INTERNATIONAL JOURNAL OF AGRICULTURE & BIOLOGY
1560–8530/2004/06–1–188–191
http://www.ijab.org

Effect of Salt Stress on Some Growth Attributes of Sugarcane Cultivars CP-77-400 and COJ-84

ALTAF HUSSAIN[1], ZAFAR IQBAL KHAN, MUHAMMAD ASHRAF, MUHAMMAD HAMID RASHID† AND MUHAMMAD SAEED AKHTAR
Department of Botany, University of Agriculture, Faisalabad, 38040-Pakistan
National Institute for Biotechnology and Genetic Engineering (NIBGE) Faisalabad–Pakistan
[1]Corresponding author's e-mail: hussainaltaf1965@yahoo.com

ABSTRACT

This study reports effect of salinity on some growth attributes of two sugarcane cultivars at grand growth stage, in comparison with the control plants. In view of data presented here for different growth attributes, it is clear that responses of two varieties of sugarcane were different at different salinity levels. However, saline growth medium caused an overall reduction in growth in both the cultivars. COJ-84 was found relatively tolerant to salinity as compared to CP-77-400. COJ-84 produces more millable stalks per hectare, stalk length and stalk weight as compared to CP-77-400 under saline conditions.

Key Words: Sugarcane; Salinity; Comparison

INTRODUCTION

Climate of Pakistan is very suitable for growth of sugarcane (*Saccharum officinarum* L.), but increasing salinity of soils is posing a major threat to its growth (Qureshi & Barrett-Lennard, 1998). Salinity is an ever-increasing environmental problem in tropical irrigated areas including Pakistan. Out of total 79.6 Mha area of Pakistan, about 6.3 Mha is salt affected (Khan, 1993). Soil salinity is a serious constraint which adversely affects plant growth and development. Economic yield of plants is of great significance which is severely affected under salinity (Shannon, 1984; Francois, 1996). Sugarcane is a typical glycophyte exhibiting stunted growth or no growth under salinity, with its yield falling to 50% or even more of its true potential (Subbarao & Shaw, 1985). Shrivastava *et al.* (1989) have assigned this growth suppression to the accumulation of toxic ions. Being highly crossbred, sugarcane exhibits a significant genetic variability in nature (Wahid *et al.*, 1997). Proper evaluation of this crop germplasm against salinity may prove highly fruitful venture for its successful cultivation in problem soils.

Salinity in the root zone of sugarcane decreases sucrose yield, through its effect on both, biomass and juice quality (Lingle & Wiegand, 1996). Saline soil reduces millable stalks per hectare, stalk length, and stalk weight (Wiegand *et al.*, 1996). These reductions reduce the tonnage harvested from salt affected fields. The influence of soil salinity on sugarcane yield and quality may be due to physical factors, such as water potential of the tissue, rather than biochemical factors.

Plant tolerance to salinity is usually ascertained by the yield response equation of Maas and Hoffman (1977). However, some other criteria have also been reported as its indicators, i.e., percentage of dead leaves (Ponnamperuma, 1977), visible growth and vigour (Srivastava & Jana, 1984), chlorophyll fluorescence (Belkhodja *et al.*, 1994) and plant growth and seed yield (Francois, 1996), but age and stage of plant growth also remains critical (Ashraf, 1994; Wilson *et al.*, 2000).

Tolerant plants have adopted certain strategies of ion regulation at root (Wahid *et al.*, 1999), stem (Wolf *et al.*, 1992) or leaf level (Kumar *et al.*, 1994). Changes in physiological processes triggered by ion excess appear as changed morphology of the plant (Meinzer *et al.*, 1994). Another aspect is the selection of salinity tolerant plants at different growth stages (Maas *et al.*, 1985). This carries significance because incidence of salinity spell at any of the growth stages may lead to drastic reduction in crop yield or even complete crop failure.

This study reports effect of salinity on some growth attributes of two sugarcane cultivars at grand growth stage, in comparison with the control plants.

MATERIALS AND METHODS

Sugarcane varieties. Two local varieties of sugarcane (*Saccharum officinarum* L.) CP-77-400 and COJ-84 were obtained from the Directorate of Sugarcane, Ayub Agricultural Research Institute (AARI), Faisalabad.

Cultivation of canes. The canes were grown in field plots (2 x 1.5 x 0.5 m). Plots were dug in the field and lined with double layer of good quality polythene sheet before refilling with 760 kg of loam soil. The control and each salinity level contained 20 one-eyed sets of each variety. The sets were placed in soil with eye position upward. After proper germination, 15 plants were maintained for each of the salinity levels till the grand growth stage (180 days after sowing) was reached.

Salinity application. At grand growth stage, four salinity levels 50, 100, 150, and 200 mM were developed based upon the full saturation percentage of the soil. The natural level of salinity in the soil was 25 mM (control). The original electrical conductivity of the soil extract (ECe) was accounted for, while developing the salinity levels. Salt solutions were prepared by dissolving NaCl in tap water. Salinity (NaCl) levels were accomplished by a daily increment of 20 mM until the final required levels were attained. The plots were flooded with water overnight to ensure thorough and uniform distribution of salt (Nasir *et al.,* 2000; Akhtar *et al.,* 2001). The plots were irrigated with underground tube-well water (8 mM) as and when needed. ECe was monitored weekly to maintain the desired levels. Recommended doses of N, P and K, i.e., 150, 100 and 100 kg per hectare, respectively were applied to the plants in order to avoid possible effects of nutrient deficiency. The canes were grown for a period of three months under saline conditions**.**

Harvesting and measurements. After three months of growth under salinity, the plants were harvested. After removing trash (dead leaves) from the standing crop, the plants were cut from the soil, washed thoroughly with tap water and immediately stored at 4^oC in the cold room. Culm and leaf lengths were measured using a meter rod while culm diameter was recorded using a vernier caliper.

Effect of salinity on growth of sugarcanes.

Effect of salinity was assessed on the following growth parameters

- average length of the culm
- average length of the leaves
- average length of internodes
- average diameter of the culm

Statistical analysis. Data of different parameters were analysed using MSTAT-C programme to determine statistically significant difference among the varieties, treatments and their interactions.

RESULTS AND DISCUSSION

Sugarcane cultivars CP-77-400 and COJ-84 treated, at grand growth stage with four NaCl levels including non-saline (control=25mM), 50, 100, 150 and 200 mM, were harvested after three months of growth under saline conditions. Data for different growth parameters are presented in (Table I).

CP-77-400 was less productive as compared to COJ-84 under non-saline conditions because its average length of culm (125.1 cm) was less as compared to that of COJ-84 (191.8 cm). The length of leaves in CP-77-400 was higher than that in COJ-84, which was 143.08 and 108.2 cm, respectively. The average internode length and culm diameter in both cultivars were almost the same and equal to 7.4 and 2.3 cm, respectively (Table I).

The salinity tolerance was evaluated in terms of percent residual growth. Both cultivars performed differently at different salt levels with respect to control. It was observed that COJ-84, known for high sugar production, was less salt tolerant as compared to CP-77-400. There was an increasing and decreasing trend in the average culm length in CP-77-400 with an increase in salt concentration of the growth medium as compared to control. A maximum decrease was found at 200 mM NaCl treatment, where the remaining culm length was only 71%. Moreover, maximum increase in culm length occurred at 50 mM NaCl level. On the other hand, culm length in COJ-84 also showed same increasing and decreasing trend at different salinity treatments, but with the difference that its values decreased at all salinity levels as compared to control. Maximum decrease (residual culm length = 61%) was at 150 and 200 mM NaCl concentrations (Table I).

The behavior of leaf length to salinity was also interesting and again both varieties behaved differently at different salinity levels. The average leaf length in CP-77-400 decreased at all salinity levels and maximum decrease was at 200 mM NaCl treatment, whereas leaf length in COJ-84 remained almost unchanged at 100, 150 and 200 mM

Table I. Growth of sugarcane cultivars CP-77-400 and COJ-84 grown under saline conditions

Cultivar	NaCl levels (mM)				
	(Control)	50	100	150	200
			Culm length (cm)		
CP-77-400	125.1	130 (104)	126.6 (101)	101.5 (81)	89.3 (71)
COJ-84	191.8	145 (76)	161.9 (84)	116.5 (61)	116 (61)
			Leaf length (cm)		
CP-77-400	143.08	134.1 (94)	118.4 (83)	120.5 (84)	112 (78)
COJ-84	108.2	138 (128)	107 (99)	111.8 (103)	99 (92)
			Internode length (cm)		
CP-77-400	7.4	7.4 (100)	8 (108)	7.2 (97)	6.6 (89)
COJ-84	7.4	6.0 (81)	7.0 (95)	5.72 (77)	5.74 (78)
			Culm diameter (cm)		
CP-77-400	2.3	2.1 (91)	2.3 (100)	2.00 (87)	2.1 (91)
COJ-84	2.2	2.31 (105)	2.2 (100)	2.11 (96)	2.11 (96)

Values in parantheses are per cent of control

NaCl levels, while an increase was observed at 50 mM NaCl concentration (Table I).The average percent residual internode length in CP-77-400 remained unchanged at 50 mM, it increased to a maximum of 108% at 100 mM and decreased to 89% at 200 mM NaCl treatments. On the other hand, internode length in COJ-84 decreased at all salinity levels and maximum decrease was at 150 and 200 mM levels (Table I).

The effect of salinity on culm diameter in CP-77-400 was prominent. Culm diameter decreased at all salt treatments except at 100 mM salt concentration where it remained unchanged. Maximum decrease was observed at 150 mM NaCl treatment. On the other hand, COJ-84 showed an increase in culm diameter at 50 mM, remained unchanged at 100 mM and decreased at 150 and 200 mM NaCl concentrations (Table I).

Analysis of variance of the data for four growth parameters (Table II) shows that there was a significant effect of salt stress on culm length, leaf length and internode length whereas the salt stress effect was non-significant on culm diameter. Varieties also differed significantly for culm length, leaf length and internode length. However, they did not differ significantly for culm diameter.

Salt stress of growth medium posed an inhibitory effect on the culm length of both cultivars. Although, COJ-84, had significantly higher values of culm length at all external NaCl levels as compared to CP-77-400. Since, both the cultivars differed markedly under control conditions, the data were transformed to percent of control (relative salt tolerance) to determine the actual degree of salt tolerance of two cultivars. On percent of control basis, CP-77-400 was higher in culm length as compared to COJ-84 at all salinity levels (Table II).

The two varieties also differed significantly in leaf length in control treatments. Thus the comparison of two varieties with respect to leaf length was done on percent of control basis. COJ-84 was found to be superior to CP-77-400 in per cent leaf length under different salt treatments (Table II).

Saline growth medium significantly reduced the internode length of both cultivars. Cultivars differed significantly in terms of means and per cent of control internode length. CP-77-400 had significantly higher internode length than COJ-84 at all external NaCl regimes (Table II).

Salt stress of the rooting medium had no significant effect on culm diameter and varieties did not differ significantly in this growth variable (Table II).

Growth results of canes provided evidence that culm and leaf length may have some interrelationship. Sugarcane cultivar COJ-84, which was more productive and salt tolerant under natural level of salinity, i.e., control (25 mM NaCl), as compared to CP-77-400, had an average culm length of 191.8 cm and leaf length of 108.2 cm, while the proportion of leaf length (143.08 cm) with respect to culm length (125.1 cm) was high for CP-77-400. Hence, the proportion of leaves to culm length was low for salt tolerant variety as compared to the sensitive one. Therefore, it may be considered that the canes growing under high level of salinity may compensate the higher ion concentration by showing increase in leaf length. Both cultivars differed in the rate of formation of nodes, because the average internode length and culm diameter remained almost same (Table I). Therefore, COJ-84 produced more nodes and showed larger culm as compared to CP-77-400.

The correlation between culm and leaf lengths become more pronounced when the canes were grown under saline conditions, and it was found that increase in leaf length resulted into concomitant decrease in culm length and hence decrease in total sugars yield. Therefore, under salinity the vegetative growth, i.e., leaf length was triggered. COJ-84, which was salt tolerant under natural conditions behaved strangely under higher levels of applied salinity and showed lower growth rate as compared to CP-77-400, (Table I). Average internode length of CP-77-400 did not decrease up to 150 mM NaCl level, whereas, COJ-84 showed decrease against all salinity levels (Table I). Furthermore, culm diameter was cumulatively increased for COJ-84 and decreased for CP-77-400 at different levels of salinity. It is evident that saline soils reduce millable stalks per hectare, stalk length, and stalk weight of sugar cane (Meinzer *et al*., 1994; Weigand, *et al*., 1996).

The suppression of growth of plants under salinity has been assigned to the accumulation of toxic ions (Shrivastava *et al.*, 1989). Many workers have explored diverse response of plants to salinity (Greenway & Munns, 1980; Flowers,

Table II. Mean squares from ANOVA for different growth attributes of two varieties of sugarcane

Source of variation	df	Mean squares			
		Culm length	Leaf length	Internode length	Culm diameter
Replications (R)	4	278.4277 ns	365.462482 ns	2.227482 ns	2.194352 ns
Varieties (V)	1	12379.51125***	1999.775282*	11.224322*	0.008192 ns
Error (E_1)	4	70.208	133.205082	0.721782	0.090152
Treatments (T)	4	5587.900325***	1416.806882***	3.421402***	0.078417 ns
V x T	4	1123.503125***	491.984482***	0.872002*	0.045117 ns
Error (E_2)	32	94.0916625	61.488107	0.27063075	0.270377

* , *** significant at 0.05 and 0.001 levels, respectively ns = non-significant
Culm length (LSD 5%) = 13.08, Leaf length (LSD 5%) = 10.57, Internode length (LSD 5%) = 0.70
Culm diameter (LSD 5%) = ns

1985; Isla *et al.,* 1998). More *et al.* (1994) working on sugarcane cultivars CO-7219, CO-740, CO-419 and CO-7527, treated with sodium salts at 48 dS/m electric conductivity after 60 days of plantation, reported that the mixture of NaCl and Na_2SO_4 decreased the reducing and non-reducing sugars, chlorophyll and potassium content but increased the proline content of leaves (effect of salinity on biochemical properties of these cultivars is discussed else where).

Assessment of pattern of accumulation of toxic ions in different plant parts of a crop species is of vital importance so as to know whether the species uses partial exclusion or inclusion mechanism for tolerating toxic ions present in growth medium. The differential responses of two varieties at different levels of salt concentration are parallel to what have earlier been found in sugarcane (Gomes & Torres, 1993; Tiwari *et al*., 1997; Chowdhury *et al*., 1998; Nasir *et al*., 2000; Plaut *et al*., 2000; Chowdhury *et al*., 2001; Akhtar *et al.*, 2001).

CONCLUSION

In view of data presented here for different growth attributes, it is clear that responses of two varieties of sugarcane were different at different salinity levels. However, saline growth medium caused an overall reduction in growth in both the cultivars. COJ-84 was found relatively tolerant to salinity as compared to CP-77-400.

REFERENCES

Akhtar, S., 2001. Some morpho-anatomical and physiological studies on sugarcane under salinity. *Int. J. Agri. Biol*., 3: 1560-5.

Ashraf, M., 1994. Breeding for salinity tolerance in plants. *Crit. Rev. Plant Sci.*, 13:17-42

Belkhodja, R., F. Morales, A. Abadia, J. Gomez-Aparisi and J. Abadia, 1994. Chlorophyll fluorescence as a possible tool for salinity tolerance screening in barley (*Hordeum vulgare* L.). *Plant Physiol*., 104: 667–73

Chowdhury, M.K.A., M.A.S. Miah, S. Ali and M.A. Hossain, 1998. Effect of salinity on germination, growth, sodium and potassium accumulation in sugarcane. *Indian J. Agri. Sci*., 68:682-3

Chowdhury, M.K.A., M.A.S. Miah, S. Ali, M.A. Hossain and Z. Alam, 2001. Influence of sodium chloride salinity on germination and growth of sugarcane (*Saccharum officinarum* L.) *Sugarcane International*, 7: 15–6

Flowers, T.J., 1985. Physiology of halophytes. *Plant Sci.*, 89: 41–56

Francois, L.E., 1996. Salinity effect on sun flower hybrids. *Agron. J.*, 88: 215–9

Gomez, P.J.F. and A.J.S. Torres, 1993. Effect of salinity in the development and production of two varieties of sugarcane (*Saccharum* Spp.) *Serie Tecnica*, 12: 35–6

Gracia, A., D. Senadhira, T.J. Flowers, and A.R. Yeo, 1995. The effect of selection for sodium transport and for agronomic characteristics upon salt resistance in rice (*Oryza sativa* L.). *Theor. Appl. Genet.,* 90: 1106–11

Greenway, H. and R. Munns, 1980. Mechanisms of salt tolerance in non-halophytes. *Ann. Rev. Plant Physiol*., 31: 149–94

Hsiao, T.C., T.C. O'Toole, E.B. Yambao, and N.C. Turner, 1984. Influence of osmotic adjustment on leaf rolling and tissue death in rice (*Oryza sativa* L.). *Plant Physiol*., 75: 338–41

Isla, R., R. Agragues and A. Royo, 1998. validity of various physiological traits as screening criteria for salt tolerance in barley. *Field Crop Res*., 58: 97–107

Khan, G.S., 1993. Characterization and genesis of saline-sodic soils in Indus Plains of Pakistan. *Ph.D. Thesis*, Dept. Soil Sci. Uni. Agri., Faisalabad–Pakistan

Kumar, S., K.M. Naidu and H.L. Sehtiya, 1994. Causes of growth reduction in elongating and expanding leaf tissue of sugarcane under saline conditions. *Australian J. Plant Physiol*., 21: 79–83

Lingle, S.E. and C.L. Wiegand, 1996. Growth and yield responses of sugarcane to saline soil: II. Sucrose biochemistry in individual internodes. *Proc. Inter American Sugarcane Seminars*. pp:93-102.

Maas, E.V. and G.J. Hoffman, 1977. Crop salt tolerance current assessment. *J. Irrig. Drain. Div. Americ. Soc. Civil Eng.,* 103: 115–34

Maas, E.V., J. Poss, and G.J. Hoffman, 1985. Salinity sensitivity of sorghum at three growth stages. *Irrig. Sci.*, 7: 1–11

Meinzer, F.L., Z. Plaut and M.Z. Saliendra, 1994. Carbon isotope discrimination, gas exchange and growth of sugarcane cultivars under salinity. *Plant Physiol*., 104: 521–36

More, P.V., B.B. Desai and U.D. Chavan, 1994. Effect of salt stress on biochemical parameters of sugarcane. *J. Maharashtra Agric. Universities*, 19: 431–3

Nasir, N.M., R.H. Qureshi and M. Aslam, 2000. Effect of salinity on emergence of sugarcane lines. *Pakistan Sugar J*., 15: 12–4

Plaut, Z., F.C. Meinzer and E. Federman, 2000. Leaf development, transpiration and ion uptake and distribution in sugarcane cultivars grown under salinity. *Plant and Soil*, 218: 59–69

Ponnamperuma, F.N., 1977. Screening rice for tolerance to mineral stress. *IRRI Res., Pap. Series* 6

Qureshi, R.H. and E.G. Barrett-Lennard, 1998. *Saline Agriculture for Irrigated Land in Pakistan:* A handbook. ACIAR, Canberra, Australia

Shannon, M.C., 1984. Breeding, selection and genetics of salt tolerance. In: Staples, R.C. and G.H. Toenniessen, (eds.), *Salinity Tolerance in Plants-strategies for Crop Improvement*, pp. 231–54. John Wiley and Sons, N.Y.

Shrivastava, A.K., K. Singh, A.K. Ghosha, R. Darash, R.K. Rai, S.P. Shunkla and K. Singh, 1989. Uptake and partitioning of sodium and chloride ions in sugarcane. *Sugarcane*, 4: 3–6

Srivastava, J.P. and S. Jana, 1984. Screening wheat and barley germplasm for salt tolerance. In: Staples R.C. and G.H. Toenniessen, (eds.), *Salinity Tolerance in Plants-strategies for Crop Improvement*, pp. 223–84. John Wiley and Sons. N.Y.

Subbarao, M. and M.A.E. Shaw, 1985. A review of research on sugarcane soils, of Jamaica. *Proc. Meeting West Indies Sugar Technol*., 2: 343–55

Tiwari, T.N., R.P. Srivastava and G.P. Singh, 1997. Salinity tolerance in sugarcane cultivars. *Sugarcane*, 1: 10–14

Wahid, A., E. Rasul and A. UR. Rao, 1997. Germination responses of sensitive and tolerant sugarcane lines to sodium chloride. *Seed Sci. Technol*., 25: 465–70

Wahid, A., I. Masood, I. Javed and E. Rasul, 1999. Phenotypic flexibility as marker of sodium chloride tolerance in sunflower genotypes. *Environ. Exp. Bot*., 42: 85–94

Wiegand, C.L., D.E. Escobar, and S.E. Lingle, 1996. Growth and yield responses of sugarcane to saline soils:I. Sensing and mapping using aerial videography. *Proc. Inter American Sugarcane Semi*., pp. 15-17

Wilson, C., S.M. Lesch and C.M. Grieve, 2000. Growth stage modulates salinity tolerance of New Zealand spinach (*Tetragonia tetragonioides* pall.) and orach (*Atriplex hortensis* L.). *Ann. Bot.,* 85: 501–9

Wolf, O., M.L. Tonnet and W.D. Jeschke, 1992. Role of stem in the partitioning of Na^+ and K^+ in salt stressed barley. *J. Expt. Bot*., 42: 697–704

(Received 28 October 2003; Accepted 14 December 2003)