

Full Length Research Paper

The efficiency of potassium fertilization methods on the growth of rice (*Oryza sativa* L.) under salinity stress

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Land salinization in the coastal region, caused by the progressing of sea or by rising of the saline ground water to the soil surface, is a principal problem in some parts of Iran. It decreases the efficiency of used fertilizers. This study was conducted with the aim of comparing the efficiency of potassium spraying and application in soil; and its effect on yield and yield components of rice under salinity stress in a greenhouse experiment. Treatments included four levels of irrigation water salinity (tap water and salinities 2, 4 and 6 dS/m) and four methods of K application: a, spraying with distilled water as control; b, application of potassium on soil; c, potassium spraying and d, application of potassium on soil plus spraying. Every treatment was replicated three times and study was conducted as a complete randomized block design. The results show that grain yield and shoots, 100 seeds weight, tiller number, root dry weight and potassium uptake in seeds and shoot significantly decreased with increasing salinity. The best method of K application was soil intake plus spraying method.

Key words: Greenhouse, ground water, salinization, spraying.

INTRODUCTION

Rice (*Oryza sativa* L.) is one of the major cereal crops in Iran and so its security is critical. Production of rice (*O. sativa* L.) ranks second among food grains, and half of the world's population subsists on rice by receiving the highest (26.2%) calories intake from it (FAO, 2009). However, salinization of paddy land in the coastal region may develop by advancement of sea or rising of the saline ground water to the upper surface of the soil. This problem is due to high levels of evaporation and salt accumulation in the root zone in arid and semi arid areas (FAO, 1997). These factors during the last decades have influenced some parts of rice fields with salinity in Guilan, Mazandaran, Khuzestan, Fars and Isfahan Provinces, Iran.

The accumulation of additional salts has harmful effects on crops which can result to nutritional disorders (Asch et

al., 2000), ions toxicity and also osmotic stress (Zhu, 2001). Overall, crop yield decreases with increasing salt concentration, but the threshold concentration and yield reduction is different in different plant species and cultivars (Ponnamperuma, 1994). Different studies have indicated that the degree of salt damage depends on salt concentration, pH, temperature, humidity, solar radiation, irrigation water depth, duration of exposure to salinity and growth step (Akbar and Ponnamperuma, 1989). Mushtaq and Zaibunnisa (2003) conducted experiments to study the effect of salinity-sodicity on stigma receptivity and grain filling of rice (of different tolerant limits against salinity alone) under field conditions along with other parameters at reproductive phase. Their results showed that viability of pollens was reduced in all the cultivars under salinity-sodicity stress showing significant effect on the salt sensitive Basmati cultivars.

Among the nutrients, potassium (K) is a macro element known to be very dynamic and a major contributor to the organic structure and metabolic functions of the plant. Adequate K supply is also desirable for the efficient use

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of Fe, while higher K application results to competition with Fe (Çelik et al., 2010). Potassium in rice producing soils is one of the limiting factors for increasing rice yield (Yang et al., 2003). There is a considerable decrease in available K due to increased cropping intensity and lower K application rates (Zhang et al., 2004).

Nelson (1978) believed that potassium has a positive role in plant growth under saline conditions, because this element plays an essential role in stomata movement, photosynthesis and regulation of osmotic pressure for plant. This nutrient increases the activity of nitroreductase enzyme, considerably (Shina, 1978). Since soil conditions and clay type affect K uptake, the use of spraying can be effective in K availability for plant. Casanova et al. (2002) reported that K and Zn deficiencies in the plant were mainly induced by soil salinity. Zhang et al. (2011) investigated the effects of applying different concentrations of the macronutrients K^+ , Ca^{2+} and Mg^{2+} on the responses of contrasting rice (*O. sativa* L.) genotypes under salt stress. A solution culture experiment was conducted in a phytotron at the International Rice Research Institute (IRRI), under controlled temperature, humidity and natural sunlight.

In view of the fact that water and potassium resources are limited worldwide, there is an urgent need for a more detailed research. Yet, the role of K fertilization in overcoming water shortage in rice has not been explored fully. Furthermore, the genetic manipulation for overcoming water and salinity stress and K deficiency in rice needs to be worked out. Therefore, we studied the efficiency of K application methods under salinity stress conditions on growth and yield attributes of rice.

MATERIALS AND METHODS

A pot experiment as 4×4 factorial in the form of complete randomized block with three replications at the Rice Research Institute, Guilan, Iran, was performed. Some properties of the studied soil are shown in Table 1. Treatments include four levels of irrigation water salinity and four methods with the use of potassium fertilizer. Therefore, 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 salt in every stage of irrigation. Four methods of K fertilizer application were: K_0 : spraying with distilled water in every 10 days (control); K_1 : the use of 65 g K_2SO_4 in soil; K_2 : spraying 5% K_2SO_4 in every 10 days; K_3 : the use of 65 g K_2SO_4 in soil plus spraying with 5% K_2SO_4 in every 10 days.

The needed soil for experiment after air drying and grinding was transferred to the plastic pots with a capacity of 11 kg. After flooding the soil and transplanting operations with 5 transplants in 25 days and after two weeks, the number of transplants was thinned to 2 when they were about 10 cm high. The whole phosphate fertilizer (from triple superphosphate source) and the half urea were used after soil preparation and before transplanting. Second part of urea fertilizer was applied in the maximum tillering stage. Water depth in all pots was set at 5 cm. In rippling time, number of tillers was counted and then shrubs were cut.

Shoots were harvested after 50 days and dry matter yield was determined after drying of the harvested shoots at 70°C for 48 h.

Grain yield, straw, 100-seeds weight and weight of empty seeds per plant were separately determined. Sub samples of dry shoots were ground and then dry-ashed in a furnace at 550°C and then extracted with 2 M HCl. The concentrations of K and Na were measured in the extracts by flame photometry. Data were analyzed using IRRISTAT software.

RESULTS AND DISCUSSION

Grain and straw yield and 100 seeds weight

Figures 1 to 3 show the effect of treatments on grain yield, straw yield and 100-seeds weight, respectively. Comparing the data showed, the minimum yield, straw and 100 seeds weight were in the rates of 8.24, 18.86 and 1.59 g/pot in treatment of S_3 (EC = 6 dS/m), respectively. This decrease can be due to the salinity effects that can lead to osmotic effect, decrease water availability, ion specific toxicity, change in nutritional balance, reduction of enzymatic and photosynthetic efficiency and other physiological disorders (Ashraf et al., 1991). Also, the salinity decreases the availability of nutrients in the soil (Cramer et al., 1991; Lutts et al., 1999).

The highest grain yield, straw and 100 seeds weight obtained in K_3 treatment (soil intake plus potassium spraying) were more than those in the control, which were 17.35, 21.6 and 2.08 g/pot, respectively. Similar results have been reported by Akbar et al. (1972) and Khatun et al. (1995). Studies of Singh et al. (1987) and Mondal et al. (1987) showed an increase in thousand grain weight of rice when potassium fertilizer was used.

Tiller number and weight of empty seeds

Figures 4 and 5 show the effect of treatments on tiller number and empty seeds weight, respectively. Based on these results, the lowest number of tillers was in S_3 treatment (EC equal 6 dS/m). Also, the method of potassium application in the soil increased tiller number of rice than other methods of K application.

With increase of salinity, empty grain weight significantly increased, so that the highest weight of empty seeds was related to S_3 treatments (salinity of 6 dS/m) and was equal to 2.07 g/pot. On the other hand, in K treatments, the maximum weight of empty seeds was related to K_0 treatment (spraying with distilled water). All potassium treatments reduced the weight of empty seeds compared to the control. The studies of Zeng and Shannon (2000), Sultana et al. (2001) and Din et al. (2001) on salinity and potassium are similar to the results of this study. Decrease in tiller number may also cause limited storage of metabolites in young growing tissue (Din et al., 2001).

Effect of potassium treatments on tiller number showed that all treatments of potassium fertilizer increased tiller more than the control, which is confirmed by the research

Table 1. Some properties of soil used in experiment.

Property	Value
pH	6.43
ECe (dS/m)	1.05
Organic C (%)	2.16
Total N (%)	0.168
Available P (mg/kg)	9.9
Available K (mg/kg)	75.0
CEC (me/100 g)	23.0
Sand (%)	10.2
Silt (%)	42.4
Clay (%)	47.4

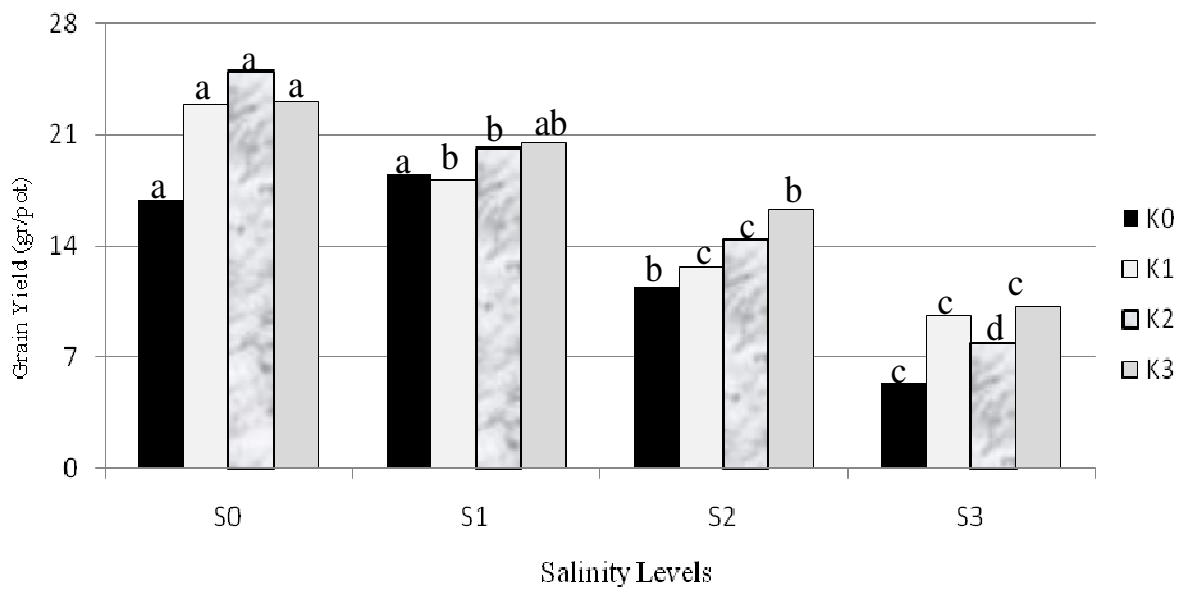


Figure 1. The effect of potassium and salinity treatments on grain yield of rice

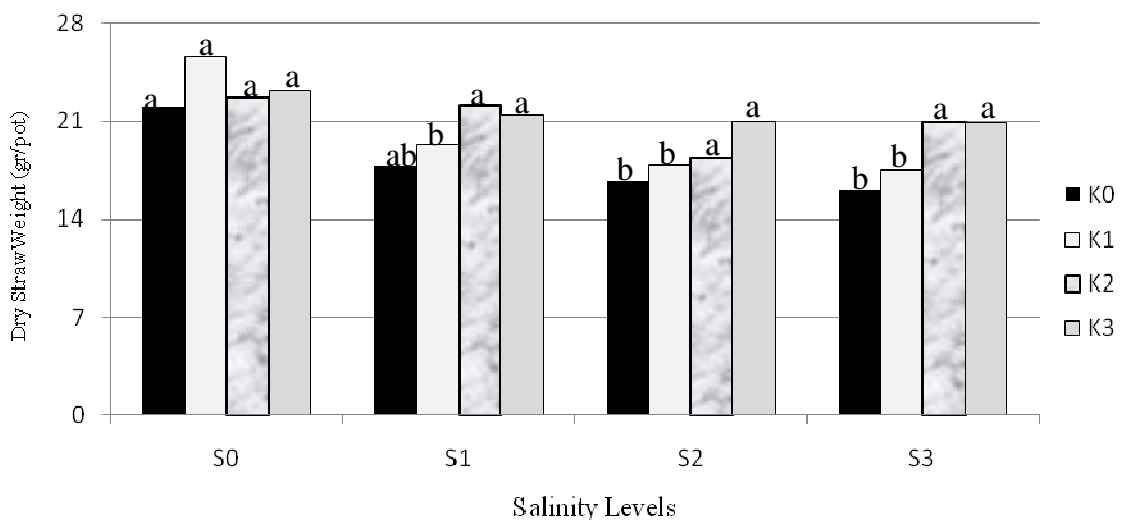


Figure 2. The effect of potassium and salinity treatments on dry straw weight of rice.

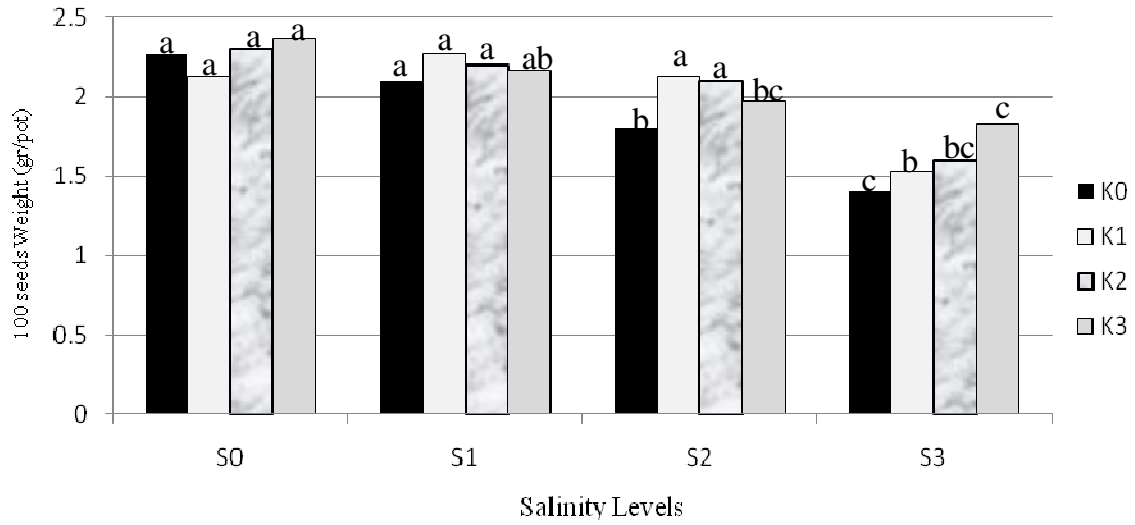


Figure 3. The effect of potassium and salinity treatments on 100 seeds weight (g/pot) of rice.

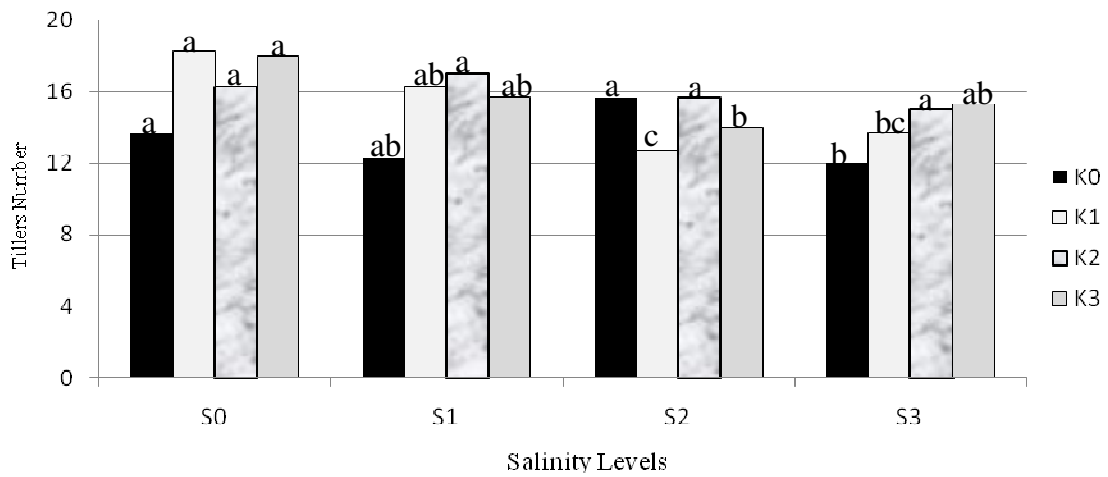


Figure 4. The effect of potassium and salinity treatments on tiller number of rice.

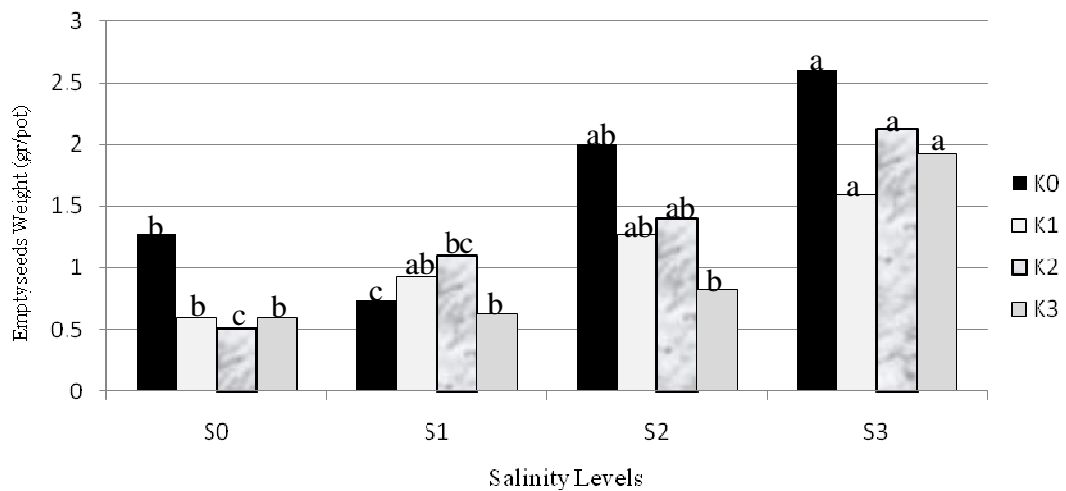


Figure 5. The effect of potassium and salinity treatments on empty seeds weight of rice.

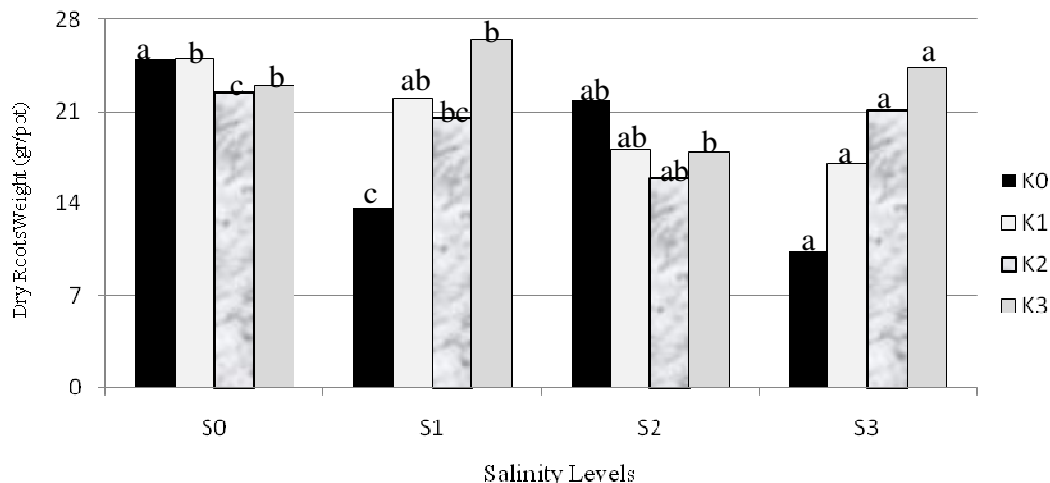


Figure 6. The effect of potassium and salinity treatments on dry root weight of rice.

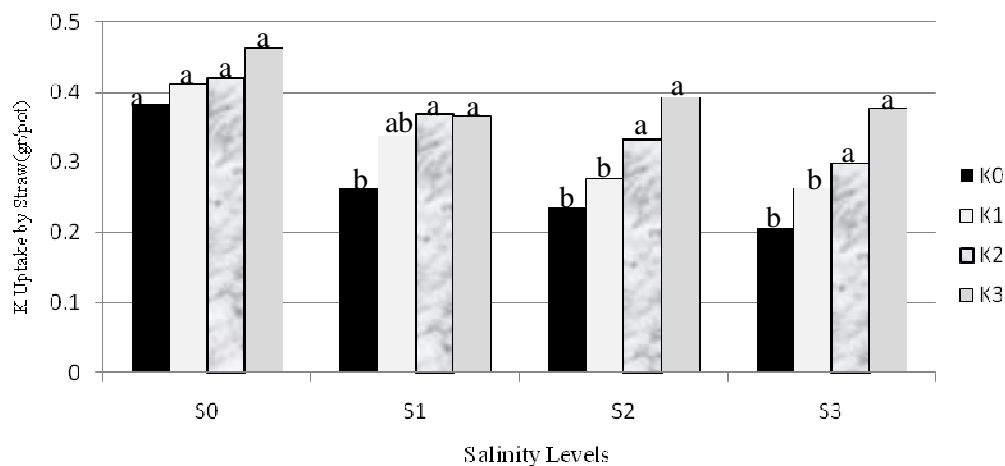


Figure 7. The effect of potassium and salinity treatments on K uptake by straw of rice.

results of Javed and Muhammad (1992) and Din et al. (2001). Bhiab et al. (2010) in a greenhouse experiment concluded that potassium application significantly increased the number of tillers in all varieties. Results of Bahmanyar and Soodaee (2010)'s study indicated that panicle length, plant height, number of tiller, number of grain per panicle, hollow grain percentage, grain and biological yield were significantly affected by N and K fertilization. Maximum grain yield (75.46 g pot^{-1}) occurred at 23 kg N ha^{-1} and $30 \text{ kg K}_2\text{O ha}^{-1}$. At flowering stage, K content of stems was higher than leaves, and N content in flag leaves was higher than other plant parts.

Root dry weight

Based on Figure 6, root dry weight significantly decreased with increasing salinity. The highest and the lowest root dry weight is related to S_0 (control) and S_2

treatments, respectively with 23.96 and 18.46 g. Also, among the methods of K application, treatment K_3 (application in soil + K spraying) created the highest root dry weight (24.42 g) and the lowest weight was related to treatment K_0 (spraying with distilled water) which was equal to 17.78. Significant difference was not observed between treatments K_1 and K_2 . Finck (1982) reported that spraying KCl leads to potassium uptake, but the amount of used fertilizer by spraying is complementary and can not be replaced by basic fertilizer.

Potassium uptake in grain and straw

The results indicate that K uptake in grain and straw decreased with increase in salinity (Figures 7 and 8). The lowest K uptake ($\text{EC} = 6 \text{ dS/m}$) was related to S_3 treatment which was 0.057 and 0.286 g/pot, respectively. In different salinities, the use of potassium increased K

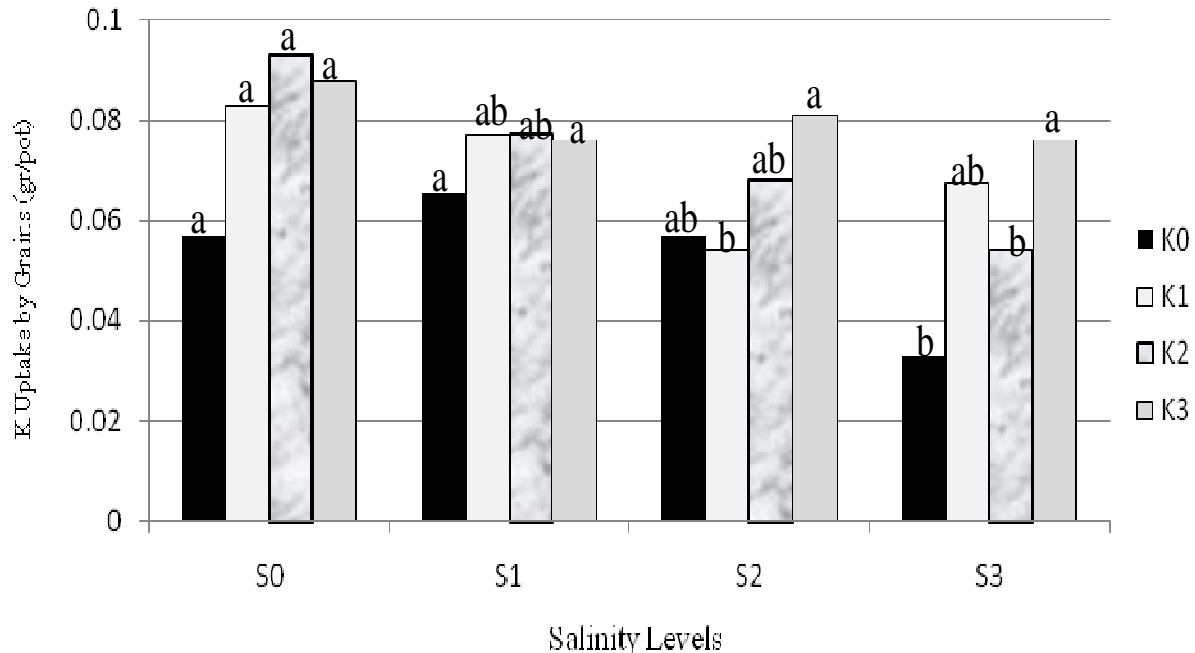


Figure 8. The effect of potassium and salinity treatments on K uptake by grains of rice.

uptake. Quampah et al. (2011) investigated the impacts of two potassium (K) levels (0 and 180 kg ha⁻¹) and two irrigation systems (lowland and upland) on yield attributes, grain yield and K uptake of rice. Potassium fertilizer increased the yield of rice, but the response of different genotypes of rice was variable. Effect of upland system on rice yield differed with K levels and rice genotypes; whereas K uptake by rice grains was significantly lower than in lowland.

In methods of K application, treatment K₃ (application in soil + K spraying) was the best method taking into consideration grain yield (0.08 g/pot) and straw yield (0.399 g/pot), respectively. Reduction of K uptake in grain and straw may also result from the competition between potassium and sodium and also because of increase in the uptake of sodium compared to K (Aslam et al., 1998; Din et., 2001; Homaei, 2002).

Conclusion

In relation to the results of this study, the grain yield and shoots, 100-seeds weight, tiller number, root dry weight decreased with increase in salinity, significantly. Also, increase in salinity caused decrease in potassium uptake in seeds and shoot, significantly. The best method of K application was soil intake plus spraying method.

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