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Effect of NaCl Salinity on Yield Parameters of Some Sugarcane Genotypes

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ABSTRACT

An experiment was conducted in tanks to study the economic yield attributes of sugarcane genotypes under 2.5 (control), 8 and 12 dS m^{-1} levels of salinity, in three differentially salt tolerant genotypes i.e. CPF-213, CP-43/33 (tolerant) and L-116 (sensitive). At high levels of salinity i.e. 12 dS m^{-1}, the genotypes CPF-213 and CP-43/33 exhibited higher yield of juice, sucrose and cane yield etc., while L-116 responded poorly for these parameters. Possible reasons for the reduced yield of cane varieties under salinity have been discussed.

Key Words: Glycophyte; Juice; Salinity; Sucrose; Sugarcane

INTRODUCTION

Rapidly increasing salinization of soil is causing great reduction in plant growth by hampering various physiological phenomena (Maas, 1986). Sugarcane (*Saccharum officinarum* L.) is a glycophyte and has been ranked as moderately sensitive to salinity (Rozeff, 1995). Globally, about one million hectares of land under sugarcane cultivation is affected by salinity or sodicity as this crop is confined to the tropical or subtropical areas (Rozeff, 1995). Plant tolerance to salinity is usually appraised as the absolute/relative growth or yield of crop in saline conditions (Qureshi *et al*., 1990; Wahid *et al*., 1997a). This is also a useful criterion for expression of salt tolerance (Maas & Hoffman, 1977). Sprouting and early growth stages are considerably more resistant to salinity than do the later developmental stages (Wahid *et al*., 1997a). Rozeff (1995) noted a 50% reduction in sprouting of sugarcane at 13.3 dS m^{-1} while same reduction of yield at 9.5 dS m^{-1} salinity. The salts interfere with sugar production in two-fold manner, first by affecting growth rate and yield of the cane and secondly by affecting the sucrose content of the stalk. Numerous investigations have touched on the effects of soil salinity on stripped cane yield, sucrose yield and physiology (Lingle & Weigand, 1997).

In sugarcane, the yield components include stripped cane yield, sucrose percentage per stalk, extractable juice per stalk and brix percentage in the cane stalk. This paper reports changes in the yield and related attributes of a standard (CP-43/33), selected tolerant (CPF-213) and sensitive (L-116) genotypes of sugarcane under three levels of salinity i.e. control (2.5 dS m^{-1}), 8 and 12 dS m^{-1}.

MATERIALS AND METHODS

Plant material. Genotypes of sugarcane (*Saccharum officinarum* L.) selected for this study were rigorously screened previously under NaCl salinity application. CPF-213 with salt tolerance limit (EC_{50}) of 18.5 dS m^{-1} and L-116 with EC_{50} of 11.2 dS m^{-1} were declared salt tolerant and sensitive, respectively (Akhtar, 2000). CP-43/33 designated as standard genotype, had previously been established as salt tolerant (Wahid *et al*., 1997a).

Experimental and growth details. Experiment was conducted in tanks (7×3.5×0.6-m (deep) filled with a loam soil (20 metric tonnes) and lined with a double layer of polyethylene sheets, during 1994-95 and 1995-96. Experiment was laid out in completely randomized fashion with three replications. Physico-chemical characteristics of the soil determined with standard methods (Qureshi & Barrett-Lennard, 1998) were; organic matter 1.2%, total N 0.72%, cation exchange capacity 16.7 meq 100 g^{-1}, pH 7.6, ECe 2.5, sodium adsorption ratio 0.17, Na^+ 2.48 mmol L^{-1}, Cl^- 8.4 mmol L^{-1}, SO_4^{2-} 3.6 mmol L^{-1} and Ca+Mg 30 mmol L^{-1}, as determined from extracted solution of the soil paste. Twenty-four single noded sets of each genotype were planted in tanks. After the emergence of sprouts, 12 plants per tank were finally retained to maintain at least 30-cm row to row and plant to plant distance. Average temperature during the experimental year 1995-96 was between 36±5°C (summer March to September) and 17±6°C (winter October to February); relative humidity 62±3% (summer) and 78±8% (winter) and rainfall was 390 mm.

Treatment application. Two salinity levels i.e. 8 and 12 dS m^{-1} were developed at maturity stages (270 days after planting) using NaCl (99% pure). Dissolving NaCl in tap water gradually developed salinity levels in six days. The plants were irrigated with subsoil water (EC=0.8 dS m^{-1}; SAR=4.9) whenever needed. Agronomically recommended dozes of N, P and K (150, 100 and 100 kg ha^{-1}, respectively) were split to add at three intervals i.e., 50, 150 and 250 days after planting. The ECe of the soil was checked at the termination of experiment, which was slightly higher than the original ECe of the soil.

Harvesting, measurements and statistics. Plants were harvested 80 days after the application of salinity. Cane stalks were cut at ground level, stripped and determined for fresh weight per plant. Stalk girth was recorded using a vernier caliper and juice was extracted using a mechanical extractor. Sucrose content of juice was measured using the method of Horecker (1966) and expressed in percentage. Data for different parameters were analyzed using MSTAT-C programme.

RESULTS AND DISCUSSION

Cane yield per tank. A significant (P<0.01) difference was noted among the genotypes for the cane yield along with significant (P<0.01) interaction of both the factors (Table I). There was a reduction in cane yield per tank in all the genotypes due to salinity but the effect was most prominent in L-116 (Fig.1a). Cane yield was comparable in the standard and selected tolerant genotypes, but was the lowest in the sensitive (L-116).

Stalk girth. Stalk girth indicated highly significant (P<0.01) difference among three cane genotypes under increased salinity (Table I). The interaction between genotypes and salinity levels was also found to be highly significant (P<0.01). There was a general trend of decrease in stalk girth in all the genotypes but the worst effect of salinity was noted in L-116; whereas, CP-43/33 and CPF-213 indicated almost similar response under increased salinity (Fig.1b).

Internodal length. All the genotypes showed highly significant (P<0.01) differences for internodal length as affected by salinity with a significant (P<0.01) interaction of genotypes and salinity (Table I). Applied salinity caused a reduction in internodal length of all the genotypes (Fig.1c), but reduction in this parameter was the lowest in the standard and tolerant genotypes as compared to the sensitive one.

Extractable juice (mL) per cane stalk. The amount of extractable juice per cane stalk differed highly significantly in all the three genotypes with the increase of salinization (Table I). The interaction of genotype × salinity was also significant (P<0.05). Applied salinity lowered the quantity of extractable juice per cane stalk in all the genotypes but a sharp decrease was evident in the sensitive genotype i.e. L-116 (Fig.1d). The standard tolerant (CP-43/33) and selected tolerant (CP-213) genotypes behaved in a similar manner.

Sucrose content. Sucrose content of the sugarcane genotypes reduced highly significantly (P<0.01) as affected by salinity, but there was no interaction of both the factors (Table I). Increased root zone salinity reduced the sucrose content of all the genotypes but the maximum reduction was noted in the sensitive genotype, L-116 (Fig.1e).

The exhibition of higher economic yield under salinity is the parameter of potential interest, and it is considered as a yardstick for tolerance to salinity. One of the most important aspects of this study was to investigate the changes in the cane yield and sugar contents. The data (Table I) revealed that applied salinity reduced the stripped cane yield, but with significant genotypic difference. The reduction in cane yield was due to reduction in stalk girth and internodal length (Fig.1b, c). As osmotic pressure of the rooting medium increases by salinization, stalk weight, internode length and juice purity decrease (Rozeff, 1995). The reduction in apparent growth and yield was apparently related to the recovery of extractable cane juice and sucrose percentage in the cane stalk (Fig.1d, e). There was a substantial reduction in the sucrose levels. Sucrose content diminish as the plant functions to extract water from the soil at the expense of carbohydrate consumption (Akhtar, 2000), loss of turgor, wilting, cessation of cell enlargement, closure of stomata, reduction in photosynthesis (Meinzer *et al*., 1994) and interference with many basic metabolic process. In an earlier study, Wahid *et al.* (1997b) attributed the reduction in the sucrose content to the inhibitory effect of NaCl on the activity of key enzyme, invertase, which plays an important role in the synthesis (loading and unloading), of sugars. A non-significant change in the levels of total sugars and a significant reduction in the level of sucrose revealed that applied salinity had an adverse effect on the activity of enzymes involved in sucrose biosynthesis. These findings are in conformity to those of Hartt (1969) and Lingle and Weigand (1997) that a decrease in the content of sucrose under saline conditions was due to the adverse effect of salinity on this enzyme.

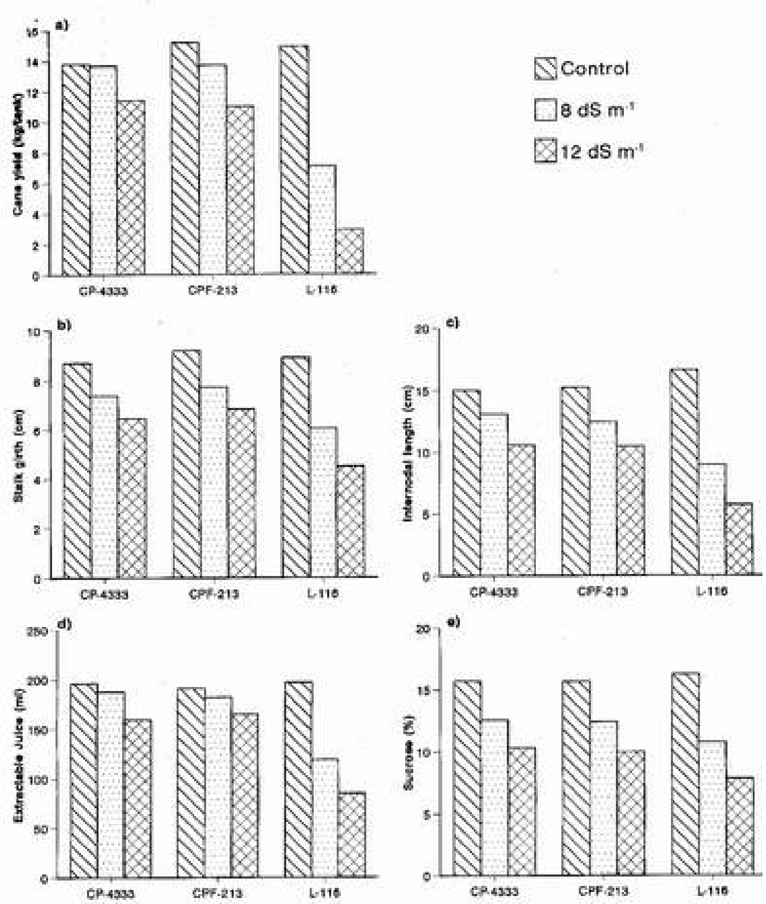
As far as the differences among genotypes are concerned, there was no difference among the standard and selected tolerant genotypes, but the sensitive genotype indicated large difference (Table I). A reduction in the quantity of extractable juice was also related to a greater fresh matter yield (r=0.99; P<0.01) and extractable juice vs. cane stalk fresh weight (r=0.96; P<0.01). These data revealed that reduced uptake of water and its retention in the stalk is a main factor in determining the growth of stalk and sucrose recovery. It is, therefore, plausible that instead of ion

Table I. Analysis of variance (F-values) of some yield characteristics of cane genotypes under increased salinity

SOV	df	Cane yield (kg/tank)	Stalk girth (cm)	Internodal length (cm)	Extractable Juice (mL)	Sucrose (%)
Genotype (G)	2	1963.20**	4.84**	17.02**	239.23**	9.87**
Salinity (S)	2	2426.43**	20.59**	102.07**	281.16**	76.91**
G × S	4	615.75**	1.18**	11.75**	71.29**	0.23^{NS}

**=significant (P<0.01); NS=non-significant

Fig. 1. Some economic yield responses of sugarcane genotypes under control (2.5 dS m^{-1}) levels of salinity



toxicity, reduced water content was a crippling factor in giving reduced stripped cane yield in sugarcane. This was due to the fact that, being a C_4 crop, it has higher requirement of water for normal growth and development (Deitz & Harris, 1997).

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