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Evaluation Response of Different Genotypes of Sugarcane to Absorb and Transfer of Nutrition Elements Affected Salinity Stress

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ABSTRACT

BACKGROUND: Salinity is one of the important a biotic stresses limiting growth and development and the capacity to tolerate salinity is a key factor in crop productivity.

OBJECTIVES: The aim of this study was to evaluate the response of sugarcane varieties to uptake and transport of ionic elements under salinity stress.

METHODS: This research was carried out to via factorial experiment based on completely randomized design with three replications along 2013 year. The treatments included salinity stress (S_1: 0 ds.m^{-1} S_2: 3 ds.m^{-1} S_3: 6 ds.m^{-1} S_4: 9 ds.m^{-1}) and different genotypes (V_1: IRC9904, V_2: IRC9906, V_3: C2, V_4: IRC9901, V_5: C3, V_6: C4, V_7: CP48-103, V_8: CP57-614, V_9: CP69-1062). Studied genotypes included of three old commercial varieties (CP69-1062, CP57-614, CP48-103), three new commercial varieties (IRC9901, IRC9904, IRC9906) and three clones tolerate salinity (C2, C3, C4).

RESULT: According result of analysis of variance effect of different level of salinity, genotypes and interaction effect of treatment on all studied traits was significant at 1% probability level. Salinity stress decreased the concentration of potassium and calcium and also increased the concentration of sodium and chlorine in the roots and shoots, so reduced plant biomass, especially in more sensitive genotypes. It seems that in addition to the importance of the root in controlling the uptake of ionic elements, there are mechanisms in other organs that are involved in the uptake and transport of these elements and genotypes also affects it.

CONCLUSION: Mean comparison result indicated the highest amount of sodium and chlorine transfer to the shoot was obtained from 9 ds.m^{-1} salinity level and IRC9906 variety and the lowest one belonged to 0 ds.m^{-1} salinity level and C4 clone.

KEYWORDS: *Calcium, Chlorine, Potassium, Sodium, Transport ions, Uptake.*

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1. BACKGROUND

Among abiotic stresses, salinity has been increasing over the time for many reasons like using chemical fertilizers, global warming and rising sea levels. Under salinity stress, the loss of water availability, toxicity of Na^+ and ion imbalance directly reduces carbon fixation and biomass production in plants (Fakhrfeshani *et al.*, 2015). In Iran, salinity has already become a major deterrent to crop production, including rice. Addition of salts to water lowers its osmotic potential, resulting in decreased availability of water to root cells. Salt stress thus exposes the plant to secondary osmotic stress, which implies that all the physiological responses, which are invoked by drought stress, can also be observed in salt stress (Sairam *et al.*, 2002). The physiological responses of a plant to salinity are often complex. Different species and varieties respond differently when exposed to salinity. The extent of sensitivity varies depending upon the plant growth stage (Zafar *et al.*, 2015). Salinity is an agricultural problem that decreases or restricts crop production in many areas. As concern about limited water resources continue to increase due to rapid expanding populations, there will be a greater need to use poor quality water in crop production. The increase in the use of saline water for irrigation poses a potential hazard to the quality of agricultural soils. Appropriate management options are required to prevent and/or relieve salinity problems in crop production. Timing of salinity stress, i.e., initiation and termination of a salinization period at different growth stages, is one such option. This option considers crop sensitivity at different growth stages, which is one of the major issues in the utilization of saline water for crop production (Yarnia and Khorshidi Benam, 2017). Sugarcane crop is an important agro-industrial sugar crop, contributing about 70% of the world sugar production. In Iran, sugarcane is grown under irrigated systems and is seriously prone to soil salinization. This problem may be a serious problem for the production and the yield of this agricultural crop. Sugarcane growth may be suppressed due to the accumulation of toxic ions (Wahid *et al*., 2009). Salinity reduced tillering, spikelet filling, florets per panicle, 1000 grain weight, grain yield, harvest index, shoot and root dry matter and K^+ uptake and increased leaf and root Na^+ in rice plants (Kranto *et al.*, 2016). The importance of cations and anions in irrigation water is clear as they influence soil physical and chemical properties. If Na^+ concentration in irrigation water is nine times that of Ca^{2+} ions, problems related to water infiltration into soil often arise, soil particle distribution is affected, and small pores in surface soil are blocked (Mohajermilani and Tavassoli, 1992). Sodium chloride salts are quickly dissolved in the water and play as ionic effects in higher plant including rice crop (Nishimura *et al.*, 2011). Excess Na^+ in plant cells directly damages membrane systems and organelles, resulting in plant growth reduction and abnormal development prior to plant death (Siringam *et al.*, 2011). Considering sodic soils in Iran often contain calcium in the form of calcium carbonate,

it may be possible to amend such soils by sulfur application. This will improve physical and chemical properties of soil and make macro- and micronutrients such as P, Fe, and Zn available to plants (Mirzashahi *et al*., 2010). Azza *et al*. (2006) have reported that saline water application had significant decrease in all growth parameters in *Dalbergiasissoo*, while application of sulfur was significantly increased those parameters under irrigation with normal or saline water up to 4000 ppm. Walker and Bernal (2008) showed that use of organic amendment materials increased cation exchange capacity (CEC), saturated exchange sites with Ca, Mg, and K, and prevented Na from entering the exchange phase. In salt stress, sodium ions cause ionic stress when enter the plant cell. Plants have mechanisms to deal with environmental stress due to their lack of ability to move from their place to another one. Under saline conditions when there is a higher level of Na^+ around the root zone, plant alters its ion uptake and resistant genotypes maintain a lower ratio of Na^+ to Ca^+, Mg^+ and high level of K^+ while sensitive genotypes could not maintain it (Zafar *et al*., 2015). Na^+ and K^+ balance plays a key role in the growth and development of higher plants under saline conditions. Several physiological processes, including the maintenance of the membrane potential and turgor, stomatal movement, regulation of osmotic pressure, and tropisms are dependent on the presence of potassium (Rahneshan *et al*., 2018). Shomeily *et al*. (2011) studied salt tolerant variants from embryo genic calli of sugarcane cultivar CP48-103 that were cultured on a selective medium containing different levels of NaCl. A total of four plants which regenerated from the tolerant calli were selected but the best in vigor were grown in *in vitro* and hydroponic systems under salinity stress as compared to source variety. With increasing supply of NaCl in both systems, root growth was more adversely affected than shoot growth. Mohammadnejad *et al*. (2016) to evaluate induction of tolerance to salt stress CP73-21 sugarcane commercial cultivar reported that the highest callus value was obtained from treated with 3 $mg.l^{-1}$. The effect of different levels of salinity 0, 33, 66, 99 and 132 mM were investigated to tolerance of callus. After 8 weeks, the callus value reduction by 33, 66, 99 and 132 mM treatments in compare to control were obtained 31, 33, 22 and 26%, respectively. K^+ can counteract Na^+ stresses thus the potential of plants to tolerate salinity is strongly dependent on their potassium nutrition. K^+ composes about 10% of the plants dry weight and is the most abundant mineral cation in the plants. It is involved in many of functions related to enzyme activation, respiration and starch and protein synthesis (Benito *et al*., 2014). For instance, about 50mM of K^+ is required for normal starch synthesis and 10-50mM is needed for activation of K^+ dependent enzymes. The optimum concentration of K^+ narrows by increasing the amount of Na^+ for many reasons such as similarity of Na^+ and K^+ in their physicochemical structure. This similarity leads to competition of Na^+ and K^+ at transporters or enzymes binding sites

that can result in K^+ deficiency and inhibition of biochemical processes that are dependent on K^+. So the capacity of a cell to maintain a high K^+/Na^+ ratio is assumed to be a critical strategy in salt tolerance. For instance, it is reported that animal cells maintain the K^+/Na^+ ratio around 20 by regulating the K^+ and Na^+ concentration around 100mM and 5Mm respectively. In plants, the optimum concentration of K^+ is reported to be about 100-150mM and the minimum value of K^+/Na^+ is about one. In contrast, the soil K^+ concentration ranges from 1 to 0.1mM and in some cases, the K^+/Na^+ ratio is less than 0.02. So an efficient and controllable potassium supply system should be available for plants (Nieves-Cordones *et al.*, 2014). Shomily (2002) showed in his research that CP69-1062 cultivar has the ability to produce shoots properly in salinity conditions and produce dry matter and distribute the roots reasonably in such conditions. Moreover, in CP69-1062 and CO1148 cultivars as the salinity increased, the ratio of chloride and sodium (sensitivity biochemical factors) to potassium (tolerance biochemical factor) was in a good condition which indicates the presence of tolerance factors in such cultivars. Also on the other hand, keeping a high level of nitrogen, phosphor, and calcium elements in the roots and stems tissue of these two cultivars is closely related to their tolerance of salinity. The stable rate of these elements in plant tissues could be used as an indicator of the sugarcane crop tolerance of salinity resulting from NaCl content.

2. OBJECTIVES

The aim of this study was to evaluate the response of sugarcane varieties to uptake and transport of ionic elements under salinity stress.

3. MATERIALS AND METHODS

3.1. Greenhouse and Treatments Information

This research was carried out to via factorial experiment based on completely randomized design with three replications along 2013 year. Place of research was located in the greenhouse of the Sugarcane Research and Education Institute in Ahvaz city at longitude 48°40'E and latitude 31°20'N in Khuzestan province (Southwest of Iran). The treatments included salinity stress (S_1: 0 $ds.m^{-1}$ S_2: 3 $ds.m^{-1}$ S_3: 6 $ds.m^{-1}$ S_4: 9 $ds.m^{-1}$) and different genotypes (V_1: IRC9904, V_2: IRC9906, V_3: C2, V_4: IRC9901, V_5: C3, V_6: C4, V_7: CP48-103, V_8: CP57-614, V_9: CP69-1062). Studied genotypes included of three old commercial varieties (CP69-1062, CP57-614, CP48-103), three new commercial varieties (IRC9901, IRC9904, IRC9906) and three clones tolerate salinity (C2, C3, C4).

3.2. Greenhouse Management

The nutrient solution of sugarcane was prepared based on the nutritional needs (Clements (1980) and modified according to the recommendations of Serenoa *et al*. (2007) based on Hoagland and Aronon (1950). Healthy and pest-free stems of the desired genotypes were transferred from the field to the laboratory and cut into single-sprout cuttings of about five centimeters. Two-

bud cuttings were cultured between two layers of perfectly moist filter paper placed in plastic trays after disinfection with 70% ethanol alcohol and washing with sterile water. The trays were placed in the oven at a temperature of about 30 ° C until the initial buds were fully formed and the filter papers were moistened daily with sterile water. The number of two buds seeds for each genotype was four times higher than the required number. The reason for this is the availability of uniform seedlings in the transfer to the hydroponic environment. After germination and emergence of cuttings, plants that had two complete leaves and were similar in appearance were transferred to a hydroponic medium containing nutrient solution. The containers (10 liters) used were made of polyethylene and the dimensions were 50 cm (length) × 30 cm (width) × 20 cm (height). On the ion lithic cap used to place the seedlings, holes were made that the smallest hole was related to the passage of the oxygen transfer pipe from the air pump to the container. In order to properly place small seedlings in each hole, small pieces of completely soft sterile sponge were used. Hydroponic culture was maintained for three weeks and then salinity treatments were applied to adapt to the nutrient solution and ensure growth in these conditions. To prevent stress on the plants, salinity treatments were applied gradually over a week. Solutions were changed every two weeks to maintain salt and nutrient concentrations. The initial pH of the nutrient solution was adjusted to level six using sulfuric acid and caustic soda. During the experiment, the pH of the nutrient solution was adjusted daily and the electrical conductivity weekly. The nutrient solution was ventilated by air pump during the day. Dry burning method was used for ionic analysis of plant tissues.

3.3. Measured Traits

The amount of sodium and potassium ions in plant tissues was determined with using a flame photometer by Hamada and ELenany (1994), chlorine ions by Richards (1954) and calcium ions by Jakson (1973).

3.4. Statistical Analysis

Analysis of variance and mean comparisons were done via SAS (Ver.8) software and LSD test at 5% probability level.

4. RESULT AND DISCUSSION

4.1. *Concentrations of sodium and chlorine in roots and shoots*

The results showed that the effect of different salinity levels of sugarcane varieties on the concentration of sodium and chlorine in shoots and roots was significant (Table 1). The highest concentration of sodium and chlorine in roots and shoots was related to IRC9906 variety at salinity level of 9 $ds.m^{-1}$ (Table 2). With increasing salinity level due to increasing the concentration of sodium in the plant growth medium, the sodium content in the roots and shoots of the plant increases significantly. Also, the lowest concentration of sodium and leaf chloride was observed in the C4 (tolerant clone to salinity) at the level of salinity of 0

$ds.m^{-1}$, which did not show a significant difference with C3 clone at the same salinity level. In comparison between the concentration of sodium in the roots and shoots, due to salinity stress, the concentration of sodium in the shoots increased more. This is because most of the sodium is transported to the aerial parts due to transpiration, where due to the loss of water through the cuticle and stomata, sodium is more it accumulates in these organs than in the underground organs such as the roots. In which no transpiration occurs (Munns *et al*., 2006). The results of Salmasi (1996) experiments showed that in all stages of sampling with increasing salinity, the amount of root sodium in wheat increased. Sodium and chlorine ions are usually the most common ions in saline soil and water. Both of them can have harmful effects on plants because by increasing the osmotic pressure of the soil solution, while creating ionic toxicity in the plant, they upset the balance of ions required by the plant, such as potassium ions (Yadelerloo and Majidi Heravan. 2008). In a study conducted by Elkahoui *et al*. (2005) on a variety of roses, they reported that salinity stress reduced the growth rate compared to the control due to the accumulation of chlorine ions, especially sodium ions in the plant.

Table 1. Result of analysis of variance of the effect of different level of salinity and variety on leaf and root sodium and chlorine content

S.O.V	df	Leaf sodium content	Root sodium content	Leaf chlorine content	Root chlorine content
Salinity (S)	3	25.65**	10.47**	2093.25**	7778.57**
Variety (V)	8	6.24**	2.21**	481.16**	688.20**
S × V	24	0.90**	0.28**	110.67**	198.17**
Error	72	0.02	0.01	8.65	15.89
CV (%)	-	6.58	8.43	3.95	5.16

$^{ns, *}$ and **: no significant, significant at 5% and 1% of probability level, respectively.

4.2. *Concentrations of potassium and calcium in roots and shoots*

The results of analysis of variance showed that the effect of different levels of salinity and sugarcane varieties on potassium and calcium concentrations of shoots and roots was significant (Table 3). The highest concentration of root and shoot potassium was observed in C4 clone (0 $ds.m^{-1}$) and the lowest one was found in IRC9906 variety (9 $ds.m^{-1}$) (Table 4). Potassium concentration in roots and shoots decreased with increasing salinity stress in plant growth medium. With increasing salinity level, a decreasing trend of potassium concentration in the plant was observed so that in two salinity levels of 6 and 9 $ds.m^{-1}$, potassium concentration in roots and shoots showed a significant decrease. With increasing sodium concentration, potassium uptake into plant roots became difficult. Due to the fact that the absorption of potassium by the plant roots is done specifically.

Table 2. Mean comparison interaction effect of treatment on leaf and root sodium and chlorine content

Salinity	Variety	Leaf sodium content ($mg.g^{-1}$)	Root sodium content ($mg.g^{-1}$)	Leaf chlorine content ($mg.g^{-1}$)	Root chlorine content ($mg.g^{-1}$)
S_1 ($ds.m^{-1}$)	V1	1.28* qrs	0.86mno	64.00qrs	55.00mn
	V2	1.66no	1.82fg	64.00qrs	60.00lm
	V3	1.30qr	0.47p	61.00st	63.33l
	V4	1.62no	1.40ijk	81.00efg	50.00no
	V5	0.62u	0.48p	57.67t	47.33o
	V6	0.39u	0.79no	62.67rs	52.33no
	V7	1.04st	1.05lm	69.00lp	62.00l
	V8	0.94t	0.88mno	62.67rs	61.67l
	V9	1.12rst	0.91mno	62.67rs	52.67no
S_2 ($ds.m^{-1}$)	V1	2.81hi	1.04lm	71.67kn	78.33ghi
	V2	3.14ef	1.22kl	94.00bc	92.00de
	V3	0.46u	0.87mno	65.00ps	74.00hij
	V4	2.56jkl	1.40ijk	64.33ps	82.67fg
	V5	1.57op	1.36jk	68.33mq	63.67l
	V6	1.24qrs	0.70o	63.00rs	62.00l
	V7	1.35pqr	0.88mno	67.33nr	75.00hij
	V8	2.75hij	1.03lm	71.67kn	76.00hij
	V9	2.34lm	0.82no	67.33nr	79.00gh
S_3 ($ds.m^{-1}$)	V1	2.88gh	2.22d	82.00ef	92.00de
	V2	3.51d	2.68c	94.33b	70.33jk
	V3	1.18qrs	1.63gh	77.67fi	72.33ij
	V4	2.82hi	2.15d	80.00eh	92.33cde
	V5	1.83n	0.94mn	72.67jm	74.33hij
	V6	1.37pq	0.92mn	66.00or	65.67kl
	V7	3.18ef	1.41ijk	70.00lo	84.33fg
	V8	3.08fg	1.55hij	76.67gj	83.33fg
	V9	2.50kl	1.41ijk	75.67hk	82.67fg
S_4 ($ds.m^{-1}$)	V1	3.82c	2.99b	82.67e	106.00b
	V2	5.74a	3.35a	104.30a	126.00a
	V3	2.85gh	1.74fgh	83.00e	88.00ef
	V4	4.58b	3.03b	81.00efg	108.00b
	V5	2.23m	1.57hi	81.efg	84.00fg
	V6	2.59ijk	1.75fgh	73.67il	75.67hij
	V7	3.52d	2.08de	89.33cd	95.33cd
	V8	3.37de	2.26d	89.00d	98.67c
	V9	2.38klm	1.91ef	83.67e	95.00cd

*Similar letters in each column show non-significant difference at 5% probability level via LSD test.

S_1: 0 $ds.m^{-1}$ S_2: 3 $ds.m^{-1}$ S_3: 6 $ds.m^{-1}$ S_4: 9 $ds.m^{-1}$

V_1: IRC9904, V_2: IRC9906, V_3: C2, V_4: IRC9901, V_5: C3, V_6: C4, V_7: CP48-103, V_8: CP57-614, V_9: CP69-1062.

With increasing salinity level, the specific site of potassium uptake is occupied by sodium ions and the uptake of potassium by plant roots becomes difficult. The activity of potassium pumps is related to the activity of the H^+-ATPase enzyme. When the plant is under salinity stress, the activity of this enzyme is disrupted by increasing the concentration of sodium in the plant. As a result, in addition to sodium at high concentrations, it prevents the uptake of potassium by the roots by creating competition. By disrupting the activity of the

H^+-ATPase enzyme, it also prevents the specific uptake of potassium by the roots (Liang *et al*., 2003). There is a negative and significant relationship between leaf sodium concentration and leaf potassium concentration which shows that with increasing salinity levels, leaf potassium concentration decreases. Also the results of analysis of variance (Table 3) showed that the effect of salinity and sugarcane varieties on the concentration of calcium in roots and shoots was significant. The highest calcium shoot concentration belonged to C4 and C2 clones and CP69 variety at 0 $ds.m^{-1}$ salinity level and the lowest one was for in IRC9906 variety at 9 $ds.m^{-1}$ (Table 4).

Table 3. Result of analysis of variance of the effect of different level of salinity and variety on leaf and root calcium and potassium content

S.O.V	df	Leaf calcium content	Root calcium content	Leaf potassium content	Root potassium content
Salinity (S)	3	22.67^{**}	13.19^{**}	38.78^{**}	4.04^{**}
Variety (V)	8	1.60^{**}	2.84^{**}	5.81^{**}	2.80^{**}
S × V	24	0.27^{**}	0.59^{**}	1.55^{**}	0.27^{**}
Error	72	0.02	0.04	0.06	0.01
CV (%)	-	6.75	6.90	9.82	7.81

$^{ns, *}$ and **: no significant, significant at 5% and 1% of probability level, respectively.

Also, no significant difference was observed between different varieties in terms of root calcium concentration at level of 0 $ds.m^{-1}$ salinity. This is due to the lack of salinity stress, but with increasing salinity, the amount of root calcium decreased. So that the lowest concentration of root calcium in IRC9906 variety was observed at a salinity level of 9 $ds.m^{-1}$. Because there is a competitive effect between sodium and calcium, therefore, with increasing salinity, the concentration of sodium in the roots and shoots increases and the amount of calcium in the roots and shoots decreases. There is clear evidence that calcium is needed to keep cell membranes healthy, and it also proves that sodium removes calcium from the cell membrane and replaces it, in which case the membrane does not do its function well. Calcium is a non-toxic mineral even at high concentrations and is very effective in non-toxic to high concentrations of other minerals such as sodium. Calcium is also known as a converter of hormonal and environmental messages into elements responsible for cellular metabolism. Salinity strongly affects the absorption and transport of calcium. During a study of salinity in maize, Lynch and Lauchi (1988) stated that salinity reduces the amount of calcium bound to the inner membrane in corn protoplasts. Kramer *et al*. (1994) reported in a study that due to salinity stress, the calcium concentration of maize shoots decreased. Khan *et al*. (1994) in an experiment stated that with increasing salinity levels, the ratio

of sodium to calcium in the plant increases and causes compensatory damage to the plant cell membrane. In a study conducted by Hajlaoui *et al*. (2009) on corn, they found that the concentration of calcium in adult leaves decreases with increasing salinity. In a study by Summart *et al*. (2010) on rice with two salinity levels of 0 and 250 mM sodium chloride, they reported that by increasing concentration of NaCl to 250 mM, the content of root Ca^{+2} decreased by half. There is a significant relationship between Ca^{+2} and K^{+} content and a negative relationship between Ca^{+2} content and Na^{+} concentration.

Table 4. Mean comparison interaction effect of treatment on leaf and root Ca^{+2} and K^{+} content

Salinity	Variety	Leaf calcium content ($mg.g^{-1}$)	Root calcium content ($mg.g^{-1}$)	Leaf potassium content ($mg.g^{-1}$)	Root potassium content ($mg.g^{-1}$)
S_1 ($ds.m^{-1}$)	**V1**	3.50bc	3.90a	2.38efg	1.92gk
	V2	2.78efg	3.97a	1.53jkl	1.51or
	V3	3.66ab	3.90a	4.93a	2.57c
	V4	2.93de	3.89a	2.74de	1.32rs
	V5	3.44c	4.00a	4.48b	2.80b
	V6	3.72a	3.78ab	5.06a	3.44a
	V7	3.60bc	3.78ab	4.36b	2.34de
	V8	3.58b	3.96a	4.28b	2.52cd
	V9	3.70a	3.79ab	4.35b	1.99fi
S_2 ($ds.m^{-1}$)	**V1**	2.46hij	2.89lm	4.47b	1.82im
	V2	2.01lm	2.36de	1.31lm	0.77v
	V3	2.82ef	3.51bc	2.84d	1.76jn
	V4	2.60fgh	2.86de	3.71c	1.03tu
	V5	2.62fgh	3.56bc	4.47b	1.95gj
	V6	3.12d	3.90a	5.24a	2.39cde
	V7	2.50hi	2.66ef	3.67c	2.10fg
	V8	2.30ijk	2.71ef	3.34c	1.77jm
	V9	2.13kl	2.54fg	2.52def	2.09fgh
S_3 ($ds.m^{-1}$)	**V1**	1.40opq	1.80hi	1.84hij	0.87uv
	V2	1.15q	1.73hij	1.30lm	0.65v
	V3	2.00lm	3.51bc	2.26fgh	2.18ef
	V4	1.29pq	1.46jk	1.09m	1.01tu
	V5	1.41op	3.00d	1.41klm	1.71ko
	V6	2.56gh	3.44c	2.00ghi	2.02fi
	V7	2.00lm	1.66hk	1.80ijk	1.61mp
	V8	1.44op	1.76hi	1.53jkl	1.64mno
	V9	1.60no	1.92h	2.22fi	1.71ko
S_4 ($ds.m^{-1}$)	**V1**	0.80r	0.84no	1.37lm	1.21st
	V2	0.42s	0.06o	0.52n	0.26w
	V3	1.59no	1.57ijk	2.29fg	1.41ps
	V4	1.16q	1.01mn	1.09m	1.65mno
	V5	2.22kl	1.62ijk	1.49jm	1.66lo
	V6	2.15kl	2.33g	2.52def	1.87hl
	V7	1.40opq	1.17lm	1.25lm	1.36qrs
	V8	1.58no	1.06mn	1.48jm	1.54nq
	V9	1.80mn	1.41kl	1.15klm	1.72ko

*Similar letters in each column show non-significant difference at 5% probability level via LSD test.

S_1: 0 $ds.m^{-1}$ S_2: 3 $ds.m^{-1}$ S_3: 6 $ds.m^{-1}$ S_4: 9 $ds.m^{-1}$.

V_1: IRC9904, V_2: IRC9906, V_3: C2, V_4: IRC9901, V_5: C3, V_6: C4, V_7: CP48-103, V_8: CP57-614, V_9: CP69-1062.

4.3. The ratio of leaf potassium to root potassium

The results of analysis of variance show that the effect of salinity and variety on the ratio of leaf potassium to root potassium was significant (Table 5). The highest ratio was belonged to C4 clone at 3 $ds.m^{-1}$ salinity level (Table 6). To reduce the effects of salinity, mentioned clone probably increased the concentration of potassium in its leaves, thus keeping its osmotic potential low and preventing sodium from entering the leaf. Resistant genotype also has more potassium than susceptible genotypes, which was consistent with the results of Akhtar *et al*. (2003) and Wahid *et al*. (1997). Flowers (2004) emphasized that the amount of plant potassium in high salt concentrations is an advantage and can be used as one of the important criteria for selecting plants in terms of salinity tolerance.

Table 5. Result of analysis of variance of the effect of different level of salinity and variety on ration of K^+leaf/K^+root, Na^+leaf/Na^+root and Na^+leaf/K^+leaf

S.O.V	df	K^+leaf/K^+root	Na^+leaf/Na^+root	Na^+leaf/K^+leaf
Salinity (S)	3	3.07^{**}	3.69^{**}	14.19^{**}
Variety (V)	8	0.53^{**}	0.4^{**}	1.59^{**}
S × V	24	0.57^{**}	0.80^{**}	0.15^{**}
Error	72	0.01	0.009	0.006
CV (%)	-	7.05	6.81	7.54

$^{ns, *\text{ and }**}$: no significant, significant at 5% and 1% of probability level, respectively.

4.4. The ratio of leaf sodium to root sodium

Also, the results of analysis of variance showed that the effect of salinity and variety on leaf sodium to root sodium ratio was significant (Table 5). The highest amount of mentioned trait was related to IRC9906 variety at 9 $ds.m^{-1}$ salinity level (Table 6). Mentioned variety was probably more sensitive to salinity and could not prevent the uptake of too much sodium in the root growth medium. Therefore, sodium absorbed by the roots is transferred from the roots to the leaves during the transpiration process and increases this ratio. Clone C4 with the lowest amount of sodium in stress treatments probably has a mechanism inhibiting the entry of sodium ions into the plant. Tolerant plants prevent the entry of sodium ions by various mechanisms. So with the distribution of ions between all organs or the production of leaves and tillers further reduce the damaging effects of salinity. Shomily (2001), Akhtar *et al*. (2003) achieved similar results during their research.

4.5. The ratio of leaf sodium to leaf potassium content

Analysis table of variance showed that the effect of salinity and variety on the ratio of leaf sodium to leaf potassium was significant (Table 5). The highest amount of mentioned trait was obtained

from IRC9906 variety at 9 ds.m^{-1} salinity level and the lowest one was obtained from C4 clone (Table 6). As mentioned earlier, C4 clone had the lowest sodium uptake in saline environments and probably also had mechanisms inhibiting sodium uptake. In addition, this clone had the highest amount of potassium in the leaves in medium and high salinity. The combination of these characteristics has made this clone have the lowest ratio of sodium to potassium.

Table 6. Mean comparison interaction effect of treatment on ration of K^+leaf/K^+root, Na^+leaf/Na^+root and Na^+leaf/K^+leaf

Salinity	Variety	K^+leaf/K^+root (mg.g^{-1})	Na^+leaf/Na^+root (mg.g^{-1})	Na^+leaf/K^+leaf (mg.g^{-1})
S_1 (ds.m^{-1})	V1	1.24mp	1.47hl	0.53il
	V2	1.01or	0.91op	1.20fj
	V3	1.88dh	1.20lo	0.26jkl
	V4	2.00cg	1.17lo	0.59hl
	V5	1.59hl	1.28jn	0.13l
	V6	1.47jm	0.49q	0.07l
	V7	1.86fi	0.99nop	0.23kl
	V8	1.64hk	1.05mno	0.22kl
	V9	2.17be	1.23kn	0.25jkl
S_2 (ds.m^{-1})	V1	2.48b	1.70def	0.63hl
	V2	1.56il	1.59fj	2.63de
	V3	1.61hl	1.54gj	0.16kl
	V4	2.09bcd	1.86def	0.69hl
	V5	2.28bc	1.18lo	0.35il
	V6	2.89a	1.11mno	0.23kl
	V7	1.74gj	1.55fj	0.36il
	V8	1.87ei	1.67dh	0.83gl
	V9	1.20mq	1.84def	0.92gl
S_3 (ds.m^{-1})	V1	2.11cf	1.30jm	1.56fgh
	V2	2.03cg	1.31jm	3.77bc
	V3	1.03or	1.35im	0.53il
	V4	1.08nr	1.31jm	2.60de
	V5	0.82rs	1.94de	1.30fi
	V6	0.98pqr	1.28klm	0.68hl
	V7	1.12nr	2.28bc	1.77efg
	V8	0.93ps	1.99cd	2.01def
	V9	1.30lo	1.76dh	1.13fk
S_4 (ds.m^{-1})	V1	1.19mq	2.27b	2.85cd
	V2	2.18be	2.71a	4.38a
	V3	162hk	1.64ei	1.25fi
	V4	0.66s	1.51jk	4.21b
	V5	0.9qrs	1.44il	1.51fgh
	V6	1.34kn	1.39kl	1.03gl
	V7	0.92qrs	1.69di	2.82cd
	V8	0.96ps	1.79hk	2.86cd
	V9	0.66s	1.23kn	2.07def

*Similar letters in each column show non-significant difference at 5% probability level via LSD test.

S_1: 0 ds.m^{-1} S_2: 3 ds.m^{-1} S_3: 6 ds.m^{-1} S_4: 9 ds.m^{-1}

V_1: IRC9904, V_2: IRC9906, V_3: C2, V_4: IRC9901, V_5: C3, V_6: C4, V_7: CP48-103, V_8: CP57-614, V_9: CP69-1062.

Akhtar *et al*. (2003) reported a significant difference in genotypes in this ratio, although the ratio of sodium to potassium increased with increasing salinity levels, but the resistant genotype had lower sodium to potassium ratio. Wahid *et al*. (1997) also observed lower sodium to potassium ratio in the resistant line than to sensitive line in sugarcane crop. They reported that the resistant line had less sodium and more potassium than the sensitive line, which adjusted the position of these ions at the root for subsequent transfer to the stem. As such, this resistant line retains more sodium in the roots than in the shoot. It should be noted that there is a negative and significant relationship between leaf sodium concentration and leaf potassium concentration.

5. CONCLUSION

Salinity stress decreased the concentration of potassium and calcium and also increased the concentration of sodium and chlorine in the roots and shoots, so reduced plant biomass, especially in more sensitive genotypes. According to the results, the highest amount of sodium and chlorine transfer to the shoot was obtained from 9 $ds.m^{-1}$ salinity level and IRC9906 variety and the lowest one belonged to 0 $ds.m^{-1}$ salinity level and C4 clone. Therefore, it seems that in addition to the importance of the root in controlling the uptake of ionic elements, there are mechanisms in other organs that are involved in the uptake and transport of these elements and genotypes also affects it.

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