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Performance of Sugarcane Varieties under Organic Amendments with Poor Quality Irrigation Water

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Abstract: Sugarcane is known to be moderately sensitive to salinity. Excess of cations such as sodium and anions like carbonate, bicarbonate and chloride present in irrigation water, may affect the growth and yield of sugarcane. To realise this problems field experiments were conducted to screen the saline tolerant sugarcane varieties for poor quality irrigation water under different amendments. The field experiment - I was conducted on sandy loam soil with treated paper mill effluent as irrigation source and experiment - II was conducted on sandy clay loam soil with saline groundwater as irrigation source, during October 2006 - January 2008 in a split plot design, with three replications. The experiment consists of seven main plot treatments i.e. basal application of 500 kg ha^{-1} gypsum (control), 50 % Gypsum Requirement (GR), 50 % GR + FYM @12.5 t ha^{-1}, 50 % GR + composted coir pith @ 12.5 t ha^{-1}, 50 % GR + vermicompost @ 5 t ha^{-1}, 50 % GR + pressmud @ 6 t ha^{-1}, 50 % GR + pressmud @15 t ha^{-1} along with 100 % NPK . The sub plot treatments consist of four saline tolerant varieties *viz.,* COC(SC)23, COSi(SC)6, COG(SC)5 and CO86032. Based on the results obtained from the field experiments, it could be concluded that the saline tolerant sugarcane variety COSi(SC)6 performed better under pressmud @ 15 t ha^{-1} + 50 % GR + 100 % NPK with *in situ* incorporation of green manures (Daincha- *Sesbania aculeata*) on 45 DAP and foliar micronutrient spray (1 % $FeSO_4$ + 0.5 % $ZnSO_4$ + 0.5 kg urea) on 45th and 75th DAP.

Key words: Irrigation water; Sugarcane varieties; Gypsum; FYM; Composted coir pith; Vermicompost; Pressmud.

INTRODUCTION

Quality of irrigation water is an important consideration in the appraisal of salinity or alkalinity conditions in an irrigated area. Since, the quality of irrigation water is instrumental for getting higher yields, the assessment of quality for irrigation water not only helps in predicting suitability of water to crop growth but also maintaining the soil health (Sellamuthu *et al.,* 2004). In India, increasing trend of irrigated area has led to 3.58 and 5.50 M ha of saline and sodic soils, respectively (FAI, 1998). This contributes about 6.40 per cent of net sown area. High salinity may interfere with the growth of vegetation. Less water can be absorbed by the plant, causing stunted growth and reduced yield due to high salinity. Sugarcane (*Saccharum officinarum*) is grown under irrigated conditions needs about 125 t of water to produce one ton of sugarcane (Jamuna *et al.,* 1994). Sugarcane is cultivated predominantly as an annual irrigated crop in both tropics and sub-tropics of India over an area of four million hectares and the production is estimated to be about 300 m t with a productivity of 70 t ha^{-1}.

Sugarcane production decreases when grown in saline (Rozeff, 1995) and sodic soil conditions (Dominguez, 1993) and over one million hectare of the world sugarcane production is affected by salinity / sodicity (Rozeff, 1995). Sugarcane is known to be moderately sensitive to salinity (Mass and Hoffman, 1977). Excess of cations such as sodium and anions like carbonate, bicarbonate and chloride present in water, increase soil pH, electrical conductivity (EC) and exchangeable sodium percentage (ESP) and may also affect the growth and yield of sugarcane.

About 1.70 lakh hectare of sugarcane growing area was reported to be affected due to varying degree of saline water irrigation in India (Sundara and Reddy, 1994). The sugarcane yield declines if the chloride and bicarbonate concentration of irrigation water exceeds 4 me L^{-1}, but there is no standard permissible limit for bicarbonate. The cane yield under such situations is decreased due to combination of osmotic effect, reduction of water availability, direct ion injury or nutritional imbalance in the plant system.

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Among the abiotic constrains, salinity of water poses a challenge to sugarcane production. Breeding of salt tolerance is difficult, whereas selection of tolerant genotypes may help in sustaining the cane yield and juice quality under such situations (Rozeff, 1995). An integrated approach is needed to facilitate the use of saline waters (Poor quality water) for irrigation, to minimize drainage disposal problems and to maximize the beneficial use of multiple water sources. Hence with this idea, the present investigation was carried out to evaluate the impact of poor quality irrigation water and amendments on growth and yield of saline tolerant sugarcane varieties.

MATERIALS AND METHODS

Characterization of poor quality water and organic amendments poor quality water:

Mainly based on the levels of EC, chloride and bicarbonate content, the irrigation waters are termed as poor quality water. The treated paper mill effluent samples collected from Tamil Nadu Newsprint and Papers Limited (TNPL), Kagithapuram, Karur and the saline groundwater samples collected from farmer's field at Vatamalaipalayam, Thudiyalur, Coimbatore, Tamil Nadu, India for their physical and bio-chemical analysis.

Organic Amendments:

The representative samples of organic amendments were taken for their chemical analysis.

Field Experiments:

Field experiments were conducted to screen the saline tolerant sugarcane varieties for poor quality irrigation water with different amendments. The field experiment - I was conducted on sandy loam soil at Pandipalayam, Karur District with treated paper mill effluent and experiment - II was conducted on sandy clay loam soil at Vatamalaipalayam, Thudiayalur, Coimbatore District with saline groundwater during October 2006 - January 2008 in a split plot design, replicated thrice. The experiment consists of seven main plot treatments *viz.,* basal application of 500 kg ha^{-1} gypsum (control), 50 % Gypsum Requirement (GR), 50 % GR + FYM @12.5 t ha^{-1}, 50% GR + composted coir pith @ 12.5 t ha^{-1}, 50 % GR + vermicompost @ 5 t ha^{-1}, 50 % GR + pressmud @ 6 t ha^{-1}, 50 % GR + pressmud @15 t ha^{-1} with common application 100 % NPK (275:60:60 kg ha^{-1}) through inorganic fertilizers. The sub plot treatments consist of four saline tolerant varities *viz.,* COC(SC)23, COSi(SC)6, COG(SC)5 and CO86032. *In situ* incorporation of green manure (Daincha - *Sesbania aculeata*) on 45 DAP and micronutrient foliar spray (1 % $FeSO_4$ + 0.5 % $ZnSO_4$ + 0.5 kg urea) were applied on 45 and 75 DAP.

The field was ploughed deep with disc plough followed by harrowing twice to bring the soil to a fine tilth. After leveling, the field was divided into ridges and furrows at a distance of 80 cm. The furrow depth was maintained at about 20 cm. Fertilizers and organic manures were applied according to treatment details. nitrogen as urea, phosphorus as single super phosphate and potassium as muriate of potash were applied @ 605:375:100 kg ha^{-1} (100 % NPK). The entire quantity of P was applied as basal dose, while N and K applied in three equal splits on 45th, 90th and 120 days after planting (DAP). All the amendments were applied as basal dose, before planting as per the treatment details. Good healthy canes from nursery crop of six month age were selected for planting. These healthy canes were obtained from sugarcane research station (SRS), Cuddalore for COC(SC)23, SRS, Sirugamani for COCSi(SC)6, SRS, Melathur for COG(SC)5 and Mudakuruchi for CO86032. Healthy two budded setts were prepared using sharp knife and planted @ 75,000 setts per ha. The cut ends were treated with 0.05 per cent carbendazim for 15 minutes. To obtain better germination, setts were planted with the buds on lateral sides. The setts were covered with loose soil for a depth of about 5 cm and then the field was irrigated. Immediately after planting, the first irrigation was given followed by life irrigation on 3rd and 7th days thereafter irrigation were given once in 8 to 10 days up to 10 months and once in 10 to 12 days up to 12 months. Earthing up was done at all three times of top dressing. Hand weeding was done twice on 25 and 45 days after planting. Detrashing was done on 120 and 180 days after planting. Harvesting of the cane crop was done at the age of 12 months. The canes from the net plot area were harvested and weighed for recording cane yield.

Biometric Observations:

With in the net plot area, ten canes were selected at random, peg-marked and subsequently used for recording observations. Germination count was recorded at 35 DAP and was expressed as percentage of germinated buds to the total number of buds planted. Tillers count was recorded at 120 DAP and expressed in thousands ha^{-1}. Tillering capacity per germinated buds was calculated using the formula.

$$\text{Tillering Capacity} = \frac{\text{Total numbers of tillers produced at 120 DAP}}{\text{Total number of buds germinated}}$$

From the total number of tillers at 120 DAP and millable canes at harvest, survival capacity of tillers in percentage was worked out using the formula.

$$\text{Survival Capacity (\%)} = \frac{\text{Millable canes at harvest}}{\text{Tillers at 120 days after planting}} \times 100$$

Yield Attributes:

Number of internodes were counted in the randomly selected canes from the net plot at harvest and expressed as number of internodes cane $^{-1}$. Diameter of the randomly selected cane samples was measured by using Veriner Caliper at bottom, middle and top portion of the cane at harvest and the mean values were expressed in cm. At the time of harvest, the total number of millable canes from the net plots were counted and expressed in thousand ha^{-1}. After removing the tops of the randomly selected canes, the length of the millable cane was measured at harvest and expressed as cm. Total cane weight was recorded at harvest from the already selected sample canes. The mean single cane weight was expressed as g cane $^{-1}$. Harvested canes were weighed from the net plot and the yield was expressed in tonnes ha^{-1}. The sample cane harvested from the net plot for juice analysis was also added to the net plot weight.

RESULTS AND DISCUSSION

Initial Characteristics of Poor Quality Irrigation Water (Table 1):

The treated effluent is light brown in colour, which was due to presence of lignin. This was in line with Srinivasachari *et al.* (1999) reported that the pulp and paper mill effluent was normally dark brown in colour. The pH of treated paper mill effluent was neutral (7.61), since lime was used to neutralize the effluent before primary and secondary treatment process. The electrical conductivity of the effluent was 2.95 dS m^{-1}, this may be due to presence of several chemicals like caustic soda, H_2SO_4, HCl and chlorine used during paper manufacturing. Similar results have been reported by Udayasoorian *et al.* (2003). In general, the vital quality parameters *viz.,* pH, EC, TDS, BOD, sulphate and per cent sodium values of treated effluent were all well within the permissible limits of TNSPCB (Tamil Nadu State Pollution Control Board) norms. But the treated effluent had higher chloride (766.8 mg L^{-1}) concentration than the TNSPCB norms. It had considerable amounts of essential plant nutrients *viz.,* ammonical nitrogen, phosphorus, potassium, calcium, magnesium and organic carbon. This was due to addition of urea and di ammonium phosphate (DAP) during the effluent treatment process and TNPL is an agro based industries, so the effluent contains appreciable levels of organic carbon. This was in line with Chatterjee *et al.* (2003), who reported that the paper mill effluent was characterized by comparatively low BOD (68 mg L^{-1}), suspended solids, COD (258 mg L^{-1}), plant nutrients (N, P and K 50.0, 1.5 and 74.0 mg L^{-1}, respectively) and Na content of 546 mg L^{-1}. The SAR of treated effluent comes under poor quality irrigation category (4.70) and it has per cent sodium of 43.60. This was supported by Udayasoorian *et al.* (1999 b), who reported that the per cent sodium content of the treated effluent had been around 40 per cent. The diluted effluent of the paper mill had slightly alkaline pH, high BOD, COD and EC with appropriate quantities of Cl, SO_4 and HCO_3 of Ca, Mg, and Na and varying amount of micronutrients (Srinivasachari *et al.,* 1999 and Udayasoorian *et al*., 1999a).

The saline ground water was colourless with neutral pH (7.47) and high EC (4.14 dS m^{-1}). This was due to the presence of higher concentration of anions and cations. The saline groundwater has higher concentration of chloride (1221 mg L^{-1}), bicarbonate (273 mg L^{-1}) and sodium (496 mg L^{-1}) than the normal irrigation water recommendations. Moreover, it has high SAR (6.90) and per cent sodium (51.01), potential salinity (35.81) than treated paper mill effluent (22.53) besides appreciable quantities of Ca, Mg and K.

According to irrigation water classification (Muthuvel and Udayasoorian, 1999), both the treated paper mill effluent and saline groundwater comes under the category of poor quality irrigation water having an EC of 3.0 – 5.0 dS m^{-1}, Cl of 7.5 – 10 me L^{-1} and SAR of 4 – 8. The groundwater had high potential salinity, so it contributes more salinity than treated paper mill effluent irrigation.

Table 1: Characteristics of irrigation water

Parameters	Unit	Values	
		Treated paper mill effluent	Saline groundwater
Colour	-	Light brown colour	Colourless
TSS	mg L^{-1}	167	-
TDS	mg L^{-1}	1760	2450
pH	mg L^{-1}	7.61	7.47
EC	dS m^{-1}	2.95	4.14
Organic carbon	per cent	0.61	BDL
BOD	mg L^{-1}	30.0	15.0
COD	mg L^{-1}	240.0	285.0
NH_4-N	mg L^{-1}	29.2	BDL
P	mg L^{-1}	1.45	BDL
CO_3	mg L^{-1}	BDL	BDL
HCO_3	mg L^{-1}	256.2	273.3
Total alkalinity	mg L^{-1}	256.2	273.3
Ca	mg L^{-1}	229.3	214.0
Mg	mg L^{-1}	38.00	108.3
Na	mg L^{-1}	295.0	495.9
K	mg L^{-1}	33.15	19.10
Chloride	mg L^{-1}	766.8	1221
Sulphate	mg L^{-1}	59.24	88.51
Potential salinity (PS)	-	22.53	35.81
Sodium Adsorption Ratio (SAR)	-	4.70	6.9
Per cent Sodium	-	43.68	51.01
Residual sodium carbonate (RSC)	-	-10.43	-15.22
Category	-	Poor quality	

Characteristics of Organic Amendments (Table 2):

The pH was neutral in FYM, vermicompost and pressmud whereas the composted coir pith was slightly acidic in nature. All the organic amendments had an EC of > 1.56 dS m^{-1}. All the organic amendments supply good quantities of primary and secondary nutrients and organic matter to the soil. These amendments had optimum C: N ratio. Among the organic materials, pressmud had higher concentrations of N, P, organic carbon, Ca and Mg than others. The pressmud originated from sugarcane (heavy nutrient feeder) and it is one of the sugar mills by product, which has good nutritive value. This was supported by Jain (2002), who reported that pressmud had appreciable quantities of nutrients like N (1.9 %), P (1.8 %), K (0.9 %), Ca (4.2 %) sulphur (3.2 %) and Mg (0.3 %).

Table 2: Characteristics of organic amendments

Parameters	Unit	Amendments			
		FYM	Vermicompost	Composted coir pith	Pressmud
pH	-	7.40	7.40	6.80	7.46
EC	dS m^{-1}	1.42	1.28	1.34	1.56
Total N	per cent	0.88	1.54	0.98	1.89
Total P	per cent	0.75	1.62	0.40	1.50
Total K	per cent	0.60	0.95	1.17	0.50
Organic Carbon	per cent	22.14	28.66	24.90	32.50
Calcium	per cent	0.55	0.68	0.50	2.00
Magnesium	per cent	0.20	1.40	0.38	1.40
C : N ratio	-	25.1:1	18.9:1	19.8:1	17.2:1

Characteristics of Initial Field Soil Samples (Table 3):

Based on the detailed textural analysis of experimental site at Pandipalayam, TNPL, Karur (field experiment - I), it has been classified as sandy loam and field located at Vatamalaipalayam, Thudiyalur, Coimbatore (field experiment - II) has been classified as sandy clay loam. The pH of the field experiment I was slightly more than neutral with an EC of 1.90 dS m^{-1}. This indicates that the soil tending towards saline sodic condition, while the pH of experimental site - II had alkaline pH with very low EC (0.11 dS m^{-1}). Both the trial sites are low in available nitrogen (< 280 kg ha^{-1}), low in phosphorus (<11 kg ha^{-1}) and high in potassium (> 280 kg ha^{-1}) with medium organic carbon status (0.50 - 0.75 per cent) in Field experiment I and low (< 0.5 per cent) in field experiment II. Based on the ESP (>15), EC and pH of the field experiment site - I, the soil was classified as saline sodic and the field experiment site - II was classified as sodic soil. Both the soil had considerable population of microbes and appreciable enzyme activities. Gypsum requirement of field experiments I and II were 7.75 and 9.50 kg ha^{-1}, respectively.

Table 3: Characteristics of field experiment soil samples

Parameters	Unit	Field sites	
		I-Pandipalayam	II-Thudiyalure
Mechanical analysis			
Clay	per cent	16.4	25.4
Silt	per cent	6.0	10.0
Sand	per cent	77.6	64.0
Textural class	-	Sandy loam	Sandy clay loam
Physical analysis			
Bulk density	Mg m^{-1}	1.18	1.25
Particle Density	Mg m^{-1}	2.35	2.22
Physico-chemical analysis			
pH	-	8.25	8.77
EC	dS m^{-1}	1.90	0.11
Available N	kg ha^{-1}	168	201
Available P	kg ha^{-1}	10.2	9.80
Available K	kg ha^{-1}	332	288
Organic Carbon	Per cent	0.55	0.48

Table 3: Continue

Exchangeable Ca	cmol (p^+) kg $^{-1}$	6.20	4.50
Exchangeable Mg	cmol (p^+) kg $^{-1}$	2.20	1.50
Exchangeable Na	cmol (p^+) kg $^{-1}$	5.20	4.20
Exchangeable K	cmol (p^+) kg $^{-1}$	1.35	0.88
CEC	cmol (p^+) kg $^{-1}$	14.95	11.08
ESP	-	34.78	37.91
Chloride	cmol (p^+) kg $^{-1}$	2.25	1.00
Gypsum Requirement	t ha^{-1}	7.75	9.50
Biological analysis			
Bacteria	(x 10^6 CFU g^{-1} of soil)	18.3	17.5
Fungi	(x 10^4 CFU g^{-1} of soil)	10.5	11.0
Actinomycetes	(x 10^3 CFU g^{-1} of soil)	5.0	5.0
Dehydrogenase	µg of TPF g^{-1} of soil	7.25	7.00
Urease	µg of ammonia release g^{-1} of soil h^{-1}	15.10	13.75
Phosphates	µg of PNPP g^{-1} of soil	11.52	11.25
Category	-	Saline sodic soil	Sodic soil

Influence of Amendments on Growth Attributes of Sugarcane Varieties with Poor Quality Irrigation Water (Table 4):

In general, sugarcane growth attributes *viz.,* number of tillers, tillering capacity and survival capacity of crop were influenced by amendments under poor quality irrigation water (treated paper mill effluent and saline groundwater).

The growth attributes like germination, number of tillers, tillering capacity and survival capacity are genetic characters inherently build up in the plant and this could be modified to some extent through external factors which subject to the availability of nutrients coupled with microbial activity. Germination percentage influenced by the varieties and not by the addition of different amendments. Hence, basal application of amendments did not favour the initial germination. Among the varieties, COC(SC)23 recorded the highest germination percentage followed by COSi(SC)6 and CO86032 under both the experimental sites (irrigation with treated paper mill effluent irrigation and saline groundwater irrigation), while the lowest germination was recorded in COG(SC)5. Germination and early growth period of crop are highly sensitive to salt stress, which may be due to the poor germination of sugarcane.

Tillering capacity and number of tillers are very important in sugarcane as it is directly related to final millable cane population at harvest. Tillering is also having significant correlation with the supply and availability of N content (Clements, 1980). But application of organic amendments were not influenced the tillering capacity and number of tillers, owing to salt stress condition which hinders uptake of nutrients by plants to produce tillers significantly. Among the varieties, COC(SC)23 produced more number of tillers.

The survival capacity of tillers, which is a conversion ratio of tillers to final millable cane is directly related to productive efficiency of the tillers and final cane yield. Application of amendments influenced the survival capacity of the sugarcane varieties. Availability of nutrients for sugarcane throughout the crop duration from inorganic fertilizers, slow release pattern of nutrients from organic amendments and *in situ* incorporation of green manures might have favoured higher survival capacity. Mathew *et al.* (2003) also have same opinion and fall in line with the findings of the present investigation. Apart from the nutrient supplies, the organic and inorganic production of acids during the decomposition and mineralization process of organic amendments and green manure might have leached the salts present in the root zone, there by reduces salt stress to crops and soil ESP. It favours the root establishment and better stand of sugarcane. After third month (90 DAP), the tiller number started declining due to natural thinning as a result of competition for light, nutrients and water. Low survival capacity was also observed when tiller numbers are high.

Among the amendments, application of pressmud @ 15 t ha^{-1} + 50 % GR and composted coir pith @ 12.5 t ha^{-1} + 50 % GR favours the tillering and survival capacity of sugarcane varieties under poor quality irrigation water. These amendments supply higher quantities of nutrients and organic matter to the soil. This was supported by Bokhtiar *et al.* (2002), who reported that the application of pressmud @ 12.5 t ha^{-1} along with inorganic fertilizer based on soil test value recorded the highest number of tillers. Sivasamy (2004) reported that the number of tillers and number of leaves in cumbu napier hybrid were more in pressmud + algae + 50 % GR applied soil under paper mill effluent irrigation. Similar observations were also reported by Dhevagi *et al.* (2000) in garden land crops *viz.,* maize, sunflower and soybean.

Table 4: Influence of sugarcane varieties and amendments on germination, number of tillers at 120 DAP, Tillering capacity and survival capacity (%) under poor quality irrigation water

Treated paper mill effluent irrigation (TPME)

Treatments	Germination (%)					Number of tillers at 120 DAP X 1000					Tillering capacity					Survival capacity (%)				
	S_1	S_2	S_3	S_4	Mean	S_1	S_2	S_3	S_4	Mean	S_1	S_2	S_3	S_4	Mean	S_1	S_2	S_3	S_4	Mean
M_1	78.30	78.30	45.80	77.57	69.99	174.0	105.7	80.0	111.7	117.8	1.50	0.90	1.20	0.97	1.14	56.7	70.5	73.8	74.0	68.8
M_2	78.30	76.53	46.87	78.60	70.08	187.3	117.0	79.0	110.3	123.4	1.60	0.93	1.20	1.00	1.18	74.6	73.5	72.4	87.4	77.0
M_3	81.70	81.07	46.87	80.87	72.63	189.0	108.0	79.7	115.3	123.0	1.60	0.97	1.17	1.03	1.19	77.9	78.1	78.0	78.0	78.0
M_4	82.40	81.07	49.73	81.70	73.73	180.0	120.3	73.7	123.7	124.4	1.57	1.00	1.17	1.00	1.18	70.8	88.5	89.8	65.5	78.6
M_5	80.33	80.33	46.37	79.30	71.58	163.0	137.0	85.0	104.0	122.3	1.43	1.17	1.30	0.93	1.21	85.6	64.3	71.6	89.6	77.8
M_6	80.63	80.63	47.17	77.57	71.50	180.0	113.0	78.0	122.0	123.3	1.60	1.10	1.07	1.07	1.21	81.4	80.7	79.2	70.6	78.0
M_7	82.40	82.40	46.67	80.00	72.87	189.0	117.0	85.0	118.0	127.3	1.63	1.00	1.17	1.10	1.23	84.4	86.2	82.2	82.0	83.7
Mean	80.58	80.05	47.07	79.37	71.77	180.3	116.9	80.1	115.0	180.3	1.56	1.01	1.18	1.01	1.19	75.9	77.4	78.1	78.4	77.5
	SEd			CD(0.05)		SEd			CD(0.05)		SEd			CD(0.05)		SEd			CD(0.05)	
M	1.28			NS		30.4			NS		0.07			NS		2.96				6.46
S	1.18			2.39		16.8			33.9		0.04			0.08		1.56				NS
M X S	3.00			NS		49.0			102.0		0.12			0.24		4.64				9.67
S X M	3.13			NS		44.4			89.7		0.11			0.21		4.12				8.32

b.Saline Groundwater

Treatments	Germination (%)					Number of tillers at 120th day X 1000					Tillering capacity					Survival capacity (%)				
	S_1	S_2	S_3	S_4	Mean	S_1	S_2	S_3	S_4	Mean	S_1	S_2	S_3	S_4	Mean	S_1	S_2	S_3	S_4	Mean
M_1	76.0	76.0	44.5	75.3	68.0	174.0	100.0	76.3	106.3	114.2	1.47	0.87	1.07	0.90	1.08	57.6	71.7	75.1	75.2	69.9
M_2	76.0	74.3	45.5	76.3	68.0	155.0	130.3	81.0	99.0	116.3	1.43	0.93	1.03	1.03	1.11	76.0	74.8	73.6	88.8	78.3
M_3	80.0	78.7	48.3	79.3	71.6	178.0	111.0	75.3	105.0	117.3	1.33	1.13	1.20	0.87	1.13	87.1	65.3	72.7	87.0	78.0
M_4	79.3	78.7	45.5	78.5	70.5	170.7	111.7	70.3	117.3	117.5	1.57	0.97	1.13	0.93	1.15	72.0	92.8	91.4	66.6	80.7
M_5	78.0	78.0	45.0	77.0	69.5	180.0	102.7	75.7	109.7	117.0	1.50	0.87	1.13	0.93	1.11	79.2	79.2	79.2	79.2	79.2
M_6	78.3	78.3	45.8	75.3	69.4	170.7	107.3	74.0	116.0	117.0	1.47	0.93	1.07	1.03	1.13	82.7	82.1	80.5	71.7	79.2
M_7	80.0	80.0	45.3	77.7	70.8	180.0	111.0	81.0	111.7	120.9	1.60	0.97	1.20	0.97	1.18	82.0	87.6	83.6	83.4	84.2
Mean	78.2	77.7	45.7	77.1	69.7	172.6	110.6	76.2	109.3	117.2	1.48	0.95	1.12	0.95	1.13	76.7	79.1	79.5	79.7	78.7
	SEd				CD(0.05)	SEd				CD(0.05)	SEd				CD(0.05)	SEd				CD(0.05)
M	1.2				NS	29.0				NS	0.03				0.06	1.5				3.3
S	1.1				2.3	19.0				39.0	0.02				0.04	1.3				NS
M X S	2.9				NS	52.0				108.0	0.05				0.11	3.3				6.8
S X M	3.0				NS	51.0				102.0	0.05				0.11	3.4				6.9

Influence of Amendments on Yield Attributes and Yields of Sugarcane under Poor Quality Irrigation Waters (Table 5&6):

There were steady correlation between growth attributes and yield attributes. The yield attributes like number of internodes, internodes length, cane diameter, millable cane length, number of millable canes and single cane weight were positively influenced by the addition of amendments on different sugarcane varieties under poor quality irrigation water. Moreover, the increased availability of nitrogen, phosphorus and potassium in addition to all the other plant nutrients released by organic manures might have contributed in enhancing the yield attributes even at recommended level of inorganic fertilizers. Similar results were reported by Dey *et al.* (1997), Vijayakumar *et al.* (1999) and Senthilkumar *et al.* (2005). Venkatakrishnan and Ravichandran (2007) revealed that the yield attributes of sugarcane increased due to organic manure application. These yield attributes were significantly influenced by pressmud application @ 15 t ha^{-1} along with 50 % GR, followed by composted coir pith application @ 12.5 t ha^{-1} + 50 % GR, which supplied good levels of essential plant nutrients to the sugarcane crop and it favoured the microbial activities, which made conducive environment for optimum growth of cane. This was supported by Singh *et al.* (2007) who reported that pressmud application produced the longest canes (224.7 cm) with highest thickness of 2.5 cm with *Sesbania* green manuring in the planted crop, while the application of recommended levels of NPK as well as pressmud compost application produced the thickest canes in ratoon (2.3 cm) and the highest ratoon yield (78.16 t ha^{-1}). Single cane weight is a function of internodes number, length and girth (cane diameter) of individual canes. Besides this, it might be due to higher nutrient uptake of cane according to Shinde *et al.* (1990).

The positive impact on availability of individual plant nutrients, humic substances from organic manures and balanced supplement of nutrients through inorganic fertilizer might have induced cell division, expansion of cell wall, meristematic activity, photosynthetic efficiency and regulation of water intake into the cells thus resulting in the better yield attributes and yield of sugarcane. This finding is in conformity with the results of Sharma *et al.* (2002) and Shankaraiah and Kalyanamurthy (2005). Venkatakrishnan and Ravichandran (2007), who reported that the addition of organic manures increased the cane yield.

Table 5: Influence of sugarcane varieties and amendments on number of internodes, internode length, cane diameter and millable cane length under poor quality irrigation water (TPME)

a. Treated paper mill effluent irrigation (TPME)

Treatments	Number of internodes					Internode length (cm)					Cane diameter (cm)					Millable Cane length (cm)				
	S_1	S_2	S_3	S_4	Mean	S_1	S_2	S_3	S_4	Mean	S_1	S_2	S_3	S_4	Mean	S_1	S_2	S_3	S_4	Mean
M_1	15.3	16.0	17.0	18.0	16.6	6.7	9.4	8.9	8.1	8.3	6.6	8.1	7.8	7.9	7.6	136.7	155.0	156.7	160.0	152.1
M_2	18.0	19.0	18.0	18.0	18.3	8.4	10.1	9.1	7.9	8.9	7.4	9.2	7.8	7.9	8.1	138.3	180.0	150.0	170.0	159.6
M_3	21.0	20.0	21.0	21.0	20.8	9.9	11.9	10.4	8.8	10.3	8.0	10.1	8.8	8.9	9.0	166.7	226.7	163.3	171.7	182.1
M_4	21.0	20.0	23.0	21.0	21.3	9.9	12.2	10.5	9.5	10.5	8.4	10.4	9.1	9.1	9.3	186.7	196.7	200.0	166.7	187.5
M_5	19.0	18.0	18.0	18.0	18.3	8.9	11.1	9.3	8.6	9.5	7.5	9.3	8.3	8.1	8.3	136.7	178.3	208.3	160.0	170.8
M_6	19.0	19.0	20.0	20.0	19.5	9.1	10.3	9.5	8.7	9.4	7.7	10.0	8.4	8.8	8.7	136.7	178.3	208.3	160.0	170.8
M_7	24.0	24.0	23.3	23.3	23.7	11.8	13.0	11.4	10.3	11.6	9.0	10.6	9.1	9.2	9.5	140.0	226.7	200.0	190.0	189.2
Mean	19.6	19.4	20.0	19.9	19.8	9.2	11.1	9.9	8.8	9.8	7.8	9.7	8.5	8.6	8.6	148.8	191.7	183.8	168.3	173.2
	SEd			CD(0.05)		SEd				CD(0.05)	SEd				CD(0.05)	SEd				CD(0.05)
M	0.37			0.81		0.2				0.4	0.2				0.3	3.0				6.5
S	0.34			NS		0.2				0.3	0.1				0.3	2.9				5.8
M X S	0.85			NS		0.4				0.8	0.4				NS	7.2				14.8
S X M	0.89			NS		0.4				0.9	0.4				NS	7.6				15.3

b. Saline Groundwater (SGW)

Treatments	Number of internodes					Internodes length (cm)					Cane diameter (cm)					Millable Cane length (cm)				
	S_1	S_2	S_3	S_4	Mean	S_1	S_2	S_3	S_4	Mean	S_1	S_2	S_3	S_4	Mean	S_1	S_2	S_3	S_4	Mean
M_1	15.0	15.3	16.0	17.0	15.8	6.5	9.1	8.6	7.9	8.0	6.4	7.9	7.6	7.7	7.4	135.3	153.5	155.1	158.4	150.5
M_2	17.0	18.3	17.0	17.0	17.3	8.1	9.8	8.8	7.7	8.6	7.2	8.9	7.6	7.7	7.8	137.0	178.2	148.5	168.3	157.9
M_3	21.0	19.0	21.0	20.0	20.3	9.6	11.5	10.1	8.5	9.9	7.8	9.8	8.5	8.6	8.7	165.0	224.4	161.7	170.0	180.2
M_4	21.0	19.0	22.0	21.0	20.8	9.6	11.8	10.2	9.2	10.2	8.1	10.1	8.8	8.8	9.0	184.8	194.7	198.0	165.0	185.6
M_5	18.0	17.7	18.0	17.7	17.8	8.6	10.8	9.0	8.3	9.2	7.3	9.0	8.1	7.9	8.1	135.3	176.6	206.3	158.4	169.1
M_6	18.3	19.0	19.0	19.0	18.8	8.8	10.0	9.2	8.4	9.1	7.5	9.7	8.1	8.5	8.5	135.3	176.6	206.3	158.4	169.1
M_7	23.0	23.0	23.0	23.0	23.0	11.4	12.6	11.1	10.0	11.3	8.7	10.3	8.8	8.9	9.2	138.6	224.4	198.0	188.1	187.2
Mean	19.0	18.8	19.4	19.2	19.1	9.0	10.8	9.6	8.6	9.5	7.6	9.4	8.2	8.3	8.4	147.3	189.7	181.9	166.6	171.4
	SEd				CD(0.05)	SEd				CD(0.05)	SEd				CD(0.05)	SEd				CD(0.05)
M	0.31				0.68	0.17				0.37	0.14				0.31	2.97				6.47
S	0.32				NS	0.16				0.31	0.14				0.28	2.83				5.71
M X S	0.79				NS	0.40				0.81	0.35				NS	7.13				14.59
S X M	0.84				NS	0.41				0.83	0.36				NS	7.48				15.10

Among the varieties, COSi(SC)6 registered higher number of internodes, greater internode length, cane diameter, millable cane length and single cane weight, followed by CO86032, whereas COC(SC)23 had higher number of millable canes. COSi(SC)6 variety performed well under different amendments and poor quality irrigation water followed by CO86032 which might be due to the genetic characters of varieties. Sugarcane crop responded well to organic amendments in the soil in terms of higher biomass production and crop yield of plant and its subsequent ratoon (Singh *et al.,* 2007).

Cane yield is the output of yield attributes. Due to the overall significant improvement in yield attributes, cane yield was high in COSi(SC)6 under pressmud application @ 15 t ha^{-1} + 50 % GR in both the irrigation sources. The yield of 132.3 and 122.5 t ha^{-1} recorded in treated paper mill effluent and saline groundwater irrigation, respectively. This might be due to slow release of available nutrients throughout the crop growth period and also saline tolerant capacity of the sugarcane variety COSi(SC)6. Soundarajan *et al.* (2007) observed that application of bioearth (composted pressmud) @ 6 t ha^{-1} along with 75 % NPK through inorganic fertilizers and *Azotobacter* found to be efficient in increasing the yield of sugarcane. Increasing N rate up to 225 kg ha^{-1} significantly increased the commercial cane yelid, while it decreased cane juice (Rawat *et al.,* 1989). Hence, cultural practices improves the soil environment could benefit root growth and sugarcane production. One such practice is the incorporation of $CaSO_4.2H_2O$ (gypsum) into the soil, which improves soil structure in heavy-textured soil, so that water infiltration and the ability of roots to penetrate the soil are enhanced.

In addition to its own manurial value, amendments and green manures were incorporated in to the soil increases the biological activity, modifies the level of available nutrients and increase the organic carbon content of the soil through biodegradation and thereby improves the physico-chemical properties of the soil. This might be the reason for the increase in cane yield (Mathew *et al*., 2003). Bokhtiar *et al.* (2002) also supported this and noticed that the addition of organic manure / green manure with chemical fertilizers produced higher cane yield as compared with treatments where only chemical fertilizers were used. Tiwari *et al.* (1998) reported that the continuous application of pressmud and nitrogenous fertilizers increased significantly the cane and sugar yield of sugarcane. Yaduvanshi and Yadav (1992) reported that the direct and residual application of 30 t ha^{-1} pressmud alone increased cane yield by 27 per cent and 39 per cent, whereas its combined application with 150 kg N ha^{-1} to each crop increased the yield by 65.5 per cent and 69.3 per cent, respectively over control. Sugarcane intercropped with green gram and pressmud application @ 25 t ha^{-1} increases cane and sugar yields (TNAU, 2000). Use of 12.5 t ha^{-1} pressmud / cowdung with chemical fertilizers based on soil test for high yield goal may be suggested for maximizing sugarcane production and achieving higher economic benefit (Bokhtiar *et al.,* 2002). Pressmud @ 12.5 t ha^{-1} + 75 % NPK increased cane yield by 20 per cent over 100 % NPK alone (Suguna Devakumari, 2005).

In general, all the yield attributes and yield were superior in treated paper mill effluent than saline groundwater irrigation. The treated paper mill effluent also contributed to the available nutrients, which favoured higher cane yield. The above findings are in line with Udayasoorian *et al.* (1999a). Gopalakrishnan *et al.* (1999) concluded that the treated paper mill effluent irrigation gave higher sugarcane yield compared to river water irrigation. Malathi (2001) also observed an increased yield of bhendi and amaranthus under effluent irrigation with amendments. This might be due to the supply of nutrients, organic carbon and low salt stress to sugarcane under treated paper mill effluent than under saline ground water. The poor physical structure, high pH, ESP of soil and high EC of irrigation water might be the reason for low productivity under saline groundwater irrigation.

Conclusion:

From this field experiments it could be concluded that invariably sugarcane varieties performed better with poor quality irrigation water under pressmud application. Among the different saline tolerant varieties COSi(SC)6 showed better performance, followed by CO86032, COC(SC) 23 and COG(SC) 5. The saline tolerant sugarcane variety COSi(SC)6 could be best under pressmud @ 15 t ha^{-1} + 50 % GR + 100 % NPK with *in situ* incorporation of green manure (Daincha - *Sesbania aculeata*) on 45 DAP, and foliar micronutrient spray (1 % $FeSO_4$ + 0.5 % $ZnSO_4$ + 0.5 kg urea) application on 45 and 75 DAP, it increased the yield and farm income.

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