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Calcium Losses from Gypsum and Farm Yard Manure Treated Saline-Sodic Soil during Reclamation

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ABSTRACT

Efficiency of gypsum size grades with and without farm yard manure (FYM) for reclaiming a saline-sodic soil were investigated. Sandy clay loam saline-sodic soil was filled in 30 cm long columns of PVC pipes having 10 cm diameter. Gypsum grades (5-16, 16-30 and 30-40 mesh) and FYM @ 10 tons ha^{-1} were used followed by leaching with canal water. The finer gypsum particles caused more leaching of calcium than the coarser ones, while all the gypsum treatments alone and in combination with FYM removed more calcium than that from the control. The removal of calcium decreased with time for all the treatments. All the gypsum particle sizes alone and in combination with FYM decreased the soil salinity (EC_e) to levels lower than the original soil. Gypsum application with FYM decreased the EC of soil to values less than 4.0 dS m^{-1}. Maximum decrease in SAR was obtained for 30-40 mesh gypsum @ 50% GR + FYM @ 10 tons ha^{-1} and minimum for control. The pH_s of soil decreased more with all the treatments than that of the control. The finer particles of gypsum in combinations with FYM proved to be more effective in increasing CEC of the soil which favored the availability of calcium to stimulate Na-Ca exchange.

Key Words: Calcium losses; Gypsum; Farm yard manure; Saline-sodic soil; Reclamation

INTRODUCTION

Soil salinity and sodicity are serious threats to irrigated agriculture in the Indus plains of Pakistan (Muhammed, 1983). These soils have low CEC because of illite type clay mineral (McNeal, 1966) as well as low organic matter. Thus during reclamation through Ca-amendment, Na-Ca exchange is expected to have lower rate (Bear, 1964). Therefore, higher amount of soluble Ca^{2+} may not cause proportional increase in Na-Ca exchange. Gypsum has been proved to be the cheapest source of Ca^{2+}, however, major objections remain its lower solubility, i.e. Ca^{2+} concentration seldom exceeds 15 $mmol_c$ L^{-1} under field conditions (Rhoades, 1982). Coarser gypsum in combination with organic amendments {e.g. pressmud, farm yard manure (FYM) and green manure} may provide sufficient Ca^{2+} in soil solution to facilitate Na-Ca exchange to maintain good permeability/infiltration. The present study was undertaken to: a) evaluate the effectiveness of different gypsum size-grades with and without FYM for reclaiming a saline-sodic soil, b) study the leaching pattern of unreacted Ca^{2+}.

MATERIALS AND METHODS

A lysimeter experiment was carried out in the wire-house, Department of Soil Science, University of Agriculture, Faisalabad. Gypsum sizes grades used were 5-16 mesh[1]: (Fraction passed through 5 mesh but retained by 16 mesh sieve), 16-30 mesh: (Fraction passed through 16 mesh but retained by 30 mesh sieve) and 30-40 mesh (Fraction passed through 30 mesh but retained by 40 mesh). The treatments were replicated thrice in the CRD which are T_1 (Control), T_2 (5-16 mesh gypsum @ 100% GR), T_3 (16-30 mesh gypsum @ 100% GR), T_4 (30-40 mesh gypsum @ 100% GR), T_5 (5-16 mesh gypsum @ 50% GR), T_6 (16-30 mesh gypsum @ 50% GR), T_7 (30-40 mesh gypsum @ 50% GR), T_8 (FYM @ 10 tons ha^{-1}), T_9 (5-16 mesh gypsum @ 50% GR + FYM @ 10 tons ha^{-1}), T_{10} (16-30 mesh gypsum @ 50% GR + FYM @ 10 tons ha^{-1}), T_{11} (30-40 mesh gypsum @ 50% GR + FYM @ 10 tons ha^{-1}).

Soil was collected from a field at Postgraduate Agricultural Research Station, University of Agriculture, Faisalabad. The soil (Table I) was air-dried, ground and passed through 2 mm sieve. Lysimeters made of polyvinyl chloride (PVC), 40 cm long and 10 cm internal diameter were used. Lower end of the lysimeters was covered with plastic wire gauze and tightly bandaged with thread and rubber band and then placed on iron stand. Glass wool layer about half centimeter thick was placed on the wire gauze and a layer (½") of sand was spread on it. Plastic bottles mounted funnels were placed below the lysimeters. The gypsum requirement (GR) of the soil was determined (Schoonover, 1952) and different size grades of gypsum

[1] millimeter=16/mesh

were prepared manually using different mesh sieves. Then 3.5 kg of soil was mixed with amendments and poured in each lysimeter. In order to calculate the bulk density and pore volume (PV) of soil, three other lysimeters were filled in the same manner. All the lysimeters were saturated with 75% of the saturation percentage with canal water (EC = 0.35 dS m^{-1}, SAR = 0.94) such that soil in columns was packed uniformly and leachate, if any, was recycled until all this applied water was retained by soil. One PV water was calculated as:

PV = {100 lb(wet wt. soil - dry wt. soil)}/{(oven dry soil wt) (water density)}

Table I. Physical and chemical characteristics of original soil

Characteristics	Unit	Value
Sand	%	52.8
Silt	%	23.0
Clay	%	24.2
Textural class		Sandy clay loam
pH_s	-	8.4
EC_e	dS m^{-1}	17.4
SAR	$(mmol\ L^{-1})^{1/2}$	49.8
Exchangeable cations		
$Ca^{2+}+Mg^{2+}$ (by difference)	$cmol_c\ kg^{-1}$	2.4
Na^+	"	4.4
K+	"	0.6
CEC	"	7.4
ESP	-	59.5
Gypsum requirement (GR)	$cmol_c\ kg^{-1}$	4.6
Calcium carbonate ($CaCO_3$)	%	5.2
Organic matter	%	0.4

After saturating the soil column, water equal to 1 PV of each treatment was added to columns. Leachates were collected and recycled thrice for complete reaction of Na-Ca exchange and then collected for analysis. In this way, five leachates were collected and analyzed for soluble cations and anions. After the completion of the experiment, soil columns were sampled and analyzed for pH_s, EC_e, soluble cations and anions, SAR and CEC.

Physical and chemical properties of soil (Table I) before and after the termination of the experiment were determined. Analyses for soluble ions and of leachate were done according to the methods described by the U.S. Salinity Laboratory Staff (USSLS, 1954). Organic matter (OM) was determined by the method described by Walkley-Black (Jackson, 1979). The data obtained was analyzed statistically following Analysis of Variance technique following completely randomized design and DMR test was applied to differentiate the treatment effects (Steel & Torrie, 1980).

RESULTS AND DISCUSSION

Leachate volume. The data (Table II) showed that treatments have significant effect on the rate of water movement through the soil columns. Maximum amount of water passed through the soil columns receiving gypsum of 16-30 mesh @ 100 and 50% GR. From control leachate volume gradually decreased with time i.e. up to fourth leachate and later almost stopped during the fifth PV. This might be due to the removal of soluble salts without enough removal of Na^+ and thereby dispersion of soil (Arora & Singh, 1980).

Table II. Effect of different treatments on leachate volume (mL)

Treatment	L_1	L_2	L_3	L_4	L_5	Mean
T_1	960 ns*	972 ks	837 v	297 w	0 x	613
T_2	963 ms	1040 dk	1072 bh	967 -s	1087 bf	1026
T_3	1010 go	1048 dj	1075 bg	980 jr	1177 a	1058
T_4	937 pt	1032 cm	1067 bh	970 ks	1133 ab	1028
T_5	910 ru	1002 hp	1073 bg	960 ns	1103 bd	1009
T_6	980 jr	1055 ci	1075 bg	970 ks	1097 be	1035
T_7	903 su	1022 fn	1043 dj	946 0t	1107 bd	1004
T_8	903 su	887 tv	1062 ch	923 qu	867 uv	928
T_9	983 jq	1028 cn	1067 bh	933 pt	1107 bd	1024
T_{10}	970 ks	1037 dl	1023 fn	960 ns	1107 bd	1019
T_{11}	937 pt	1022 fn	1063 bh	987 iq	1120 ac	1026
Mean	956 D	1013 B	1042 A	899 E	991 C	

*ns = nopqrs; Figures sharing the same letter(s) in columns or rows are statistically similar at P=0.05.

Leachate volume in all the treatments except control increased up to the third PV but decreased by the time of collection of fourth leachate and again increased in fifth PV. This shows that the applied gypsum acted initially as a source of electrolytes (Loveday, 1976) and along with the original solute concentration facilitated the water infiltration which gradually decreased due to decrease in EC. After the collection of the third leachate a decrease in electrolyte concentration owing to the leaching of solutes including calcium (Chawala & Abrol, 1980) resulted in decreased volume of leachate. However maximum leachate was collected in L_5T_3, where gypsum of 16-30 mesh @ 100% was applied and minimum leachate volume was observed with L_4T_1, where the leaching was almost stopped by the termination of experiment.

Calcium in leachate. The Ca^{2+} in leachate from the control and FYM treatments was lower than those in leachates from all the other treatments (Table III). It is attributed to low CEC that has low rate of Na-Ca exchange (Bear, 1964). Therefore, all the soluble calcium might not be utilized to replace adsorbed sodium and ultimately Ca^{2+} leached out of the soil columns.

Maximum Ca^{2+} in leachates was from the treatment where gypsum of 16-30 mesh @ 100% GR was applied followed by the 30-40 mesh gypsum @ 100% GR while Ca^{2+} leaching through the soil columns was lower where gypsum of 5-16 mesh @ 50% GR and 100% GR, 16-30 mesh @ 50% GR and 30-40 mesh gypsum @ 50% GR was added. It could be inferred that Ca^{2+} released from coarser particles @ 50 and 100% GR and finer particles @ 50% GR was maximally consumed in Na-Ca exchange. This observation is of practical importance to decrease the cost of reclaiming salt-affected soils through increasing the Na-Ca exchange efficiency by controlling the soluble Ca^{2+} in soil solution which in turn could be achieved by the application of coarser particles of gypsum in combination with FYM. The removal of Ca^{2+} was higher in the first leachate than the following ones as Ca^{2+} reservoir was depleting with time (Murtaza *et al.*, 1998).

Soil salinity (Ec_e). There was maximum reduction in EC_e with 30-40 mesh gypsum @ 50% GR + FYM @ 10 tons ha^{-1}, followed by FYM @ 10 tons ha^{-1}, 5-16 mesh gypsum @ 50% GR + FYM @ 10 tons ha^{-1} (Table IV). Although EC_e in the control soil column decreased considerably but was still higher than the critical level of 4.0 dS m^{-1}. All the combinations of gypsum with FYM decreased the EC_e to values less than 4.0 dS m^{-1} except with 16-30 mesh gypsum @ 50% GR + FYM @ 10 tons ha^{-1}. The results indicated that all the mesh sizes of gypsum from 5-40 are equally effective in lowering the Ec_e.

Soil sodicity (SAR). The data (Table IV) showed that treatments have significant effect to decrease the soil SAR. The decrease being maximum with 30-40 mesh gypsum @ 50% GR + FYM @ 10 tons ha^{-1} which indicates that FYM helped to enhance the release of

Table III. Effect of different treatments on Ca^{2+} ($mmol_c$ $leachate^{-1}$) of leachate

Treatment	L_1	L_2	L_3	L_4	L_5	Mean
T_1	12.81 bk*	16.17 bf	8.12 cp	0.56 op	0.00 p	7.64
T_2	16.56 bd	13.64 bj	9.01 ep	6.14 ip	2.09 np	9.49
T_3	15.45 dh	15.59 bg	8.05 ep	8.73 do	4.87 kp	10.54
T_4	16.97 bc	13.85 bi	6.05 ip	7.28 hp	7.33 gp	10.30
T_5	12.60 bk	8.84 co	7.92 fp	3.98 mp	1.61 np	6.99
T_6	15.57 bg	18.11 b	8.19 ap	4.20 lp	1.68 np	9.55
T_7	16.25 be	13.14 bj	9.05 cn	3.46 lp	5.43 jp	9.47
T_8	8.64 do	12.69 bk	11.63 bl	2.16 np	1.33 np	7.29
T_9	27.46 a	8.09 ep	5.89 ip	2.94 mp	2.28 np	9.33
T_{10}	13.76 bi	13.21 bj	12.61 bk	4.79 kp	1.91 np	9.26
T_{11}	15.30 bh	13.20 bj	10.94 bm	4.77 kp	2.29 np	9.30
Mean	15.58 A	13.32 B	8.77 C	4.34 D	2.80 D	

*bk = bcdefghijk; Figures sharing the same letter(s) in columns or rows are statistically similar at P=0.05.

Ca^{2+} from gypsum and its adsorption, and replacing of Na^+ by increasing soil CEC. All the treatments decreased the SAR values to lower than the critical levels of 13. The decrease of SAR in control might be due to calcium in irrigation water, valance dilution effect (Eaton & Sokoloff, 1935) or due to mineral weathering (Rhoades, 1968). However, SAR of the control soil was much higher than the other treatments.

Soil reaction (pH_s). The data (Table IV) indicates that treatments have significant effect on pH of the soil. Maximum decrease was observed in the gypsum treatments with or without FYM compared to the control. The decrease in pH_s in the control might be due to valence dilution effect which might be due to desorption of Na^+.

Table IV. Treatment effects on reclamation of soil after infiltration of 5 PV of water

Treatment	EC_e (dS m^{-1})	SAR	pH_s	CEC ($cmol_c$ kg^{-1})
Original soil	17.40	49.75	8.41	7.40
T_1	7.33 a	14.36 a	8.64 a	7.21 f
T_2	5.17 b	9.55 b	8.03 cd	7.38 de
T_3	4.37 bcd	5.02 cd	8.04 cd	7.51 c
T_4	5.01 bc	7.77 bcd	8.03 cd	7.47 cd
T_5	3.55 bcd	4.85 cd	7.99 d	7.19 f
T_6	4.84 bc	9.07 bc	8.18 bc	7.33 e
T_7	3.12 bcd	4.48 d	8.18 bc	7.48 cd
T_8	3.02 cd	3.82 d	8.58 a	7.44 cde
T_9	3.95 bcd	4.57 d	8.13 bcd	8.14 b
T_{10}	4.53 bcd	6.83 bcd	8.10 bcd	8.24 b
T_{11}	2.57 d	3.37 d	8.21 b	8.44 a

Figures sharing the same letter(s) in columns are statistically similar at P=0.05.

Cation exchange capacity (CEC). The data (Table IV) shows that treatments have significant effect on CEC of the soil. Maximum increase in CEC was observed in treatment where 30-40 mesh gypsum @ 50% GR + FYM @ 10 tons ha^{-1} was applied followed by the 16-30 mesh gypsum @ 50% GR + FYM @ 10 tons ha^{-1} and 5-16 mesh gypsum @ 50% GR + FYM @ 10 tons ha^{-1}. It might be due to the fact that decomposition of organic matter could produce CO_2 which dissolved in water to produce carbonic acid. This acid would increase the Ca^{2+} release from gypsum by lowering the pH and dissolving lime mineral (Robbins, 1985). This resulted in more Na-Ca exchange. In general addition of FYM with or without gypsum slightly increased the CEC of the soil.

CONCLUSIONS

All the treatments ameliorated the soil. Gypsum application in combination with FYM decreased the SAR, EC_e and pH_s significantly to greater extent. Combination of FYM enhanced the efficiency of gypsum for reclaiming saline-sodic soils by reducing the loss of Ca^{2+} in the leachate.

REFERENCES

Arora, Y. and N.T. Singh, 1980. Effect of leaching rate on the Na-Ca exchange and removal of sodium from sodic soils. *J. Indian Soc. Soil Sci.*, 29: 268-9.

Bear, F.E., 1964. *Chemistry of Soil.* Reinhold Publishing Company, New York, USA. pp. 310-4.

Chawala, K.L. and I.P. Abrol, 1980. The fineness of gypsum and reclamation of sodic soil. *Proc. In: Symposium on salt-affected soils.* February 18-21, Kernal (India), pp. 339-47.

Eaton, F.M. and V.P. Sokoloff, 1935. Adsorbed sodium in soils as affected by soil to water ratio. *Soil Sci.*, 1: 528-34.

Jackson, M.L., 1979. *Soil Chemical Analysis. Advanced Course.* 2nd ed. 11th Printing Madison, WJ, USA.

Loveday, J., 1976. Relative significance of electrolyte and cation exchange effects when gypsum is applied to a sodic clay soil. *Australian J. Soil Res.*, 14: 361-71.

McNeal, B.L., 1966. Clay mineralogy variability in some Punjab soils. *Soil Sci.*, 102: 53-8.

Muhammed, S., 1983. Salt-affected soils and their reclamation, pp. 1-15. Presidential address, Section of Agriculture and Forestry. 29th Pakistan Sci. Conf., December 26-30, University of Karachi, Pakistan.

Murtaza, G., A. Ghafoor, A.M. Ranjha and M. Qadir, 1998. Calcium losses during reclamation of medium textured low CEC saline-sodic soils. *J. Arid Land Stud.*, 7: 175-8.

Rhoades, J.D., 1968. Mineral weathering correlation for estimating the sodium hazard of irrigation waters. *Proc. Soil Sci. Soc. Amer.*, 32: 648-52.

Rhoades, J.D., 1982. Reclamation and Management of salt-affected soils after drainage. pp. 123-97. *Proc. Soil and Water Management Seminar,* November 29-December 2, Leithbridge, Alberta, USA.

Robbins, C.W., 1985. The $CaCO_3$-CO_2-H_2O system in soils. *J. Agron. Edu.*, 14: 3-6.

Schoonover, W.R., 1952. *Examination of Soils for Alkali.* Extension Service, University of California Berkeley, California, Mimeograph. USA.

Steel, R.G.D. and J.H. Torrie, 1980. Principal and Procedures of Statistics. 2nd ed. McGraw Hill Book Company, New York, USA.

USSLS, 1954. *Diagnosis and Improvement of Saline and Alkali Soils.* Handbook No. 60, Washington, D.C., USA.

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