Effect of chloride and sulfate salinity on nutrient uptake in Iranian rice (*Oryza sativa* L.)

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Abstract
Most of the studies on crops exposed to salinity stress under controlled in vitro conditions have used single salts only, usually NaCl. Studies involving the usage of natural salts mixtures of NaCl and Na_2SO_4 have been very few. Therefore a greenhouse experiment was conducted to determine the effects of both NaCl and Na_2SO_4 on mineral nutrient status of rice. Rice seedlings were hydroponically exposed to different salt concentrations and compositions for 21 days. The results revealed that only the root length was decreased by increasing salt level. The amounts of Na^+, K^+ and Mg^{2+} of shoot and root tissues increased at high salt levels. However Ca^{2+} content of root decreased with increasing salinity level. The Na^+/K^+ ratio was maintained in both shoot and root under salinity condition. An antagonistic effect between SO_4^{2-} and Ca^{2+} uptake was observed. A careful consideration of cation concentrations in shoots indicated that there is a gradual increase in Na^+ while K^+, Ca^{2+} and Mg^{2+} remained almost constant with salinity levels up to 5 dS/m. It is assumed that the composition of sodium salts plays a functional role in cationic balance within the Fajr genotype. As a conclusion the response of plant to salinity depends upon salt compositions.

Key words
Rice, salt stress, sodium salt compositions, mineral nutrients, nutrient imbalance.

Interaction
Salinity is a major constraint to rice production. Development of management alternatives (Shannon 1997) and improvement of salinity tolerance in current cultivars (Epstein *et al.* 1980) are the strategies for reducing salinity impacts in crop production. It was documented that many species have the ability to compartmentalize and accumulate Na^+ and Cl^- in older leaves. Only at high salinity levels, or in sensitive species which cannot control Na^+ transport or compartmentalize the ions, the ionic effect dominates the osmotic effect (Munns and Tester 2008). toxic ionic effects of excess Na^+ and Cl^- uptake, and reduction in nutrient uptake (K^+, Ca^{2+}) because of antagonistic effects, are effects of salinity on rice growth (Dobermann *and fairhurst* 2000). The high salinity increases sodium concentration and sodium uptake. During a long time in salinity, therefore, the sodium toxicity cause to reduce the yield (Castillo *et al*. 2003). There are antagonistic effects on nutrient uptake by plants that cause nutrient disorders particularly of K and Ca under salinity conditions. Excessive Na^+ concentration inhibits Ca^{2+} uptake in many plants (Grieve and Fujiyama 1987; Dobermann *and Fairhurst* 2000). Rice as a salt-sensitive crop is a species native to swamps and freshwater marshes and its cultivated varieties provide one of the world's most important food crops. Salinity stress causes a number of effects on plants such as osmotic effects, ion toxicity and nutrient imbalance. Whereas in nature the soil solution is a complex mixture of various cations like Na^+ and Ca^{2+} and anions like Cl^- and SO_4^{2-}. Therefore, the objectives of the present study were: (i) to determine the influence of both NaCl and Na_2SO_4 concentrations and composition on K^+, Ca^{2+} and Mg^{2+} uptake by Fajr genotypes during seedling stage and (ii) to examine the relationships between Na^+/K^+, Na^+/Ca^{2+} and Na^+/Mg^{2+} and growth characteristics of the rice seedlings under salinity condition.

Materials and method
One cultivar of irrigated land (Japonica group) rice (*Oryza sativa* L.), cv. Fajr is salt-tolerant and was selected from Rice Research Institute of Iran. Rice seeds were hydroponically grown for 21 days by half strength modified Hoagland's nutrient solution as control (pH=5.7±0.2 and EC=1±0.1 dS/m). Salinity treatments have been created at the concentrations of 3, 5 and 7 dS/m. Each concentration level was prepared by NaCl, Na_2SO_4 and their mixtures in the ratios of 1:1, 2:1 and 1:2 molar concentrations. The roots of rice seedlings were scanned by WINRHIZO system (chemistry lab, Land Resource Management Department, UPM). Subsequently, for mineral nutrient analysis (Ca^{2+}, Mg^{2+}, K^+ and Na^+) as described by Sahrawat *et al.* (2002), Five hundred mg of samples (root or shoot part) were ashed using a muffle furnace for 6 hours at 550 °C. Concentrated HCl and HNO_3 (20%) were added to ash and heated for 1 hour. The mixture was decanted

to a 25 ml volumetric flask and washed from the beaker with distilled water. The solution was analyzed for K^+, Ca^{2+}, Mg^{2+} and Na^+ by inductively coupled argon-plasma emission spectrometry (ICP trace analyzer; Land Resource Management department, University Putra Malaysia).. Differences between individual means were identified using Tukey's range test at the 5% significance level.

Results

The data analysis from scanned roots showed that the root length was only affected by salinity stress. The root length decreased when salinity level increased. Fajr genotype demonstrated the different shoot height and dry biomass when salt stress was created by different salt compositions. The tallest and the shortest shoot height were observed at NaCl and 1:1 molar ratio, respectively (Figures 1 and 2). Water content of root was not affected by salt concentration, while a significant difference in water content of shoot was observed under salinity condition. The water content of shoot decreased when 2:1 molar ratio as salt treatment was applied (Figure 3). After salt stress for 21 days, Fajr genotype showed a very large increase in Na^+ content in both shoot and root compared to control. The Na^+ and K^+ concentrations were increased by raising the salinity level. However the Na^+/K^+ ratio was maintained in both shoot and root under salinity condition (Figure 4). Na^+/K^+ ratio in both shoot and root tissue did not show significant difference when salt composition was changed. Na^+/Ca^{2+} ratio of root tissue decreased when Cl^- concentration dominated in root medium. However salt treatment with SO_4^{2-} dominance caused an increase of Mg^{2+} content in root tissue. This result was similar to the study of Mor and Manchanda (1992). Ca^{2+} concentration of root tissue decreased up to 7 dS/m, but salinity stress significantly increased magnesium concentration of root cells up to 5 dS/m.

The root characteristics such as root length, root surface area, root volume, tips and fork were not significantly influenced by salt composition. The Fajr genotype had different shoot dry biomass as the salt composition was changed. The highest and the lowest dry biomass were recorded for NaCl at 5 dS/m and 1:1 molar concentration ratio at 7 dS/m, respectively. The most reduction of shoot height was observed for mixtures of NaCl and Na_2SO_4 (1:1, 1:2 and 2:1 molar ratios). The K^+ amount in shoot tissue was more at 1:2 molar ratio than other salt compositions. Ca^{2+} content of root tissue was reduced at 1:2 molar ratio less than for other salt compositions, but the maximum amount of Ca^{2+} was observed at 2:1 molar ratio (Figure 5). The elements were transferred from root to shoot cells at 1:2 molar ratio more than for other salt compositions. Significant correlations between Na^+/K^+, Na^+/Ca^{2+} or Na^+/Mg^{2+} and growth parameters were not observed.

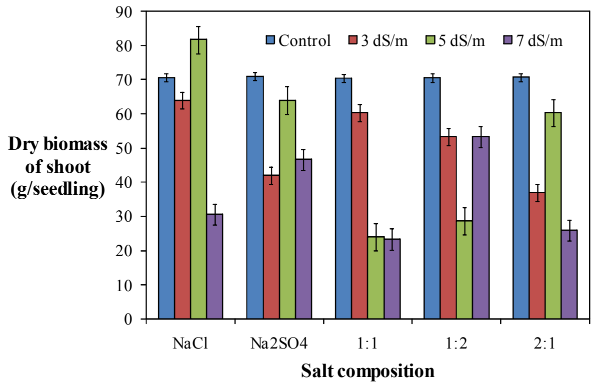

Figure 1. Fajr genotypebiomass differently responded to salt compositions. Vertical bars represent ±SE.

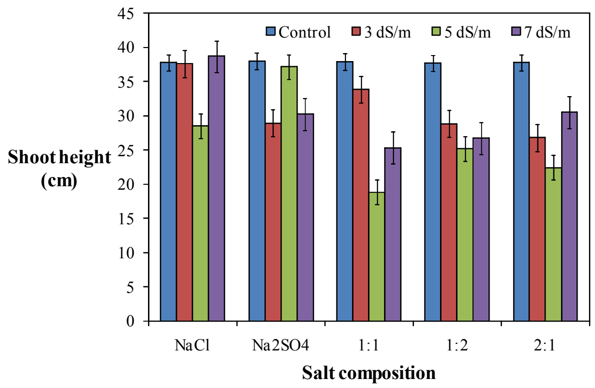

Figure 2. Shoot height at different salt compositions and salt levels. Vertical bars represent ±SE.

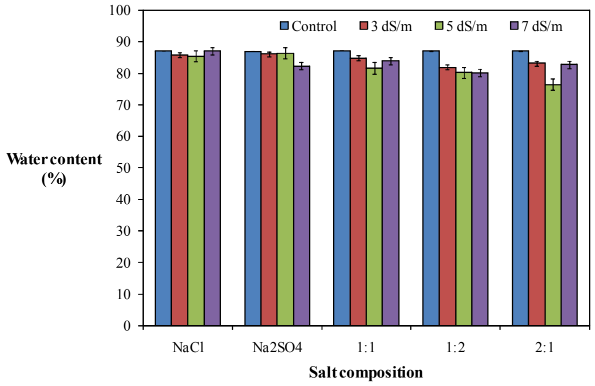

Figure 3. Water content of shoots depended upon salt composition and concentration. Vertical bars represent ±SE.

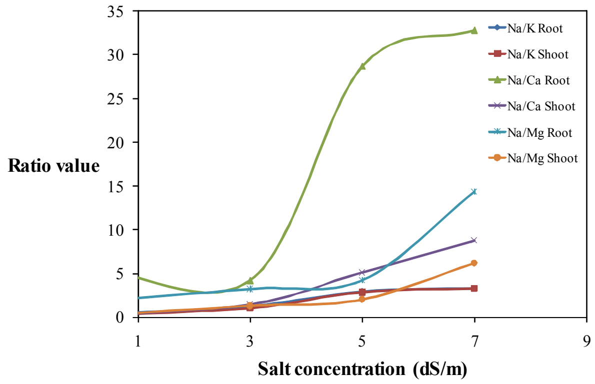

Figure 4. Increasing salt concentration increased the element ratio in both shoot and root.

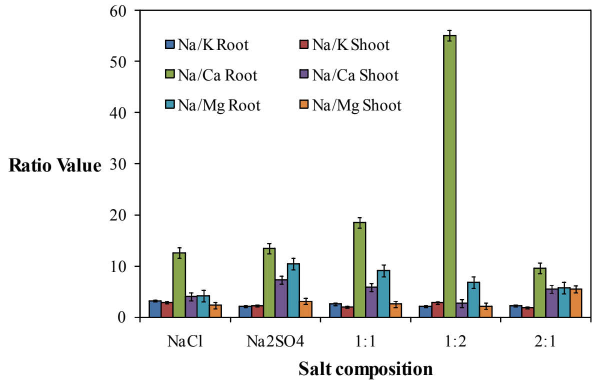

Figure 5. Nutrient ratios in shoot and root were changed by different salt composition. Vertical bars represent ±SE.

Conclusion

The reaction of the salt tolerant Fajr genotype to salt compositions showed extreme variability with salt composition. It seems that salt concentration has more effect on root growth than shoot growth (Munns 2002). Fajr genotype apparently had the lowest Ca^{2+} uptake from nutrient solution when chloride-sulfate (with sulfate dominance) solution was applied. It seems that SO_4^{2-} has an antagonistic effect on Ca^{2+} uptake. It is concluded that Na^+ accumulated in shoot can be deleterious but K^+, Ca^{2+} and Mg^{2+} accumulation compensate for Na toxicity. A careful consideration of cation concentrations in shoots indicated that there is a gradual increase in Na^+ while K^+, Ca^{2+} and Mg^{2+} remained almost constant with salinity levels up to 5 dS/m. It is assumed that the composition of sodium salts play a role in cationic balance within the Fajr genotype. Mineral nutrients imbalance in salt stressed plants is due to interaction between anions (SO_4^{2-} and Cl^-) and nutrients. This interaction was intensified when the salt compositions were 1:1, 1:2 and 2:1 molar ratios. Therefore the degree of salt tolerance during rice growth for different sodium salt compositions may not always be the same.

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