MANAGEMENT OF SALT-AFFECTED SOILS FOR SUGARCANE PRODUCTION

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ABSTRACT
To evaluate the effect of gypsum and manure on the yield and quality of sugarcane and properties of sodic soils, an experiment was conducted on farmer's field at Dosehra area, District Charsadda during Kharif 2004. Ten treatments comprised of control (T_1), gypsum @ 25 % of the soil requirement (T_2), gypsum @ 50 % (T_3), gypsum @ 75 % (T_4), gypsum @ 100 % (T_5), farm yard manure (FYM) @ 20 tons ha^{-1} (T_6), gypsum @ 25 % + FYM 10 tons ha^{-1} (T_7), gypsum @ 50 % + FYM 10 tons ha^{-1} (T_8), gypsum @ 75 % + FYM 10 tons ha^{-1} (T_9) and gypsum @ 100 % + FYM 10 tons ha^{-1} (T_{10}) were replicated three times under RCB design. The results pertaining to the cane height, cane diameter, cane yield, juice yield, sucrose content and total soluble solids (% Brix) showed significant ($P < 0.01$) improvement due to amendments. Manure alone increased cane height by 69 % over control. Gypsum at various rates increased height by 102 % and gypsum + manure boosted it by an average of 131 % over control. Cane diameter was increased by manure to the extent of 25.8 % and by gypsum to 43.8 %. Maximum increase in cane diameter of 52.4 % over control was resulted in T_{10}. Manure gave 43 % increase over control in cane yield and gypsum 9 to 92 %. Manure with different rates of gypsum resulted in increasing cane yield by 90 to 236 % over control. Juice yield got increased by 155 to 183 % due to the combined application of manure and gypsum. Manure alone was effective in increasing juice yield by 69 % over control. Sucrose content was increased by maximum of 11.7 % and brix by 20 % in T_{10}. Soil conditions were also improved by amendments. Maximum reduction of 15 % in soil pH, 47 % in sodium adsorption ratio (SAR) and 100 % in gypsum requirement (GR) was recorded with combined application of gypsum @ 100 % and 10 tons manure ha^{-1}.

INTRODUCTION
The constraints and prospects of sugarcane production as a cash crop in the NWFP are well documented. Demonstration trials conducted at many locations of the NWFP indicate great potential of sugarcane as a highly remunerative crop with scopes for intercropping for increased net return per unit area. Cane development activities are required to be strengthened to meet the growing demand of sugar and "*gur*" in the country. In view of the increasing vulnerability of the region to drought and salinity, massive introduction of sugarcane-based farming in the region deserves attention. The causes responsible for lower production of sugarcane include water logging, use of poor quality ground water, soil salinity and sodicity. Lingle and Wiegand (1997) reported that each dS m^{-1} increase in EC_e decreased Brix (% soluble solids in juice) and Pol (% sucrose in juice) by about 0.6 %, decreased apparent purity (Pol as a percentage of Brix) by 1.3 %, increased juice conductivity by 0.8 dS m^{-1} and increased cane residue (fiber) by 0.5 %. The management and reclamation of salt affected soils and other factors influencing low productivity of sugarcane include the use of gypsum for reclaiming sodic soils which is a proven technology (Henry and Rhebergen, 1994; Ham *et al.*, 1997). There are ample evidences of increase in yield of cereals and oilseed crops due to the application of gypsum and more so with gypsum + organics (Sundara, 1996; Ham *et al.,* 1997; Chaudhary *et al.,* 2004). High salt contents in the root zone limit the production of sugarcane. This experiment has been initiated to manage sodic soil for higher production of sugarcane.

MATERIALS AND METHODS
This experiment was conducted on a site of the farmer's field at Dosehra area, Charsadda, NWFP, Pakistan during Kharif 2004. Ten (10) treatments consisting of control (T_1), gypsum @ 25 % of the soil requirement (T_2), gypsum @ 50 % (T_3), gypsum @ 75 % (T_4), gypsum @ 100 % (T_5), FYM 20 tons ha^{-1} (T_6), gypsum @ 25 % + FYM 10 tons ha^{-1} (T_7), gypsum @ 50 % + FYM 10 tons ha^{-1} (T_8), gypsum @ 75 % + FYM 10 tons ha^{-1} (T_9) and gypsum @ 100 % + FYM 10 tons ha^{-1} (T_{10}) were used in three replications under RCB design. There were a total of 30 plots each of size 67.5 m^2. Gypsum and manure in the required quantities for different treatments were applied and thoroughly mixed with the soil before plantation of cane. Uniform application of recommended rates of N, P_2O_5 and K_2O @ 150, 100, 100 kg ha^{-1} was also made in the field. The soil of the experimental field was sodic having highly alkaline pH (pH 9.2, ECe 3.30 dS m^{-1}, SAR 22.05). The soil was calcareous (5.51 % lime) with medium organic matter content (0.96 %) and was silt loam in texture. The soil had gypsum requirement (GR) of 19 tons ha^{-1}. Composite soil samples of each treatment plot were collected after harvesting of sugarcane for determination of their physico-chemical properties as per the standard methods. Electrical conductivity of the soil saturation extract was determined with the help of conductivity meter according to the method given by Ryan *et al.* (2001). Soil pH of the saturation extract was determined by the method of McLean (1982) using pH meter. Soil organic matter was determined using wet combustion method as

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described by Nelson and Sommer (1982). Lime content in soil samples was determined by acid-neutralization method (Richards, 1954). Gypsum requirement (GR) of the soil samples was determined according to the method given by Richards (1954). Sodium adsorption ratio (SAR) was also determined according to the method of Richards (1954) using the following equation.

$$SAR = Na/[(Ca + Mg)/2]^{0.5}$$

(where all concentrations are expressed in $mmol_c\ L^{-1}$).

Growth and yield data were recorded at maturity of the crop. Cane height of the ten tagged plants in each treatment was determined using common measuring tape. Diameter of cane was measured in the middle portion of each of ten cans in each treatment with the help of Vernier Caliper and average was computed. Fresh weight of sugar cane of the two central rows per treatment was recorded with the help of weight measuring spring balance. The cans harvested from the central two lines in each treatment for recording the yield data were processed in the milling machine for extraction of juice. The juice weight was recorded. Five cane stalks of each treatment were randomly collected, cleaned and crushed in a power crusher to get a full jug of juice. The juice was kept for 15-20 minutes to let settle down the impurities. The juice samples were then processed for quality assessment in the laboratory at Sugar Crops Research Institute, Mardan. Percent sucrose and juice pH were determined according to the procedure given by Chen (1985). Total soluble solids (Brix %) in juice samples were determined using Brix hydrometer according to the method given by Chen (1985). For the determination of sucrose polarization method was employed where juice was purified by adding 2 g lead acetate to 20 ml juice. The polarimeter reading of the purified juice was converted into sucrose through Schmitz's table (Chen, 1985).

RESULTS AND DISCUSSION

Sugarcane Yield

The data of the experiment conducted on sugarcane are presented in Table I. The results showed that the use of amendments increased crop yield on sodic soils. Both cane growth, cane yield and quality were improved when the soil was treated with gypsum and/or manure. Cane height increased by 55 % and diameter by 34 % over control with gypsum application at the rate of 25 % of the soil requirement and increased further with higher rates. Similarly cane height and diameter were increased by 69 % and 30 % respectively with manure application alone. Manure application along with gypsum improved the effect of gypsum regarding cane height and cane diameter.

Maximum cane yield of 70610 kg ha^{-1} was obtained in T_{10} treatment representing 237 % increase over that of control treatment. Gypsum application at various rates increased cane yield by 9.9 to 125 % over control. Farm yard manure application increased yield by 44 % and was better than gypsum application @ 25 % of GR as the later treatment gave a yield increase of 9.9 %. Manure application along with various rates of gypsum gave a yield increase of 15 to 74% than at corresponding rates of gypsum alone. Juice quantity per unit cane weight and sucrose content were also maximal in T_{10}.

Cane juice yield was also increased with the application of gypsum. Juice yield was increased further when manure was added with gypsum and maximum juice yield of 28446 kg ha^{-1} was obtained with combined application of 100 % gypsum and 10 tons manure per hectare representing 180 % increase over control. The data suggested that both the amendments were effective in improving sugarcane yield on sodic soils which may be attributed to their nutritive effect on plant growth as well as ameliorative effect on the soil properties. Similar results of yield increase with the application of manure and gypsum were also reported by Sundara (1996), Ham *et al.* (1997) and Chaudhary *et al.* (2004).

Juice Quality

The data given in Table II showed that the effect of gypsum treatments on the juice pH was not consistent. Gypsum application did not affect juice pH whereas manure alone significantly decreased pH to the extent of about 23 % compared with control. Unlike pH, amendments have affected sucrose concentration and total soluble solids of juice. Sucrose concentration increased by 2, 3 and 6 % over that of control with 25, 50 and 75 % gypsum application and declined with further increase. Total soluble solids (TSS) of juice were increased by 6 to 11 % as an effect of gypsum application at various rates. Manure alone increased TSS of juice by an extent of 15 %. Maximum increase of 20 % was found in T_{10} where gypsum @ 100 % and manure @ 10 tons ha^{-1} were applied to the soil in combination. The results emphasize the need of joint application of manure and gypsum in sodic soils for improving juice quality of sugarcane when raised on salt affected soils. These results are supported by the findings of Govindasmy and Chandrasekaran (1992) who obtained improved sugar yield with the application of humic acid. Kumar *et al.* (1999) reported more sugar yield with the application of gypsum. Lingle and Wiegand (1997) reported decreased % brix of sugarcane with increasing soil

EC. Chaudhary *et al.* (2004) obtained good quality sugarcane juice with the application of gypsum/FYM.

Soil Properties

Values of soil pH ranged from 8.06 to 9.08 representing medium to high alkalinity with a mean values of 8.80 (Table III). All the treatments decreased soil pH, may be because of reduction in sodium content of soils with amendments (Fig 1). The depressing effect of gypsum may be attributed to the release of Ca in soil solution to flush out Na. FYM improves the efficiency of gypsum and releases organic acids and CO_2, both help reduce soil pH. Similar findings were also reported by Mehta (1986).

Electrical conductivity of all the soil samples varied from 2.40 to 4.75 dS m^{-1} with a mean value of 3.94 dS m^{-1} and was increased by gypsum but decreased by manure. Since gypsum is a salt, therefore it has contributed to the salt content of soils. Favourable effect of the manure on decreasing EC may be attributed to the improvement in porosity which might have resulted enhanced salts leaching. These results are also supported by the findings of Ghafoor *et al.* (1986) and Sharma *et al.* (1981).

SAR of the all the samples ranged from 10.08 to 18.13 with mean value of 13.74. The data indicated that amendments have significantly decreased SAR. Lower SAR value recorded was in T_{10}. The reduction in SAR may be the result of increased Ca^{+2} + Mg^{2+} and decreased Na^{+} with the application of amendments. So, SAR has been reduced to a considerable level through the application of amendments (Fig 2). Similar findings were also reported by Ghafoor and Muhammad (1981). Muhammad and Khaliq (1975) and Shad and Hashmi (1970) showed that gypsum + manure was more effective in reclaiming calcareous saline sodic soils than gypsum or manure alone.

Gypsum requirement of the soil samples ranged from nil to 18.45 with mean value of 8.54 tons ha^{-1} (Table III). Data showed that amendments had reduced gypsum requirement (GR) significantly. Application of gypsum @ 75 % and 100 % along with manure @ 10 tons ha^{-1} eliminated the need of soil for gypsum. Beneficial effects of gypsum on soil improvement were also reported by Verma and Abrol (1980).

Economic Analysis

Looking at the data in Table IV, it is evident that the highest net return of Rs. 60991/- with a VCR of 5.55 was calculated for the treatment receiving full recommended dose of gypsum and FYM (T_{10}). The next best treatment was found to be gypsum @ 25 % of soil requirement in combination with 10 tons manure ha^{-1} (T_7) which gave the highest VCR of 5.86 but a net return of only Rs. 23566/- ha^{-1}. Although T_7 has higher V.C.R of 5.86, yet T_{10} was regarded the best because of higher net return coupled with greater improvement in soil health accrued by the treatment.

CONCLUSION

Profitable yields of good quality sugarcane are possible by treating sodic medium textured soils with gypsum and manure. Gypsum @ 100 % of the soil requirement in combination with FYM @ 10 tons ha^{-1} turned out to be the best treatment producing significant improvement in the growth, yield and quality of sugarcane. Sodic soils are improved for the growth of sugarcane when amended with gypsum and manure through reducing significantly soil pH, SAR and GR.

Table I ***Effect of amendments on the yield and quality of sugarcane***

Treatments	Cane height (cm)	Cane diameter (mm)	Cane yield (kg ha^{-1})	Cane juice (kg ha^{-1})
Control	53.00 d	14.30 c	21016 g	10161 d
Gypsum 25%	82.66 cd	19.20 ab	22990 fg	14778 cd
Gypsum 50%	114.00 abc	20.86 ab	30960 ef	16395 c
Gypsum 75%	112.00 abc	22.20 a	35050 de	16420 c
Gypsum 100%	113.66 abc	22.26 a	40400 cd	16729 b
FYM @ 20 tons ha^{-1}	89.66 cd	18.53 b	30100 ef	17132 c
25% Gyp+10 t FYM ha^{-1}	110.00 abc	21.53 ab	39960 cd	25177 ab
50% Gyp+10 t FYM ha^{-1}	123.50 ab	21.53 ab	45980 bc	25177 ab
75% Gyp+10 t FYM ha^{-1}	123.00 ab	22.26 a	52540 b	26819 ab
100% Gyp+10 t FYM ha^{-1}	133.00 a	22.40 a	70610 a	28446 a

Means followed by similar letters are non-significant at $P < 0.05$

Table II ***Effect of amendments on the quality of sugarcane juice***

Treatments	Juice pH	Non-reducing sugar (% sucrose)	Total soluble solids (% brix)
Control	3.06 a	4.03 b	11.60 d
Gypsum 25%	3.12 a	4.10 b	12.37 cd
Gypsum 50%	3.06 a	4.13 b	12.77 bc
Gypsum 75%	3.07 a	4.26 ab	12.90 bc
Gypsum 100%	3.05 a	4.13 b	12.33 cd
FYM @ 20 tons ha^{-1}	2.37 b	4.20 b	13.40 ab
25% Gyp+10 t FYM ha^{-1}	3.03 a	4.13 b	13.57 ab
50% Gyp+10 t FYM ha^{-1}	3.09 a	4.23 b	13.73 a
75% Gyp+10 t FYM ha^{-1}	3.07 a	4.26 ab	13.73 a
100% Gyp+10 t FYM ha^{-1}	3.05 a	4.50 a	13.93 a
$LSD_{0.05}$	0.4071	0.2465	0.8309

Means followed by similar letters are non-significant at $P < 0.05$

Table III ***Effect of gypsum and farmyard manure application on soil properties***

Treatment	pH	EC ($dS\ m^{-1}$)	SAR	Gyp. Req. (tons ha^{-1})
Control	9.09 a	2.64 c	18.13 a	18.45 a
$Gyp_{25\%}$	8.69 ab	3.04 abc	14.54 ab	16.42 ab
$Gyp_{50\%}$	8.53 abc	4.56 ab	13.36 ab	10.40 b
$Gyp_{75\%}$	8.50 bc	4.75 a	12.52 ab	5.33 c
$Gyp_{100\%}$	8.47 bc	4.75 a	11.01 b	1.00 d
FYM (20 t/ha)	8.72 ab	2.40 c	14.29 ab	16.52 ab
$Gyp_{25\%}$ + $FYM_{10\ t}$	8.72 ab	2.98 bc	13.24 ab	9.63 b
$Gyp_{50\%}$ + $FYM_{10\ t}$	8.61 abc	3.20 abc	12.72 ab	7.66 bc
$Gyp_{75\%}$ + $FYM_{10\ t}$	8.39 bc	3.34 abc	10.94 b	0.00 d
$yp_{100\%}$ + $FYM_{10\ t}$	8.06 c	4.12 ab	10.08 b	0.00 d
$LSD_{0.05}$	0.504	0.407	5.77	0.379

Means followed by similar letters are non-significant at $P < 0.05$

Table IV ***Economic analysis of treatment effects on yield of sugarcane crop***

Treatments	Yield (kg ha^{-1})	Yield increase over control (kg ha^{-1})	Input Cost (Rs. ha^{-1})	Value of increased yield (Rs. ha^{-1})	Net Return (Rs. ha^{-1})	VCR
Control	21016	--	--	--	--	--
G_{25}	22990	1974	2850	2961	111	1.04
G_{50}	30960	9944	5900	14916	9016	2.53
G_{75}	35050	14034	8750	21051	12301	2.41
G_{100}	40400	19384	11400	29076	17676	2.55
M_{20}	30100	9084	4000	13626	9626	3.41
$G_{25} + M_{10}$	39960	18944	4850	28416	23566	5.86
$G_{50} + M_{10}$	45980	24964	7900	37446	29546	4.74
$G_{75} + M_{10}$	52540	31524	10750	47286	36536	4.40
$G_{100} + M_{10}$	70610	49594	13400	74391	60991	5.55

Cost of inputs:
FYM = Rs.200/- per ton
Gypsum = Rs. 600/- per ton

Value of produce:
Suagrcane = Rs. 60/- per 40 kg

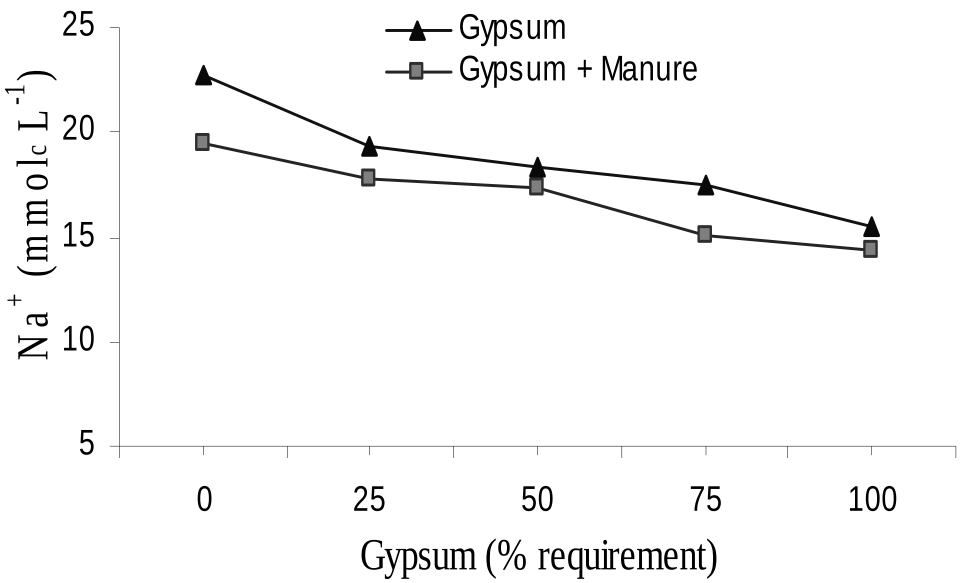

Fig 1. Effect of treatments on Na^+ concentration of soil solution

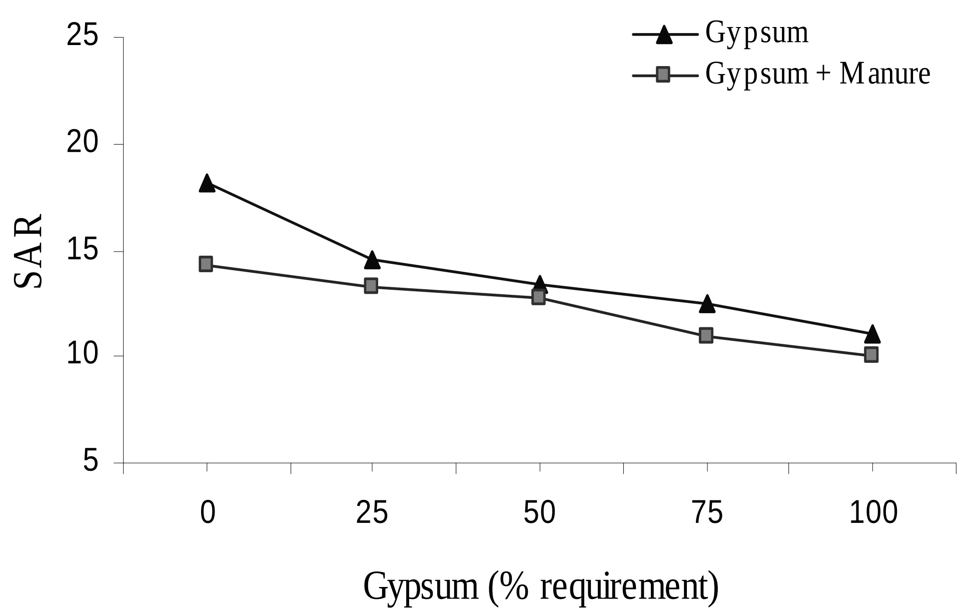

Fig. 2. Effect of treatments on the Sodium Adsorption Ratio (SAR)of soil

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