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CONCENTRATION OF Ca$^{2}_{+}$ IN IRRIGATION WATER FOR RECLAIMING SALINE-SODIC SOILS

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~~Saline-sodic/sodic~~ soils need soluble Ca"+for replacing adsorbed Na' during their reclamation. Low cation exchange capacity (CEC) of soils could be a rate limiting factor for Na'-Ca"+exchange in saline-sodic soils of Pakistan. Hence an increase in soluble Ca"+might not result in a proportionate increase in the Na+-Ca"+exchange and soil amelioration. Calcium chloride was added to canal water to obtain 6, 12 and 18 mel,", and to brackish water (EC=2 dS m', SAR=10) to obtain 6 and 18 mel," concentration ofCa"+.The volume ofthe applied solutions was equal to 3 times ofthe saturation percentage of 10 kg of strongly saline-sodic soil filled in glazed pots (EC=27 dS m', SAR=141.2), after infiltration of which leachates were collected and analyzed. The SAR and Na' concentration of leachate decreased to about 50 % of those in the original soil with all the Ca" levels applied. The me of Na' leached per me Ca"+added were 28.7,13.5,8.9,29.8 and 7.9 for the Ca"' concentration as me L of 6, 12 and 18 in canal water and 6 and 18 in brackish water, respectively. A similar decrease in sodium adsorption ratio (SAR) of the post-experiment soil and leachates by all the treatments indicated lower Ca"+in irrigation water to be better for soil amelioration than its higher concentration.

Key words: Ca"'in irrigation water, saline-sodic soils

INTRODUCTION

Salt balance should be the most ideal if salt input remains equal to salt output in soil-water-plant system for sustainable agriculture. But in arid and semiarid climate, like that of Pakistan, it is seldom achieved. Under the agroclimatic conditions of Pakistan, salt input into soils remained higher than output because of which a continuous process of salination/sodication persisted since the beginning of irrigated agriculture and is expected to continue unless the soil/water/crop management is done on scientific lines. Moreover, 46 MAF of groundwater is pumped (Anonymous, 1998) and applied to grow crops, of which 70-75% is unsuitable for irrigation without some amendmentltreatment (Ahmad, 1993). As a consequence, salt-affected soils increased to 6.30 mha in 1993 (Khan, 1993) which were 5.73 mha in 1983 (Mohammed, 1983).

Saline-sodic soils, irrespective of their calcareousness, need Ca"+for Na+-Ca"'exchange for their reclamation. Low cation exchange capacity (CEC) of soils of Pakistan is one of the rate limiting factors for optimum Na+-Ca"+exchange (Ghafoor and Salam, 1993) since a major part of our soils contains illite type clay minerals (Anonymous, 1986; Ranjha et al., 1993) which result in soil CEC of about 6-10 cmol.kg'. It is, therefore, easy to understand that an increase in soluble Ca"+ in soil solution, which is generally achieved through the application of finely powdered gypsum, incurring higher costs, might not result in a proportionate increase in Na+-Ca"+exchange rate and soil amelioration. Hence the present studies were planned to determine optimum Ca^{2}+ concentration in canal or brackish water for cost-effective improvement of saline-sodic soils.

MATERIALS AND METHODS

A bulk sample of loamy clay saline-sodic soil (EC=27 dS m', SAR=141.2, clay = 31.6 %, CEC = 5.0 me 100g', GR = 1.9 me 100g', lime = 15.7 IkJ) was collected from 0-15 cm layer and was ground to pass through 2 mm sieve. Then 10 kg soil was filled in glazed pots. For irrigation, synthetic brackish water (BW) of zero residual sodium carbonate, RSC (EC=2 dS m', SAR=10) was prepared by dissolving sodium chloride, sodium sulphate, calcium chloride and magnesium chloride salts. To this synthetic water, Ca'Cl, was added to obtain Ca"+concentration of 6 or 18 me L^{1} and in canal water (CW) 6,12 or 18 me L^{1}. The simple canal water (Ca"+= 1.4 me L') served as the control treatment. These solutions were added equal to 3 times of saturation percentage (SP) of 10 kg soil filled in pots. After infiltration of which leachates were collected and analyzed for EC, SAR and soluble ions (CO,", HCO", Cl, Na" K+, Ca"+, Mg"+). Upon termination of the experiment, soil samples were collected and analyzed for p'H,, EC", SAR and soluble ions (CO/, HCO", Cl, Na+, K', Ca"+, Mg"+). The analytical methods followed were those of Page et al. (1982). The data collected were statistically analysed following the ANOVA technique of Steel and Torrie (1984).

Table 1: Volume (mf,J) ofleachate collected from a saline-sodic soil

Ca^{2}> in Irrig. water	Leachate I	Leachate II	Leachate III	Total
CW, 1.4 me L'	750	780	210	1740
CW, 6me L"	690	840	290	1820
CW, 12 me L'	630	665	330	1625
CW, 18me L'	610	660	473	1743
BW,6meL'	670	825	5'13	2098
BW,18meL'	710	750	665	2125
SE	0.46^{NS}	0.22^{NS}	0.88^{NS}	-

Table 2. Sodium (me leachate .I) removed from saline-sodic soil

Ca^{2}> in Irrig. water	Leachate I	Leachate II	Leachate HI	Total
CW, 1.4 me L'	267.9	243.3	33.8	545.0
CW, 6 me L't	260.0	255.3	50.0	565.2
CW, 12 me L't	263.8	212.0	53.4	529.2
CW, 18 me i,'	206.4	157.6	75.6	439.6
BW, 6 me L"	268.2	227.0	90.2	585.4
BW, 18me i,'	264.9	226.6	94.2	586.4
SE	51^{NS}	70^{NS}	21^{NS}	-

RESULTS AND DISCUSSION

Leachate

Volume: The volume of all the three leachates remained statistically similar (Table 1) perhaps due to very high soil EC (27 dS m'). It is a general consensus that higher the solute concentration (EC), better will be the infiltration of water through soils (Reeve and Bower, 1960) and thus the high soil EC masked the treatment effects on soil leachability. A gradual decrease in volume of leachate I through III points the favourable contribution of solutes for infiltration rate.

Sodium: The removal of sodium during leaching of soil (Table 2) was statistically similar for all the leachates in response to the applied treatments. However, the amount of Na' leached gradually decreased with time. The non-significant differences among treatments show that high Ca^{2}> concentration failed to replace more of the adsorbed sodium because the rate limiting factor for replacing Na' by applied Ca" was the low soil CEC. Previously it has been reported (Ghafoor and Salam, 1993) that in low CEC soils, Ca"+ concentration in soil solution ranged between 6-10 me L'I for optimum rate of Na' desorption.

Calcium: The removal of Ca^{2}+ from the soil also remained statistically similar for all the three leachates at applied Ca^{2}> levels in irrigation waters (Table 3). It appears that when Ca is added equal to or higher than 12 me L', 'part of it precipitates as CaCO, because of its low solubility «0.001%). Such precipitation has to be promoted in the presence of high native lime contents of 15.7% in the present soil (Rhoades, 1990). However, in the presence oflnw Ca^{2}> in irrigation water as in simple canal water, the native soil lime may contribute to the soluble Ca" because of high water potential (Bresler et al., 1982) to affect Na' desorption during soil reclamation.

Na+:Ca"+**Ratio:** The Na' to Ca^{2}> ratio in leachates ranged from 16.3 to 31.7 while as a mean of the three leachates it varied from 23.3 to 26.6 (Table 4). These values again indicate that Na' was being desorbed and leached at almost constant rate and even the higher concentration of Ca^{2}> in leaching solution could not effect a proportionate increase in Na' desorption rather Ca^{2}+ applied at higher rates was consumed in some other processes like precipitation of CaCO,. Considering milliequivalents of Na' removed per milliequivalent of added Ca^{2}+ (Table 5), lower concentrations of Ca^{2}+ in leaching solutions proved

Table 3. Calcium (me leachate^{-1}) removed from a saline-sodic soil

Ca^{2+} in Irrig. water	Leachate I	Leachate II	Leachate III	Total
CW, 1.4 me L^{-1}	12.2	8.0	1.4	21.6
CW, 6 me L^{-1}	13.3	8.1	1.7	23.1
CW, 12 me L^{-1}	10.0	7.6	3.0	20.6
CW, 18 me L^{-1}	7.3	6.2	4.6	18.2
BW, 6 me L^{-1}	10.9	7.5	5.0	23.4
BW, 18 me L^{-1}	9.2	7.8	4.8	21.8
SE	2.5^{NS}	2.4^{NS}	5.5^{NS}	-

Table 4. Sodium to calcium ratio in leachate (cations expressed as me leachate^{-1})

Ca^{2+} in Irrig. water	Leachate I	Leachate II	Leachate III	Mean
CW, 1.4 me L^{-1}	22.1	30.3	24.7	25.7
CW, 6 me L^{-1}	19.5	31.7	28.7	26.6
CW, 17 me L^{-1}	26.3	28.0	17.6	24.0
CW, 18 me L^{-1}	28.2	25.4	16.3	23.3
BW, 6 me L^{-1}	24.7	30.2	17.9	24.3
BW, 18 me L^{-1}	28.9	29.1	19.6	25.8

Table 5. Sodium (me) removed per calcium (me) added

Ca^{2+} in Irrig. water	Leachate I*	Leachate II	Leachate III	Mean**
CW, 1.4 me L^{-1}	190.7	173.8	24.1	99.0
CW, 6 me L^{-1}	185.7	42.6	8.3	2G.5
CW, 12 me L^{-1}	188.4	17.7	4.5	11.1
CW, 18 me L^{-1}	147.4	8.8	4.2	6.5
BW, 6 me L^{-1}	191.6	37.8	15.0	26.4
BW, 18 me L^{-1}	189.2	12.6	5.3	9.0

Leachate collected after CW applied @ 3 times of soil SP;** mean of leachate II and III only.

more efficient in enhancing Na+-Ca^{2+} exchange, particularly during the second and third leachates. This observation is of economic significance because decreasing the fineness of gypsum will become cost effective, although soil reclamation may complete in slightly longer time. Moreover, coarser gypsum particles will help sustain the solute concentration in soil solution which in turn will favour the infiltration rate of soils.

Soil Amelioration

All the treatments decreased soil EC and SAR non-significantly (Table 6), although complete soil reclamation was achieved which, however, was not expected with such a small amount of water application. However, the soil pH responded inconsistently to the tested treatments although the

Table 6. Postexperiment soil characteristics

Ca^{2+} in irrigation water	Soil -pH.	Soil EC_e	Soil SAR
Orig. soil	8.4	27.0	141.2
CW, 1.4 me L^{-1}	8.5	14.4	69.1
CW, 6 me L^{-1}	8.5	14.8	67.2
CW, 12 me L^{-1}	8.3	15.0	59.8
CW, 18 me L^{-1}	8.3	14.2	55.4
BW, 6 me L^{-1}	8.5	15.4	75.1
BW, 18 me L^{-1}	8.3	14.7	61.9
SE	0.1^{NS}	1.5^{NS}	5.2^{NS}

treatment differences were statistically similar.. A similar improvement of highly saline-sodic soil with the tested treatments indicated that to maintain higher Ca'+ concentration in soil solution is not significantly beneficial.. Thus to economise soil reclamation, relatively coarse grades of gypsum (passed through 16 mesh instead of 30 mesh) should be preferred.

Conclusions: The Na' removed in leachates increased while Na' in soil decreased with all the Ca" levels applied in irrigation waters. On average, me of Na'Teached per me Ca^{2}+ added were 25.5, 11.1 and 6.5 for Ca"' concentration of 6, 12 and 18 me L^{1} in canal water and 26.4 and 9.0 for Ca'+ concentration of 6 and 18 me L^{1} in brackish water, respectively. A similar decrease in soil EC and SAR indicated lower Ca'+ in irrigation water is better than its higher concentration for sodic and saline-sodic soil amelioration for which coarser size grades of locally available gypsum will prove more cost effective than its finer size grades.

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