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Potassium Applications on Rice (*Oryza sativa*L.) Genotypes under Saline Environment

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Abstract: Potassium (K) nutrition play a vital role in improving plant health by mitigating the severity of disease, drought and salinity stresses and improve yield of plants. We assessed the performance of three rice genotypes (DR-92, DR-51 and IR-6) using potassium treatments under saline environment. The experiments were laid down in completely randomized design with five potassium treatments (T=0.0, T2= 37.0, T=40.7, T= 44.4 and T= 48.1 kg ha^{-1}) at Green house, Shah Abdul Latif University Khairpur. The recommended rates of N:P fertilizer (160:90 kg ha^{-1}) were applied. Five seedlings of twenty-five days old were transplanted in each pot filled with ten kg of naturally occurring saline soil (EC 6.25 dS m^{-1}). Agronomic parameters were recorded at the time of maturity. Ionic analysis i.e. the contents of K^+, Na^+ and K^+/Na^+ ratio were determined in shoot dry matter and grains. The results revealed a significant increase in vegetative and yield components of rice genotypes at higher potassium applications. Moreover, Na^+ contents in grain and straw samples of rice genotypes decreased with increasing potassium applications. Overall, genotype DR-92 followed by DR-51 performed better with potassium application to mitigate salt stress.

Keywords: Salinity, Rice, Genotypes, K Applications.

I. INTRODUCTION

Rice (*Oryza sativa* L.) is one of the important food crops cultivated around the world. Its growth and development are susceptible to the availability of the macronutrient. Potassium (K), a vital macronutrient, plays a crucial role in the physiological processes in plant body, consequently affecting the crop production in relation to grain yield, control on abiotic stress, and disease resistance (Ahmed *et al*., 2016; Zhang *et al*., 2017). The physiological functions of potassium include promoting chlorophyll synthesis, carbohydrates metabolisms, activating enzymes, enhancing membrane permeability to ions, conferring to drought resistance, frost, and pests, and enhancing anti lodging (Amtmann *et al*., 2009; Maathuis *et al*., 2009; Zhang *et al*., 2017). It contributes significantly to cell turgor, especially in rapidly expanding cells, and acts as a counter action for anion accumulation and electrogenic transport processes (Amtmann *et al*., 2006; White and Karley, 2010). Potassium is also an important nutrient for the formation of pollen tube and its growth (Liu *et al*., 2016).

Although Potassium is the eighth most abundant element present in lithosphere (Wedepohl, 1995). Only a limited fraction is available to plants for absorption (Zörb *et al*., 2014). Therefore a massive amount of potassium fertilizers is applied to crop fields worldwide annually to increase crop production (Britto *et al*., 2008). The rice plants require a high quantity of potassium to stabilize yield. Modern high-yielding rice varieties remove much higher amount of potassium than phosphorous and nitrogen (Choudhury *et al*., 1997; Liu *et al*., 2009; Sharma *et al*., 2013).

The application of potassium fertilizer is effective in reducing the adverse impact of sodium ions in the saline soil (Khan *et al*., 2014). Proper application of potash fertilizer is attractive for the sufficient use of Fe, while its higher application results to competition with Fe (Celik *et al*., 2010). Commonly, rice growers pay much attention to N and P fertilizers, while the application of potassium is largely ignored, particularly on salt-affected soils (Akhtar *et al*.,

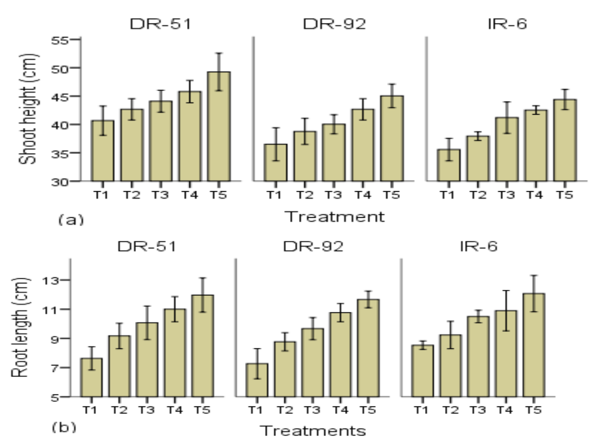

Fig. 1. The effect of five potassium treatments on the vegetative growth, (a) Shoot length and (b) Root length, of rice genotypes. The bar represent mean at 95% confidence level.

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Table-1 Physico-chemical properties of soil analysed before transplanting.

Properties	Values
Textural class	Silty clay
Sand	16.25 %
Silt	52.3 %
Clay	31.5 %
EC	6.3 dSm^{-1}
pH (1:5, H_2O)	7.5 %
Organic matter contents	0.8 %
Extractable K	70 mg/kg

2003; Li *et al*., 2014). This study was aimed to investigate the effect of potassium on the growth and yield of various rice genotypes under saline conditions **(Fig. 1)**.

2. MATERIAL AND METHODS

The experiment was conducted in July 2017, at Department of Botany, Shah Abdul University Khairpur. Three rice genotypes namely DR - 92, DR- 51 and IR-6 were used in experiments as the genotypes are widely grown in the rice growing regions of Sindh. Experiment was conducted in Complete Randomized Design (CRD) with three replications. Soil was analyzed for different physico-chemical properties before transplanting **(Tab. 1).** The soil was silty clay in texture, saline in nature, slightly alkaline in reaction, both low in organic matter and extract table K.

The soil sample were prepared and analyzed for the characteristic of organic matter using method of Walkley and Black (Walkley and Black, 1934), soil texture using Bouyoucos hydrometer (Bouyoucos, 1965). Electrical conductivity (EC) was determined by using digital meter (WTW LF-530, Inolab., Germany) in 1:5 soil water extract (Jackson, 1958). The instrument was calibrated with standard solution of KCl (1.0 M) at 25 °C. Soil pH was analyzed by using digital meter (JENWAY 3510, UK) previously calibrated using buffer solutions of pH 4, 7 and 9.2.

Initially a nursery was established in normal soil. Twenty-five days old seedling was transplanted in plastic pots (one plant $hill^{-1}$,3 hills pot^{-1}). Four treatment of Potassium (T1= Control (without K fertilizer), T2= 37 kg ha^{-1}, T3= 40.7 kg ha^{-1}, T4= 44.4 kg ha^{-1}, T5= 48.1 kg ha^{-1}) were applied along with the recommended rates of N:P (160:90 kg ha^{-1}) fertilizer (Channa, 2013). Agronomical parameters such as plant shoot height (cm), root length (cm), number of productive tillers $plant^{-1}$, panicle length (cm), 1000 grains weight (g), biological yield $plant^{-1}$, harvest index (%)were recorded at maturity. The contents of K^+, Na^+ and K^+/Na^+ ratio were determined in shoot dry matter and rice grains using Dry-Ash Method (DAM) through (JENWAY) flame photometer (Chapman and Pratt, 1961). Harvest index (%) was computed using formula: Harvest index (%) = Grain yield /Biological yield x 100.

In order to measure the effect of potassium treatments Percent increase over control (PIOC) of the growth and yield

PIOC = (Volume in treatment-Value in control) (Value in control) x 100

All the data were statistical analyzed using analysis of variance (ANOVA). Least Significant Difference (LSD) test used to compare treatment means using software STATISTIX® (VERSION 8.1) Analytical Software Inc., Tallahassee, FL., USA.

3. RESULTS

A. Effect of potassium on growth parameters of rice genotypes

The results revealed that shoot height and root length of rice genotypes were significantly increased by potassium fertilizer compared to the control in saline soil **(Fig. 1).** The study recorded an average 13% and 24% increase in shoot height and root length, respectively, in all genotypes (**Fig.2).** The mean shoot and root length in DR-51 was higher among the genotypes. The effect of potassium applications on shoot height (Anova, two way, df=4, F=17.8, $p < 0.01$) and root length (Anova, two way, df=4, F=10.30, $p < 0.01$) were found to be statistically significant. However, the response of genotypes to potassium treatments vary significantly for shoot length (Anova, two way, df=2, F=22.11, p<0.01). The same was not found to be statistically different for root length (Anova, two way, df=2, F=0.13, p=0.9).

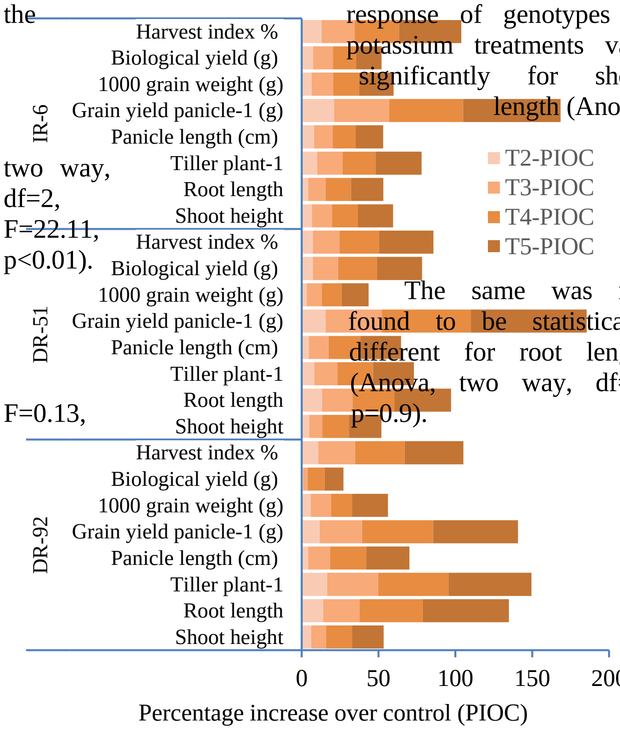

Fig. 2: Percent increase over control in selected growth and yield parameters of rice genotypes at various treatments of Potassium.

B. Effect of potassium on yield components of rice genotypes

The higher potassium applications also had a positive influence on the inflorescence and yield characters **(Fig. 3).** DR-92 (37% mean) and IR-6 (19.5% mean) produced more number of tillers per plant^{-1} on increased potassium applications(Fig.3). The genotypes produced mean 25% more tillers per plant^{-1}. The genotype DR-51 produced higher panicle length (mean 9.6 cm), biological yield (mean 19.6 g) and harvest index (5.5%) at potassium treatment 5, whereas DR-92 was recorded with the highest grain yield panicle^{-1} and thousand grain weight (mean 43.1 g). All genotypes produced significantly higher number of tillers (Anova, two way, df=4, F=12.5, p<0.01), increased panicle length (Anova, two way, df=4, F=20.5, p<0.01), grain yield panicle^{-1} (Anova, two way, df=4, F=48.1, p<0.01), and thousand grain weight (Anova, two way, df=4, F=1139.0, p<0.01) on the applications of potassium.

The response of rice genotypes also significantly varied to potassium treatments for panicle length (Anova, two way, df=2, F=5.35, p<0.01), number of productive tillers (two way Anova, df=2, F=7.14, p<0.01), thousand grain weight

yield panicle^{-1} (Anova, two way, df=2, F=2.32, p=0.15) did not vary among the genotypes. Biological yield (Anova, two way, df=4, F=190, p<0.01) and harvest index (Anova, two way, df=4, F=19.74, p<0.01) of rice genotypes also increased significantly with the increased potassium applications. The production of biological yield among genotypes vary significantly (Anova, two way, df=2, F=125.27, p<0.01) whereas the harvest index did not vary

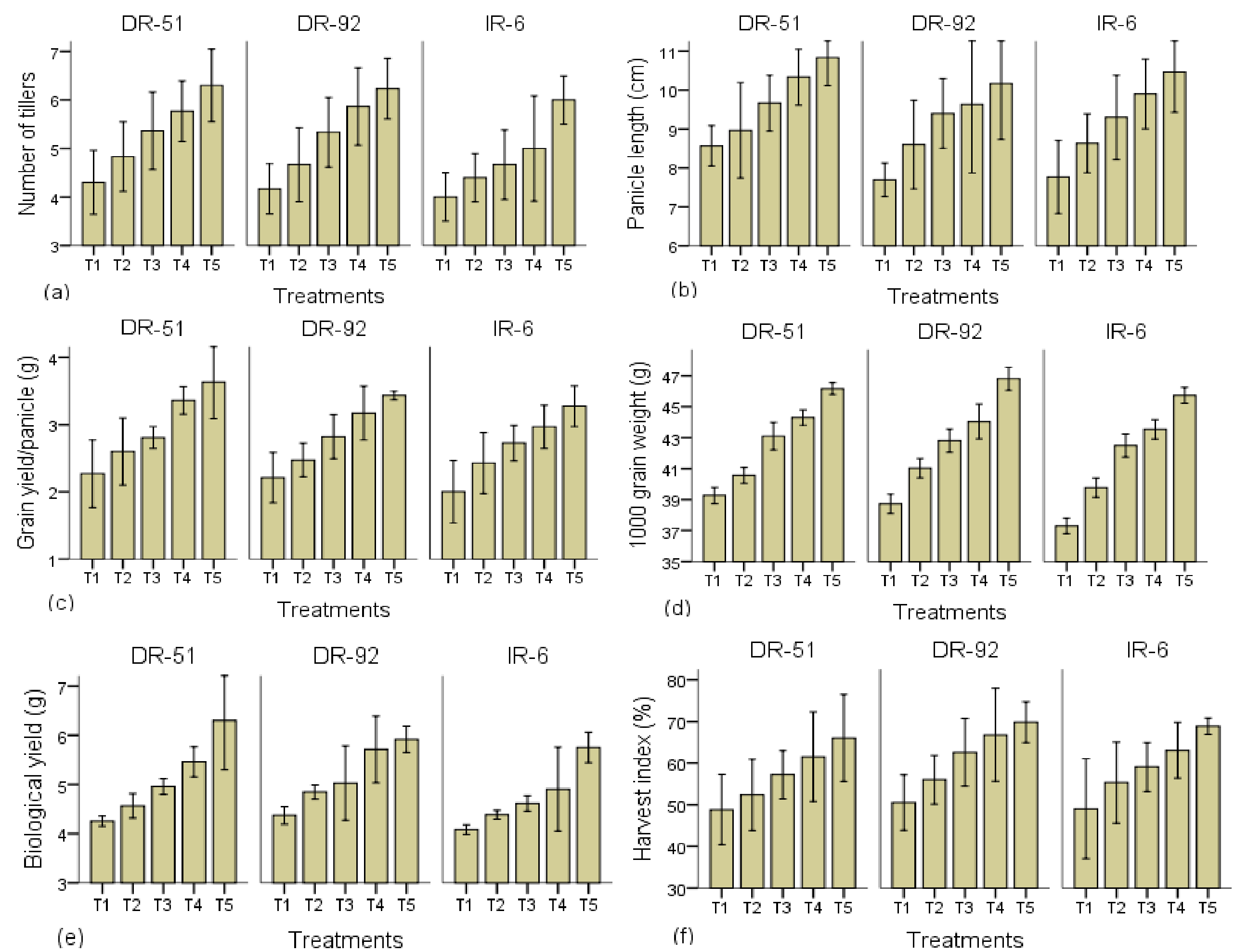

Fig. 3. The effect of five potassium treatments yield parameter of rice genotypes (a) Number of tillers , (b) Panicle length , (c) Grain yield per panicle, (d) Thousand grain weight, (e) Biological yield, and (f) Harvest index. The bar represent mean at 95% confidence level.

among genotypes (Anova, two way, df=2, F=2.34, p=0.113).

C. Ion analysis in grains and straw samples

The data revealed that content of K^+ both in straw and grains of all three rice genotypes significantly increased with increased potassium levels as compared to control **(Fig.4).** The maximum accumulation of K^+ in straw (26.6 mean) and grains (22.8 mean) took place in genotype Dr-92 followed by DR-51. It was also noted that content of K^+ in straw was higher than that of grains in all rice genotypes almost in all the treatments. However, the K^+ contents were significantly higher in rice straw (Anova, two way, df=4, F=6.86, p<0.01) at higher potassium applications. The effect was not significantly different among rice genotypes (Anova, two way, df=2, F=2.16, p=0.133). The K^+ contents in grains were not found to be significantly different at all treatments (Anova, two way, df=4, F=0.30, p=0.8) and among the genotypes (Anova, two way, df=2, F=0.01, p=0.9).

Whereas content of sodium (Na^+) in straw and grains of rice genotypes reduced with increased potassium levels as compared to control (Fig.4). The genotype IR-6 revealed a minimum accumulation of sodium in straw (mean 387.3 ppm), in contrast the lowest accumulation of sodium in grains (mean 397.3 ppm) was observed in DR-92, followed by IR-6 (mean 386.6 ppm). The further analysis revealed that the effect of potassium treatments on the accumulation of Na^+ in straw (Two way ANOVA, df=4, F=17.2, p<0.01) and grain (two way ANOVA, df=4, F=4.34, p<0.01) was highly significant. The accumulation of sodium contents in the straw vary significantly among the genotypes (Anova, two way, df=2, F=, p<0.01) whereas all genotypes roughly accumulated equal amount of sodium in their grains (Two way ANOVA, df=2, F=0.24, p=0.8).

The data revealed that content of K^+/Na^+ ratio both in straw and grains of all three rice genotypes increased with increased potassium applications as compared to control. Its maximum (0.096) accumulation in straw was witnessed in genotype DR-51 followed by DR-92 (0.08). The effect if increasing level of potassium treatment on the K^+/Na^+ ratio in straw (Anova, two way, df=4, F=7.06, p<0.01) and grain (Anova, two way, df=4, F=11.35, p<=0.01) were found to be significant. Whereas this ratio did not vary among the genotypes for K^+/Na^+ in straw (Anova, two way, df=2, F=0.51, p=0.6) and grain (Anova, two way, df=2, F=1.07, p=0.4).

4. DISCUSSION

Salinity affects the plant growth and yield of rice crop. The imbalanced application of fertilizers is a major yield limiting factor. In the rice growing areas, farmers pay much attention to N and P fertilizers, while the K^+ application is

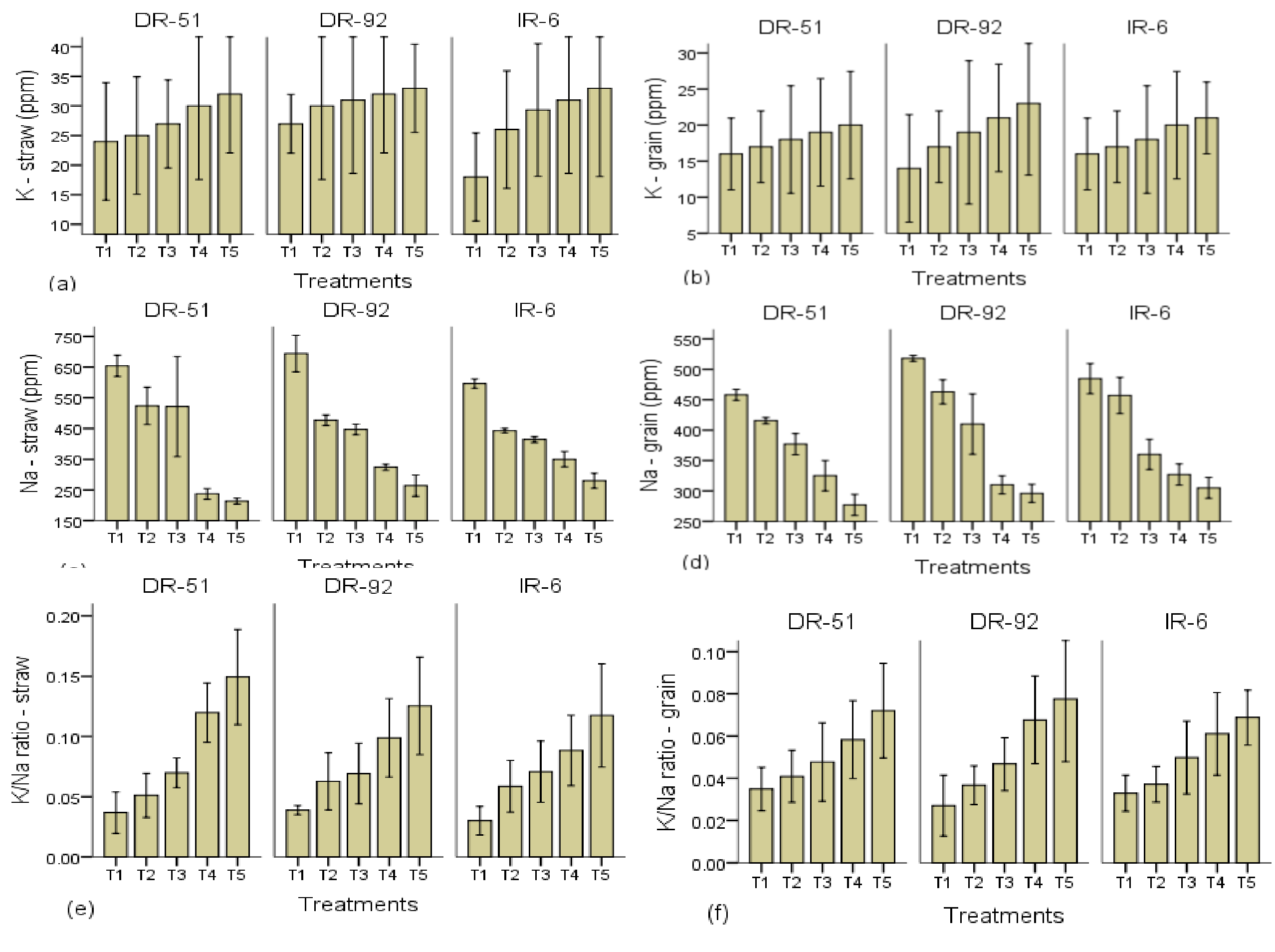

Fig. 4. The effect of five potassium treatments on ion contents of rice genotypes (a) K^+ contents in straw, (b) K^+ contents in grain, (c) Na^+ contents in straw, (d) Na^+ contents in grain, (e) K^+/Na^+ ratio in straw, and (f) K^+/Na^+ ratio in grain. The bar represent mean at 95% confidence level.

ignored, particularly on salt-affected soils in Pakistan (Akhtar *et al.,* 2003). The application of potassium fertilizer reduces the effect of salinity on vegetative characteristics and therefore the yield of crop. This study tested the selected genotypes commonly grown in Pakistan. The results revealed that under saline soil the application of potassium fertilizer were effective to increase the growth and yield attributes. Shoot height of rice genotypes was significantly increased due to application of potassium treatments. Other studies have also reported the similar impact of potassium application in other genotypes of rice (Biswas *et al*., 2001; Mukherjee and Sen, 2005). These result are also in consensus with Singh *et al.*, (2013) who found an increase of vegetative characteristics of wheat crop in response to effective management of potassium fertilizer. The potassium is involved in various physiological activities which benefit plant growth. It improved the micro and macro nutrients uptake in above ground parts resulting in vigorous growth and increased canopy for photosynthetic activity and dry mass of plant (Meena *et al*., 2002; Banerjee and Pal, 2009).

The results also indicated a significant effect of potassium treatments on yield parameters of the genotypes. The genotypes produced a higher number of reproductive tillers. The panicle length increased; resulted in having more grain/ seeds per panicle and grain weight. A similar increase in yield characteristics with the use of potassium have been reported in other hybrid rice genotypes (Mitra *et al*., 2001; Meena *et al.,* 2003; Krishnappa *et al*., 2006). Potassium affects the variations in plant hormones; for examples the delaying production of abscisic acid for few days, therefore resulting in increased yield characters due to translocation of food to seed for few extra days (Yuan and Huang, 1993). Potassium is also know to promote the production of cytokinin; a hormone that encourage zygote formation (Yuan and Huang, 1993); hence more seeds per panicle were produced as expected.

Potassium and sodium play a vital role in the growth of plants. The K^+/Na^+ ratio is often considered an important criteria for screening the salt tolerant plants. The varieties that maintain high K^+/Na^+ ratio produce higher yields and considered as salt tolerant. The potassium contents in straw and grain has a positive relationship with yield (Banerjee *et al*., 2018). The present study found a higher concentration of potassium in plant body and reduced level of sodium at higher rate of potassium applications. It was also evident that K^+/Na^+ ratio increased in straw and grains in almost all rice genotypes with potassium treatments. Zhang *et al*., (2010) also found an higher accumulation of K^+ and reduction in levels Na^+ ratio in plants at higher application of Potassium. A similar changes of ions in plant parts are also reported by Wakeel (2013). The potassium is said to compete with sodium contents and acts for osmotic regulation by maintaining a required $K^{+/}Na^+$ ratio in plants (Hasanuz zaman *et al.*, 2018).

5. CONCLUSION

It can be concluded from present study that all rice genotypes responded significantly to use of potassium applications. Potassium fertilization increased in vegetative growth and yield of rice genotypes under salt stress over control. Increasing K levels significantly decreased Na^+ content in grains and straw samples of rice. Better performance of rice genotypes was observed at T5 (48.1 Kg ha^{-1}) as compared to control in salinity environment. On the basis of all yield & yield components, trend of rice genotypes remained as DR-92 > DR-51 > IR-6.

6. REFERENCES:

Ahmed, I., M. Afar, and F.J.M. Maathuis (2016) Over expression of the rice AKT1 potassium channel affects potassium nutrition and rice drought tolerance. *Journal of Experimental Botany* 67 (9): 2689–2698

Akhtar, M. E., M. T. Saleem, and M. D. Stauffer (2003) *Potassium in Pakistan Agriculture*. Pak. Agri. Res. Council, Islamabad.

Amtmann, A., J. P. Hammond, P. Armengaud, and P. J. White (2006) Nutrient sensing and signaling in plants: potassium and phosphorus. *Advances in Botanical Research* 43: 209–257.

Amtmann, A., and P. Armengaud (2009) Effects of N, P, K and S on metabolism: new knowledge gained from multi-level analysis. *Curr. Opin. Plant Biol*. 12: 275–283.

Banerjee, H. and S. Pal (2009) Integrated nutrient management for rice-rice cropping system. *Oryza* 46:32–36.

Banerjee, H., K. Ray, S.K. Dutta, K. Majumdar, T. Satyanarayana, and J. Timsina (2018) Optimizing Potassium Application for Hybrid Rice (*Oryza sativa* L.) in Coastal Saline Soils of West Bengal, India. *Agronomy* 8: 292.doi:10.3390/agronomy8120292

Biswas J. C., M. T. Ahmed, and M. R. Islam (2001) Lodging vs. Non-lodging in BRRI dhan. *Bangladesh Journal of Training Development* 14(1&2): 107-113.

Bouyoucos, G. J. (1965) Hydrometer method improved for making particle size analysis of soil. *Agr. J*. 54: 464-465.

Britto, D. T., and H. J. Kronzucker (2008) Cellular mechanisms of potassium transport in plants. *Physol. Plant*. 133: 637–650

Celik, H., B. B. Asik, S. Gurel and A.V. Katkat (2010) Potassium as an intensifying factor for i

Agric Biol. 12:359-364.

Channa, G.S. (2013) Comparing salinity tolerance of five high yielding, non-aromatic rice (*Oryza sativa* L.) cultivars of Sindh. M.Phil. thesis. Dept. Botany, Shah Abdul Latif University, Khairpur.

Chapman, H.D. and P.F. Pratt (1961)*Methods of analysis for soils, plants and waters*. Division of Agricultural Sciences, University of California: Riverside.

Choudhury A.T., S. K. Zaman, and N.I. Bhuiyan(1997) Prospect of mixed fertilizer application in wetland rice culture. *Thai Journal of Agricultural Science*30: 477-482.

Hasanuzzaman, M., M. H. Bhuyan, K. Nahar, S. Hossain, J. Mahmud, S. Hossen, A. Masud, A. Moumita, andM. Fujita (2012) Potassium: A Vital Regulator of Plant Responses and Tolerance to Abiotic Stresses. *Agronomy* 8: 31. doi:10.3390

Jackson, M.L. (1958)*Soil Chemical Analysis*. Prentice Hall, Constable and Company Ltd. London.

Khan, Q., P. Ahmed, M.J. Khan and B. Imam (2014) Response of wheat to phosphate and potash fertilizer in a newly developed tube well irrigated soil of Rodh Kohi. *Soil Environ*.33 (1): 67-71.

Krishnappa, M., K. N. Gowda, V. Shankarnarayan, K. Maharudrappa and M. M. Khan. (2006). Effect of graded levels and split application of potassium on its availability and yield of rice, *Jou. of Potassium Research* 6 (4):156-161.

Li, J., J. Lu, X. Li, T. Ren, R. Cong, and L. Zhou (2014) Dynamics of potassium release and adsorption on rice straw residue. *PLOS ONE* 9: e90440. Doi:10.1371/journal

Liu, G., Y. Li , and D. M. Poterfield (2009). Genotypic Differences in Potassium Nutrition in Lowland Rice Hybrids. *Communication in Soil Science Plant Analysis*40:1803-1821.

Liu, L., C. Zheng , B. Kuang, L. Wei, L. Yan,T. Wang (2016) Receptor-Like Kinase RUPO Interacts with Potassium Transporters to Regulate Pollen Tube Growth and Integrity in Rice. *PLoS Genet* 12(7): e1006085.doi:10.1371/journal.pgen.1006085

Maathuis, F. J. M. (2009) Physiological functions of mineral macronutrients. *Curr. Opin. Plant Biol*. 12: 250–258

Meena, S.L., S. Singh, Y. S. Shivay (2003) Response of rice (*Oryza sativa* L.) to N and K application in sandy clay loam soils.*Indian Agricultural Science* 73(1): 8-11.1.

Meena, S.L., S. Singh, Y. S. Shivay (2002) Response of hybrid rice (*Oryza sativa*) to nitrogen and potassium application. *Ind. J. Agron.* 47: 207–211.

Mitra, G.N., D. Sahoo and K.K. Rout (2001) Effect of N-K interaction on yield, nutrient uptake and grain quality of rice-groundnut cropping sequence in the alluvial soils of Orissa. *Journal of Potassium Research* 17 (1-4): 71-78.

Mukherjee D, and A. Sen (2005) Influence of rice husk and fertility levels on the nutrient content of rice (Oryza sativa). Department of Agronomy, Institution of Agricultural Science, Varansi. *India Agricultural Science Digest* 25(2):151-152.

Sharma S, G. Chander, T. S. Verma, S. Verma (2013) Soil potassium fractions in rice-wheat cropping system after twelve years of Lantana residue incorporation in a northeast Himalayan Alfisol. *Journal of Plant Nutrition* 36: 1809-1820.

Singh, D., P. C. Ram, A. Singh, S. R. Dar, J. P. Srivastava (2013) Alleviation of soil salinity by zink fertilizer in wheat (*Triticum aestivum* L.) . *Plant archives* 13: 311-316.

Wakeel, A. (2013) Potassium–sodium interactions in soil and plant under saline-sodic conditions. *J Plant Nutr Soil Sci.*176:344–54.

Walkley, A. and I. A. Black (1934) Anexamination of Degtjareff methods for determining soil organic matter and proposed modification of the chromic acid titration method. *Soil Science*37: 29-38.

Wedepohl, K. (1995) The composition of the continental crust. *Geochim Cosmochim Acta* 59: 1217-1232.

White P. J., A. J. Karley (2010) Potassium. In: Hell, R., and R. R. Mendel (eds).*Cell Biology of Metals and Nutrients*. Springer, Berlin.

Yuan, L., and J. G. Huang (1993) Effects of potassium on the variation of plant hormones in developing seeds of hybrid rice. *J. South West Agric. Univ*. 15: 38–41.

Zhang , X., J.Hua, W. Hua, C. Jun, W. Jiahui, H. Jiang, G. Longbiao, Q. Qian and X. Dawei (2017) Transcriptome Analysis of Rice Seedling Roots in Response to Potassium Deficiency. *Scientific Reports*7:5523 | DOI:10.1038/s41598-017-05887-9

Zhang J. L., T. J. Flowers, and S. M. Wang (2010) Mechanisms of sodium uptake by roots of higher plants. *Plant Soil* 326: 45-60.

Zörb, C., M. Senbayram, and E. Peiter (2014) Potassium in agriculture - Status and perspectives. *Journal of Plant Physiology*. 171:656-669.