Evaluating the Salinity Tolerance of Maize (*Zea mays* L.) Genotype under Brackish Water Application in Punjab-Pakistan

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Abstract: Context to screen out the tolerance ability of *Zea Mays* at existing marginal environmental conditions, a study was chalked out with the hypothesis to point out the salinity thrive by maize under brackish water irrigation practice for their sustainability options in existing agro-ecosystem. In this regard, solution culture study was initiated under controlled conditions at Soil & Water Testing Laboratory for Research, Multan. All the recorded growth attributes such as shoot fresh/dry weight, root fresh/dry weight, showed a hetrogenic behavior to various brackish water irrigation application. Salinity build up in all the leaves was quite different. Highest growth retardation has been noted in T5 amid all other treatments due to possessing high strength of salt stress (i.e., EC, SAR, RSC). Normal water had maintained lower buildup of Sodium content in leaves of maize. It has been concluded from the findings that Sahiwal 02 and Akbar genotypes performed better by retarding the uptake of Na and boosting the uptake of K due to their selection mechanism in all types of brackish water irrigation. Such findings would be best viable option and paradox for policy makers to develop a suitable cropping system at marginal environmental areas of Punjab.

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1. Introduction

Salinity is the major constraint in agricultural production of Pakistan due to aridity factor. Besides this, it is also becoming environmental and community threat due to continuous dumping up of low quality water. As our irrigation system through Indus basin is not in generally but particularly enhancing salinization due to availability of low quality water for irrigation. In addition to this, our country is also facing per capita demand of water. The water requirement would reach to 107 MAF by 2013 (Ghafoor *et al*., 2002b). 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 (Kahlown and Azam, 2003)**.** Latif and his colleague Baig (2004) also pointed out that our pumped underground water (70-80%) has more strength of Na^+ and total soluble salts as compared to the international standards for permissible limits for irrigation water. Rafiq (1990) estimated development of surface salinity and/or sodicity (on an area of about 3×10^6 ha) in our country due to usage of low quality groundwater without appropriate management practices. It is essentially to feed our surging population which increasing 3% annually. One has to grow various crops to meet their grain needs and shelter on harsh areas. Growth of most agricultural crops irrigated with poor quality water suffers adversely (Minhas, 1996; Chaudhry *et al*., 2001; Murtaza *et al*., 2005). Among other crops, maize (*Zea mays* L.) is an important crop and is not only consumed by human beings as food grains, but also provides feed for livestock and poultry in our agro-ecosystem. Maize genotypes, being halophytic in nature is much less expensive. In our country, it is cultivated on an area of 1022 thousand hectare with an annual production of 3560 thousand tones (2012). It is moderately salt tolerant crop; the threshold salinity for corn is 1.7 dS m^{-1} (Maas and Grattan, 1999). In another report by Rhodes *et al*. (1992) said that it 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. The research advancement also indicated that the reduction in shoot dry weight (upto 61%) was reported by Abou El-Noor (2002) in saline water treatment (EC 5.6 dS m^{-1}). Similarly Irshad *et al*. (2002) reported that soil salinity reduced all the growth attributes of maize. Similarly, Abid *et al*. (2001) verified that salt stress environment has not only decreased the agronomic growth attributes but chemical metabolism was also retarded in the maize crop.

Zeng *et al*. (2002) reported the same response for rice genotypes to salt tolerance at different growth stages like maize crop as previously discussed by various scientists.

In these consequences, a little bit information is available in scientific community regarding to performance of maize cultivars under brackish water irrigation in controlled dogma. 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. The objective of the present investigation was to screen out different maize genotypes brackish water containing different salts combinations at seedling stage.

2. Material and Methods

2.1. Raising of Nursery

The present investigation was carried in solution culture conducted in wire house of Soil & Water Testing Laboratory for Research, Multan. Seeds of nine maize genotypes were sown in gravels contained in iron trays, and irrigated with water 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.

2.2. 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). 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^{-}

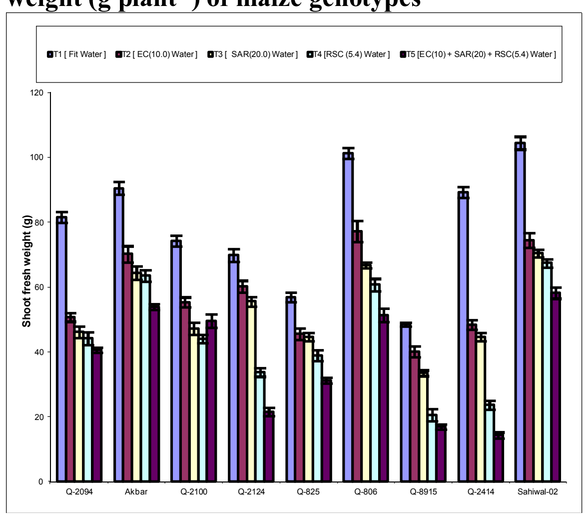
3. Results

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.

3.1 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 it was minimum in in T_5 (EC-SAR- RSC water). Among all the genotypes 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) than to other brackish water treatments. In T_5 (EC-SAR-RSC water) Sahiwal-02, Akbar and Q-806 remained high yielding genotypes while performance of Q-8915 responded very poor.

Figure 1. Effect of brackish water on shoot fresh weight (g $plant^{-1}$) of maize genotypes



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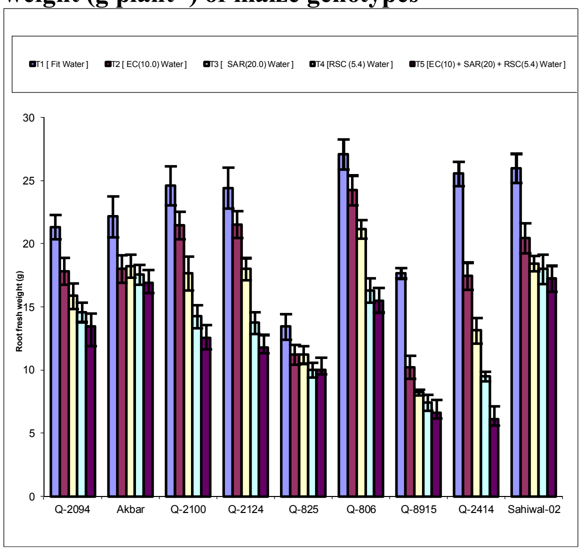
3. 2 Root fresh weight (RFW)

The effect of brackish water application on root fresh weight of different maize genotypes has been presented in Fig. 2. Root fresh weight was more in fit water treatment and lowest was observed in T_5 (EC-SAR- RSC water). On median content basis, Sahiwal-02 produced more root fresh weight followed by Q-806 and Akbar in all brackish water treatments. The lowest RFW was found in Q-8915. Root fresh weight responded in similar fashion like shoot fresh weight pertaining to adverse effects of all treatments.

Figure 2. Effect of brackish water on root fresh weight (g plant^{-1}) of maize genotypes



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3.3 Plant Height (PH)

Data presented in figure 3 indicated that brackish water significantly decreased the shoot length of maize genotypes. Higher shoot length reduction was noted in T5 as compared to other treatments. While fresh water yielded more shoot length. 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.

3.4 Root length (RL)

Root length also adversely affected by brackish water treatments (Fig. 4). Statistical analysis of data showed reduction in mean root length in brackish water application treatments significantly when 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.contrarily to all genotypes, root length responded similar to shoot length in its behavior. Their order of root length trends was viz a viz like Sahiwal-02 produce more root length followed by Q-806 and Akbar and Q-825 have the lowest root length.

Figure 3. Effect of brackish water on Plant Height (cm) of maize genotypes

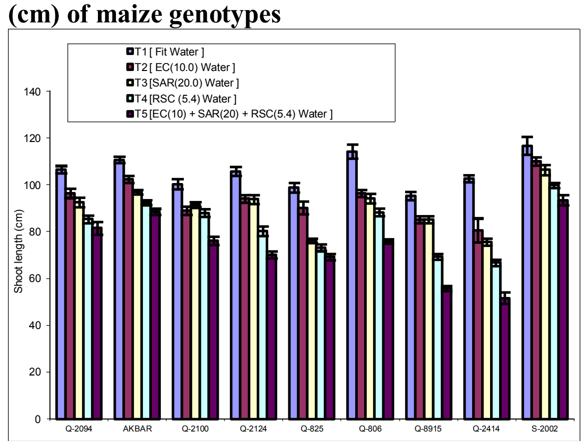

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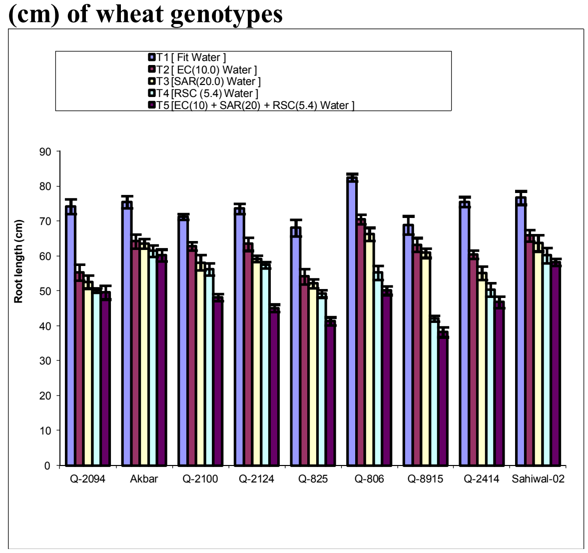
Figure 4. Effect of brackish water on root length (cm) of wheat genotypes



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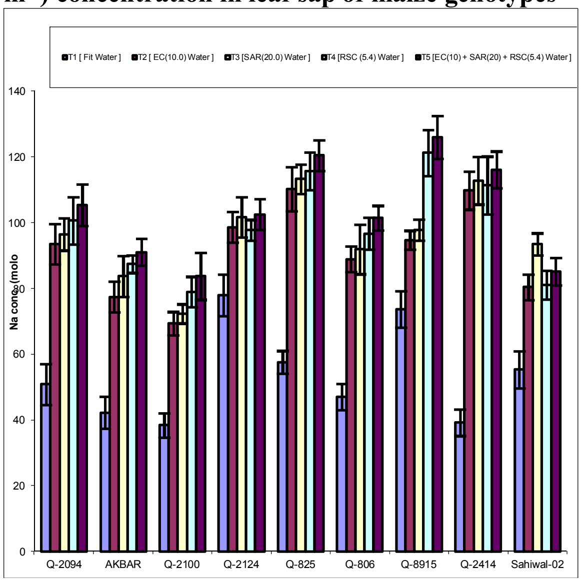
3.5 IONIC CONCENTRATION IN THE LEAF SAP OF MAIZEGENOTYPES

3.5.1 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).

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



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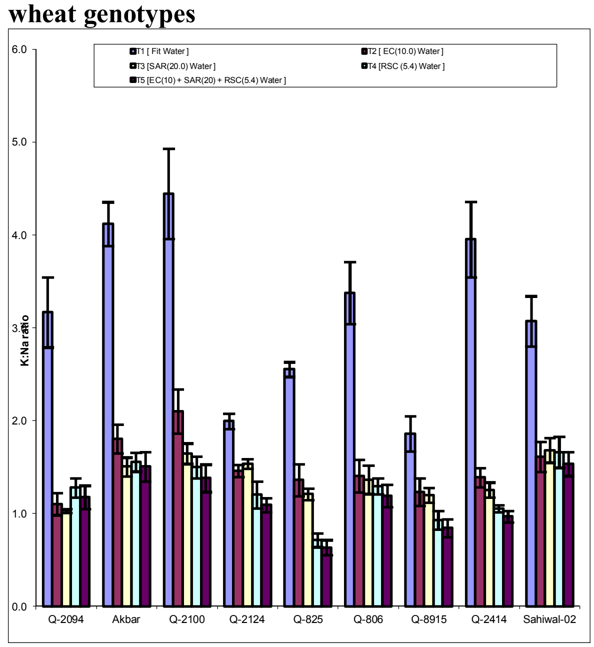
However, the increase in salt concentration due to brackish water application increased the Na^+ concentration in leaf sap of maize genotypes. Among the genotypes, Q-805 accumulated highest Na^+ concentration in all brackish water treatments and minimum was in Q-2100. Results revealed that Sahiwal-02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

3.5.2 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 all 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.

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



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4. Discussions

Owing to low quality water for irrigation, salinity build up is consistently increasing in our existing agro-ecosystem. It is the dire need to focus on the halophytic nature of the maize genotypes for their sustainability in our existing ecosystem. However, among all other crops, maize crop also has been pointed out as halophytic nature. Its seedling is quite selective in absorption of Na^+ mineral.

Therefore, **y**oung seedling of maize genotypes exhibited a gross ability to adjust osmotically in response to high salt stress. Growth parameters measured as per our record; however our data coincides the salt elevation impact due to usage of brackish irrigation water. Observed by Cicek and Cakirlar, 2002; Feng and Cong, 2005, the maize plant growth was retarded due to use of brackish water for irrigation purpose**.** Prior to this reduction in shoot fresh weight and other growth parameters were less in Sahiwal-02 and Akbar genotypes than to others genotypes under brackish water treatments. Hence these genotypes performed better under different type brackish water treatments and should be incumbanced in existing cropping system at marginal lands.

Ionic concentration plays a vital role for the metabolic activity of cell. The cortical cells have the ability to absorb the various nutrient elements for the growth and development of the cell at subsequent growth stages. These cells have a very good mechanism to absorb the halo-nature element in maize crop in order to boost up its growth and development. No drought Na^+ element has a negative impact on the growth attributes. Our data has clearly indicated that Na^+ concentration is less in leaf sap but has a little negative impact due to selective absorption of K^+ by cortical cells. Various scientists have shown different opinion in this regards. Serraj and Sinclair (2002) 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 which was reported by Hasegawa *et al*., 2000.

Nawaz *et al*. (1998) 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.

Different genotypes are differing in selectivity of K^+ over Na^+ which causes high K^+: Na^+ ratios in plant leaf sap (Jeschke & Hartung, 2000). Increased Na^+ and Cl^- concentration and decreased K^+ concentration in expressed leaf sap under salinity was also reported by Qureshi *et al*. (1991), Akhtar *et al*. (1994) and Rashid *et al*. (1999). 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. Our results also coincide with the Schachtman and Munns, 1992.

The plant height is a major index for the yield contributing factor which entirely depends on the availability of nutrient indices in this essence. Prior to this, marginal conditions always hinder the metabolic activities of any crop in the foresaid existing environmental consortia. Synchronizing the negate impact of any stress is a major lingering pull to alleviate the osmotic impact on every cell lamella. Its enhancement due to growth and development mechanism is entirely dependent on availability of their structural and functional essential element like K^+ and nitrogen nutrient. However, our data clearly indicing the enhancement of plant height due to availability of K^+ contents by decreasing the Na^+ content through selective absorption mechanism. However, Rahmatullah *et al*. (2012) have noted the similar findings and strongly supported to our results. Another report by Babu and his colleagues (2012) has shown the clear linear relationship to plant height with the availability of nutrient. Similarly the root:shoot ratio, root length and shoot length also responded similarly like to plant height. Various scientists (Snapp & Shennan 1994; Shafqat *et al*., 1998;Blanco *et al*., 2002; Liang Peng *et al*., 2007; Bilgin *et al*., 2008; Khan, 2009; Mahmood *et al*., 2009; Behmani *et al*., 2012) have shown the similar response of various crops under brackish water irrigation scheme.

Conclusion

The finding concludes that sodium contents were recorded in Sahiwal 02 Genotype by enhancing the higher buildup of K which results higher K: Na ratio. It could be inferred that the genotype possesses 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. It is summarized that Q-2100 and Q-806 genotypes may be encouraged to policy makers to induct in cropping scheme at marginal areas of Pakistan.

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