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PROVISION OF CALCIUM IONS FOR RECLAMATION OF SODIC SOILS

BY
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ABSTRACT

Reclamation of sodic soils requires the supply of calcium ions for the replacement of exchangeable sodium ions in them. Powered gypsum is generally used to meet this requirement. High calcium carbonate content is a general characteristic of these soils. Calcium carbonate is insoluble in water and is incapable of producing any significant amount of calcium ions. Sulphuric acid and hydrochloric acid can break it up fo form their respective calcium salts. Their use was tested with success and the results achieved, there from, are presented in this paper.

INTRODUCTION

The lands, in the arid and semiarid regions, of Pakistan get low rainfall. The moisture movement trend, in them , is upward with marked high capillary. The salts, inherently present in them, have the trend to accumulate in upper layers. Consequently these lands become salt affected. The salts they contain are mostly sodium chloride(NaCl) and sodium sulphate (Na_2 So_4). They are highly soluble in water. The arid lands are also of calcareous character. Calcium Carbonate ($CaCo_3$) present in them, is insoluble in water. A very small amount of it is converted into calcium bicarbonate [(Ca $(HCO_3)_2$] which seldom exceeds beyond 4.3 mq/L.

The presence of excess of sodium chloride and sodium sulphate in these lands increases their Sodium Adsorption Ratio (SAR). Consequently these lands are also of sodic type.

The salt affected lands are to be reclaimed to make them suitable for cropping. The simple way to remove the salts from them, beyond the depth of root zones of crops, is to dissolve them in excess of water. The saltwater solution so formed is removed through its deep percolation or surface flushing.

The eradication of sodicity, by application of simple water, is a very long process and involves years of time.

To accelerate this process the advantage of powered gypsum application is taken which gives plenty of calcium ions in water to replace the Exchangeable Sodium (E.S) in the soil within a short period of time.

Since these lands are of calcareous type, there is no dearth of calcium ions in them, as dormant calcium carbonate. The application of a mineral acid breaks calcium carbonate to form its salt. Mostly sulpheric acid is used which produces the needed gypsum.

Close to 1970 a Caustic Soda Plant was installed of Kala Shah Kaku, where caustic soda (NaOH)is manufactured. The raw material used for this purpose is sodium chloride.

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During the caustic soda manufacturing process about 80 tons of hydrochloric acid is produced daily as a byproduct which, in the absence of a P.V.C. Plant, is dumped into a near-by surface drain.

In 1982 the Pakistan Agricultural Research Council initiated a Hydrochloric Acid Project to find out the prospects to make its use for the reclamation of sodic lands. We executed this project. The results achieved, there from, are given in this presentation.

REVIEW OF LITERATURE

Kelly(1951) applied gypsum to an alkali soil at the rate of 10 to 12 tons per acre. The plots were flooded continuously for three weeks. He found that the Exchangeable sodium was effectively removed to the depth of 5 feet and practically a highly sodic land was converted into a highly productive land.

Hussain Muhammad (1968) reported that it takes 6-8 years for reclaiming a saline sodic soil by rice culture and that the application of gypsum accelerates the replacement of exchangeable sodium.

B.K. Khasla and I.P Abral (1972) reported that the amount of gypsum needed to neutralize the soluble carbonates is known to be indicative of minimum amount of amendments required to start the reclamation of a saline sodic soil high in carbonates.

Altaf and Asghar (1985) found, that with the application of gypsum, even through it is applied to the extend of ½ to 1/4th requirements of the soil, the reclamation of a saline sodic soil can be achieved within a limited period of time.

Altaf (1986) reported that the reclamation of a saline sodic calcareous land can be done within a short period of time with the use of chemical amendments.

Altaf (1986) pointed out that ½ and 1/4th applications, of gypsum requirement, are almost equally useful to facilitate the reclamation of a saline sodic soil.

Altaf (1987) achieved successfully the reclamation of a saline sodic soil in the field with the use of brackish water and gypsum.

Altaf and Asghar (1988) got Rapid Reclamation of an unbroken saline sodic soil with the application of Brackish water and gypsum.

Altaf and Nazir (1990) reclaimed a highly deteriorated water logged land with gypsum application and its surface flushing within the period of a week in the month of December and raised the Berseem crop (Egyptian clover) which compared fairly well with crop sown in October and November.

Altaf and Zahid (1990) reclaimed an impermeable saline sodic soil with gypsum treatment and with surface flushing of the soil with in a period of a fortnight and got the flourishing first rice crop.

Altaf (1998) submitted that the reclamation of salt affected lands, is shifting away salts from the root zone of crops by drainage and replacement of exchangeable sodium, therein, by calcium ions. The easily available source of calcium ions, in nature, is gypsum.

MATERIAL AND METHODS

The study was started in the month of November, 1983 at the Mian Channu Reclamation Research Station. Each plot size was of $1/40^{th}$ of an acre. The experiment was designed with Randomised Block System. It had 10 treatments with 4 applications of each treatment.

The treatments included control and the use of Hydrochloric acid (HCl) sulphuric acid ($H_2 SO_4$) and gypsum $CaSO_4 . 2H_2O$).

The soil samples were taken from depths 0.0 to 6".0 and 6".0 to 1.0' of the soil.

The mixed samples of 1.0' were analysed for their mechanical ingredients, sand, silt and clay to find out the texture of the soil in various plots.

The soil samples from 0.0 to 6" and 6" to 1.0' were analysed to determine the PH of the soil saturated paste and the chemical ingredients the saturation extract contains to find out the salinity and sodicity status of the soil.

In general the soil samples contained 15% to 20% calcium carbonate.

Gypsum was spreaded in the plots and was mixed with the upper 3 and 4 inches of the soil. Hydrochloric acid and sulphuric acid were applied, on the basis of their gypsum equivalents, with first irrigation.

Canal water was used for irrigation. 6 successive irrigations were applied for leaching. Each irrigation was of 10.0 cm depth.

The first crop sown was berseem. The crop was seeded in the plots on November 15, 1984. The total delta applied to the crop was 124.5 cms and the rainfall received during the growth period of the crop was 1.39 cm. The final cutting of the crop was done in the month of May, 1985. Before sowing the crop 60 Lbs, N and P each were applied in the form of urea and super-phosphate respectively.

RESULT AND DISCUSSION

The textural classification of soil indicates (Table-1) that mostly it varies from clay loam to sandy clay loam. In some applications it has been silty clay loam to sandy clay loam.

The chemical analysis of the soil samples shows (Table-II) that the soil was highly saline and of sodic type. In many cases the PH of the saturation paste was higher than 9.0 which indicates the presence of sodium carbonate in the soil mass.

The gypsum requirements of the (Table-III), in different treatments, varied. The main values fell between 8.5 to 13.5 tons per acre per foot depth of the soil.

It reveals that the soil was highly deteriorated and presented itself as a good site to check and compare the efficiency of different soil amendments to reclaim such lands.

The chemical analysis results of the soil after completing the reclamation process, show (Table-II) that salinity and sodicity in the first one foot depth of the soil profile had been removed in all the treatments except in case of control.

The yield of the berseem crop (Table-IV) in treatments, pertaining to amendments applications, confirms the same.

CONCLUSIONS

1. Salinity is removed, with the application of excess of water, by leaching or surface flushing.
2. In calcareous soils, Hydrochloric acid and sulphuric acid produce calcium chloride and calcium sulphate (gypsum) respectively.
3. Powered gypsum is easy to be handled and is cheap. Sulphuric acid also produses gypsum in calcareous lands. Its handling is also more costly than gypsum. Hydrochloric acid, available from the particular plant, has a strength of only 32 percent. It is a by-product. Its handling is also difficult, and involves somewhat heavy carriage cost.

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TABLE - I

TEXTURAL CLASSIFICATION OF THE SOIL (FIELD PLOTS)

Treatment	Rep:	% Clay	% Silt	% Sand	Textural Name
Control	R_1	20	35	45	C.L.
	R_2	25	30	45	C.L.
	R_3	22	18	60	L.
	R_4	15	30	55	L.
Full HCl	R_1	23	32	45	L/C.L.
	R_2	20	35	45	L.
	R_3	18	22	60	L.
	R_4	15	25	60	L.
1/2 HCL	R_1	30	30	40	C.L.
	R_2	22	28	40	C.L.
	R_3	23	22	55	C.L./L.
	R_4	25	25	50	C.L.
1/4 Hcl	R_1	16	34	50	L.
	R_2	20	35	45	C.L.
	R_3	20	25	55	L.
	R_4	20	20	60	L.
Full H_2SO_4	R_1	20	30	50	L.
	R_2	20	30	50	L.
	R_3	23	22	55	L.
	R_4	18	27	55	L.
1/2 l H_2SO_4	R_1	20	35	45	L.
	R_2	18	27	45	L.
	R_3	22	33	45	L/C.L.
	R_4	15	25	60	L.
1/4 l H_2SO_4	R_1	20	45	35	L.
	R_2	25	20	35	C.L.
	R_3	17	28	55	L.
	R_4	15	25	60	L.
Full Gypsum	R_1	20	35	45	C.L.
	R_2	18	47	35	L/C.L.
	R_3	22	23	55	L.
	R_4	20	30	50	L.
1/2 Gypsum	R_1	18	47	35	L.
	R_2	22	33	45	C.L.
	R_3	20	30	50	L/C.L.
	R_4	20	35	45	L.
1/1 Gypsum	R_1	18	27	55	L.
	R_2	25	35	40	L.
	R_3	23	22	55	L.
	R_4	18	27	55	L.

TABLE - II

SATURATION EXTRACT ANALYSIS OF THE SOIL:

	BEFORE STARTING THE LEACHING PROCESS					AFTER COMPLETING THE LEACHING PROCESS			
TREATMENT CONTROL									
Replications	Depth	S.P.	pH	E.C.x10^3	SAR	S.P.	pH.	E.C.x 10^3	SAR
R_1	0-6"	33.0	7.9	30.0	78.7	34.0	8.3	0.8	2.3
	6"-12"	36.0	8.0	32.0	86.8	34.0	8.3	0.7	0.6
R_2	0-6"	33.0	7.9	37.0	105.0	30.0	8.0	2.0	10.0
	6"-12"	31.0	8.0	35.0	129.5	32.0	8.0	3.5	9.0
R_3	0-6"	29.0	9.1	10.0	98.0	25.0	9.3	1.6	14.0
	6"-12"	33.0	9.4	28.0	278.0	25.0	9.5	2.1	19.0
R_4	0-6"	39.0	8.9	27.0	268.0	23.0	8.9	1.2	10.5
	6"-12"	35.0	8.9	32.0	318.0	24.0	9.0	1.6	14.0
Treatment Full HCl									
R_1	0-6"	36.0	7.8	14.0	36.0	34.0	8.3	0.9	0/80
	6"-12"	34.0	7.8	30.0	66.0	34.0	8.3	0.6	0.70
R_2	0-6"	33.0	7.9	28.0	69.0	32.0	8.0	1.8	0.98
	6"-12"	33.0	7.5	12.0	67.5	31.0	8.1	1.5	2.50
R_3	0-6"	33.0	9.5	40.0	398.0	34.0	7.9	2.4	0.40
	6"-12"	32.0	9.5	25.0	248.0	31.0	7.9	2.0	1.0
R_4	0-6"	33.0	8.9	32.0	367.8	28.0	8.3	0.8	2.3
	6"-12"	34.0	9.4	25.0	248.0	26.0	8.3	0.8	2.8

Treatment 1/2 HCl

Replications	Depth	S.P.	pH	E.C.x10^3	SAR	S.P.	pH.	E.C.x 10^3	SAR
R_1	0-6"	33.0	9.1	30.0	266.0	31.0	8.3	1.5	7.8
	6"-12"	32.0	9.4	28.0	278.0	30.0	8.3	2.2	15.8
R_2	0-6"	33.0	9.3	23.0	228.0	30.0	8.4	1.6	10.8
	6"-12"	30.0	9.3	12.5	123.0	30.0	8.3	1.6	7.6
R_3	0-6"	33.0	9.1	30.0	344.7	30.0	8.6	2.0	4.1
	6"-12"	31.0	9.4	30.0	298.0	31.0	8.0	1.5	2.8
R_4	0-6"	36.0	37	37.0	112.0	27.0	8.3	0.8	3.4
	6"-12"	37.0	37	37.0	103.5	25.0	8.3	1.3	5.3
R_1	0-6"	34.0	7.8	12.0	29.09	30.0	8.0	1.0	3.3
	6"-12"	35.0	8.1	5.0	14.05	30.0	8.3	1.2	7.3
				Treatment 1/4 HCl					
R_2	0-6"	30.0	9.2	45.0	400	31.0	8.2	1.5	7.0
	6"-12"	30.0	9.2	40.0	460	31.0	8.2	2.6	10.8
R_3	0-6"	26.0	8.8	7.0	98.0	25.0	8.2	1.3	6.4
	6"-12"	32.0	9.5	9.5	93.0	23.0	8.3	1.2	8.6
R_4	0-6"	39.0	7.6	32.0	128.6	31.0	8.3	1.2	2.4
	6"-12"	34.0	8.0	32.0	110.6	30.0	8.0	1.0	2.8

Treatment Full H_2SO_4

Replications	Depth	S.P.	pH	E.C.x10^3	SAR	S.P.	pH.	E.C.x 10^3	SAR
R_1	0-6"	34.0	8.1	35.0	106	30.0	7.9	2.9	0.70
	6"-12"	34.0	8.4	32.0	150	30.0	7.9	2.9	1.30
R_2	0-6"	33.0	9.2	32.0	368.0	30.0	7.9	3.8	0.90
	6"-12"	32.0	9.2	23.0	328.0	32.0	7.4	3.1	5.10
R_3	0-6"	33.0	9.1	37.0	739.0	29.0	7.5	5.5	5.90
	6"-12"	32.0	9.5	37.0	368.0	30.0	7.5	6.0	6.80
R_4	0-6"	35.0	7.4	38.0	92.0	26.0	7.5	2.2	1.10
	6"-12"	33.0	8.0	38.0	95.0	30.0	7.5	1.9	0.50
				Treatment 1/2 H_2SO_4					
R_1	0-6"	33.0	7.7	13.0	27.7	30.0	7.5	2.8	1.60
	6"-12"	35.0	7.7	8.0	15.7	30.0	8.0	2.0	2.60
R_2	0-6"	33.0	9.6	27.0	539.0	29.0	8.3	2.6	19.10
	6"-12"	29.0	9.5	25.0	248.0	28.0	8.3	3.2	26.30
R_3	0-6"	33.0	7.7	30.0	133.0	30.0	7.5	2.7	4.60
	6"-12"	32.0	8.2	30.0	163.0	26.0	7.8	2.2	7.60
R_4	0-6"	33.0	7.6	29.0	85.0	26.0	7.3	2.1	0.50
	6"-12"	34.0	8.0	27.0	68.5	29.0	7.3	2.0	0.80

Treatment 1/4 H_2SO_4

Replications	Depth	S.P.	pH	E.C.x10^3	SAR	S.P.	pH.	E.C.x 10^3	SAR
R_1	0-6"	35.0	8.0	13	73.0	32.0	8.3	0.8	1.5
	6"-12"	35.0	8.3	5.5	39.6	34.0	8.3	0.7	0.9
R_2	0-6"	33.0	9.0	33	328.0	30.0	8.2	2.5	9.2
	6"-12"	31.0	9.2	33	328.0	31.0	8.2	1.5	3.5
R_3	0-6"	30.0	9.3	35	348.0	26.0	8.4	2.0	12.7
	6"-12"	32.0	9.4	35	403.0	28.0	8.4	1.7	11.7
R_4	0-6"	33.0	9.4	39	388.0	28.0	7.9	2.4	4.6
	6"-12"	35.0	9.4	37	368.0	26.0	7.5	2.8	14.3
				Treatment Full Gypsum					
R_1	0-6"	35.0	8.1	43.0	193.0	35.0	8.1	2.4	8.0
	6"-12"	34.0	8.4	33.0	248.8	35.0	8.2	1.9	3.7
R_2	0-6"	37.0	7.6	35.0	109.0	30.0	7.9	3.3	2.3
	6"-12"	31.0	7.8	32.0	88.7	29.0	7.9	3.1	1.2
R_3	0-6"	26.0	9.5	10.0	140.0	27.0	7.8	7.0	17.1
	6"-12"	31.0	9.5	11.0	108.0	26.0	7.8	7.5	17.2
R_4	0-6"	33.0	7.5	36.0	139.0	25.0	7.7	1.9	0.9
	6"-12"	38.0	7.8	33.0	121.0	29.0	7.7	2.6	1.7

Treatment 1/2 Gypsum

Replications	Depth	S.P.	pH	E.C.x10^3	SAR	S.P.	pH.	E.C.x 10^3	SAR
R_1	0-6"	35.0	8.35	2.9	11.3	33.0	7.5	2.9	1.0
	6"-12"	32.0	8.4	2.8	17.1	33.0	7.5	1.8	4.2
R_2	0-6"	38.0	9.5	23.0	228.0	31.0	7.3	4.7	2.4
	6"-12"	31.0	9.5	25.0	248.0	32.0	7.8	3.0	3.3
R_3	0-6"	33.0	7.7	28.0	68.1	30.0	7.8	2.5	0.9
	6"-12"	33.0	7.8	27.0	66.8	32.0	7.8	2.6	0.8
R_4	0-6"	38.0	8.9	25.0	221.0	29.0	7.8	2.8	1.7
	6"-12"	35.0	9.5	23.0	203.0	30.0	7.8	2.3	1.0
				Treatment 1/4 Gypsum					
R_1	0-6"	34.0	7.6	5.0	8.0	30.0	7.7	2.9	0.4
	6"-12"	34.0	8.0	4.8	6.25	31.0	7.5	3.1	0.4
R_2	0-6"	33.0	9.2	25.0	352.0	32.0	7.7	3.8	5.1
	6"-12"	31.0	9.5	23.0	264.0	31.0	7.7	5.0	8.2
R_3	0-6"	34.0	9.6	35.0	348.0	27.0	7.7	10.0	24.8
	6"-12"	31.0	9.4	36.0	345.0	26.0	7.7	10.5	26.9
R_4	0-6"	35.0	7.5	13.0	61.0	31.0	7.5	2.2	0.8
	6"-12"	39.0	7.8	23.0	119.0	31.0	7.5	1.4	3.9

TABLE - III

GYPSUM REQUIREMENTS (TONS / ONE FT.) OF THE SOIL BEFORE STARTING THE LEACHING PROCESS

Rep:	Full HCL	Half HCL	Qtr HCL	Full H_2SO_4	Half H_2SO_4	Qtr H_2SO_4	Full Gypsum	Half Gypsum	Qtr Gypsum	Control
R_1	8.0	9.0	9.5	6.0	6.0	6.0	7.0	6.0	7.0	8.0
R_2	9.5	9.0	17.5	16.0	13.0	11.5	7.0	14.0	15.0	6.0
R_3	25.5	22.5	14.5	27.0	9.0	16.0	13.5	9.0	23.5	14.0
R_4	15.0	7.0	12.0	6.0	12.0	10.5	14.0	10.0	12.0	6.0
Average	**12.5**	**11.9**	**13.8**	**13.8**	**10.0**	**11.0**	**10.4**	**9.8**	**14.9**	**8.5**

TABLE - IV

YIELD OF BERSEEM IN K.gm/PLOT
HARVESTED IN APRIL, 1985

Rep.	Full HCL	1/2 HCL	1/4 HCL	Full H_2SO_4	1/2 H_2SO_4	1/4 H_2SO_4	Full Gypsum	1/2 Gypsum	1/4 Gypsum	Control
R_1	608	658	742	620	673	681	636	690	635	654
R_2	733	631	629	640	654	718	714	690	663	669
R_3	606	692	691	755	688	701	683	691	658	430
R_4	719	744	758	712	755	754	723	737	725	485
Average	666.5	681	705	682	698	714	689	702	670	559.5

TABLE -V

MATEREOLOGICAL DATA

MEAN MONTHLY TEMPERATURE (FIUP STUDY)

Month	Maximum Temperature	Minimum Temperature
November, 1983	75.13°F	53.26°F
December, 1983	63.16°F	42.77°F
January, 1984	19.8°C	3.8°C
February, 1984	21.5oC	5.6oC
March, 1984	27.7°C	15.8°C
April, 1984	33.7°C	19.7°C
May, 1984	42.0°C	24.7°C

"Rainfall Data

Month	Rainfall	Dates
November, 1983	-	
December, 1983	-	
January, 1984	0.1"	1/22/84
February, 1984	0.2"	2/19/84
March, 1984	0.5"	3/19/84
April, 1984	0.12, 0.2, 0.27	1/4, 17/4, 21/4/1984
May, 1984	-	