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Rice Response to Different Methods of Potassium Application under Salinity Stress Condition

[1]*Reyhaneh Far Ebrahimi*, [1]*Parvaneh Rahdari*, [2]*Hassan Shokri Vahed*, [3]*Parisa Shahinrokhsar* and [2]*Shahryar Babazadeh*

[1]Faculty Member of Islamic Azad University, Tonkabon Branch, Iran
[2]Faculty Member of Rice Research Institute, Iran
[3]Faculty Member of Agricultural and Natural Resource Research Center, Rasht, Iran

Abstract: Salinity is an environmental stress that limits growth and development in plants. With appropriate fertilizers application methods on salinity conditions can reduce its harmful effects and increased productivity of salinized soils. A pot experiment was carried out in 2011 in Rice Research Institute of Iran to examine the effects of potassium application methods on the response of rice (*Oryza sativa* L.) under different soil salinity levels. Four methods of potassium application: K_0: spraying with distilled water every 10 days interval (control); K_1: the use of 65mg K Kg^{-1} soil; K_2: spraying 5% K_2SO_4 solution in every 10 days interval; K_3: the use of 65mg K Kg^{-1} soil plus spraying with 5% K_2SO_4 solution every 10 days interval and four levels of irrigation water salinity (tap water and salinities 2, 4 and 6 dSm^{-1}) were investigated in complete randomized block design with three replications. Results showed that soil salinity affected growth and yield component parameters in most of the cases. Potassium application alleviated the stress condition and significantly improved dry matter yield and yield components in rice. Grain, straw, total biological yield, harvest index, 100 grains weigh, root dry weigh and total tillers significantly were decreased with increasing salinity,while grain protein was increased with increasing salinity. The interaction between salinity levels and methods of potassium application was significant only for root dry weight. Based on the results use of 65mg K Kg^{-1} soil plus spraying with 5% K_2SO_4 solution every 10 days interval was most effective in increasing the above features.

Key words: Pot experiment · Potassium · Salinity · Rice · Spraying

INTRODUCTION

Rice is major grain crop and carbohydrate source, supplying the necessary daily calories for more than half the world's population [1, 2]. It has been predicted that the demand for rice in the world will increase from 560 million tons to 780 million tons by the year 2020 [3]. However, environmental stress is a serious issue confronting rice production, especially the problem of salinity [4, 5]. Rice is one of the most important grains and is the second most important food in Iran [6]. Most paddy fields in Iran are located in the marginal Caspian Sea in Mazandaran and Guilan provinces with totally 78% of cultivation area and rice yield. These lands are often influenced by the salinity of sea water and this is one of the important factors of rice yield reduction. Soil salinity is a major environmental stress that adversely affects plant growth and metabolism. Salinity occurs in two distinctly different regions: (1) Costal regions where salinity is induced by inundation with seawater containing high amounts of soluble salts and (2) arid and semi-arid regions where evaporation is considerably higher than total precipitation and as a consequence, water movement is upward (capillary movement of water) resulting in the accumulation of salts in the root zone. Several authors summarized that salt stress significantly decreased shoot, root and total dry matter of plants and noticed an increasing degree of reduction in dry matter production with increasing salinity levels [7, 8]. Under saline conditions, the mineral nutrition of most plants can be expected to be detrimentally affected. The interactions between K^+ and Na^+ may be emphasized under such conditions and ultimately decrease plant growth [9].

Corresponding Author: Hassan Shokri Vahed, Faculty Member of Rice Research Institute, Iran. E-mail: shokri_v@yahoo.com.

In saline soils and other similar soils the unfavorable conditions as well as inadequate and imbalance use of plant nutrients causes a considerable decline in paddy yield. Potassium is a macronutrient for plants that is required for physiological processes such as the maintenance of membrane potential and turgor, activation of enzymes, regulation of osmotic pressure, stomata movement and tropisms [10]. Nelson [11] believed that potassium has a positive role in plant growth under saline conditions, because this element plays an essential role in photosynthesis, osmoregulatory adaptations of plant to water stress. Adequate potassium supply is also desirable for the efficient use of Fe, while higher potassium application results to competition with Fe [12]. Saqib *et al.* [13] reported a significant reduction in all growth parameters considered and an increased concentration of Na^+ and Cl^-, decreased concentration K^+ and decreased K^+:Na^+ ratio. Most of yield decreases caused by abiotic stresses result from salinity, drought, high or low temperature, inadequate mineral nutrient supply and soil acidity. Therefore, for sustaining food security, a high priority should be given to minimizing the detrimental effects of environmental stresses on crop production by (1) applying modern breeding techniques and biotechnological tools and (2) increasing physical and chemical fertility as well as maintaining productivity of cultivated soils by adequate and balanced supply of mineral nutrients [14].

MATERIALS AND METHODS

A pot experiment was arranged in a 4×4 factorial manner in a complete randomized block design with three replication at the Rice Research Institute of Iran in the year 2011. Treatments include four methods of use of potassium fertilizer and four levels of irrigation water salinity. Methods of K fertilizer application were: K_0, spraying with distilled water every 10 days interval (control); K_1, the use of 65mg K Kg^{-1} soil; K_2, spraying 5% K_2SO_4 solution every 10 days interval; K_3, the use of 65mg K Kg^{-1} soil plus spraying with 5% K_2SO_4 solution every 10 days interval. Irrigation of pots was done by tap water as control treatment and also with water having electrical conductivity of 2, 4 and 6 dS/m (respectively S_0, S_1, S_2 and S_3 treatments). The EC of irrigation water was established by adding NaCl in every stage of irrigation. The soil sample was taken from the wetland rice soil of Guilan province in north of Iran (36°36' to 38°37' N and 48°25' to 50°34' E) with electrical conductivity (EC) value of 1.15 dS/m. The soil was air dried and sieved through 5 mm screen before filled in to pots of ten-kilogram capacity. Texture of the soil was12.2% of sand, 40.4% silt, 47.4% clay, pH= 6.2, EC= 1.15 dS/m, P(ppm)= 9.8, K(ppm)= 85, total N(%)= 0.188 and OC(%)= 2.12. The recommended rate of N and P fertilizers was applied uniformly at planting in the form of Urea (46% N) and TSP (46% P_2O_5), respectively. Finally, analysis of variance (ANOVA) was done to determine treatment differences.

RESULTS AND DISCUSSION

Some results of soil physical and chemical properties are given in Table 1. The data obtained indicated that salinity of irrigation water and potassium application methods generally affected growth and productivity of rice (Fig. 2,3). Based on the analysis of variance, rice root dry weight was significantly (P<0.05) affected by salt levels, methods of potassium application and the interaction of both (P<0.01). Results showed that rice root dry weight was reduced by increasing salt levels. The highest mean root dry weight was recorded at control with 25.3 (g/pot) and the lowest at EC= 6 dSm^{-1} (S_3) with 18.3 (g/pot). The maximum root dry weight was obtained in K_3 where was applied 65 mg K Kg^{-1} soil plus spraying with 5% K_2SO_4 solution every 10 days interval. Kaya, *et al* [15] reported that plants grown at high salinity had very leaky root systems as evidenced by high potassium efflux; this leakiness was ameliorated by foliar spray of KH_2PO_4. Generally, the root permeability of plants was decreased significantly under salt stress. This could be an explanation for the reduction in water absorption rate and nutrient uptake under salinity condition and eventually decrease root dry weight.

Number of tillers was significantly decreased by increasing salinity levels and the minimum values were noted at EC of 6 dSm^{-1}. The decrease in number of tillers might be due to limited supply of metabolites to young growing tissues [16]. Similar results were also reported by Mohiti *et al*. [17] and Javed and Muhammad [18]. The results showed that number of tillers increased significantly (P<0.01) by the application of potassium over control. The maximum numbers were produced where potassium was applied through soil application as well as spraying (K3). The results are in agreement with those reported by Mohiti *et al* [17]. Bhiah *et al.* [19] in a greenhouse experiment concluded that potassium application significantly increased the number of tillers in all varieties of rice plant. The interaction between salinity levels and methods of potassium application was non-significant in number of tillers (Table 2).

Table 1: Some physical and chemical properties of soil applied in present experiment

pH	Ec_e [dS/m]	OC [%]	Total N [%]	Ava. P [mg/kg]	Ava. K [mg/kg]	CEC [me/100g]	Sand [%]	Silt [%]	Clay [%]
6.23	1.15	2.12	0.188	9.8	85.0	24	12.2	40.4	47.4

Table 2: Probabilities of significance for different traits of rice grown under different salt levels and methods of K application

Traits	Different methods of K application	Salinity levels	Potassium × Salinity	CV [%]
Grain yield	**	**	ns	15.6
Straw yield	*	**	ns	13.7
Biological yield	**	**	ns	10.5
Harvest index	ns	**	ns	12.0
Grain protein	ns	**	ns	9.1
Root dry weigh	*	*	**	20.5
100 grains weigh	*	**	ns	7.3
Number of tillers	*	*	ns	12.4

*,**: Significant and highly significant differences [p=0.05 and p=0.01, respectively], ns= Non significant differences

K_0, spraying with distilled water in every 10 days interval [control]; K_1, the use of 65mg K Kg^{-1} soil; K_2, spraying 5% K_2SO_4 solution in every 10 days interval; K_3, the use of 65mg K Kg^{-1} soil plus spraying with 5% K_2SO_4 solution in every 10 days interval

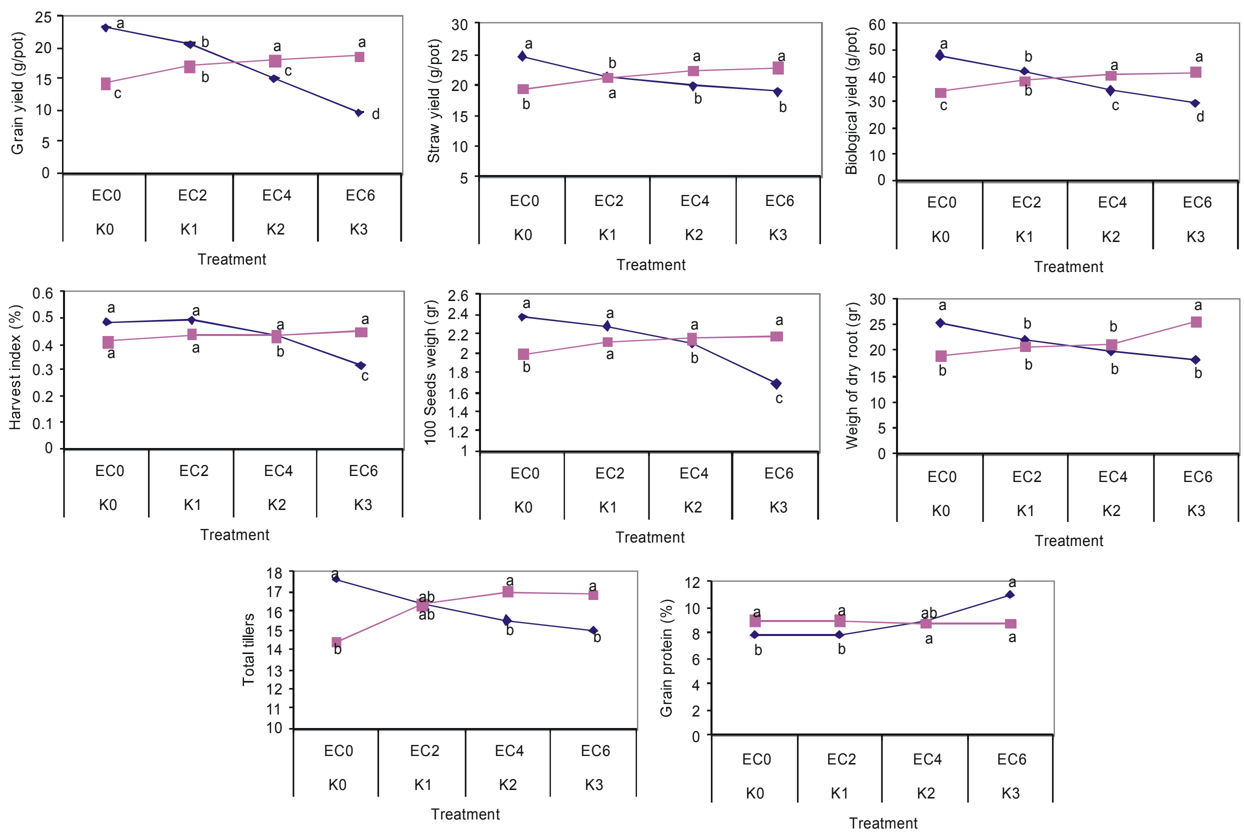

Fig. 1: Effect of salinity levels [□] and different methods of K application [■] on some traits rice plant

Based on the analysis of variance, the overall effect of salinity was highly significant (*P*<0.01) on grain, straw, total biological yield, 100 grains weigh and harvest index of rice (Table 2). Comparing the data showed, the minimum grain, straw, total biological yield, 100 grains weigh and harvest index were in the rates of 9.44, 18.84, 29.5, 1.69 g/pot and 31.9% in treatment of EC= 6 dSm^{-1} (S_3), respectively. The effect of salinity levels and potassium application methods on some of rice plant characteristics can be seen in Fig. 1. The decrease in these traits with increasing soil salinity might be due to reduced growth of rice as a result of reduced uptake of water and

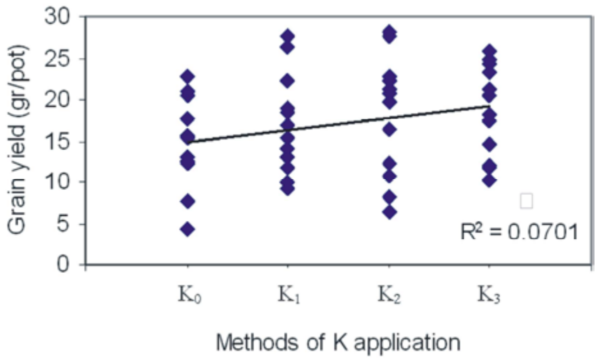

Fig. 2: Effect of potassium application methods on Grain yield of rice plant

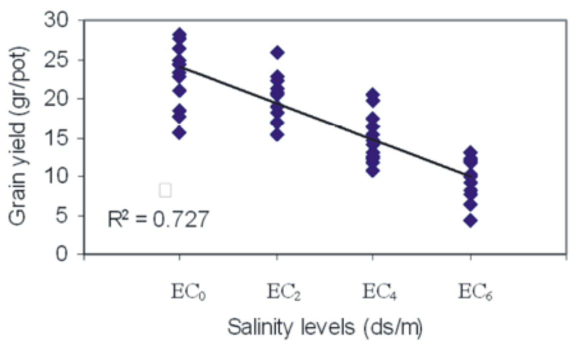

Fig. 3: Effect of salinity levels of irrigation water on grain yield of rice plant

nutrients and reduction of enzymatic and photosynthetic efficiency and other physiological disorders [20, 21]. Similar results were also reported by Nadeem *et al*., [22]. Methods of potassium application was not significant on harvest index and grain protein but was significant on grain and total biological yield (P<0.01) and straw yield, root dry weigh, 100 grains weigh and total tillers (P<0.05) (Table 2). The highest grain yield (18.7 g/pot), straw yield (22.8 g/pot), total biological yield (41.5 g/pot) and 100 grains weigh (2.2 g/pot) were noted in K3 where potassium was applied in soil plus foliar spray. This increase might be due to the participation of potassium in mechanism of stomata movement, photosynthesis and osmoregulatory adaptation of plants to water stress in saline soils [20]. Sultana *et al*., [23] reported when nutrients are applied to the leaves, the nutrient elements might penetrate into the leaves and restrict the inhibition due to toxic effects of Na^+ and Cl^- or minimizes the salinity induced nutrient deficiency. Jurgens [24] reported that potassium absorption by plant leaves is possible under saline conditions and potassium absorbed under such conditions might help the plants for regulating stomata opening and closing.

The effect of salinity was significant (P<0.01) on grain protein while different methods of K application and interactions between salinity and potassium was not significant. The results showed that grain protein increased with increasing salinity. The highest protein content of 11% in EC= 6 dSm^{-1} was obtained. Likely higher uptake of N in grain at higher levels of salinity can be important reasons for this. This results agrees with previous findings for other crops such as barley [25], sweet corn [7], tomatoes [26] in which an increase in total N concentration was observed when grown in saline substrate.

CONCLUSION

In the light of this experiment, it can be concluded that:

- Rice grown at high salinity exhibited reduced grain, straw, total biological yield, 100 grains weigh, number of tillers, harvest index and increased grain protein compared to control.
- Increase grain protein can be reason higher uptake of N in grain at higher levels of salinity.
- Use of potassium alleviated the adverse effects of high salinity on rice plant and improved all traits mentioned above.
- High NaCl induced potassium deficiency in rice plant.
- The best method of potassium application in salinity condition was soil intake plus spraying method.

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