DIFFERENTIAL SALT TOLERANCE OF SUGARCANE GENOTYPES

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Screening of crops for salt tolerance is important to sustain food production under salt stress. Ten sugarcane genotypes were grown in solution with adding nil and 100 mM NaCl. Various plant nutrients were supplied by using Johnson' s nutrient solution. Sugarcane genotypes grown for 28 days at two levels of salinity i.e. 1.0 & 10 dS m^{-1} differed significantly in their biomass and K^+/Na^+ ratio. Addition of 100 mM NaCl (EC = 10 dS m^{-1}) to root medium significantly ($P < 0.05$) increased Na^+ concentration and decreased plant biomass accumulation. The total dry matter of ten sugarcane genotypes significantly correlated with K^+/Na^+ ratio ($r = 0.81$). The genotypes HSF 240 and CP 77-400 produced maximum biomass and K^+/Na^+ ratio and proved to be salt tolerant. Various salt sensitive genotypes of sugarcane were CPF 243 > SPF 213 > SPF 245 > SPF 242 ≥ SPF 244.
Key words: Genotype, salinity, sugarcane, hydroponics.

INTRODUCTION

Sugarcane (*Saccharum officinarum* L.), grown in arid and semiarid regions by irrigation, is frequently subjected to soil salinity (Lingle and Weigand, 1997). The crop is moderately sensitive to salinity and annual loss of over two billion rupees has been reported in Pakistan on this account only (Wahid *et al.*, 1997). The decrease in yield is 0% at an EC_e 1.7 dS m^{-1}, 10% at 3.3, 25% at 6, 50% at 10.4 and 100% at an EC_e 18.6 dS m^{-1} (Blackburn, 1984). Rozeff (1995), however, suggested that a steep decline in growth may take place once the EC_e rises above 3 dS m^{-1}, although plants may survive up to 10-15 dS m^{-1} depending upon genotypes. Segovia (1989), on the other hand, showed a drastic decrease in growth of sugarcane at fairly low salinity levels.

Salinity inhibits plant growth by ion toxicity, nutritional imbalances, osmotic effect and oxidative stress (Leigh and Wyn Jones, 1984; Zhu, 2001; Chinnusamy *et al.*, 2005). High Na^+ concentration in the external solution cause a decrease in both K^+ and Ca^{2+} concentrations in tissues of many plant species (Hu and Schmidhalter, 2005) due to the antagonism of Na^+ and K^+ at uptake site in the roots, the effect of Na^+ on K^+ transport into the xylem (Lynch and Lauchli, 1984) or the inhibition of uptake processes (Suhayda *et al.*, 1990). Excess of Na^+ in plant tissues increases the utilization of energy that the plants must use to acquire water from the soil and to make biochemical adjustments. This energy is diverted from processes that lead to growth and yield (Yeo, 1983), which consequently resulted in reduced plant growth.

There is increasing evidences that plant species/ genotypes greatly differ in their ability to grow in saline habitats (Flowers and Yeo, 1995; Wahid *et al.*, 1997; Akhtar *et al.*, 2001; Chinnusamy *et al.*, 2005). The differential growth performance of plant species/genotypes under salinity might be related to their ability to uptake and transport of Na^+, affinity for K^+ over Na^+ and salt exclusion mechanisms. Husain *et al.* (2004) reported that in bread and durum wheat salt tolerance is associated with low rates of transport of Na^+. According to Gorham (1990) selectivity for K^+ over Na^+ varies among plant species as well as among genotypes within a species. The degree to which different plant species/genotypes can resist soil salinity may partly be related to their abilities to selectivity absorb K^+ over Na^+.

Present experiment was designed to study the relative salt tolerance of ten sugarcane genotypes grown in nutrient solution salinized with NaCl.

MATERIALS AND METHODS

Stem portions of ten sugarcane genotypes viz: SPF 245, SPF 244, CPF 237, SPF 242, SPF 213, CP 82-1172, CP 43-33, HSF 240, CPF 243 and CP 77-400 containing single node were obtained from Sugarcane Research Institute, Ayub Agricultural Research Institute, Faisalabad, and planted in plastic trays containing pre washed gravel. Distilled water was used to maintain optimum moisture for sprouting and seedling establishment. After 10 days, the seedlings were transferred to iron tubs containing 100 L ½ strength Johnson's solution (Johnson *et al.*, 1957). Potassium nitrate (KNO_3), calcium nitrate ($Ca(NO_3)_2.4H_2O$), and magnesium sulfate ($MgSO_4.7H_2O$) were used to add 8 mM nitrogen (N), 2 mM calcium (Ca), 5 mM magnesium (Mg) and 4 mM sulfur (S) to the growth medium. Different micronutrients added to the tubs included 25 μmol

boron (B) (H_3BO_3), 2 μmol manganese (Mn) (($MnSO_4$), 2 μmol zinc (Zn) ($ZnSO_4$), 0.5 μ mol molybdenum (Mo) (H_2MoO_4) and 50 μmol (Fe) (Fe-EDDHA) in solution form. The experiment was laid out in completely randomized design (CRD) with three replications (Steel and Torrie, 1980). The solution tubs were continuously aerated. Two salinity levels, nil and 100 mM NaCl were developed stepwise, three days after transplanting. Nutrient solution pH was monitored and maintained daily at 6 to 6.5 by using 0.01 mol L^{-1} KOH and/or H_2SO_4.

Four weeks after transplanting, the plants were harvested, washed with distilled water, separated into roots and shoots, dried at 70 °C for 48 hours and weighed to obtain shoot dry weight (SDW) and root dry weight (RDW). Dried plant samples ground in a Wiley mill to pass a 20-mesh screen. For K^+ and Na^+ analysis, 0.2 g portion of ground samples was digested with di-acid mixture of HNO_3 and $HClO_4$ (3:1) and digested solution was diluted to 50 ml with distilled water (Yoshida *et al.*, 1976). The concentration of K^+ and Na^+ in the digested solution was determined by flame photometer (Jenway PFP 7, ELE Instrument Co. Ltd.).

The data were subjected to statistical analysis using computer software MSTAT-C (Russell and Eisensmith, 1983) and following methods described by Gomez and Gomez (1984). Completely randomized design was employed for analysis of variance and Duncan's multiple range test was used to compare the treatment means.

RESULTS

Plant growth

The shoot and root dry matter yield of various sugarcane genotypes decreased significantly (P <0.05) with increasing salinity (Table 1). However, the magnitude of decline in shoot and root growth varied significantly (P <0.05) among various genotypes. Maximum total dry matter produced at higher salinity was 20.4 g $plant^{-1}$ in HSF 240 and 18 g $plant^{-1}$ in CP 77-400. Due to higher root medium salinity (100 mM NaCl) minimum average reduction of 23.5% in total dry matter production observed in HSF 240 and CP 77-400 genotypes of sugarcane. Hence, they were ranked as salt tolerant. On the other hand, CPF 243, SPF 213 and SPF 245 were severely affected by salinity. Minimum total dry matter produced was 1.2 g $plant^{-1}$ in CPF 243, 2.6 g $plant^{-1}$ in SPF 213 and 4.0 g $plant^{-1}$ in SPF 245. These genotypes exhibited maximum reduction in total dry matter production (76% average) and appeared as salt sensitive. Under salinity stress, the total dry matter production by all sugarcane genotypes significantly correlated with K^+/Na^+ ratio (r = 0.81). It was indicated that higher amounts of Na^+ in plant tissues significantly reduced dry matter production.

Table 1. Shoot, root and total dry matter of ten sugarcane genotypes grown in nutrient solution salinized with nil and 100 mM NaCl

Genotypes	Shoot dry matter (g $plant^{-1}$)		Root dry matter (g $plant^{-1}$)		Total dry matter (g $plant^{-1}$)	
	Control	NaCl @ 100 mM	Control	NaCl @ 100 mM	Control	NaCl @ 100 mM
SPF 245	10.7 efg*	3.5 hi	1.7 de	0.5 hi	12.4 f-i	4.0 jk
SPF 244	14.3 def	9.5 fg	1.7 de	1.7 de	16.0 d-g	11.2 ghi
CPF 237	31.9 a	13.5 ef	2.3 bc	1.9 cd	34.2 a	15.4 d-h
SPF 242	13.2 ef	7.3 gh	1.2 efg	0.9 fgh	14.4 e-h	8.3 ij
SPF 213	14.2 def	1.7 i	1.5 de	0.9 fgh	15.7 d-h	2.6 k
CP 82-1172	14.6 de	9.4 fg	1.2 efg	1.5 def	15.8 d-h	10.9 hi
CP 43-33	15.1 de	10.8 efg	1.9 cd	1.3 ef	17.0 def	12.2 f-i
HSF 240	23.2 b	18.6 cd	2.6 ab	1.7 de	25.8 b	20.4 cd
CPF 243	4.8 hi	1.1 i	0.75 gh	0.1 i	5.6 jk	1.2 k
CP 77-400	22.1 bc	13.2 ef	2.4 abc	2.8 a	24.5 bc	18.0 de

* Figures sharing similar letter do not differ significantly at P <0.05 according to Duncan' s Multiple Range Test.

Ionic relation

Sodium concentration in shoots and roots of ten sugarcane genotypes differently increased with salinity. Shoot Na^+ concentration ranged between 2.9-5.5 mg g^{-1} in control. It increased to 14.2 (HSF 240) to 68.5 mg g^{-1} (CPF 243) with the application of 100 mM NaCl. Similarly, 1.7-4.6 folds increase was found in root Na^+ concentration among sugarcane genotypes compared to control (Table 2). Maximum shoot Na^+ concentration in CPF 243 was followed by SPF 213 and SPF 245 in descending order. Least affected were HSF 240 and CP 77-400, which also produced maximum dry matter under salinity stress. It was interesting to note that HSF 240 and CP 77-400 had lower ratio of shoot Na^+ to root Na^+, an important characteristic of salt tolerant genotypes, compared to others.

Table 2. Shoot and root sodium concentration of ten sugarcane genotypes grown in nutrient solution salinized with nil and 100 mM NaCl

Genotypes	Shoot Na^+ Concentration (mg g^{-1})		Root Na^+ concentration (mg g^{-1})	
	Control	NaCL @ 100 mM	Control	NaCL @ 100 mM
SPF 245	4.1 i*	49.5 c	10.1 ef	28.9 a
SPF 244	3.9 i	43.1 d	7.8 fg	32.0 a
CPF 237	5.5 i	26.7e	10.7 ef	30.5 a
SPF 242	5.1 i	43.6 d	10.2 ef	29.5 a
SPF 213	4.6 i	59.6 b	9.1 efg	30.2 a
CP 82-1172	5.5 i	21.5 f	6.5 g	20.3 c
CP 43-33	2.9 i	20.2 fg	8.9 efg	24.3 b
HSF 240	3.6 i	14.2 h	9.9 ef	23.5 b
CPF 243	4.2 i	68.5 a	9.1 efg	15.2 d
CP 77-400	3.6 i	15.8 gh	11.3 e	25.9 b

* Figures sharing similar letter do not differ significantly at P <0.05 according to Duncan' s Multiple Range Test.

Applied salinity significantly (P< 0.05) increased Na^+ concentration and consequently reduced K^+/Na^+ ratio, however it varied widely among various sugarcane genotypes. The K^+/Na^+ ratio in plants grown in control (nil NaCl) ranged between 1.69–3.73. It reduced to 0.10–1.46 with the application of 100 mM NaCl. Maximum K^+/Na^+ ratio in HSF 240 was followed by CP 77-400 and CPF 237 in descending order. Lowest value of K^+/Na^+ ratio was found in CPF 243. Four out of ten sugarcane genotypes (SPF 245, SPF 244, SPF 242 and SPF 213 exhibited similar K^+/Na^+ ratio (Fig. 1).

DISCUSSION

Salinity is one of the major abiotic stresses that adversely affect crop quality and productivity. Various approaches like engineering techniques and the use of amendments as well as mineral nutrients are advocated to improve plant survival under salt stress (Marschner, 1995). Nevertheless, plant species and their genotypes differ genetically in their adaptation to salt stress environment (Rezoff, 1995; Wahid *et al.*, 1997). Characteristics like dry matter production, Na^+ accumulation and K^+/Na^+ ratio have been considered useful guide to assess plants for salt tolerance. Selection of crop genotypes on this basis is an important strategy to minimize yield losses in saline soils (Santa-Maria and Epstein, 2001). Reduction in dry matter production of ten sugarcane genotypes in the presence of 100 mM NaCl was due to toxicity of Na^+ and its imbalances with other nutrients like K^+ and Ca^{2+}. It consequently resulted in metabolic imbalances which reduced growth and yields (Zhu, 2002). Chinnusamy *et al.* (2005) also reported that under salt stress, the predominant cause of reduced plant growth appeared to be ion toxicity rather than osmotic stress. Ion cytotoxicity was caused by the displacement of K^+ by Na^+ in biochemical reactions and conformational changes and the loss of functions of proteins as Na^+ ions penetrated the hydration shells and interfered with non covalent interactions between their amino acids. The magnitude of decline in dry matter production among sugarcane genotypes varied possibly because of their differential selectivity for K^+ over Na^+ (Ashraf, 2002; Curtain and Naidu, 1998).

Plants absorbed more Na^+ under salinity stress. Differential increase in Na^+ accumulation in shoots and roots of sugarcane genotypes might be related to their capabilities to absorb and transport Na^+ to shoots. Qadir and Schubert (2002) reported that plant species/genotypes varied not only in their rates at which they absorbed Na^+ but also in manner by which they transported Na^+ to their shoots. Sodium in higher amounts in plant tissues significantly reduced growth which was evident from our results where the genotypes CPF 243 and SPF 213 had maximum Na^+ concentration in their shoots and produced minimum dry matter, characteristics of salt sensitive genotypes. By contrast, the genotypes HSF 240 and CP 77-400 had minimum shoot Na^+ concentration and produced maximum dry matter. These results were in agreement with Munns *et al.* (2006) who reported that the salt tolerance in wheat was associated with low shoot Na^+ concentration.

Accumulation of Na^+ and impairment of K nutrition is a major characteristic of salt-stressed plants. Therefore, K^+/Na^+ ratio in plants is considered as a good indicator to determine plant resistance to salinity (Santa-Maria and Epstein, 2001). Reduction in K^+/Na^+ ratio of sugarcane genotypes in the presence of salinity could be due to the antagonism of Na^+ and K^+ (Suhayda *et al.*, 1990). Wide differences among sugarcane genotypes for K^+/Na^+ ratio could be associated with their ability to restrict both the uptake of Na^+ by root

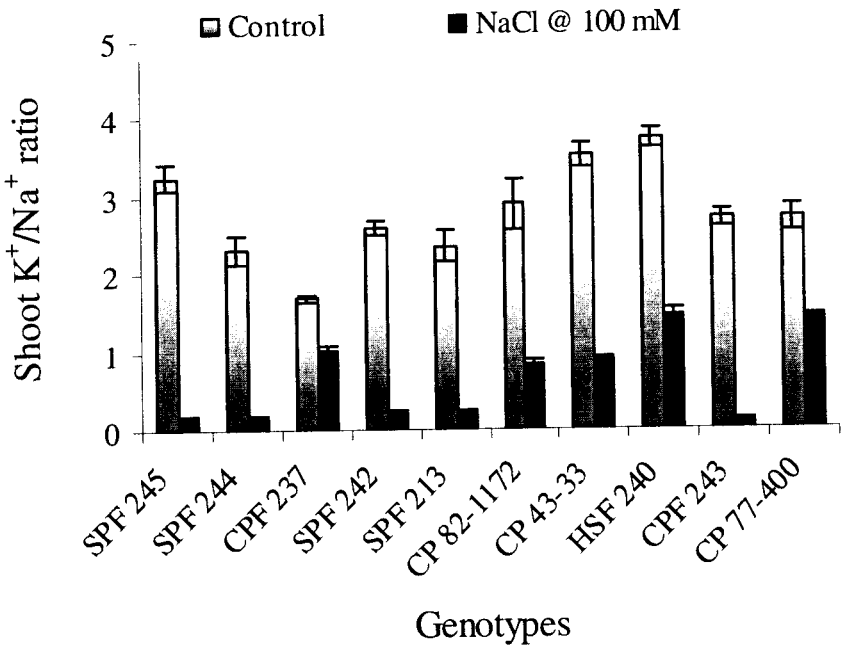

Fig. 1. Shoot K^+/Na^+ ratio of ten sugarcane genotypes grown in nutrient solution salinized with nil and 100 mM NaCl

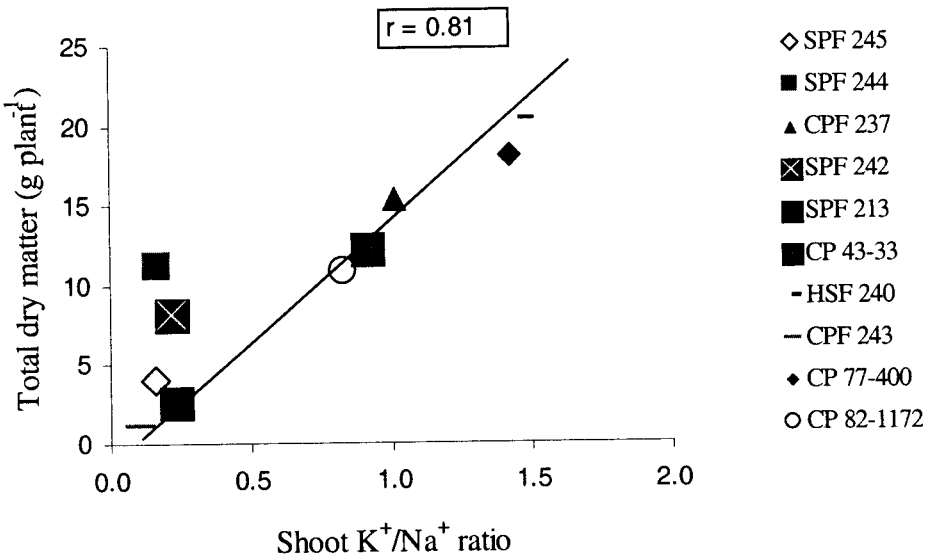

Fig. 2. Total dry matter production of sugarcane genotypes in relation to Shoot K^+/Na^+ ratio at 100 mM NaCl

cells from soil and also the movement of Na^+ to shoots by controlling their influx into the root xylem from root cells (Hu and Schmidhalter, 1997).

CONCLUSIONS

Sugarcane genotypes were significantly different in their dry matter production, Na^+ accumulation and

K^+/Na^+ ratio when grown in the presence of NaCl. The genotypes HSF 240 and CP 77-400 had minimum shoot Na^+ concentration, produced maximum biomass and maintained higher K^+/Na^+ ratio under salinity stress. These genotypes appeared to possess highest potential of making better growth in salt affected soils among ten sugarcane genotypes. Wide differences in growth of sugarcane genotypes observed in this experiment encourage screening of more germplasm against salinity, especially in field, to identify salt tolerant genotypes.

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