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Soil health management strategies in salt affected soil for sustainable sugarcane productivity

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Abstract
Soil salinity and alkali problems are becoming serious in irrigated area due to indiscriminate use of irrigation water. Accumulation of salts in the soil due to water quality and poor drainage disturbs the physical, biological and chemical properties of soil that reduce the crop productivity. Soil and agronomic management practices in saline and alkali soils like sub-soiling, selection of salt tolerant sugarcane varieties, proper cropping sequence, irrigation water management, nutrient management etc. Field research was conducted at Vasantdada Sugar Institute; Pune revealed that cross sub-soiling practice with one meter distance proved useful for breaking the hard pan beneath the surface of field and leaching of the salts from the soil. Selection of salt tolerant sugarcane varieties like CoM 0265 and sugarcane based cropping sequence with salt tolerant crops like sugar beet, spinach, radish, carrot and dhaincha were found to be beneficial in saline sodic condition. Irrigation water management through drip, application of acid forming chemical fertilizers and soil amelioration with gypsum, iron pyrite and sulphur were also found important agronomical strategies to sustain the sugarcane productivity.

Keywords: Salinity, sugarcane, sub-soiling, amelioration

Introduction
In sugarcane growing areas, the problem of salt accumulation in the soils leading to saline, saline alkali and alkali soil conditions is increasing due to excess use of irrigation water, quality of irrigation water and use of high chemical fertilizer without supplement of organic matter. Soil salinity and alkali problems generally occur in arid or semiarid climates where rainfall is not sufficient to leach out the soluble salts, however, salinity problem is becoming serious in the irrigated areas. Sugarcane is known to be moderately sensitive to salinity (Mass and Hoffman, 1977). Excess of cations such as sodium, calcium and anions like carbonate, bicarbonate and chloride increases soil pH, electrical conductivity (EC) and exchangeable sodium percentage (ESP) that affect the sugarcane yield. In Maharashtra State, about 20 percent sugarcane growing area is facing the salinity or alkali problem that significantly reduces the crop productivity. Salinity disturbs the soil physical condition, destroys beneficial micro flora and fauna and nutrient availability and their uptake. Agronomic management in saline and alkali soils through cultural practices like sub-soiling, selection of the appropriate variety, cropping sequence, irrigation methods, organic manuring and right type of chemical fertilizers, crop rotation and amelioration play a vital role in improving soil fertility and sugarcane productivity.

Sub-Soiling in salt affected soils
Sub-soiling is an effectual pre tillage practice, which breaks the hard pan in sub soil layer and improves the drain ability of soil that leach out the accumulated salts from the surface of soil. Field experiment was conducted to study the effect of sub-soiling and harrowing practices in deep black ill drained soils on yield and quality of plant cane and its successive ratoon crop at Vasantdada Sugar Institute (VSI), Pune. The data presented (Table 1) shows that there was significant increase in cane yield as a result of sub-soiling before plantation of cane. The highest plant cane and sugar yield of 86.66 and 12.58 t ha^{-1} was recorded where cross sub-soiling was done at one meter distance which was significantly superior over rest of the treatments of sub-soiling.

The sub-soiling practice with single 1 meter, 1.5 meter distance and cross sub-soiling with 1.5 meter distance were found on par in comparison with each other. The cane and sugar yield of ratoon crop also increased in all the treatments of sub soiling compared to control. The field experiment conducted at VSI (Anon, 1991) also showed increase in average cane yield with cross subsoiling at 2 meter spacing. The bulk density improved significantly, however the infiltration rate increased by two folds due to sub-soiling at 2 meter spacing. It indicated that cross sub soiling with 1 meter to 2 meter distance needs to be practiced before plantation of sugarcane in saline sodic soils.

Organic Manuring

Organic matter has been used in the reduction of aggregate break down in saline sodic soils. Application of organic matter enhances the microbial activity that transforms the newly added organic matter in to polysaccharides and long chain of aliphatic compounds capable of stabilizing the soil aggregate. Bulky organic manures, green manures, crop residues and other biomass materials can be used for reclaiming saline and sodic soils. Raut *et al.* (1995) [17] studied the comparative performance of vermicompost by using FYM, Gypsum and vermicompost along with agricultural waste, sugarcane trash and sunflower hules for studying the improvement in an alkali soil. The highest earthworm count was recorded in the treatment where vermicompost was applied as 20 t ha^{-1}. The soil pH decreased from 9.0 to 8.3 within 180 days. The sodium content was reduced from 16.1 to 6.3% with various treatments. The use of Vermicompost was effective in the improvement of an alkali soil.

Salt tolerant sugarcane varieties

Sugarcane varieties differ in their ability to tolerate the salt accumulation in soil. Therefore, selection of sugarcane variety is an effective good management tool for cultivation in salt affected soils. In earlier experiments conducted at MPKV Rahuri on soil having soil pH 8.7 and electrical conductivity 4.20 dSm^{-1}, the sugarcane genotype CO 86032 under saline sodic soil recorded the higher cane yield (54.73 t ha^{-1}) which was on par with COM 9516 (52.00 t ha^{-1}). The higher cane yield by CO 86032 and COM 9516 was associated with genetically ability of these two varieties to produce more number of tillers sustainable up to milliable cane (Kadlag *et al*., 2011) [6]. The newly released sugarcane variety CoM 0265 has good ability to tolerate salt accumulation and gave better results in saline sodic soils of Maharashtra. Tolerance in various crops and their genotypes has been associated with their ability to exclude sodium/chloride from shoot (Greenway and Munns, 1980, Qudar, 1988) [5]. Genotype Co VSI 9805 and CoM 0265 were observed to be moisture stress tolerant under alkaline soil condition. (Pawar *et al.*, 2009) [11]. Selective uptake and compartmentalization of ions possessed by the crop varieties is considered to be one of the basis for tolerance to salinity.

Planting techniques in saline sodic soil

A suitable technique of sugarcane planting for better germination and survival in salt affected soils is most important. The set planting technique was significantly superior over (51.35 t ha^{-1}) polybag planting technique because of early vigor of set seedling due to stored material in sugarcane set, which required less energy to establish in saline condition. The polybag seedlings had to adjust with saline sodic soil for establishment and thereafter start growing and tillering (Kadlag *et al.*, 2011) [6].

Another experiment was conducted at CSRS Padegaon in polythene lined micro plots with four sugarcane genotypes viz. CoM 9516, CoG 93079 and Co 86032, Co 85012 with calcareous, saline, sodic and normal soils. In the genotype CoM 9516, the reduction in growth and yield contributing characters under salt affected soils were significantly less than the other genotypes. It may due to salinity by its osmotic adjustment because of accumulation accumulation of proline and potassium under salt stress (Wagh *et al*., 2004) [23].

Sugarcane based cropping sequence

Sugarcane based cropping sequence with various salinity tolerant crops *viz*. sugar beet, spinach, dhaincha, carrot and raddish preceding to sugarcane was studied in sodic soils at VSI, Pune. These crops were sown by opening ridges and furrow in Rabi season and after harvest at appropriate age of respective crop, sugarcane was planted in the same furrow without any pre tillage. The results indicated that there was no significant influence of any preceding crop on sugarcane yield. However, considering the yields and market value of sequence crops, the estimated equivalent cane yield (Table 2), under sugar beet-sugarcane sequence was found significantly higher (108.59 t ha^{-1}) compared to radish-sugarcane sequence (88.40 t ha^{-1}), spinach (87.03 t ha^{-1}), carrot (80.99 t ha^{-1}) sequence crops and control plot (64.73 t ha^{-1}). Spinach, carrot and radish preceeding to sugarcane were found at par with each other with respect to equivalent cane yield. Dhaincha a green manuring crop incorporated in soil before sugarcane planting increased cane yield to the tune of 69.82 t ha^{-1} compared to control. Therefore, it is revealed that sugar beet, spinach, radish and dhaincha crops preceding to sugarcane planting in suru season were beneficial cropping sequences in sodic soils. Shannon and Noble (1990) [22] also reported that sugarcane is highly salt tolerant crop with sugar beet (Beta vulgaris), barly and cotton as sequence crops to tolerate salt accumulation in soils. Therefore, selection of cropping sequence with salt tolerant crops needs to be adopted to improve farm profitability in saline or sodic soils.

Water management in salt affected Soils

Salinity occur over time due to irrigation, as occurs, since water contains some dissolved salts. When the plants use the water, the salts are left behind in the soil and eventually begin to accumulate. The studies conducted at VSI during 2000-2001 revealed that irrigation with water quality having average electrical conductivity of 0.59 dSm^{-1} added 8.48 t ha^{-1} of soluble salts to the soil under sugarcane over the crop period (Yadav and Patil, 2001) [24] Therefore, proper irrigation management plays an important role in avoiding salinity problem in soil. In salt affected soils, drip irrigation system maintains the soil moisture at field capacity level that helps to keep salt in diluted concentration in soil solution. In conventional irrigation system soil moisture cannot be maintained at field capacity level all the time during irrigation interval, which affects the crop growth. As the soil moisture reduces towards the wilting point, the salt concentration increases in soil solution that affects the nutrient uptake due to increased osmotic pressure. Therefore, drip irrigation is more suitable in salt affected soils compared to conventional irrigation (Phonde and More, 2009) [13]. Generally, the soil pH in the range of 6.5 to 7.5 is optimum for the availability of the essential plant nutrients in the soil. The required soil pH adjustments in wetting zone is possible by selecting acid forming and alkali forming fertilizers through drip.

Table 1: Effect of sub-soiling on cane and sugar yield

Treatment	Sugarcane Yield (t ha^{-1})		CCS Yield (t ha^{-1})	
	Plant	Ratoon	Plant	Ratoon
T_1-No Sub-soiling	57.65	46.90	8.12	6.63
T_2- Sub-soiling (1.0 m)	80.41	51.85	11.59	7.52
T_3- Sub-soiling (1.5 m)	75.76	54.21	11.02	7.50
T_4-Cross-Subsoiling(1 m)	86.66	57.57	12.58	8.31
T_5-Cross-Subsoiling (1.5m)	75.97	54.69	11.05	7.31
SE ± CD at 5%	2.03±6.03	0.83±2.69	0.29±0.86	0.22±0.74

Table 2: Cane yield and equivalent cane yield of different sequencing crops

Treatment	Cane Yield (t ha^{-1})	Yield of Sequence crops (t ha^{-1})	Market value of the sequence crops (Rs/ha)	Equivalent to Cane Yield (t ha^{-1})
T_1- Control- Sugarcane	64.73	00	00	64.73
T_2- Sugarbeet –Sugarcane	70.04	51.40	77100	108.59
T_3- Spinach – Sugarcane	66.09	8.75	41875	87.03
T_4- Dhaincha – Sugarcane	69.82	11.62	00	69.82
T_5- Carrot – Sugarcane	63.49	7.00	35000	80.99
T_6- Radish – Sugarcane	61.43	15.30	53945	88.40
SE± CD at 5%	3.4 NS	-	-	3.4±10.51

Table 3: Effect of different levels and sources of potassium on yield and quality of sugarcane

Treatments	Cane Yield (t ha^{-1})			Sugar Yield (t ha^{-1})		
	I Year	II Year	Pooled	I Year	II Year	Pooled
T_1 - Control	101.50	109.28	105.395	11.346	12.357	11.852
T_2- 175 kg K_2O –MOP	107.73	116.33	112.033	12.697	13.711	13.204
T_3 - 175 kg K_2O –SOP	111.02	119.66	115.347	13.273	13.768	13.520
T_4 - 200 kg K_2O –MOP	112.49	121.03	116.762	13.295	13.954	13.625
T_5 - 200 kg K_2O –SOP	116.75	126.55	121.652	14.712	16.245	15.479
T_6 -225 kg K_2O –MOP	117.81	131.00	124.408	14.42	16.280	16.499
T_7 -225 kg K_2O –SOP	125.76	138.07	131.917	16.25	19.993	18.127
SE	4.52	5.22	3.89	0.76	1.11	0.69
CD at 5%	13.95	16.09	12.00	2.35	3.44	2.15

Table 4: Effect of nutrient management and mulching on cane yield and CCS yield

Treatment details	Cane yield (t ha^{-1})		Mean	CCS yield (t ha^{-1})		Mean
	Plantcane	Ratoon		Plantcane	Ratoon	
A. Main Treatment						
M_1 (Conventional fertilizer)	95.98	87.93	91.96	13.74	14.15	13.95
M_2 (Acid forming fertilizer)	99.88	89.98	94.93	14.39	14.19	14.29
SE± CD at 5%	2.48 NS	1.46 NS		0.40 NS	0.24 NS	
B. Sub treatment						
S_1 (Control)	91.61	86.81	89.21	13.36	14.14	13.75
S_2 (Two combine spray)	103.75	87.58	95.67	14.93	14.27	14.6
S_3 (Four alternate spray)	98.42	92.47	95.45	13.86	14.10	13.98
SE± CD at 5%	3.03±6.30	1.79±3.71		0.49±1.01	0.30 NS	
C. Sub-sub treatment						
T_1 (With trash mulching)	98.23	88.51	93.37	14.05	14.25	14.15
T_2 (Without trash mulching)	97.63	89.40	93.52	14.07	14.09	14.08
SE± CD at 5%	2.48 NS	1.46 NS		0.40 NS	0.25 NS	

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SE± CD at 5%	2.48 NS	1.46 NS		0.40 NS	0.25 NS	

Nutrient management in salt affected soil

Management of soil fertility especially for N and K in salt affected soils is essential because these nutrients are required in high amounts for good crop growth and high production (Noaman, 2004) [10]. Elevated levels of salt in soil and high soil pH adversely affect the transformations and availability of several plant nutrients. Realizing the seriousness of problem of salt accumulation and decreasing productivity, the study was undertaken to analyze the effect of levels of potassium viz. 175, 200 and 225 kg K ha^{-1} and sources like MOP (KCl) and SOP (K_2SO_4) on sugarcane variety Co-86032 in saline sodic conditions. The findings showed (Table 3) that increase in the levels of K fertilizers improved sugarcane yield. The highest yield in both 1st as well as 2nd year (125.76 t ha^{-1} and 138.07 t h^{-1} respectively) was recorded in treatment where 225 Kg K ha^{-1} was applied through sulphate of potash fertilizer followed by T5 (117.81 t ha^{-1} and 131.00 t ha^{-1}) i.e. 225 Kg K_2O ha^{-1} applied through Muriate of potash. At each level, sugar yield was also observed to be higher in the treatments where the source of K was sulphate of potash as compared to the treatments where Muriate of potash was applied. RMQ Lana *et al.* (2003) [18] also affirmed that sugarcane yield increased with increasing potassium rate. Similarly Ashraf *et al*., (2008) [3] recommended application of K through SOP and N through Calcium ammonium nitrate for salt affected soils to enhance sugarcane yield.

The field experiment was conducted (2012-14) to study the nutrient management for sugarcane (var. Co86032) under sodic soil condition in suru season at VSI. The results indicated that there was no any significant effect of conventional and acid forming fertilizers on cane yield of plant cane and ratoon crop (Table 4). Two combine sprays of Multimicronutrient (8 : 8: 8% -NPK) and multimicronutrient liquid fertilizer (Fe- 2.5%, Mn- 1.0%, Zn – 3.0%, Cu- 1.0%, Mo- 0.1%, B - 0.5%) i.e. First spray @ 5 lit ha^{-1} each in 500 lit. water at 60 days after planting and second spray @ 7.5 lit ha^{-1} in 750 lit water at 90 days after planting increased cane and sugar yield by 13.25% in sodic soil in plantcane however four alternate sprays of 1.0% Multimacro and multimicro nutrient liquid fertilizer at 60, 75, 90 and 105 days after harvesting of ratoon crop increased cane yield by 6.51% in sodic soil. Cane yield was improved due to trash mulching in sodic soil but difference was not significant.

Amelioration

Zende (1989) [8] studied at VSI that saline calcareous soils pose a different problem in their reclamation than the saline sodic soils at VSI. Five different amendments were used to improve this soil to get higher cane yield. The use of iron pyrites at 4 t ha^{-1} and 5 t ha^{-1} showed beneficial for increasing the cane yield. The increase in cane yield over control plot was 27 t ha^{-1} under iron pyrites and 28 t ha^{-1} under sulphur application. Gypsum at 1 t ha^{-1} also showed increase in cane yield to the tune of 19 t ha^{-1}. Another study was conducted at VSI during 1999-2000 to check effectiveness of gypsum in comparison with other amendments and it was proved that Iron pyrite and pressmud cake were the best amendments for improvement of saline calcareous soil. Pawar *et al* (1987) [12] also assessed the effect of pressmud and pyrite on the availability and uptake of micronutrients by sugarcane grown on a saline calcareous soil at MPKV, Rahuri. It was noticed that the application of pressmud (5 t ha^{-1}) plus pyrites (2 t ha^{-1}) had a beneficial effect on reducing the chlorosis in sugarcane due to increased availability of Fe, Mn, and Zn. The application of gypsum is not effective to reclaim the calcareous soil and hence it is necessary to use soil amendments like sulphur, pressmud and FYM or compost to reclaim alkaline soils of the farm. Pressmud can serve as a good source of organic manure (Bokhtiar *et al*., 2001) [4] an alternate source of crop nutrients and soil ameliorates (Razzaq, 2001) [19].

Conclusion

Soil salinization significantly affected the crop productivity and consequently food security. Therefore, prevention and reclamation of salt affected soils require soil and agronomic management strategies including cross sub-soiling, use of salt tolerant cane varieties, proper sequencing with salts tolerant crops, drip irrigation, adequate organic manuring, nutrient management, mulching, multinutrient liquid fertilizer sprays at tillering and grand growth stage management and amelioration help in improving salt affected soil for sustainable sugarcane productivity.

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