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# Evaluation of Sugarcane (*Saccharum officinarum* L.) different Genotypes to the Uptake and Transport of Ionic in Salt Stress Conditions

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**ABSTRACT: Sugarcane, as an important sugar crop, is planted in the tropical and subtropical countries most of which are facing the problem of soil or water salinity. This study was conducted to evaluate the ionic elements uptake and transport of sugarcane genotypes in salt stress conditions in south west Iran Sugarcane Research and Training Institute in hydroponic greenhouses. A factorial experiment within a completely randomized design (RCD) at three replications under greenhouse controlled conditions and hydroponics. The treatments included 9 sugarcane genotypes and salinity 4 levels (0, 3, 6 and 9 ds.m$^{-1}$). The results of the experiment showed that salinity decreased the concentration of potassium, calcium, and also increased the concentration of sodium and chlorine in root and shoot which ultimately led to reduced plant biomass, especially in more sensitive cultivars. Besides this, the results showed that the root had an effective role in control, uptake, and transport of ions to the shoot. It was indicated that most of the aerial transport of sodium and chlorine was observed in salt treated cultivar IRC99-06 at 9 ds.m$^{-1}$, while the lowest transfer of Na $^{+}$ and Cl$^{-}$ treated 0 ds.m$^{-1}$ was observed in clone C4. So, it seems that in addition to the fundamental importance of the control of ion uptake mechanisms, there are mechanisms in other organs effecting absorption and transport of these elements as well as genotype.**

**Keywords:** Salt, sugarcane roots, ionic elements, clone.

## INTRODUCTION

Sugarcane (*Saccharum officinarum* L.) is one of the main plants which provides people with most of the sugar consumption. Due to increasing demand for sugar consumption, cultivation of the crop and ancillary products are expanded in the arid and semi arid subtropical regions of south western Iran. But due to the increasing demand for sugar, the plant cultivation has quickly spread to dry subtropical regions (Bernstein et al., 1966). Water and soil salinity in Iran is a major problem in the agricultural sector. According to the researches, about 33/7 million hectares of agricultural lands in Iran are facing the problem of salinity (Imam, 2004). In recent years, due to salinity and water shortage a lot of herbal products in various areas of the country have been damaged. Reasons creating high salinity in soil EC can be pointed out as such: high water evaporation from the soil surface and use of water with low quality and high EC. Soltani Hoveize *et al* (2007) in a study on sugarcane showed that with the increase in salinity levels (0, 25, 50 and 75 0/0 Nacl), the amount of intake and transport of chloride and sodium salt increased and depending on the genotype, different amounts of sodium salts in ratio to potassium and calcium was absorbed. Besides this, chlorine absorption has been far less than other salts in resistant types.Summart *et al.* (2010) stated that if rice be grow under salt stress (Nacl: 250 mM), sodium concentration rises to 40-fold in comparison to plants growing under natural conditions. Hajlaoui *et al.* (2009) in a study tested four levels of salt on maize in relation to the concentration of sodium in the root. They stated that with the increase of salinity, sodium concentration increases 165, 270, and 400 percent respectively compared to the control treatment. Shomeili (2004) in a study reported that the increase of salt stress led to the increase of accumulation of sodium ions and other chloride salinity and the decrease of potassium in the stem and root of all susceptible and resistant cultivars as well. This study aimed to assess the uptake and transport of sugarcane different genotypes in ionic salt stress conditions.

## MATERIALS AND METHODS

The present study was performed in Sugarcane Research & Training Institute in hydroponic greenhouses. In conducting the test six varieties of sugarcane were used among which three were old commercial ones (CP69-1062, CP57-614, CP48-103) and three new promising varieties cultivars ( IRC99-01, IRC99-04, IRC99-06). And also three salt tolerant clones were used: C2, C3, and C4. Salinity 4 levels (0, 3, 6 and 9 $ds.m^{-1}$). A factorial experiment in a completely randomized design (CRD) with three replications was performed in hydroponic systems. The sugarcane nutrients dietary was provided through Clements's (1980) solution as recommended by Serenoa *at al.* (2007), based on Hoagland's (1950) modified model. The desired healthy and free from pests and diseases setts were taken from field to the laboratory and were cut into about five- centimeters parts. A two single setts were placed between two completely wet filter papers. The buds was disinfected with 70% ethanol and washed with sterile water once. It was grown in plastic trays. The trays were placed in an oven at 30°C until the first bud germinated perfectly. The filter papers were humidified with sterile water. The number of two- bud seed sprouts planted for each variety was four times of the required number. This was so in order to obtain similar seedlings to be taken to the hydroponic environment. After germination and scions' emergence, plants that had two full leaves and apparently similar to each other were selected and transported to hydroponics environment containing nutrient medium. The ten-liter containers were polyethylene with dimensions 50(L) × 30(W) × 20(H) cm. There were holes on the polystyrene lid to place the seedlings. The smallest hole was allocated to a pipe transferring oxygen from the air pump into the container. To establish every single small seedling into its place, a small soft sterile piece of sponge was used. To get the seedlings adapted to the nutrient solutions and to be ensured from the growth of seedlings in as such environment, the seedlings were kept for three weeks and then salt treatments were applied. To prevent salinity, stress applied to the plants was gradual- in a week time span. In order to keep the concentration of salt and nutrients stable, the solutions were replaced every two weeks. The initial PH of the solution was adjusted with sulfuric acid and soda in level six. During the experiment, the nutrient solution PH was adjusted daily, while the EC was adjusted weekly. The nutrient solution was air conditioned daily by a pump. In order to perform ion plant tissue analyze, dry method was used. The amount of sodium and potassium ions in plant tissues was determined by using a Flamphotometer in Hamada and EL-enany method (1994), chloride in Richards method (1954) and also by calcium ion in Jackson method (1973). The data obtained from the above measurements were analyzed by SAS, while the mean values were compared through the LSD at 5%.

## RESULTS AND DISCUSSION

*A. Sodium and chloride concentrations in roots and shoots*

Results showed that the effects of salinity and sugarcane genotypes were significant on Na and Cl concentrations in shoot and root (Table 1). The highest concentrations of sodium and chloride salinity levels were observed in roots and shoots in variety IRC99-06 in levels 9 $ds.m^{-1}$ (Table 2). With increase levels of salinity in plant growth culture, the sodium content increased in the roots and shoots of plants significantly. Besides this, the lowest concentrations of Na and Cl in roots were seen in C4 clone in level 0 $ds.m^{-1}$ which showed no significant difference in the levels of C3 clone salinity. The comparison between the sodium concentration of roots and shoots obtained from the effect of salinity, sodium concentration in shoots increased since most of sodium is transferred to shoot during the evapotranspiration period. Due to loss of water through the cuticle and stomata, sodium concentration is seen more than in the underground organs such as roots, in which sweating not occurring (Munns *et al.,* 2006). Salmasi (1996) studies showed that with salinity increase, in all processes of sample picking, the sodium amount increase was seen in roots of sweat. Na and Cl ions are the commonest ions in soil and salt water which could have harmful effects on plants. They increase the osmotic pressure of soil solution and create ion toxicity in the plant and disturb the ions balance needed for the plant such as potassium (Yadeorlo and Hervan, 2004).

*B. Potassium and calcium concentrations in roots and shoots*

Analysis of variance showed that the effects of salinity and sugarcane genotypes were significant on potassium and calcium concentration of roots and shoots (Table 1). The highest concentration of potassium in roots and shoots was observed in clone C4 at 0 $ds.m^{-1}$ salinity, while the lowest concentration of potassium in roots and shoots was in IR-06 at 9 $ds.m^{-1}$ salinity levels (Table 2). Salinity increase in plant growth culture led to potassium decrease concentration in root and shoot. Potassium concentration decreased with the increase in salinity levels in the plant where the salinity levels in 6 and 9 $ds.m^{-1}$ showed a significant decrease in potassium concentrations in roots and shoots. Increase in sodium concentration leads to disturbance in potassium absorption on root as a point for nutrients exchange. Since potassium is uptake by plant roots exclusively, with the increase of salinity the specific seats allocated to potassium absorption are occupied by sodium ions and this results to potassium uptake through plant roots disturbance .Potassium pumps activity is related to enzyme activity .When the plant is under salt stress, the enzyme activity is disrupted by the increase of sodium concentration in the plant and this results to high concentrations of sodium and then potassium uptake by roots is prevented.

**Table 1: Analysis of variance of measured traits in the leaves and roots is affected by treatments.**

| variation sources | Degree of freedom | Leaf Na | Root Na | Leaf Cl | Root Cl | leaf Ca | Root Ca | Leaf K | Root K | Leaf K/Root k | Leaf Na/Root Na | Leaf Na/ Leaf K |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Salinity** | 3 | 25.65** | 10.47** | 2093.25** | 7778.57** | 22.67** | 13.19** | 38.78** | 4.04** | 3.07** | 3.69** | 14.19** |
| **Genotype** | 8 | 6.24** | 2.21** | 481.16** | 688.20** | 1.60** | 2.84** | 5.81** | 2.80** | 0.53** | 0.40** | 1.59** |
| **Salinity* Genotype** | 24 | 0.9** | 0.28** | 110.67** | 198.17** | 0.27** | 0.59** | 1.55** | 0.27** | 0.57** | 0.8** | 0.15** |
| **Error** | 72 | 0.02 | 0.01 | 8.65 | 15.89 | 0.02 | 0.04 | 0.06 | 0.01 | 0.01 | 0.009 | 0.006 |
| **C.V** | | 6.58 | 8.43 | 3.95 | 5.16 | 6.75 | 6.90 | 9.82 | 7.81 | 7.05 | 6.81 | 7.54 |

** Significant at p<0.001.

Sodium disturbs the activity of this enzyme and in a competitive environment prevents the absorption of potassium done by roots (Liang *et al.,* 2003). There is a significant negative correlation between concentrations of leaves sodium and leaves potassium, indicating that with the increase of salinity levels, leaf potassium concentration decreases. Also, the analysis of variance (Table 1) shows that the effect of salinity and sugarcane genotypes had a significant effect on roots and shoots calcium concentration. The highest concentration of calcium shoot was in clones C2, C4, and CP69-1062 in the salinity level of 0 ds/m, while the lowest calcium concentration of the shoot was observed in IR-06 shoot 9 ds/m salinity level (Table 2). Besides these there was no significant difference in calcium concentration in salinity 0 ds/m in roots which is due to the absence of salinity, whereas with the increase of salinity, calcium amount got decreased. The minimum calcium concentration was observed in the root of IR-06 at 9 ds/m salinity. Because of the competitive effects existing between sodium and calcium, the increase of salinity increased sodium concentration in roots and shoots and these results to decrease in calcium concentration in roots and shoots. There are obvious reasons suggesting that calcium is necessary to maintain the wellbeing of cell membranes. These, also, demonstrated that sodium takes calcium out of cell membrane and occupies its seat so that the membrane is not doing its function properly. Calcium is also a non-toxic mineral and even at its high concentrations is non-toxic. Calcium is also known as a converter of hormonal and environmental messages into elements concerned in cell metabolism. Salinity affects the absorption and transport of calcium highly.

**Table 2: Comparison of the results of experimental treatments effect on measured traits in leaves and roots.**

| Salinity level | Genotype | Leaf Na (Mg/gr ) | Root Na (Mg/gr ) | leaf Cl (Mg/gr ) | Root Cl (Mg/gr ) | leaf Ca (Mg/gr ) | Root Ca (Mg/gr ) | leaf k (Mg/gr ) | Root k (Mg/gr ) | Leaf /Root k k (Mg/gr ) | ıf Na/Root Na (Mg/gr ) | Leaf /leaf k Na (Mg/gr ) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 0 ds.m$^{-1}$ | IR-04 | 1.28qrs | 0.86mno | 64.00qrs | 55/00mn | 3.50bc | 3.90a | 2.38efg | 1.92g-k | 1.24m-p | 1.47h-l | 0.53i-l |
| | IR-06 | 1.66no | 1.82fg | 64.00qrs | 60.00lm | 2.78efg | 3.97a | 1.53jkl | 1.51o-r | 1.01o-r | 0.91op | 1.20f-j |
| | C2 | 1.30qr | 0.47p | 61.00st | 633.33l | 3.66ab | 3.90a | 4.93a | 2.57c | 1.88d-h | 1.20l-o | 0.26jkl |
| | IR-01 | 1.62no | 1.49ijk | 81.00efg | 50.00no | 2.93de | 3.89a | 2.74de | 1.32rs | 2.00c-g | 1.17l-o | 0.59h-l |
| | C3 | 0.62u | 0.48p | 57.67t | 47.33o | 3.44c | 4.00a | 4.48b | 2.80b | 1.59h-l | 1.28j-n | 0.13l |
| | C4 | 0.39u | 0.79no | 62.67rs | 52.33no | 3.72a | 3.78ab | 5.06a | 3.44a | 1.47j-m | 0.49q | 0.07l |
| | CP-48 | 1.04st | 1.05lm | 69.00l-p | 62.00l | 3.60bc | 3.78ab | 4.36b | 2.34de | 1.86f-i | 0.99nop | 0.23kl |
| | CP-57 | 0.94t | 0.88mno | 62.67rs | 61.67l | 3.58b | 3.96a | 4.28b | 2.52cd | 1.64h-k | 1.05mno | 0.22kl |
| | CP-69 | 1.12rst | 0.91mno | 62.67rs | 52.67no | 3.70a | 3.79ab | 4.35b | 1.99f-i | 2.17b-e | 1.23k-n | 0.25jkl |
| 3 ds.m$^{-1}$ | IR-04 | 2.81hi | 1.04lm | 71.67k-n | 78.33ghi | 2.46hij | 2.89lm | 4.47b | 1.82i-m | 2.48b | 1.70def | 0.63h-l |
| | IR-06 | 3.14ef | 1.22kl | 94.00bc | 92.00de | 2.01lm | 2.36de | 1.31lm | 0.77v | 1.56i-l | 1.59f-j | 2.63de |
| | C2 | 0.46u | 0.87mno | 65.00p-s | 74.00hig | 2.82ef | 3.51bc | 2.84d | 1.76j-n | 1.61h-l | 1.54g-j | 0.16kl |
| | IR-01 | 2.56jkl | 1.40ijk | 64.33p-s | 82.67fg | 2.60fgh | 2.86de | 3.71c | 1.03tu | 2.09bcd | 1.86def | 0.69h-l |
| | C3 | 1.57op | 1.36jk | 68.33m-q | 63.67l | 2.62fgh | 3.56bc | 4.47b | 1.95g-j | 2.28bcd | 1.18l-o | 0.35i-l |
| | C4 | 1.24qrs | 0.70o | 63.00rs | 62.00l | 3.12d | 3.90a | 5.24a | 2.39cde | 2.89a | 1.11mno | 0.23kl |
| | CP-48 | 1.35pqr | 0.88mno | 67.33n-r | 75.00hig | 2.50hi | 2.66ef | 3.67c | 2.10fg | 1.74g-j | 1.55f-j | 0.36i-l |
| | CP-57 | 2.75hig | 1.03lm | 71.67k-n | 76.00hig | 2.30ijk | 2.71ef | 3.34c | 1.77j-m | 1.87e-i | 1.67d-h | 0.83g-l |
| | CP-69 | 2.34lm | 0.82no | 67.33n-r | 79.00gh | 2.13kl | 2.54fg | 2.52def | 2.09fgh | 1.20m-q | 1.84def | 0.92g-l |
| 6 ds.m$^{-1}$ | IR-04 | 2.88gh | 2.22d | 82.00ef | 92.00de | 1.40opq | 1.80hi | 1.84hij | 0.87uv | 2.11c-f | 1.30j-m | 1.56fgh |
| | IR-06 | 3.51d | 2.68c | 94.33b | 70.33jk | 1.15q | 1.73hij | 1.30lm | 0.65v | 2.03c-g | 1.31j-m | 3.77bc |
| | C2 | 1.18qrs | 1.63gh | 77.67f-i | 72.33ij | 2.00lm | 3.51bc | 2.26fgh | 2.18ef | 1.03o-r | 1.35i-m | 0.53i-l |
| | IR-01 | 2.82hi | 2.15d | 80.00e-h | 92.33cde | 1.29pq | 1.46jk | 1.09m | 1.01tu | 1.08n-r | 1.31j-m | 2.60de |
| | C3 | 1.83n | 0.94mn | 72.67j-m | 74.33hij | 1.41op | 3.00d | 1.41klm | 1.71k-o | 0.82rs | 1.94de | 1.30f-i |
| | C4 | 1.37pq | 0.92mn | 66.00o-r | 65.67kl | 2.56gh | 3.44c | 2.00ghi | 2.02f-i | 0.98pqr | 1.28klm | 0.68h-l |
| | CP-48 | 3.18ef | 1.41ijk | 70.00l-o | 84.33fg | 2.00lm | 1.66h-k | 1.80ijk | 1.61m-p | 1.12n-r | 2.28bc | 1.77efg |
| | CP-57 | 3.08fg | 1.55hig | 76.67g-j | 83.33fg | 1.44op | 1.76hi | 1.53jkl | 1.64mno | 0.93p-s | 1.99cd | 2.01def |
| | CP-69 | 2.50kl | 1.41ijk | 75.67h-k | 82.67fg | 1.60no | 1.92h | 2.22f-i | 1.71k-o | 1.30l-o | 1.76d-h | 1.13f-k |
| 9 ds.m$^{-1}$ | IR-04 | 3.82c | 2.99b | 82.67e | 106.00b | 0.80r | 0.84no | 1.37lm | 1.21st | 1.19m-q | 2.27b | 2.85cd |
| | IR-06 | 5.74a | 3.35a | 104.30a | 126.00a | 0.42s | 0.60o | 0.52n | 0.26w | 2.18b-e | 2.71a | 4.38a |
| | C2 | 2.85gh | 1.74fgh | 83.00e | 88.00ef | 1.59no | 1.57ijk | 2.29fg | 1.41p-s | 1.62h-k | 1.64e-i | 1.25f-i |
| | IR-01 | 4.58b | 3.03b | 81.00efg | 108.00b | 1.16q | 1.01mn | 1.09m | 1.65mno | 0.66s | 1.51g-k | 4.21b |
| | C3 | 2.23m | 1.57hi | 81.00efg | 84.00fg | 2.22jkl | 1.62ijk | 1.49j-m | 1.66l-o | 0.90qrs | 1.44i-l | 1.51fgh |
| | C4 | 2.59ijk | 1.75fgh | 73.67i-l | 75.67hij | 2.15kl | 2.33g | 2.52def | 1.87h-l | 1.34k-n | 1.39kl | 1.03g-l |
| | CP-48 | 3.52d | 2.08de | 89.33cd | 95.33cd | 1.40opq | 1.17lm | 1.25lm | 1.36qrs | 0.92qrs | 1.69d-i | 2.82cd |
| | CP-57 | 3.37de | 2.26d | 89.00d | 98.67c | 1.58no | 1.06mn | 1.48j-m | 1.54n-q | 0.96p-s | 1.49h-k | 2.86cd |
| | CP-69 | 2.38klm | 1.91ef | 83.67e | 95.00cd | 1.80mn | 1.41kl | 1.15klm | 1.72k-o | 0.66s | 1.23k-n | 2.07def |

Values in the same column followed by the same letter are not different (p>0.05)

*C. Leaves to roots potassium ratio*

As results of analysis of variance (Table 1) show, the effect of potassium salt and genotypes were significant on leaves potassium ratio to the root potassium. The highest proportion was of clone C4 salinity level 3 $ds.m^{-1}$ (Table 2). This clone probably, in order to reduce the effects of salinity, increases the potassium concentration in its leaves and hereby keeps its own osmotic potential at low level and prevents sodium entering into leaves. Resistant genotypes also had more potassium than that available in susceptible ones. This is in compliance with the findings of Akhtar *et al.* (2003). Flowers et al. (2004) emphasized that the amount of potassium in high concentrations of salt is an advantage and can serve as an important index for the selection of plants in their salt tolerance.

*D. Leaves to roots sodium ratio*

Results of variance analysis (Table 1) showed that the sodium salt and genotypes have significant effect on leaves sodium to roots sodium. The highest levels were observed in the IR-06 in salinity level 9 $ds.m^{-1}$ (Table 2). This variety is probably more sensitive to salinity and not able to prevent the too much sodium absorption occurring in the root growth culture. Accordingly, the absorbed sodium by the roots is transferred from the roots to the leaves in the transpiration and this has increased the proportion. Clone C4, as the one having the least amount of sodium in the treatment of stress, may have a mechanism preventing the entry of sodium ions into the plant. Tolerant plants prevent the entry of sodium ions by means of various mechanisms including the distribution of ions between leaf and tiller to reduce the damaging effects of salt. Shomeili (2004), and Akhtar *et al.* (2003) also had reached these findings in their studies.

*E. Sodium to potassium ratio in the leaves*

Analysis of variance (Table 1) shows that salinity and the genotypes had a significant effect on ratio of sodium of leaf to leaf potassium ratio. The highest levels of salinity were observed in IR-06 at 9 $ds.m^{-1}$ and the lowest level was obtained in clone C4 (Table 2). As it was mentioned previously, C4 had the least sodium absorption in saline soils probably it has inhibitory mechanisms to sodium absorption as well. In addition, this clone has the highest amount of potassium in leaves in medium and high salinity. All these features mean that this clone bears the lowest ratio of sodium to potassium. Akhtar *et al.* (2003) pointed to this significant ratio difference and stated that although the ratio of sodium to potassium increased with salinity increasing, the resistant genotype had less sodium ratio to potassium ratio. There is a negative meaningful correlation between the leaves sodium concentration and leaves potassium concentration.

## CONCLUSION

Salinity stress is effective on the content of the ionic elements of sugarcane different genotypes. The increase in salinity levels led to the increase in the amount of Na and Cl in the examined genotype leaf and root. But clone C2, C3, and C4, probably could counter the harmful effects of Na and Cl ions using the preventative uptake mechanisms and preventing the transfer of Na and Cl from the root to the shoot. The obtained results from Na and K measurement exhibited that the accumulation of Na ion in the plant was more than the accumulation of K ion. The increase in salinity level contributed to the increase in the amount of Na and its transport to shoots which led to growth decrease and lessening in the plant dry weight. Accordingly, preventing the uptake and transport and distribution of the two harmful Na and Cl ions can be applied as the three important mechanisms in salinity tension tolerance in sugarcane. Based on the results gained from this study, it can be concluded that the C4 clone has the tolerance potentiality to salinity along with more dry material production in salinity tension conditions.

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