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Management of High Bicarbonate Irrigation Waters for Growing Crops

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ABSTRACT

A greenhouse experiment was conducted to study the effect of six synthetic waters having two TDS levels (10 and 20 me L^{-1}) and three RSC levels (0.0, 2.5 and 5.0 me L^{-1}) on maize crop using gypsum @ 0, 50 and 100% of GR. Gypsum was also compared with sulphur, pressmud and farmyard manure in a sandy loam soil using cropping sequence of wheat-maize-wheat. Dry matter yield of maize and grain yield of both wheat crops decreased significantly by increasing TDS and RSC of synthetic waters. With the exception of soil pH, ECe and precipitation of $CaCO_3$ in soil increased by using synthetic saline sodic waters. The response of gypsum on first maize crop was little. Amendments like gypsum, sulphur, pressmud and farmyard manure exhibited positive effect on maize and wheat yield. FYM @ 20 t $acre^{-1}$ and water application of G-50% and G-100% both in maize and wheat and S-100% only in wheat produced significantly higher grain and straw yield. The sodic waters thus can be used safely by using gypsum and other amendments.

Key Words: Gypsum; Sulphur; FYM; Pressmud; Wheat; Maize

INTRODUCTION

Pakistan has abundant land resources but the supply of surface irrigation water is much less for adequately exploiting the soil potentials. To cope with the needs of crops, efforts are being made to augment the supply of irrigation water through installation of tubewells in various regions of Pakistan. Unfortunately, a large part of pumped-up water is brackish and unfit for irrigation (Ahmad, 1993). The unjudicious use of sodic water has spoiled the good land and crop yields suffered seriously (Hassan *et al*., 1996). Precipitation of CO_3 and HCO_3 in soil as $CaCO_3$ has further aggravated the situation (Rhoades & Loveday, 1990).

Several researchers (Yasin *et al*., 1998; Hussain *et al*., 2000) have recommended the use of gypsum and acids (HCl, H_2SO_4, etc.) to counteract the ill effects of high bicarbonate waters. Earlier studies (Hanif *et al*., 1975) have reported the useful effect of gypsum in amending waters. The present study was, therefore, conducted to evaluate the adverse effect of bicarbonate waters on soil properties and assess ameliorative role of amendments for using such waters.

MATERIALS AND METHODS

The study was conducted in the greenhouse on non-saline loam soil (pH 7.65, EC_e 2.05 dS m^{-1}, SAR 0.98) collected from the field. After processing, 12 kg soil was placed in each pot. Following two experiments were conducted:

Experiment No. 1. Three crops, i.e. wheat, maize and wheat were grown in the same sequence in the pots. The experiment was laid out in CRD with factorial arrangement having three repeats. Basal dose of 75 kg N as urea for each crop and 50 and 40 kg P_2O_5 as triple super phosphate per one million kg of soil was applied to maize and wheat, respectively. Phosphorus was applied at sowing; whereas, N was applied half at sowing and half at first irrigation. Six synthetic waters having two TDS levels (10 and 20 me L^{-1}) and three RSC levels (0.0, 2.5, 5.0 me L^{-1}) were prepared from stock solutions just before each irrigation (Table I).

Table I. Chemical composition of irrigation waters

Waters	TDS me L^{-1}	RSC me L^{-1}	Eff. Salinity me L^{-1}	SAR	SAR_{adj}
W1	10.0	0.0	5.2	5.73	5.96
W2	10.0	2.5	3.5	5.73	7.54
W3	10.0	5.0	2.2	5.73	9.50
W4	20.0	0.0	10.5	8.10	12.60
W5	20.0	2.5	8.8	8.10	13.80
W6	20.0	5.0	6.5	8.10	14.70
Canal	2.8			0.33	

Various amendments used consisted of two levels of gypsum i.e. 50 and 100% of gypsum requirement (GR) applied both through water (G-50%-W, G-100%-W) and soil (G-50%-S, G-100%-S); two levels of sulphur (S-50% and S-100% equivalent to 50 and 100% of GR); two levels of FYM (10 and 20 t $acre^{-1}$) and one level of pressmud which was 50% of GR (PM-50%-S) and a control (no amendment). Gypsum requirement was calculated according to Eaton (1954) while sulphur and pressmud were applied on equivalent basis. Sulphur was applied one month before sowing crop, while FYM, pressmud and gypsum were applied in soil three days before sowing. Amendments G-50%-W and G-100%-W were mixed in synthetic waters just before each irrigation. Crops were irrigated with synthetic waters. Total of 20 and 16 liters per pot of synthetic water was used both for maize and wheat respectively. Crops grown in the sequence were harvested at maturity. Oven-dry weight was recorded and data were analyzed using CRD with factorial arrangement.

Experiment No. 2. The soil used in this experiment was the same as described in the first experiment. Twelve kg soil was placed in each pot. Basal dose of 75 kg N as urea and 50 kg P_2O_5 as TSP per million kg of soil was applied in each pot. The synthetic waters used here were same as shown in Table I and were prepared just before each irrigation. Three levels of gypsum, viz., control (no gypsum), 50% and G-100% of the requirement were applied through water. Gypsum requirement was calculated according to Eaton (1954). Before sowing maize, pots were saturated with synthetic saline waters. After few days, when field capacity moisture was attained, upper 4-5 inches soil was pulverized for seed bed preparation. Twelve seeds of maize sown in each pot were thinned to seven after germination. Subsequently, seven irrigations of one liter each were given with synthetic saline-sodic waters. Crop was harvested at the end and oven-dry weight of maize fodder was recorded. Soil samples were taken from each pot for pH, EC_e and $CaCO_3$ determinations. The data collected were subjected to statistical analysis (Steel & Torrie, 1980).

RESULTS AND DISCUSSION

Wheat yield (first crop). Grain yield of wheat is presented in Table II.

Table II. Grain yield of first wheat (g pot^{-1}) as affected by saline-sodic waters and amendments used

Amendments	W1	W2	W3	W4	W5	W6	Mean
G-50% (w)	12.4	11.8	10.9	12.1	11.0	9.68	11.3bc
G-100% (w)	12.0	11.8	1.7	11.9	11.3	11.3	11.5bc
G-50% (s)	12.5	12.5	10.0	12.2	11.7	10.0	11.5bc
G-100% (s)	11.8	12.2	10.7	11.4	10.8	10.4	11.1c
S-50% (s)	11.8	10.5	10.0	11.6	10.4	9.64	10.7c
S-100% (s)	13.2	13.0	12.1	12.7	12.3	12.1	12.6a
PM-50% (s)	12.8	12.2	7.6	12.3	11.1	7.1	10.9c
FYM 10-t/a	12.4	11.3	10.7	11.5	11.0	10.8	11.3bc
FYM 20 t/a	13.6	12.7	12.3	12.6	11.4	10.7	12.2ab
Control	10.8	10.6	8.1	10.6	8.00	7.3	9.40d
Mean	12.4a	11.8b	10.4cd	12.0b	10.9c	10.0d	

Mean followed by the same letter(s) are statistically non-significant.

The data revealed a decreasing yield trend with saline-sodic water irrigation. Waters with smaller TDS values (W1, W2 and W3) produced significantly more grain yield than with waters having greater TDS values (W4, W5 and W6). Similarly, waters with small RSC values (0 and 2.5 me L^{-1}) produced significantly more grain yield than higher RSC (5.0 me L^{-1}) values. Adverse effect of RSC under larger than smaller TDS values was more prominent. It is evident from the results that presence of HCO_3 ions in water through precipitation of Ca as $CaCO_3$ caused poor plant growth and yield (Rhoades & Loveday, 1990). Hussain *et al*. (2000) also noted significant yield losses in subsequent wheat and rice crops with high bicarbonate irrigation waters.

Application of amendments significantly improved grain yield of wheat. Significantly higher grain yield (12.6 g pot^{-1}) was obtained with sulphur (100% of GR) followed by FYM @ 20 t acre^{-1}. All four gypsum treatments produced lesser yield than sulphur and FYM treatments but were statistically at par with each other. Haider and Farooqi (1972) mentioned that tubewell waters possessing SAR values ranging from 10-14 can be used successfully, provided gypsum is applied to soil. Pressmud and sulphur (50% of GR) produced smaller grain yields and were relatively inferior. In earlier studies, pressmud had also been found less efficient than other amendments (Muhammed & Khaliq, 1975). FYM @ 20 t acre^{-1} produced good yield and was statistically at par with sulphur (100%). Like sulphur and gypsum, it can be used for amelioration of brackish water successfully. Sowami and Sexena (1975) also noted similar results of FYM.

Maize yield. Effect of saline-sodic waters on maize crop sown after wheat is presented in Table III. Increasing levels of TDS and adjusted SAR, decreased average yield of maize significantly. Synthetic water W_1 having TDS = 10 me L^{-1} and effective salinity (Eaton, 1954) of 5.2 me L^{-1} gave significantly higher stover yield (36.7 g pot^{-1}) than W2 and W3. Out of saline waters having TDS of 20 me L^{-1} (W4 to W6), W4 proved significantly better than W5 and W6. It is clearly evident that waters with higher TDS and SAR_{adj} depressed maize yield significantly as compared with waters having lower TDS and adjusted SAR values. Similar response of sodic water on wheat was obtained by Hassan *et al*. (1996).

Table III. Dry matter yield of maize (g pot^{-1}) as affected saline-sodic waters and amendments used

Amendments	W1	W2	W3	W4	W5	W6	Mean
G-50% (w)	45.7	35.3	35.7	35.8	33.7	27.4	35.6ab
G-100% (w)	41.7	33.3	35.8	46.0	33.4	21.3	35.3ab
G-50% (s)	31.9	32.7	30.7	30.0	28.1	26.0	29.9cd
G-100% (s)	36.6	35.9	32.4	34.3	33.0	28.4	33.4bc
S-50% (s)	34.4	33.2	30.6	41.2	32.2	25.9	32.9bc
S-100% (s)	37.3	30.0	28.7	34.5	30.8	22.8	30.0cd
PM-50% (s)	37.7	31.8	29.9	30.5	28.3	26.9	30.9cd
FYM 10 t/a	33.1	31.7	31.1	32.1	26.1	26.0	29.9cd
FYM 20 t/a	38.3	37.7	36.9	36.9	36.8	34.7	38.6a
Control	30.7	29.0	26.4	26.8	26.1	25.5	27.4d
Mean	36.7a	33.1c	31.8cd	34.8b	30.9d	26.5e	

Mean followed by the same letter(s) are statistically non-significant at 0.05 probability.

While comparing means for various amendments, FYM (20 t acre^{-1}) produced (38.6 g pot^{-1}) significantly more maize yield than all amendments except G-50%-W and G-100%-W, where it was statistically at par with them. Gypsum (G-50% and G-100%) applied through water produced more maize yield and was superior than gypsum applied through soil. Yield produced in both gypsum treatments applied through soil (G-50%-S and G-100%-S) and sulphur (50% and 100% of GR) were statistically at par with each other. Yield produced in control (no amendments) was minimum but was statistically similar to PM-50% and FYM 10 t acre^{-1}.

Wheat yield (2nd crop). Waters significantly affected the grain yield of 2nd wheat crop (Table IV). Waters having low TDS (10 me L^{-1}) produced significantly more yield than waters having more TDS (20 me L^{-1}). Maximum average grain yield was produced in W_1 (TDS = 10 me L^{-1} and SAR_{adj} = 5.96) and it decreased with increasing level of TDS and adjusted SAR. Higher effective salinity and adjusted SAR values in high TDS waters (W_4-W_6) probably reduced plant growth and yield significantly. Hassan *et al.* (1996) and Hanif *et al.* (1975) found similar results. Comparing the means for amendments, it can be seen that on overall average basis, maximum yield of 10.3 g pot^{-1} was obtained in FYM @ 20 t $acre^{-1}$ followed by gypsum (G-100%-S) and sulphur applied @ of 100% of GR.

Table IV. Grain yield of second wheat (g pot^{-1}) as affected by saline-sodic waters and amendments used

Amendments	W1	W2	W3	W4	W5	W6	Mean
G-50% (w)	8.2	8.0	7.8	6.1	5.9	5.9	7.0e
G-100% (w)	10.4	10.7	10.6	9.2	9.3	9.1	9.9ab
G-50% (s)	8.0	8.2	7.9	7.6	5.8	4.7	6.7e
G-100% (s)	9.6	9.5	9.6	7.6	6.9	7.4	8.4c
S-50% (s)	8.4	8.6	8.5	7.3	7.2	6.9	7.8d
S-100% (s)	11.8	11.5	11.4	9.4	7.9	7.7	9.9ab
PM-50% (s)	7.8	7.5	7.0	5.7	5.5	3.7	6.2f
FYM 10 t/a	10.8	10.7	10.3	6.6	6.5	6.1	8.5c
FYM 20 t/a	12.3	12.0	11.7	8.7	8.6	8.3	10.3a
Control	7.3	7.0	6.6	5.6	5.3	3.1	5.8f
Mean	9.5a	9.4a	9.1b	8.2c	6.9d	6.3e	

Mean followed by the same letter(s) are statistically non-significant at 0.05 probability.

Among four gypsum treatments, minimum grain yield was recorded in gypsum 50% soil application and maximum yield (9.9 g/pot) was obtained with G-100% applied through water. This indicated that gypsum (100% GR) applied through water was better and did combat the hazardous effect of irrigation water more effectively. The difference in yield for gypsum (50% of GR) applied both through water and soil was however, non-significant. The improvement in yield due to pressmud application was non-significant over control. Results also indicate that yield response to lower doses of amendments was poor than higher doses. Perhaps, presence of more Ca is necessary for proper amelioration of bicarbonate waters (Rhoades & Loveday, 1990).

Maize yield (2nd experiment). In another experiment, effect of saline-sodic water on maize dry matter is given in Table V. Crop yield was significantly reduced with waters having higher TDS (20 me L^{-1})

Table V. Dry matter yield of maize (g pot^{-1}) as affected by saline-sodic water and gypsum application

Gypsum levels	W1	W2	W3	W4	W5	W6	Mean
No gypsum	12.3	12.0	11.9	11.5	10.2	8.5	11.1^{NS}
G-50%	10.8	10.5	10.7	11.4	10.3	9.2	10.5
G-100%	12.6	11.5	11.1	11.0	9.8	8.5	10.7
Mean	11.9a	11.3a	11.2a	11.3a	10.1b	8.7c	

Mean followed by the same letter(s) are statistically non-significant

values. Effect of increasing RSC on maize yield was significant under higher TDS waters but same was not true in water having low TDS. Minimum yield (8.7 g pot^{-1}) was obtained in W6. It might be due to precipitation of Ca + Mg as their CO_3 with corresponding increase in sodium hazard (Hanif *et al*., 1975). Relative effect of irrigation water salinity (EC_{iw}) and average root zone salinity on maize yield were also examined (Table VI). Correlation of maize yield was negative and highly significant with average root zone salinity. Similarly, correlation of maize yield with irrigation water salinity (EC_{iw}) and effective salinity (Doneen, 1954) was significant but correlation was low.

On the average, effect of gypsum used for amelioration of saline-sodic waters was non-significant in maize. Lack of response towards yield increase is likely ascribed to fewer irrigation applied to maize crop and increase in effective salinity due to gypsum application. In contradiction to it, use of Ca source or gypsum has in earlier studies reduced the hazardous effect of saline water (Ghafoor & Salam, 1993).

pH of soil. After harvesting maize crop, pH of soil samples was determined. Synthetic water had no significant effect on soil pH (Table VII). Perhaps, low delta of water for maize crop and buffering capacity of soil did not permit a significant change in soil reaction. Qureshi *et al.* (1977) also found non-significant change in soil pH due to brackish water irrigation. However, an increasing trend of soil pH with corresponding increase in RSC values was found. Marked changes in soil pH may occur with application of such water for prolonged time (Hanif *et al*., 1975).

Electrical conductivity of soil. As far as electrical conductivity of soil is concerned (Table VIII), it significantly increased both by the application of saline-sodic water and with gypsum application. Deterioration of soil in term of salt accumulation was more in high TDS waters. Similarly, damaging effect of gypsum amended

Table VI. Correlation and regression analyses relating maize yield to various indices of salinity

Index of salinity	Correlation	Regression equation
	Irrigation water salinity parameters	
EC_{iw} (dS m^{-1})	- 0.62*	y = 12.93 – 0.144x
Effective salinity, me L^{-1} (Eaton, 1954)	- 0.23 ^{NS}	
Effective salinity, me L^{-1} (Doneen, 1954)	- 0.57*	y = 11.6 – 0.33x
	Average root zone salinity parameters	
Average EC_e of soil	- 0.82	y = 16.22 – 1.61x

water with respect to soil ECe was more in these waters. Results are in agreement to earlier studies (Qureshi *et al*., 1977). Since there was no provision for leaching, more accumulation of salts occurred with repeated irrigations and gypsum application. Maximum increase in ECe was found in G-100%.

Table VII. Soil pH as affected by saline-sodic waters and gypsum application

Gypsum level	W1	W2	W3	W4	W5	W6	Mean
No gypsum	7.75	7.83	7.88	7.83	7.62	7.98	7.85^{NS}
G-50%	7.87	7.88	7.90	7.85	7.83	7.93	7.87
G -100%	7.85	7.83	7.78	7.80	7.80	7.83	7.82
$Mean^{NS}$	7.82	7.85	7.82	7.85	7.50	7.91	

Table VIII. Electrical conductivity (dS m^{-1}) of soil as affected by saline-sodic waters and gypsum application

Gypsum level	W1	W2	W3	W4	W5	W6	Mean
No gypsum	2.22	2.55	3.22	3.62	4.23	4.23	3.24c
G-50%	2.93	3.14	3.15	3.57	3.75	3.68	3.36b
G-100%	2.53	2.98	3.40	3.67	3.95	4.33	3.48c
Mean	2.56e	2.89d	3.26c	3.61b	3.94a	4.08a	

Mean followed by the same letter(s) are statistically non-significant

$CaCO_3$ in soil. Precipitation of $CaCO_3$ from synthetic saline water increased with repeated irrigation (Table IX). Significantly more precipitation happened to occur at higher RSC level, it being maximum at RSC value of five and minimum being at RSC of zero. It is quite evident that waters containing higher bicarbonate ions caused greater accumulation of $CaCO_3$ in soil. Bower *et al.* (1968) explained that precipitation of applied HCO_3 from irrigation water depends on pHc of water and LF. Gypsum used in water and total dissolved salts had no significant effect on precipitation of HCO_3 in the soil.

Table IX. Calcium carbonate (%) formation in soil as affected by saline-sodic waters and gypsum application

Gypsum level	W1	W2	W3	W4	W5	W6	Mean
No gyps.	1.35	1.55	1.91	1.41	1.57	1.66	1.57^{NS}
G-50%	1.30	1.22	1.73	1.52	1.39	1.60	1.46
G-100%	1.19	1.50	1.66	1.30	1.79	1.87	1.57
Mean	1.31b	1.42b	1.77a	1.40b	1.58ab	1.71a	

Mean followed by the same letter(s) are statistically non-significant

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