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Effect of salinity stress on morphological and yield attributes of sugarcane (*Saccharum of ficinarum* L.) genotypes

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Abstract
Ten commercial sugarcane genotypes frequently grown in U.P. and other states of India were cultivated under two different salinity levels of ECiw 10 dSm^{-1} and 20 dSm^{-1} along with the control. Salinity, maintained by irrigation through demineralized water mixed with specific ratio of NaCl, Na_2SO_4, $CaCl_2.2H_2O$ at 3:1:2, at formative phase (40-150 DAP) of plant and there observation were taken at the grand growth phase (160-240 DAP), except for yield parameters that were taken at the time of harvesting (360-365 DAP). Morphological and yield attributes were evaluated at both the stress levels respectively. Although, salinity reduces overall growth of all the ten varities yet some of them were able to ameliorate the stress effect. The genotypes CoPant 97222, CoS 7250, Co 98014, Co 5009 and Co 5011 found to be tolerant CoLk 99270 and Co 8279 as moderate and Co 0118, Co 0238 and CoSe 8457 as salinity susceptible in present case for the respective electrical conductivity of irrigating water.

Keywords: Salinity, electrical conductivity, sugarcane, genotypes

Introduction

In India, Andhra Pradesh, Karnataka, Maharashtra, Tamil Nadu and Uttar Pradesh are the important sugarcane growing states, where Uttar Pradesh alone occupies 50 per cent of the sugarcane area and contributes to 30 percent of the production. It is the highest sugarcane producing State in sub-tropical zone having area about 22.77 Lakh ha with production of 118.23 lac tons in 2018-19 as per ISMA (Indian sugar mills association).

After textile sugar industry is the second largest agro industry in the India, that shares two percent of gross domestic product (GDP), which plays a vital role in the socio-economic transformation of the country (FAO, 2016) [7]. The projected sugarcane production in India by the year 2020 is estimated to be 415.00 MT with the limited area and prevailing environmental conditions. Sugarcane is grown in wide range of temperature and climate plays a major role in influencing the growth rate of sugarcane crop. It is a typical glycophytic plant that suffers stunted or no growth under salt stress. Yield potential reduces upto 50% to its original performance. For sustainable production and productivity enhancement, tolerance to biotic and abiotic stresses, nutrient management are the important factors (Patade 2011) [17]. More than one-third of irrigated land is considered to be affected by salinity (Flowers *et al*., 1997) [8] and its continuous increase is posing a greater threat in the world. Excess salinization in soil affects the plant development and growth rate of most of the crops worldwide Giri *et al*., 2003 [10]; Hameed *et al*., 2014 [11]; Ahanger *et al*., 2014 [1]; Wu *et al*., 2014 [30]. Salinity induces both of the osmotic and ionic stress, where ion cytotoxicity is mainly due to Na^+, Cl^- and SO_4^{-2} ions that reduces growth of the plant (Zhu, 2002) [31].

Soil salinity occupies a prominent place among the soil problems that threaten the sustainability of agriculture over a vast area in the world. As per USDA salinity Laboratory, a saline soil is having an electrical conductivity of the ‘saturated paste extract’ (ECe) of 4 dS/m at 25 °C with exchangeable Na of 15%. Salinity is one of the major abiotic stresses among all, that hampers the crop production worldwide and tends to loss in total profit (Kumar *et al.*, 2010; Tavakkoli *et al.*, 2011) [13, 26]. About 800 Mha of land is found to be affected by salt stress, containing excessive soluble salts approx. 397 Mha or exchangeable sodium about 434 Mha around the world (FAO, 2005; Munns, 2005) [6, 16]. Cropping in arid and semiarid regions are facing high salinity stress, as these regions get less precipitation and more evaporation rate (de Azevedo Neto *et al*., 2006; Ahmad *et al*., 2012) [5, 2].

Most of the indogangetic plane covering the states of Punjab, Haryana, U.P. Bihar and some parts of Rajasthan, arid tracts of Gujarat and Rajasthan and semi-arid tracts of Gujarat, Madhya Pradesh, Maharashtra, Karnataka and Andhra Pradesh are also largely affected by saline lands (Shrivastava and Kumar, 2015) [24]. In view of this, the objective of present of study is to evaluate the morphological and yield attributes of sugarcane genotypes for the selection of tolerant one so as to use in crossbreeding programme for development of high yielding cane.

Material and methods
The experiment was conducted in a Complete Random Design (CRD) with three replications for each treatment and control, at Sardar Vallabhbhai Patel University of Agriculture & Technology, Meerut (U.P.) India. Sugarcane genotypes were planted in a plastic pot for their evaluation under control and stress at two different levels of salinity, ECiw 10 dSm^{-1} and ECiw 20 dSm^{-1} by irrigation. Treatments were given by mixing desired amount of NaCl, Na_2SO_4, $CaCl_2.2H_2O$ at the ratio of 3:1:2, thoroughly into the demineralized water and continuously watering the plant at interval of 7 days to the formative stage (40-150 DAP) of plant. Data for evaluation were taken at grand growth phase (160-240 DAP) except for brix percentage that was taken at harvesting (360-365 DAP). The experimental soil taken was sandy loam with initial pH of 6.2 and ECe (Electrical conductivity of the extract of a saturated soil paste) 1.39 dSm^{-1}. The ECe levels of experimental soils were checked at the time of planting by conductivity meter and maintained throughout the experiment.

Morphological and yield parameters
Plant height, was measured from the base of the plant to the top fully opened leaf of the main shoot i.e. ligular leaf +1 and expressed in cm. Leaf area per plant was computed using index leaf method of Stickler *et al*., (1961) [25] as, Leaf area = (L x W x F) where, L = Maximum length (cm), W = Maximum width (cm), F = Factor, (0.76). Number of tillers per plant was computed by taking the average of three potted plant. Length of middle internode was measured by using scale and expressed in cm. Cane girth of stalk was taken using vernier calliper and measurement was expressed in cm. Total number of internode on the sugarcane stalk was counted from three hills in each treatment at grand growth phase and the average of that three hills were represented as total number of internode per plant. Leaf area index was calculated according to Sestak *et al*., 1971 [21].

$$\text{Leaf area index} = \frac{\text{Leaf area/ Hill}}{\text{Land area/Hill}}$$

Brix was recorded using brix hydrometer and corrected brix reading were worked out by noting the room temperature at the time of observation with the help of bur standards.

Salt Tolerant Trait Indices (STTI)
Salt tolerant trait indices (STTI) for each of the studied trait were calculated according to the formula of Ali *et al*., (2007) [4].

$$\text{STTI} = \frac{\text{Value of trait under stress condition}}{\text{Value of trait under control condition}} \text{X100}$$

Statistical analysis
The data were subjected to statistical analysis using OPSTAT-1 and SPSS (version 19.02) with significance at $P \leq 0.05$.

Result and discussion
Salinity at critical stage of plant growth can affect its yield significantly. The threshold value for sugarcane under salinity is 1.7 dSm-1 and per unit decrease in yield of sugarcane under salinity is 5.9% (Rao *et al*., 2015) [18]. Present study comprises of various morphological and yield parameters *viz*. plant height, cane girth, numbers of tillers per hill, internodal length, leaf area, leaf area index, brix percentage, internode per plant, that were undergone for cluster analysis according to Ward's minimum variance. The genotypes CoPant 97222, CoS 7250 Co 98014, Co 5009 and Co 5011 found to be tolerant for the ECiw value of 10 dSm^{-1} and ECiw of 20 dSm^{-1} as can be seen in the Fig. 1 and 2 based on the relative performance of the genotypes with there mean values. The wide range of relative salt tolerance indices for different trait indicates that genotype has broad genetic base for these trait. These relative salt tolerance indices then further computed for different agronomic parameters Cluster group rankings were obtained based on Ward's minimum variance to show the relatedness of one variety to another on the basis of selected parameters as shown in Fig. 3 and 4. Wahid, (2004) [27] studied the comparative account on two sugarcane clone, CP 4333 and CP 713002 for the analysis of effect of salt treatment and their response towards it at two different growth stages. Area of leaf and dry weight get significantly affected by salinity at grand growth phase of plant, with more effect on dry weight hence overall specific leaf weight reduced. To suppress the effect of excess ions tolerant species produces additional tillers. Tolerance and susceptibility of these selected varieties are different with each other as shown in the present result, and these data are in conformity with the data obtained by Lingle *et al*., (2000) [14]; Akhtar *et al*., (2001) [2]; Hussain *et al*., (2004c) [12]. Salinity reduces the sugar production, plant growth, yield and sucrose percent, present result shows that brix percent also reduces with respect to control under salinity (Wahid *et al*., 1997a; Rao *et al*., 2015) [27, 28]. Present result is also in support with Lingle and Wiegand, (1997) [15] that have shown the reducing brix and purity percent of var. CP 70-321 when grown in saline soil of 2 to 10 dS/m. Wiegand *et al*., (1996) [29], also confirm that growth, yield and millable stalks per cane affected when the salinity increases above Ece 10 dS/m. As per their study, Co 92038 and Co 85004 were signified as tolerant while Si 94050 and Co 85036 as susceptible. Likewise, the variety Co 5011, CoPant 97222, CoS 7250 better represent the tolerant and Co 0118, Co 0238 and CoSe 8457 as salinity susceptible in present case. As the EC of irrigation water increases plant height, cane girth and number of tillers decrease significantly, as confirmed by the study of Santana *et al*., (2007) [19], and Simões *et al*., (2016) [22], in the ten sugarcane varieties they used (VAT 90212, RB 72454, RB 867515, Q 124, RB 961003, RB 957508, SP791011, RB 835089, RB 92579 and SP 943206). While in this case, Co 0118 variety shows major growth reduction. Leaf area also reduces with the increase in salinity from 5.2 dSm-1 to 8 dSm-1 as confirmed by the study of García and Medina, (2010) [9], in two sugarcane genotypes V78-1 and PR 692176. During present study, we have found CoS 7250 as salt tolerant under 10 and 20 dSm-1 which is also confirmed by the study of Saxena *et al*., (2010) [20] who had treated the plant with 8 dSm-1 for 150 days and found

lowest reduction in dry matter as compared to another variety used in this study *viz*. CoS 95255, CoSe 96436 and CoS 0326, also the salt tolerance nature of CoPant 97222 is reported by Srivastava and Srivastava, (2012) [23].

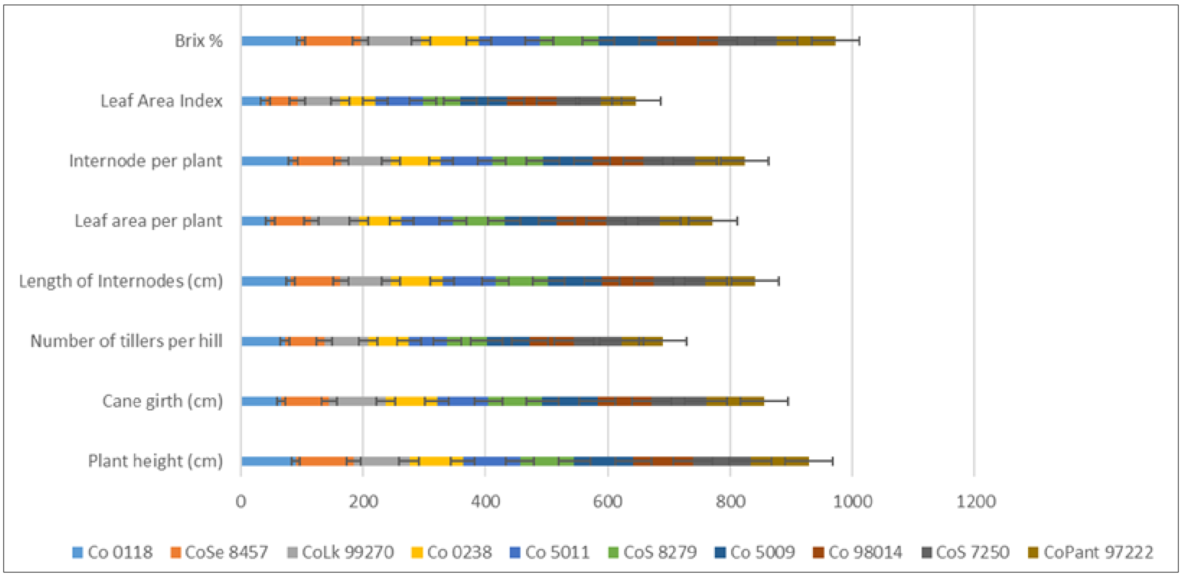

Fig 1: Relative salt tolerance indices of ten sugarcane genotypes at (EC_{iw} 10 dSm^{-1}).

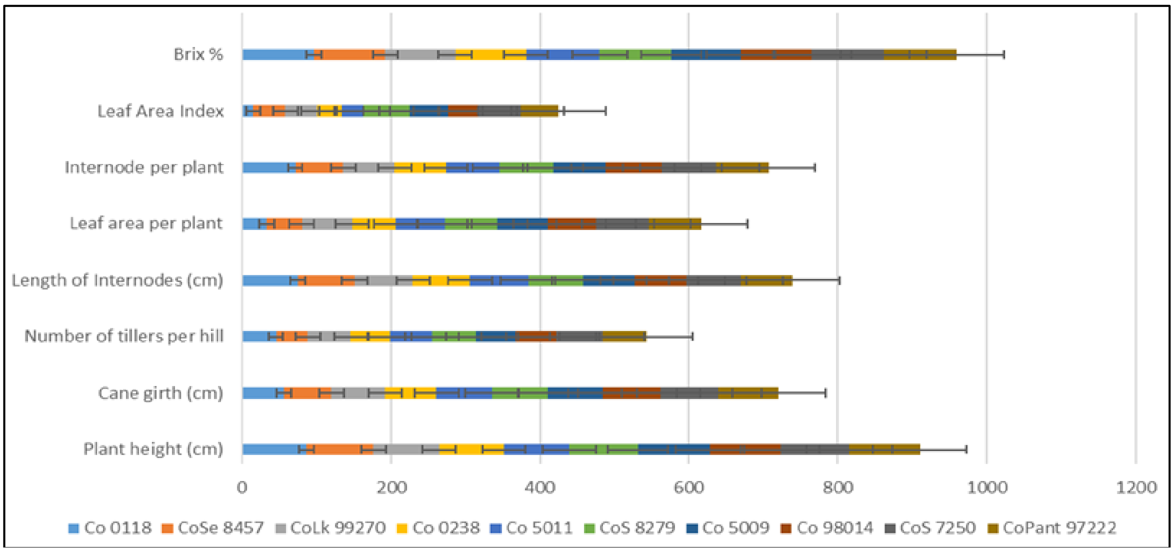

Fig 2: Relative salt tolerance indices of ten sugarcane genotypes at (EC_{iw} 20 dSm^{-1}).

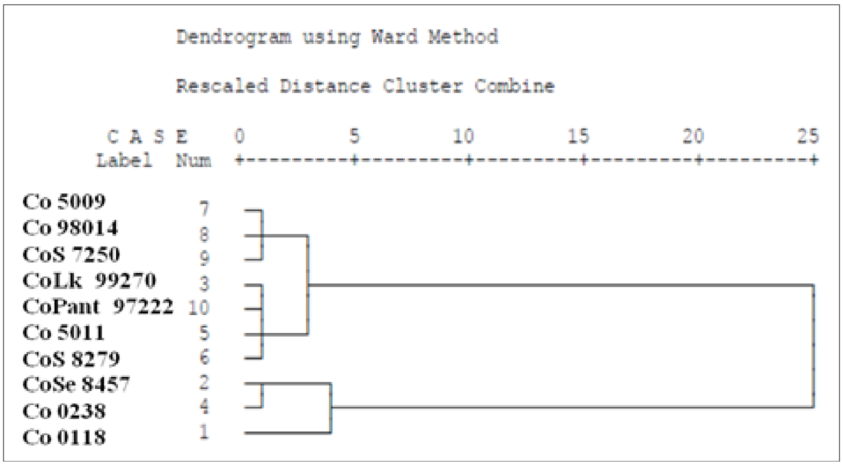

Fig 3: Tree diagram of sugarcane through Ward's minimum variance for eight morphological and yield characters based on salt tolerance indices at (EC_{iw} 10 dSm^{-1}).

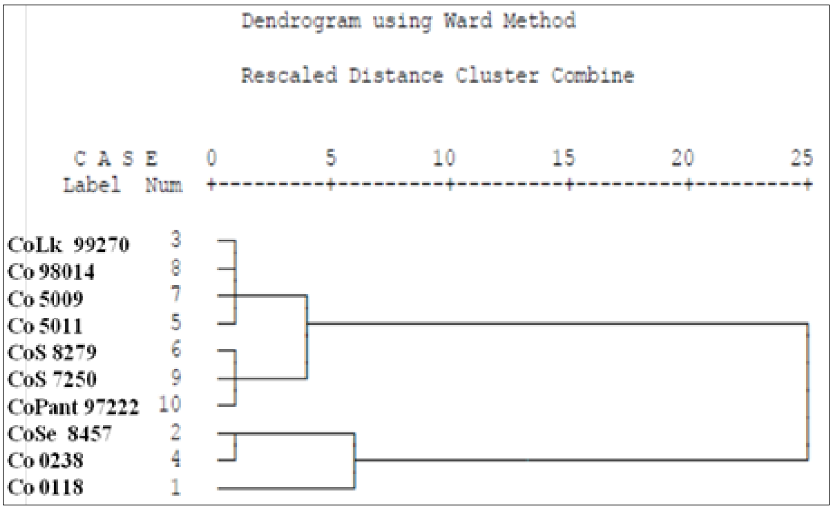

Fig 4: Tree diagram of sugarcane through Ward's minimum variance for eight morphological and yield characters based on salt tolerance indices at (EC_{iw} 20 dSm^{-1}).

Conclusions

Deleterious effects of salinity reduces growth and yield performance of the plant. Culm length and diameter decreases significantly with respect to control at both the salinity levels with respect to normal condition. Sugarcane productivity depends on the length and diameter of plant that get adversely affected by the stress. Salt stress causes physical drought to the plant that slower the ability of plant to take up the water from soil, consequently morphological along with physiological and biochemical phenomenon of plant supresses leads to yield loss. Leaf area index and brix could be one of the basic parameters of plant yield loss. Tolerant and moderate genotypes can further be incorporated into breeding programme and tissue culture techniques to produce multiple of that kind of plant in less time, while susceptible one can be cross breed with the tolerant variety for their trait enhancement.

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