*. 2004; Zayed *et al.* 2007; Maqsood *et al.* 2008; Heidari and Jamshid, 2010; Shahriaripour *et al.* 2010; Ebrahimi *et al.* 2012; Kamrani 2013; Singh *et al*. 2013; Wakeel 2013). Unfortunately no systematic information is available in Bangladesh about the role of K and Zn in alleviating detrimental effects of soil salinity on crop plants. Rice is central to Bangladesh's economy and agriculture, accounting for nearly 18% GDP (BBS 2012). There is a great possibility to increase rice production in saline areas with proper nutrient management.

Therefore, the improvement of crop production in saline soils could be achieved by balanced fertilization particularly efficient management of K and Zn fertilizers with suitable high yielding crop varieties. This research work was undertaken to minimize the adverse effects of salinity on rice by proper management of mineral nutrients particularly potassium and zinc and examine the effects of potassium and zinc fertilizers on K^+/Na^+ ratio and nutrient uptake by rice under salinity conditions.

MATERIALS AND METHODS

The field experiment was carried out at the farmer's field of the salinity affected areas of Khulna district. The land was prepared by repeated ploughing and cross ploughing followed by laddering. The experiment was done in boro season as salinity problem is much higher in dry season. Salt-tolerant rice variety BINA dhan-10 (Boro) was used as test crop. Seedlings of rice were transplanted in the experimental fields during boro season.

The experiment was laid out in a randomized complete block design in a factorial arrangement with three replications. Treatments were the combination of different levels (0-200% of recommended fertilizer dose-RFD) of K and Zn. Four levels of K (0, 100, 150 and 200% of RFD) and four levels of Zn (0, 100, 150 and 200% of RFD) were employed. There were following sixteen treatment combinations

$T_0 = K_0Zn_0$	$T_8 = K_{150}Zn_0$
$T_1 = K_0Zn_{100}$	$T_9 = K_{150}Zn_{100}$
$T_2 = K_0Zn_{150}$	$T_{10} = K_{150}Zn_{150}$
$T_3 = K_0Zn_{200}$	$T_{11} = K_{150}Zn_{200}$
$T_4 = K_{100}Zn_0$	$T_{12} = K_{200}Zn_0$
$T_5 = K_{100}Zn_{100}$	$T_{13} = K_{200}Zn_{100}$
$T_6 = K_{100}Zn_{150}$	$T_{14} = K_{200}Zn_{150}$
$T_7 = K_{100}Zn_{200}$	$T_{15} = K_{200}Zn_{200}$

The K and Zn were supplied from sulphate of potash and zinc sulphate fertilizers, respectively. K and Zn fertilizers were applied in two split doses, first dose at final land preparation and second dose at maximum tillering stage. All experimental plots received recommended doses of N, P and S fertilizers. Irrigation, intercultural operations and other management practices were performed as and when required. The water salinity and soil salinity were monitored from the transplanting to the harvest stage. The crops were harvested at full maturity. Grain and straw yields and different plant parameters were recorded after harvesting.

Plant and soil samples were analyzed in the Department of Soil Science of BAU and BINA. Plant samples were analyzed for N, P, S, Na, K and Zn contents following standard methods. 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.

RESULTS AND DISCUSSION

Effects of potassium and zinc on yield components of rice (BINA dhan-10)

Plant height, panicle length, number of effective tillers, number of grains per panicle and 1000-grain weight was significantly influenced due to different treatments (Table 1). All the K and Zn treatments gave significantly higher plant height, panicle length, number of effective tillers, number of grains per panicle and 1000-grain weight over the control treatment (T_0-K_0Zn_0). The highest plant height (127.7cm) was recorded for the treatment T_{15} ($K_{200}Zn_{200}$), T_{14} ($K_{200}Zn_{150}$), T_{10} ($K_{150}Zn_{150}$) and T_6 ($K_{100}Zn_{150}$) and the lowest (126.5 cm) was recorded for T_0 (K_0Zn_0) treatment (Table 1). The highest panicle length (27.9 cm), number of grains per panicle (121.3) and 1000-grain weight (25.9 g) were recorded for the treatmentT_{14} ($K_{200}Zn_{150}$) and the lowest panicle length (25.7 cm) and number of grains per panicle (96.7) were recorded for the treatment T_0 (K_0Zn_0). But the lowest 1000-grain weight (23.9 g) was recorded for T_4 ($K_{100}Zn_0$) treatment (Table 1). The highest number of effective tiller (17) was recorded for the treatment T_{15} ($K_{200}Zn_{200}$), T_{14} ($K_{200}Zn_{150}$), T_{13} ($K_{200}Zn_{100}$), T_{11} ($K_{150}Zn_{200}$), T_{10} ($K_{150}Zn_{150}$), T_7 ($K_{100}Zn_{200}$) and T_6 ($K_{100}Zn_{150}$) and the lowest (13) was recorded for T_0 (K_0Zn_0) treatment (Table 1). These results were also in agreement with Singh *et al.* (2013) who conducted the experiment on wheat and found that efficient management of potassium nutrients increased different growth parameters of wheat. Kamrani *et al.* (2013) also showed the similar result in wheat.

Table 1. Effects of potassium and zinc on the yield components of rice (BINA dhan-10)

Treatments	Plant height (cm)	Panicle length (cm)	Number of effective tillers per hill	Number of grains per panicle	1000-grain weight (g)
T_0	126.5e	25.7f	13d	96.7f	24def
T_1	127.3bcd	26.3e	14cd	101f	24.8bcd
T_2	127.4abc	27.1bcd	15bc	109.3cde	24.4bcdef
T_3	127.5abc	27cd	15bc	107.5de	24.7bcde
T_4	127d	26.7de	15bc	101.2ef	23.9f
T_5	127.3bcd	26.9d	16ab	107.7de	24.4bcdef
T_6	127.7a	26.9d	17a	114.5bc	24.1de
T_7	127.6ab	26.9d	17a	108.9cde	24.4bcdef
T_8	127.1cd	26.8de	16ab	113.7bcd	23.6f
T_9	127.3bcd	27cd	16ab	119.5ab	23.7f
T_{10}	127.7a	27.1bcd	17a	119.9ab	24.1def
T_{11}	127.6ab	27.1bcd	17a	118.7ab	23.9ef
T_{12}	127.1cd	27.5abc	16ab	115.7ab	24.6bcde
T_{13}	127.3bcd	27.6ab	17a	118.1ab	25.2ab
T_{14}	127.7a	27.9a	17a	121.3a	25.9a
T_{15}	127.7a	27.7a	17a	118ab	25bc
SE (±)	0.97	1.03	1.21	3.23	1.11

Effects of potassium and zinc on the yield of rice (BINA dhan-10)

Grain yield

Grain yield of rice (BINA dhan-10) responded significantly to the application of K and Zn (Figure 1). All the K and Zn treatments produced significantly higher grain yield over control T_0 (K_0Zn_0) treatment (Figure 1). Among the treatments, T_{15} ($K_{200}Zn_{200}$) and T_{14} ($K_{200}Zn_{150}$) showed the highest grain yield (4.33 t/ha) which was similar to T_{10} ($K_{150}Zn_{150}$) and T_9 ($K_{150}Zn_{100}$) treatment while treatment T_0 (K_0Zn_0) showed the lowest grain yield (3.57 t/ha) (Figure 1). In terms of grain yield magnitude, the treatments may be ranked in the order of $T_{14}> T_{10}> T_9>T_{13}> T_{15}> T_{11}> T_6> T_{12}> T_7> T_8> T_5> T_4> T_2> T_3> T_1> T_0$. The results were also in agreement with Kamrani *et al.* (2013); Heidari and Jamshid, (2010) that grain yield of rice increases due application of potassium fertilizer at higher doses.

Straw yield

Straw yield of rice (BINA dhan-10) was significantly influenced due to different treatments of K and Zn (Figure 1). All the K and Zn treatments gave significantly higher straw yield over the control T_0 (K_0Zn_0) treatment (Figure 1). The highest straw yield (5.35 t/ha) was recorded for the treatmentT_{14} ($K_{200}Zn_{150}$) which was identical with T_{10} ($K_{150}Zn_{150}$) and T_9 ($K_{150}Zn_{100}$) treatment and treatment T_0 (K_0Zn_0) showed the lowest straw yield (4.41 t/ha) which was identical with T_1 (K_0Zn_{100}) and T_3 (K_0Zn_{200}) treatments (Figure 1). In terms of straw yield magnitude, the treatments may be ranked in the order of $T_{15}> T_{14}> T_{10}>T_9 > T_{13}> T_{11}> T_6> T_{12}> T_7> T_8> T_5> T_4> T_3> T_2> T_1> T_0$. Kamrani *et al.* (2013); Heidari and Jamshid, (2010) also found an increase in grain and straw yield due to efficient management of K and Zn nutrients which restricts the uptake of sodium in plant and thereby reduces the salinity problem.

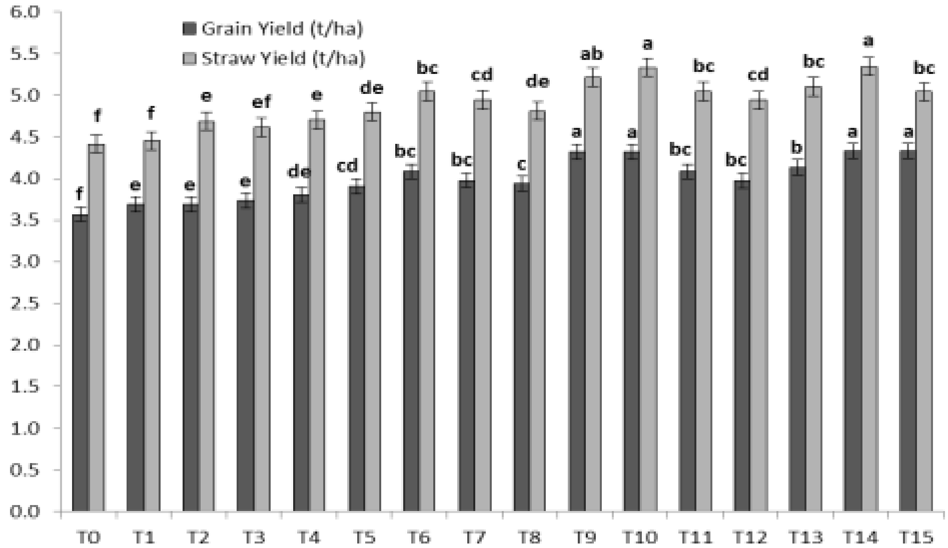

Fig. 1. Effects of potassium and zinc on grain and straw yield of rice (BINA dhan-10)

Nutrients uptake by rice plant

Nitrogen uptake by grain and straw

A significant variation in N uptake by grain and straw was observed due to different treatment combinations (Table 2). The range of N uptake by grain was 22.71 to 32.72 kg/ha. The highest N uptake (32.72 kg/ha) by grain was obtained in treatment T_{14} ($K_{200}Zn_{150}$). The next highest grain N uptake was obtained in T_{15} ($K_{200}Zn_{200}$), which was statistically similar to treatments T_{14}, T_{11}, T_4 and T_{10}. The lowest N uptake (22.71 kg/ha) by grain was found in T_1 treatment. Similarly, the range of N uptake by straw was 17.85 to 33.36 kg/ha. However, the highest N uptake straw was obtained in treatment T_{13}, which was statistically higher than all other treatments. The lowest N uptake by straw was found in treatment T_1. The range of total N uptake both by grain and straw of BINA dhan-10 was 40.56 to 61.16 kg/ha (Table 3). The highest total N uptake (61.16 kg/ha) was recorded in treatment T_{14} which was higher than all other treatments but statistically similar to T_{13}, T_{15} and T_{10}. The lowest total N uptake (40.56 kg/ha) was found in treatment T_1. The result showed that the total N uptake both by grain and straw were more prominent due to combined application of potassium and zinc at different doses. Similar results were observed by Rahman *et al.* (2005) who also concluded that potassium application increases the nutrients uptake by rice under saline condition by maintaining proper shoot and root growth.

Phosphorus uptake by grain and straw

The results presented in Table 2 showed that P uptake by grain and straw differed significantly due to different treatment combinations. The range of P uptake by grain varied from 4.56 to 7.77 kg/ha. The highest P uptake (7.77 kg/ha) by grain was recorded in treatment T_{10}, Which statistically identical with treatments T_6, T_9 and T_{15}. The lowest P uptake was recorded in treatment T_4 (4.56 kg/ha). However, P uptake of straw showed a significant difference due to different treatments. The range of P uptake by straw varied from 5.43 to 8.62 kg/ha. The highest P uptake of straw recorded in treatment T_{14}, which was statistically similar to treatments T_{13} and T_{15}. The lowest P uptake by straw was observed in treatment T_3 (5.43 kg/ha). The total P uptake by grain and straw ranged from 10.23 to 14.97 kg/ha. The highest total P uptake (14.97 kg/ha) was obtained in treatment T_{15} which was statistically identical to T_{14} and T_9. The lowest total P uptake was observed in T_3 which was statistically identical to T_0 and T_1 treatments (Table 3). The results were also in agreement with Singh *et al.* (2013) that nutrient concentration in plant increases due to addition of potassium fertilizer. Wakeel (2013) also found slight increase in nutrient uptake due to higher doses of potassium which helps plants to maintain proper growth and development of plants.

Table 2. Effects of potassium and zinc on nutrient uptake by rice grain and straw

Treatments	Nutrient uptake (kg/ha)							
	Grain				Straw			
	N	P	S	Zn	N	P	S	Zn
T_0	22.99f	4.64e	5.70de	0.08c	18.52e	5.60c	6.18e	0.12e
T_1	22.71f	4.79e	6.64bc	0.10b	17.85e	5.83c	7.74bcd	0.15bcd
T_2	25.48def	5.69cd	5.69de	0.11ab	18.36e	6.09c	8.43abcd	0.17bc
T_3	24.04ef	4.80e	5.97cde	0.12ab	25.82cd	5.43c	7.38c	0.17bc
T_4	29.85ab	4.56e	6.09bcd	0.09b	23.38d	6.58b	7.05d	0.13d
T_5	26.16cde	5.44de	6.60bc	0.11ab	22.91d	5.76c	7.68bcd	0.17bc
T_6	28.58c	6.66abc	6.93ab	0.10b	22.92d	6.05c	7.07d	0.15bcd
T_7	29.03bc	6.00bcd	7.60a	0.12ab	26.30c	6.43c	7.41cd	0.16bcd
T_8	24.29ef	5.92bcd	4.36f	0.09b	23.19d	5.85c	8.79abc	0.15bcd
T_9	25.34ef	7.18a	5.19ef	0.12ab	26.30c	6.78b	8.57abc	0.14cd
T_{10}	30.22ab	7.77a	6.91ab	0.13a	29.33b	5.87c	8.53abc	0.13d
T_{11}	30.23ab	5.72cd	6.13bcd	0.12ab	27.74bc	6.05c	9.08ab	0.18ab
T_{12}	27.85bcd	5.57cde	4.38f	0.09b	29.48bc	6.88bc	7.86bcd	0.15bcd
T_{13}	26.60cde	4.96de	4.76f	0.10b	33.16a	8.16ab	8.87ab	0.16bcd
T_{14}	32.72a	5.63cd	6.49bcd	0.12ab	28.44bc	8.62a	9.62a	0.16bcd
T_{15}	31.92a	6.92ab	5.25ef	0.13a	28.16bc	8.05ab	8.51abc	0.21a
SE (±)	1.47	0.11	0.89	0.02	1.21	0.44	0.59	0.03

Sulphur uptake by grain and straw

The results presented in Table 2 indicate that S uptake by grain and straw influenced significantly due to different treatment combinations. The S uptake of grain ranged from 4.36 to 7.60 kg/ha. The highest S uptake of 7.60 kg/ha by grain was found in treatment T_7, which was statistically similar to treatments T_6 and T_{10}. The lowest S uptake of 4.36 kg/ha was found in T_8 treatment which was statistically identical to T_9, T_{12}, T_{13} and T_{15}. On the other hand, the S uptake by straw varied from 6.18 to 9.62 kg/ha. The highest quantity of S uptake (9.62 kg/ha) by straw was recorded in treatment T_{14}, which was statistically identical with the treatments T_2, T_8, T_9, T_{10}, T_{11}, T_{13} and T_{15}. The lowest S uptake (6.18 kg/ha) by straw was found in treatment T_0 (K_0Zn_0). The total S uptake of grain and straw varied from 11.89 to 16.11 kg/ha. The highest quantity of total S uptake (16.11 kg/ha) was found in treatment T_{14} which was statistically identical with T_7, T_{10} and T_{11}. On the other hand, the lowest total S uptake (11.89 kg/ha) was observed in T_0 treatment which was statistically similar to T_4, T_8 and T_{12} (Table 3). Similar results were also observed by Wakeel (2013) in rice that higher potassium content in soil helped plant to increase the uptake of other nutrients (sulphur) by interacting with sodium. Maqsood *et al.* (2008) also conducted an experiment on rice and found that potassium application increases the uptake of NPS as well as potassium content in plants.

Table 3. Effects of potassium and zinc on total nutrient uptake by rice

Treatments	Total nutrient uptake by rice (kg/ha)			
	N	P	S	Zn
T_0	41.51h	10.24f	11.89e	0.20g
T_1	40.56h	10.62ef	14.38bc	0.25def
T_2	43.84h	11.78de	14.12bcd	0.28bcd
T_3	49.87fg	10.23f	13.35d	0.29bc
T_4	53.23e	11.14e	13.13de	0.22f
T_5	48.95g	11.20e	14.28bcd	0.27cde
T_6	51.30ef	12.72cd	14.00cd	0.25def
T_7	55.65d	12.45cd	15.02abc	0.28bcd
T_8	47.48g	11.76de	13.11de	0.24ef
T_9	51.64ef	13.96ab	14.36bcd	0.26cde
T_{10}	59.54abc	13.64bc	15.44ab	0.25def
T_{11}	57.97b	11.77de	15.20abc	0.31ab
T_{12}	57.33cd	12.45cd	12.24e	0.24ef
T_{13}	59.76ab	13.12bc	13.63d	0.26cde
T_{14}	61.16a	14.25ab	16.11a	0.28bcd
T_{15}	60.09ab	14.97a	13.84d	0.33a
SE (±)	1.44	0.91	1.01	0.03

Zinc uptake by grain and straw

Results indicate that the Zn uptake by grain and straw of BINA dhan-10 was significantly affected by the different treatments (Table 2). Zinc uptake by grain varied from 0.08 to 0.13 kg/ha. The highest Zn uptake (0.13 kg/ha) of grain was observed in T_{15} and T_{10} treatments, which was higher than all other treatments but statistically similar to treatments T_2, T_3, T_5, T_7, T_9, T_{11} and T_{14}. The lowest Zn uptake (0.08 kg/ha) of grain was recorded in treatment T_0, (K_0Zn_0). Zinc uptake by straw ranged from 0.12 to 0.21 kg/ha in the different treatments. The highest Zn uptake (0.21 kg/ha) by straw was recorded in treatment T_{15}, which was higher than all other treatments but statistically similar to T_{11} treatment. The lowest Zn uptake (0.12 kg/ha) by straw was observed in T_0 (K_0Zn_0). The total Zn uptake by grain and straw ranged from 0.20 to 0.33 kg/ha. The highest total Zn uptake (0.33 kg/ha) was obtained in treatment T_{15} which was statistically similar to T_{11} treatment. The lowest total Zn uptake (0.20 kg/ha) was observed in T_0 treatment (Table 3). Shahriaripour *et al.* (2010) also found that Zn uptake increased in plant when applied at higher doses and Zn accumulation was higher in rice straw than grain. The results are also in agreement with Singh *et al.* (2013) that addition of zinc at higher dose could alleviate the salinity problem.

Effects of potassium and zinc on K^+/Na^+ ratio of rice (BINA dhan-10)

In grain

K^+/Na^+ ratio in rice grain (BINA dhan-10) responded significantly to the application of K and Zn (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} ($K_{200}Zn_{200}$) demonstrated the highest K^+/Na^+ ratio (0.42) which was identical with T_{14} ($K_{200}Zn_{150}$) treatment and treatment T_0 (K_0Zn_0) demonstrated the lowest K^+/Na^+ ratio (0.29) (Figure 2). Zhang *et al.* (2010) also found that higher doses of potassium increased K uptake and decreased Na uptake in saline condition. Wakeel (2013) also found that higher K^+/Na^+ ratio might be helpful for salinity tolerance and this higher ration could be maintained through addition of potassium fertilizer at higher doses in rice.

In straw

K^+/Na^+ ratio of rice straw (BINA dhan-10) was significantly influenced due to different treatments of K and Zn (Figure 2). The highest K^+/Na^+ ratio 0.44) was recorded for the treatmentT_{15} ($K_{200}Zn_{200}$) which was identical with T_{14} ($K_{200}Zn_{150}$) treatment while treatment T_2 (K_0Zn_{150}) showed the lowest K^+/Na^+ ratio (0.33) (Figure 2). Zhang *et al.* (2010) also found that higher doses of potassium increased K uptake and decreased Na uptake in saline condition. Wakeel (2013) also found that Na uptake in rice decreased with the increasing amount of K in soil.

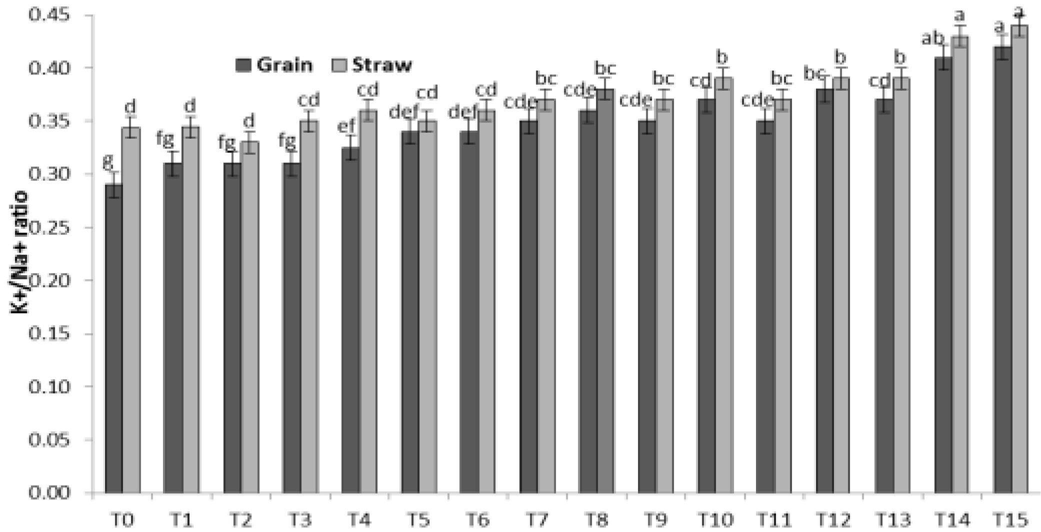

Fig. 2. Effects of potassium and zinc on K^+/Na^+ ratio in rice (BINA dhan-10)

CONCLUSION

Soil salinity caused a reduction in growth and yield of rice. Application of K and Zn fertilizers resulted in increases in growth and yield of rice under saline condition. It can be concluded that higher doses of K and Zn fertilization (treatment T_{14}-$K_{200}Zn_{150}$) are suitable for rice cultivation in saline areas. Balanced fertilization particularly efficient management of K and Zn fertilizers at higher doses ($K_{200}Zn_{150}$) in two splits with salt-tolerant high yielding rice cultivar could be practiced in saline areas.

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