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Responses of Maize (*Zea mays* L.) Genotypes to Brackish Water at Seedling Stage

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Abstract

Seedling growth and ion content of different maize genotypes was assessed at solution culture at different concentration of brackish water to determine their tolerance ability. Growth was recorded as shoot fresh / dry weight, root fresh / dry weight, root / shoot length and leaf analyses for major inorganic ions (Na^+, K^+ & Cl^-). Results showed reduction in growth parameters in all treatments but it was greater in T_5 which contain combination of highest EC, SAR and RSC. The concentration of sodium and chloride ions in leaf sap increased while that of potassium decreased under brackish water salinity as compared to fit water. Among genotypes Sahiwal-02 and Akbar restricted the uptake of Na^+ and preferred K^+ uptake and thus maintained high K^+: Na^+ ratio and performed better in all types of brackish water.

Key words: Maize -- brackish water tolerance -- ion content -- seedling growth

Introduction

Under agro-climatic conditions of Pakistan, evapo-transpiration is several times higher than rainfall (2025 and 150 mm, respectively), which is responsible for net upward movement of salts through capillary action. So that, salinization of soil is a major environmental, agricultural and community problem throughout the Indus Basin of Pakistan. Irrigation systems are particularly prone to salinization, with about half the existing irrigation systems of the world now under the influence of salinization or water logging, due to low quality irrigation water. The shortfall in irrigation water requirement is likely to reach 107 MAF by 2013 [1]. In order to supplement to present canal water availability at farm-gate (43 MAF), 0.565million tube wells are pumping underground water to fulfill the crop water requirement [2]. Estimates show that about 70–80% of pumped water in Pakistan (67,842 million m^3) contains soluble salts and/or sodium ions (Na^+) levels above the permissible limits for irrigation water [3]. Rafiq [4] estimated development of surface salinity and/or sodicity on an area of about 3×10^6 ha in the country as a result of using marginal-quality drainage and groundwater without appropriate management practices. Growth of most agricultural crops irrigated with poor quality water suffers adversely [5-7]. Maize (*Zea mays* L.) is an important crop and provides raw material for agro-based industry. It is not only consumed by human beings in the form of food grains, but also provides feed for livestock and poultry. Obviously, the most efficient way to increase maize fodder production is to improve the salt tolerance of maize genotypes because increasing the salt tolerance of maize is much less expensive. In Pakistan, it is grown on an area of 1022 thousand hectare with an annual production of 3560 thousand tones [8]. Maize is moderately salt tolerant crop; the threshold salinity for corn is 1.7 dS m^{-1} [9]. In another report by Rhodes et al. (1992) maize can be grown at EC_e 1.5 to 3.0 and reduction in yield of maize is a common phenomenon because of poor quality irrigation water. Reduction in shoot dry weight (upto 61%) was reported by Abou El-Noor [10] in saline water treatment (EC 5.6 dS m^{-1}). Similarly Irshad et al., [11] reported that soil salinity reduced the plant height, shoot and root dry weight of maize. Abid et al., [12] studied the effect of salinity and SAR of irrigation water on the growth of maize and observed that plant height and biomass yield, relative growth rate (RGR), net assimilation rate (NAR) and relative leaf growth rate were depressed with EC_{iw} and SAR_{iw}.

Sufficient information is not available about the performance of different maize varieties irrigated with brackish water. In general, plants are the most sensitive to salinity during the vegetative and early reproductive stages and less sensitive during flowering and during the grain filling stage. However, a difference in the salt tolerance among genotypes may also occur at different growth stages. Zeng et al., [13] reported that various responses of different rice genotypes to salt tolerance exist at different growth stages. The objective of the present investigation was therefore to asses the response of different wheat genotypes to brackish water (different salts combinations) at seedling stage.

Materials and Methods

The present investigation was carried in solution culture conducted in wire house of Institute of Soil & Environmental Sciences, University of Agriculture, Faisalabad. Seeds of nine maize genotypes were sown in gravels contained in iron trays, and irrigated with water

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daily. When nursery was germinated, a small amount of ½ strength Hoagland nutrient solution was applied to supply the essential nutrients for the establishment of nursery.

Treatments of Synthetic Brackish Water and Nursery Transplantation

At 2-3 leaf stage, plants were transferred to foam plugged holes in polystyrene sheet, floating over 200 L capacity iron tubs lined with polyethylene sheet, containing Hoagland's nutrient solution. After two days different amount of salts (Na_2SO_4, $NaHCO_3$, $CaCl_2.2H_2O$ and $MgSO_4.7H_2O$) calculated by using quadratic equation were added to developed five treatments as T_1 fit water (EC=1.3 (dS m^{-1}), SAR=2.59 (mmol $L^{-1})^{1/2}$, RSC= 0.60 me L^{-1}); T_2 EC water (EC=10 (dS m^{-1}), SAR=8.0 (mmol $L^{-1})^{1/2}$, RSC= 0.80 me L^{-1}) ; T_3 SAR water (EC=2.4 (dS m^{-1}), SAR=20.0 (mmol $L^{-1})^{1/2}$, RSC= 1.0 me L^{-1}); T_4 RSC water (EC=2.6 (dS m^{-1}), SAR=8.5 (mmol $L^{-1})^{1/2}$, RSC= 5.4 me L^{-1}) and T_5 EC- SAR-RSC water (EC=10 (dS m^{-1}), SAR=20.0 (mmol $L^{-1})^{1/2}$, RSC= 5.40 me L^{-1}). Aeration was provided with air pump 8 hours a day. Seedlings were arranged according to Completely Randomized Design (CRD) factorial arrangement. The pH was maintained daily at 6.0-6.5, and nutrient solution was changed after 15 days. After 30 days of stress plants were harvested and data were collected for growth parameters [Shoot /root length (cm $plant^{-1}$); Shoot / root fresh weight (g $plant^{-1}$); Shoot / root dry weight (g $plant^{-1}$)] and Leave sap analysis for $Na^{+,}$ K^+ and Cl^-.

Results

Growth of maize genotypes in terms of shoot and root length, shoot fresh and dry weight and root fresh and dry weight was observed in different brackish water treatments. The effect of brackish water on plant growth and ionic concentration in leaf sap of wheat genotypes is explained as under.

Shoot fresh weight (SFW)

The adverse effects of different levels of brackish water were observed on shoot fresh weight (SFW) of all maize genotypes (Fig. 1). The variation among genotypes under same and various levels of brackish water was also statistically significant. The maximum mean SFW was observed at control (fit water) while minimum was recorded in T_5 (EC-SAR- RSC water). The comparison of genotypes indicated that Sahiwal-02 produced highest SFW followed by Q-806 and Akbar in all brackish water treatments. The lowest SFW was produced by the Q-8915. Maximum reduction in SFW was observed in T_5 (EC-SAR-RSC water) as compared to other brackish water treatments. In T_5 (EC-SAR- RSC water) Sahiwal-02, Akbar and Q-806 were high yielding genotypes while performance of Q-8915 was very poor.

Root fresh weight (RFW)

The effect of brackish water application on root fresh weight of different maize genotypes presented in Fig. 2 showed reduction in mean RFW of genotypes. Root fresh weight was maximum in fit water treatment and lowest was observed in T_5 (EC-SAR- RSC water). On an overall average basis, Sahiwal-02 produced the highest root fresh weight followed by Q-806 and Akbar in all brackish water treatments. The lowest RFW was found in Q-8915. Adverse effects of treatments were same as on shoot fresh weight, maximum reduction in RFW was in T_5 (EC-SAR- RSC water) as compared to other treatments.

Shoot length (SL)

Data presented in Figure 3 indicated that brackish water significantly decreased the shoot length of maize genotypes and this decrease was more in T_5 (EC-SAR- RSC water) as compared to other treatments. Thus maximum shoot length was observed in control (fit water) and lowest was noted in T_5 (EC-SAR- RSC water). Maize genotypes also showed different response in term of shoot length (cm) under different brackish water concentrations. On an overall average basis maximum plant height was attained by Sahiwal-02 followed by Akbar and Q-806 while minimum was found in Q-2414. Genotypic comparison showed that with different brackish water treatments (excluding control), the maximum average plant height was observed in T_2 (EC water) and minimum was in T_5 (EC-SAR- RSC water). Different genotypes in each brackish water treatment differed significantly and Sahiwal-2002 performed best under all treatments followed by Akbar.

Root length (RL)

Root length also adversely affected by brackish water treatments, data regarding reduction in root length are presented in Fig. 4. Statistical analysis of data showed reduction in mean root length in brackish water application treatments significantly compared with control (fit water). The reduction was more severe in T_5 (EC-SAR- RSC water). However, when genotypes were considered separately under specific treatment there was consistent trend of reduction in root length. On basis of an overall comparison, of genotypes showed same trend as in shoot length and Sahiwal-02 produce more root length followed by Q-806 and Akbar and Q-825 have the lowest root length.

IONIC CONCENTRATION IN THE LEAF SAP OF MAIZEGENOTYPES

Sodium concentration in leaf sap

The concentration of Na^+ determined in the leaf sap of maize genotypes under control (fit water), EC water, SAR water, RSC water and EC-SAR -RSC water are presented in Fig. 5. Brackish water treatments significantly increased Na^+ concentration with respect to control and maximum was found in T_5 (EC-SAR- RSC water) and lowest in T_2 (EC water).

However, the increase in salt concentration due to brackish water application increased the Na^+ concentration in leaf sap of maize genotypes. Among the genotypes, Q-805 accumulated highest Na^+ concentration in all brackish water treatments and minimum was in Q-2100. Results revealed that Sahiwal-02 and Akbar performed better in all brackish water treatments.

Potassium sodium ratio in leaf sap (K^+: Na^+)

On the basis of chemical analysis of maize leaf sap, K^+: Na^+ ratio was calculated in different maize genotypes under brackish water treatments. The data regarding K^+: Na^+ ratio presented in Fig. 4.6 showed the variation in K^+: Na^+ ratio in different maize genotypes leaf sap under different brackish water treatments. Results revealed that significant variation among the genotypes in same treatment as well as in different treatments. On an average basis, the maximum ratio was maintained by Q-2100 followed by Akbar and Sahiwal-02 and minimum was found in Q-8915and Q-825. Among the treatments, the highest ratio was observed in control (fit water) which reduced as the concentration of salts increased in brackish water treatments. The maximum reduction was observed in T_5 (EC-SAR- RSC water) as compared to other treatments. In T_5 (EC-SAR- RSC water) maximum variations in K^+: Na^+ ratio was noted and only two maize genotypes (Sahiwal-02 and Akbar) maintained highest ratio.

Discussion

Young seedling of maize genotypes exhibited a gross ability to adjust osmotically in response to high salt stress. Growth parameters measured were adversely affected by salt concentration in brackish water. This is in good agreements with results observed by others that brackish water reduced the maize plant growth [14 & 15]**.** The reduction in shoot fresh weight and other growth parameters were less in Sahiwal-02 and Akbar genotypes as compared to others in all brackish water treatments. So that these genotypes have ability to perform better under different type brackish water treatments.

The increased Na^+ concentration in leaf sap under salinity could be due to high salt concentration in the rooting medium [16] and passive sodium diffusion through damaged membranes, i.e. leakiness resulting in decreased efficient exclusion of Na^+. Nawaz et al., [17] reported increased Na^+ concentration in leaf sap due to enhanced inward movement and inhibited outward active exclusion of this ion under the combined stress of salinity and water logging. Serraj and Sinclair [18] reported that accumulation of Na^+, Cl^- and organic solute caused reduction in osmotic potential and due to osmotic adjustment plants maintained water uptake. Higher concentration of Cl^- become toxic in same range as that Na^+, if Na^+ and Cl^- are sequester in the vacuoles of cell, K^+ should accumulate in cytoplasm [19]. Different genotypes are differ in selectivity of K^+ over Na^+ which cause high K^+:Na^+ ratios in plant leaf sap [20]. In creased Na^+ and Cl^- concentration and decreased K^+ concentration in expressed leaf sap under salinity was also reported by Qureshi et al., Akhtar et al., and Rashid et al. [21-23]. The increased potassium in leaf sap of some of the genotypes under salinity stress could be due t o efficient potassium absorption by selective inclusion of sodium by cortical cells [24].

Conclusion

Under brackish water salinity stress sodium concentration in genotype Sahiwal-02 was low while that of K^+ high and resultantly a high K^+:Na^+ ratio was observed. It can be inferred that the genotype possess K^+:Na^+ selectivity characteristic of salt tolerance. The K^+ concentration of Akbar under brackish water salinity stress was also high and consequently these genotypes maintained a good tolerance in non-halophytes selectivity characteristic. Among other genotypes Q-2100 and Q-806 also performed better in all brackish water treatments.

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Figure 1: Effect of brackish water on shoot fresh weight (g plant-1) of maize genotypes

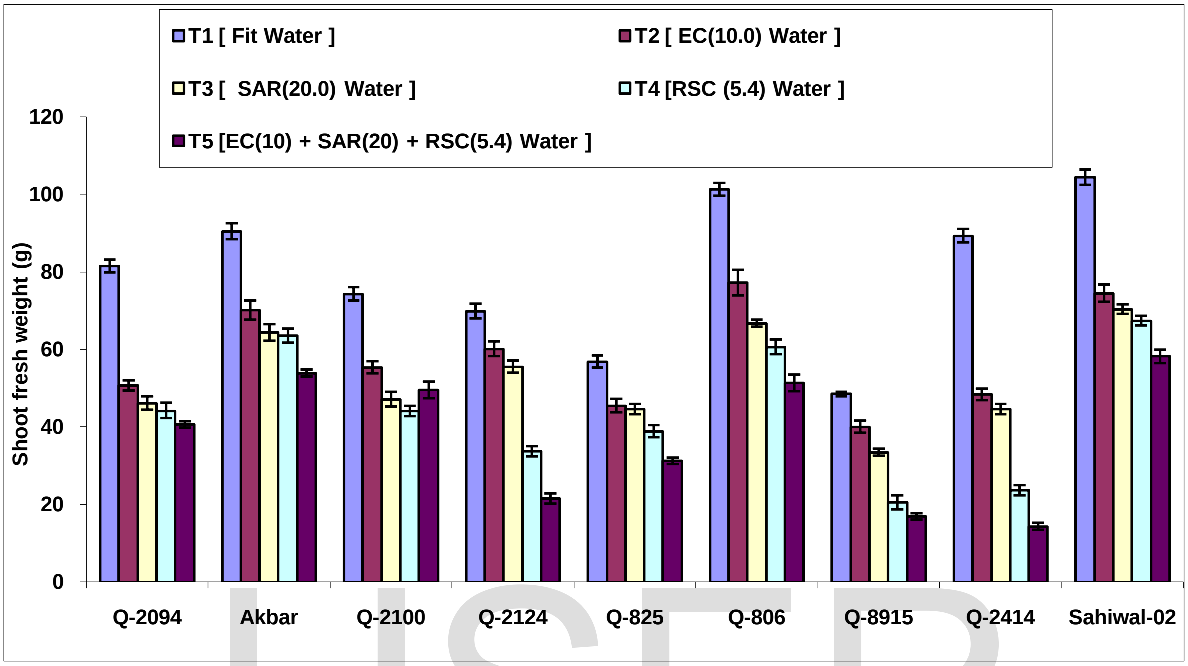

Figure 2: Effect of brackish water on root fresh weight (g plant-1) of maize genotypes

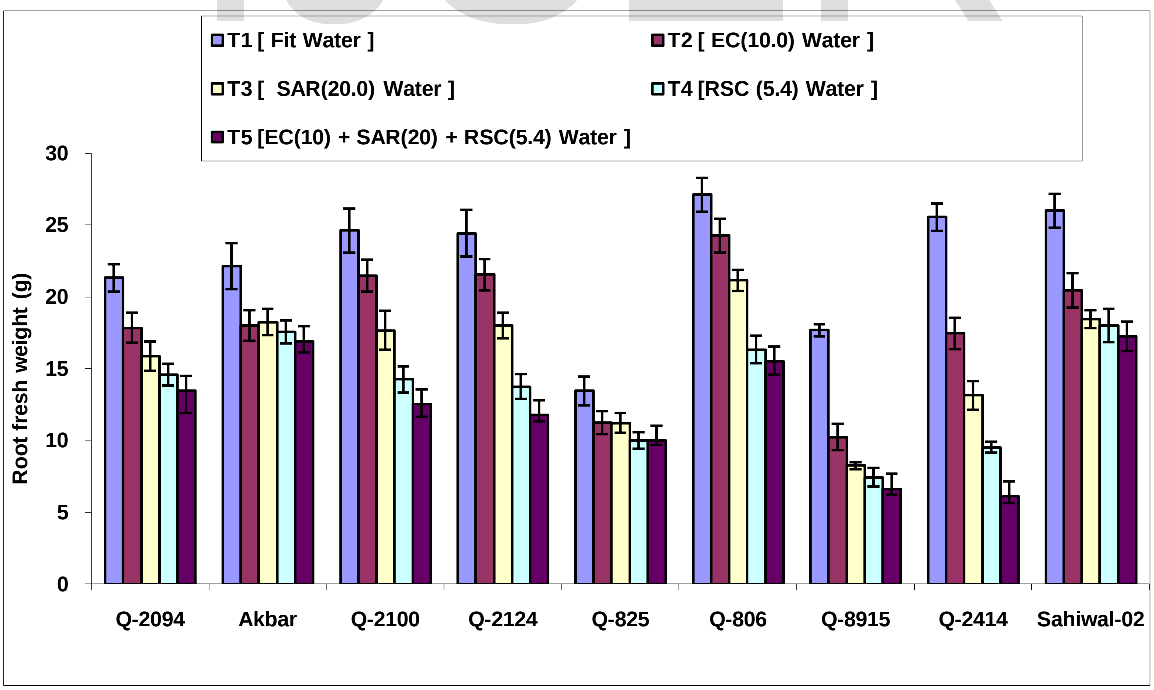

Figure 3: Effect of brackish water on shoot length (cm) of maize genotypes

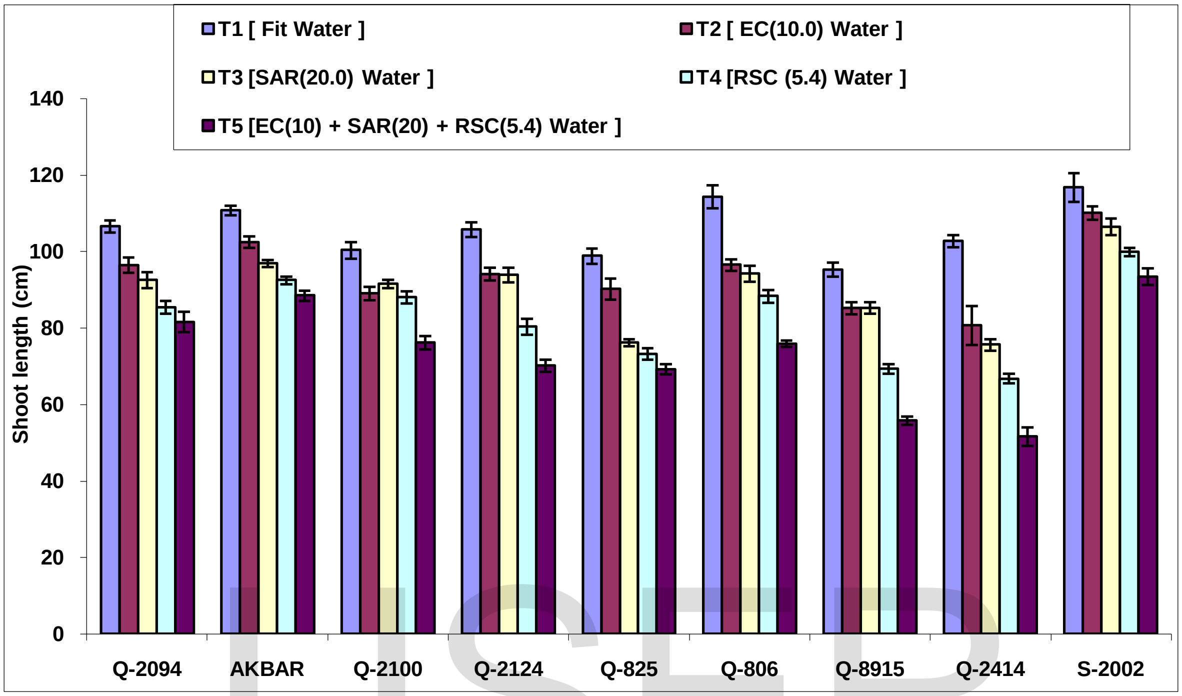

Figure 4: Effect of brackish water on shoot length (cm) of maize genotypes

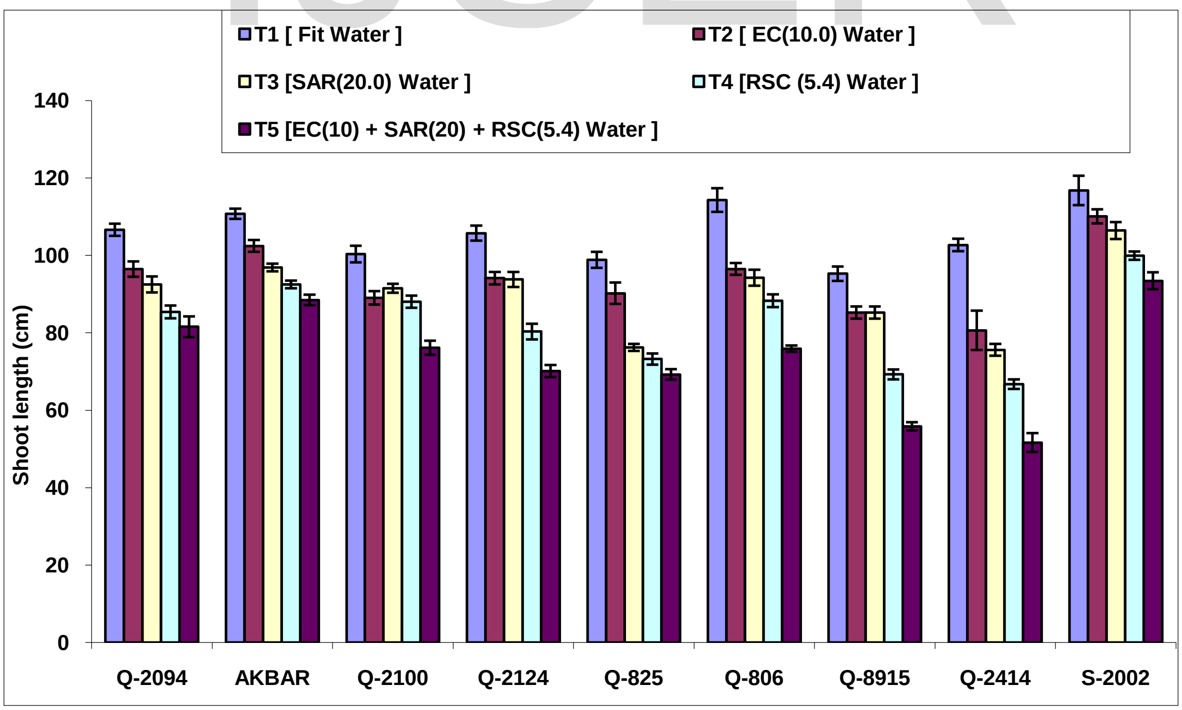

Figure 5: Effect of brackish water on sodium (mol m-3) concentration in leaf sap of maize genotypes

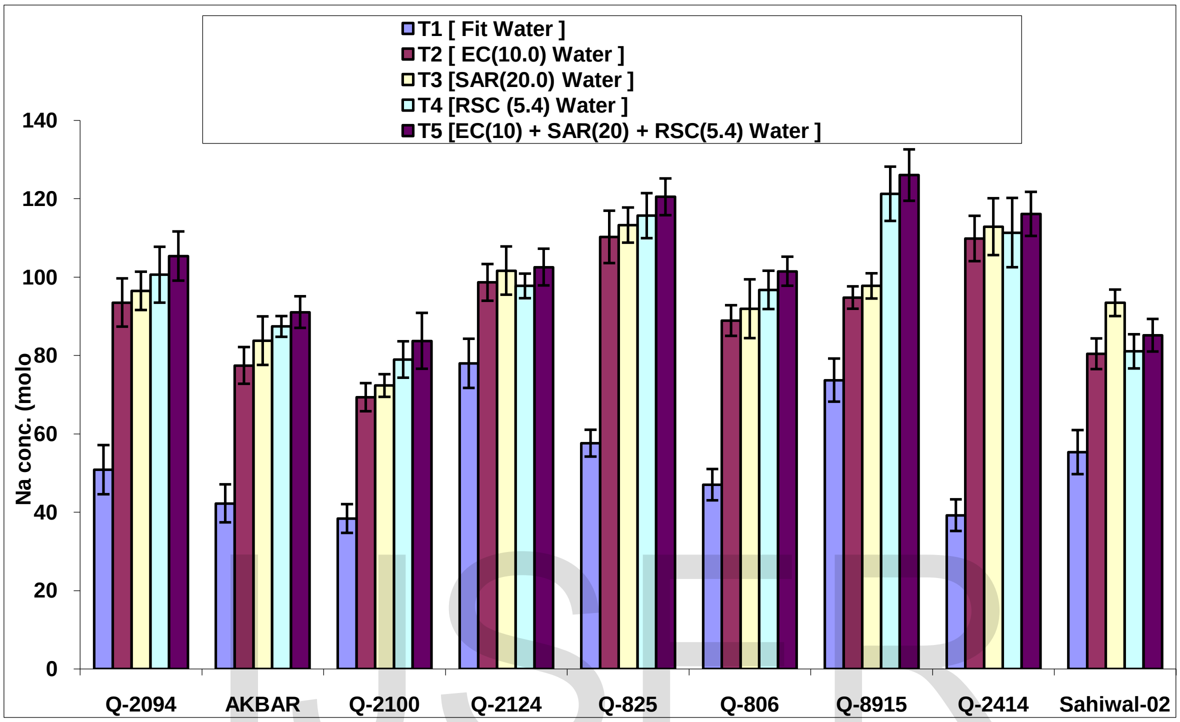

Figure 6. Effect of brackish water on potassium sodium ratio (K+: Na+) in leaf sap of wheat genotypes