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Full length Research paper

Effect of Gypsum on the Reclamation of Saline-Sodic Soil in Arid Region of Jacobabad, Sindh-Pakistan

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An experiment was conducted on a sandy clay loam saline-sodic soil at Zulfiqar Farms, to evaluate the effectiveness of different treatments of gypsum on reclaiming saline-sodic soil for different soil depths in arid region of Jacobabad, Sindh – Pakistan. The experiment was laid out in a complete randomized block design (RCBD) with three replicates and with plot size of 50 ft x 50 ft respectively. The following five treatments were kept in study: T_1 = Control (without gypsum application), T_2 = 25% gypsum requirement (G.R) of the soil, T_3 = 50% gypsum requirement (G.R) of the soil, T_4 = 75% gypsum requirement (G.R) of the soil, and T_5 = 100% gypsum requirement (G.R) of the soil respectively. The subject study revealed that the gypsum application with different treatments brought a positive effect in reducing soil pH, ECe, SAR and ESP. Amongst different treatments, T_5 – 100% gypsum requirement of the soil was observed to be more suitable dose as it reduces the overall maximum soil pH 7.23 for 0-6 inch soil depth after leaching. Likewise, the overall maximum reduction in ECe, SAR, and ESP after leaching was 4.07 dS/m, 2.65, and 12.52 for 18-24 inch soil depth for same treatment T_5 respectively. Application of 100% gypsum requirement of the soil seems to be an economical and optimum dose to reclaim saline-sodic soil.

Key words: Saline-sodic soil, reclamation, pH, ECe, SAR, ESP, Gypsum, leaching, Jacobabad, Gypsum.

INTRODUCTION

Irrigated agriculture has faced the challenge of sustaining its productivity for centuries. Because of natural hydrological and geochemical factors, as well as irrigation induced activities, soil and water salinity and associated drainage problems which continue to plague agriculture. Pakistan land resources are badly affected by waterlogging and salinity. In addition to this, about 25% of the area (16.24 mha) is affected moderately, to strongly by salinity and sodicity. Due to which crop yields are being reduced considerably. To bring these soils back to their potential production level, reclamation and management measures are essential. Excessive salt accumulation usually hampers crop growth because of osmotic, nutritional, and toxicity effects. Saline soils can be easily reclaimed by simple leaching whereas sodic and saline-sodic soils need addition of amendments. A large percentage of the sodic and saline-sodic soils in Pakistan contain natural lime ($CaCO_3$) at varying depths due to its low solubility. Calcium in this form is effective in soil exchange reactions with sodium (FFC Pak, 2015).

For sodic or saline-sodic soils, the addition of gypsum can accelerate the leaching of Na, decrease the ESP and electrical conductivity (EC), and increase water infiltration, water-holding capacity, and aggregate stability (Makoi et al., 2010). The reclamation of sodic and saline-sodic soils with chemical amendments is an established technology. The reclamation of saline-sodic soils uses many different methods such as physical amelioration

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(deep ploughing, subsoiling, sanding, profile in-version), chemical amelioration (amending of soil with various reagents: gypsum, calcium chloride, limestone, sulphuric acid, sulphur, iron sulphate), electro-reclamation (treatment with electric cur-rent). The most effective methods are based on the removal and exchange of soluble sodium and changing the ionic composition of soils by added chemicals with simultaneous leaching of sodium salts out of the soil profile Makoi and Ndakidemi, 2007).

Such material after leaching can decrease soil pH, ECe, SAR, ESP and promote aggregation (Al-Busaidi and Cooksen, 2003). The selection of reclamation agents should take into account not only their influence on the soil itself, but also their price and environmental hazard. It should to be keep in mind that crops during the root developing stage had less resistance power against salinity due to which the germination affects moderately to severely for most of the crops. Against this backdrop, the present investigation was conducted with the objectives of to evaluate the effectiveness of different treatments of gypsum on reclaiming saline-sodic soil for different soil depths i.e. 0-6, 6-12, 12-18, 18-24 inches in arid region of Jacobabad, Sindh – Pakistan.

MATERIALS AND METHODS

Site location and soil sampling

The experiment was carried out in a saline-sodic soil in an arid region of Zulfiqar Farms in Jacobabad, Sindh – Pakistan. This farm is located at 28° 16’ 51" N and 68° 26’ 19" E and with an altitude of 56 m (184 ft) from the sea level. For the determination of soil physical and chemical properties, soil samples were collected before and after application of the treatments. From each plot, soil samples were collected at 0-6, 6-12, 12-18, 18-24 inch depths by using soil auger. The samples were labelled, packed and brought to the laboratory for analysis accordingly. The laboratory analysis confirmed that soil had soil texture sandy silty clay between 0 and 24 inch depth. The overall pH 8.55, ECe 9.71 dS/m, SAR 13.15, and ESP 18.5 and gypsum requirement suggested 5.67 tons per acre respectively.

Field Experimental Procedure

A sandy clay loam saline-sodic soil from Zulfiqar Farms in Jacobabad district was used for reclamation. One acre of fallow plot was selected for the research. The experiment was laid out in a complete randomized block design (RCBD) with three replicates and with plot size of 50 ft x 50 ft respectively. Average gypsum requirement, estimated from SAR, for reclamation was about 5.67 tons per acre. The following five treatments were kept in study: T_1 = Control (without gypsum application), T_2 = 25% gypsum requirement (G.R) of the soil, T_3 = 50% gypsum requirement (G.R) of the soil, T_4 = 75% gypsum requirement (G.R) of the soil, and T_5 = 100% gypsum requirement (G.R) of the soil respectively. The water table was below 15 ft from the ground surface. As high amount of Sodium was accumulated with the soil particles due to which soil become hard and the water percolation becomes very low therefore, in order to increase the percolation rate two crosswise application of chisel plough was provided to the land and 2/3 of total recommended dose of each treatment for each sub-plot was broadcasted and then mixed with two crosswise operation of cultivator accordingly. Experimental plots were prepared by constructing bunds of about 1ft height and 1 ft width with the help of hand tools. These bunds were properly compacted to minimize the wastage of water by leakages. Canal water, available on rotation basis, was applied to plots.

Then before irrigation the remaining 1/3 of recommended dose of each treatment for each plot was provided to the plots and leaching was started in May 2013. Irrigation water was applied in 6 equal splits of 4 inch depth, each at the interval of 10-15 days accordingly. For the determination of soil physical and chemical properties before and after reclamation soil samples were collected after the completion of experimental study and were analyzed by standard methods described by USDA-NRCS (2002). Finally data collected were analysed statistically using one-way ANOVA statistics.

RESULTS AND DISCUSSION

The reclamation of saline-sodic soils is a very important goal throughout the world. These soils can be reclaimed by providing a source of calcium (Ca^{2+}) to replace excess sodium (Na^{+}) from the cation exchange sites. The replaced Na+ is leached from the root zone through leaching irrigation. However, to reduce such limitations to agricultural productivity, it is important to understand the effect and placement methods of cheap and readily available amendments. Based on these considerations the subject research was carried out to analyze the effect of gypsum soil amendment for the reclamation of saline-sodic soil in the arid region of Jacobabad, Pakistan. The subject study revealed that soil pH, ECe, SAR and ESP differed very significantly between applications of differ-

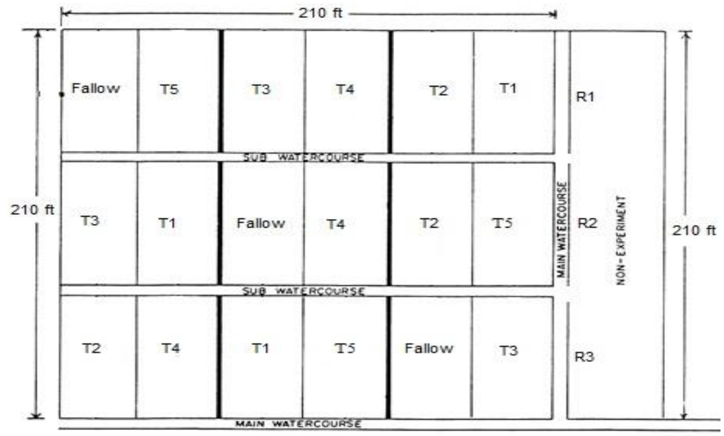

Figure 1. Layout Plan of Experimental Site

Table 1. Percent change in pH during 11 weeks of leaching a saline-sodic soil under different treatments of gypsum application for different soil depths.

Treatments	Initial pH	Final pH	Initial pH	Final pH	Initial pH	Final pH	Initial pH	Final pH
	Soil Depth (0-6 Inches)		Soil Depth (6-12 Inches)		Soil Depth (12-18 Inches)		Soil Depth (18-24 Inches)	
I		7.62a		8.01a		7.86a		7.76a
II		7.53b		7.95b		7.79b		7.54b
III	8.10	7.48b	8.55	7.84c	8.34	7.74b	7.98	7.44c
IV		7.32c		7.79c		7.56c		7.36d
V		7.23d		7.55d		7.49d		7.34d
One – Way ANOVA (F-Statistics)		1.79.5**		188.45**		184.88**		175.91**
CV (%)		8.84		9.22		9.10		8.62

Values followed by dissimilar letters in the same column are significant at P≤0.05 according to Fischer LSD. (** = P≤ 0.01. I = Control for which no gypsum was added; II = 25% gypsum requirement (G.R) of the soil; III = 50% gypsum requirement (G.R) of the soil; IV = 75% gypsum requirement (G.R) of the soil; V = 100% gypsum requirement (G.R) of the soil.

ent rates of gypsum amendment as mentioned in Table: 01 - Table: 04. The effect of the different treatments on the above discussed parameters upto 24 inch depth during the subject research are described as under:

Soil pH

Soil pH for different soil depths i.e. 0-6, 6-12, 12-18, 18-24 inches was reduced significantly (P≤0.05) by different treatments of Gypsum application after leaching (Table 1). The maximum pH reduced after leaching with irrigation water were 7.23 for 0-6 inch soil depth, 7.59 for 6-12 inch soil depth, 7.44 for 12-18 inch soil depth, and 7.38 for 18-24 inch soil depth for T_5 treatment respectively. It is an evident from the statistical data that the soil pH after 11 weeks of the experiment, decreased maximum with 100% gypsum requirement (G.R) of the soil. However, the statistical analysis showed minimum reduction results for treatment T1 for different soil depths. Similar results were reported by (Gharaibeh et al., 2009), in which gypsum incorporated and mixed with soil and concluded that if such method applied, it could reduce pH in saline-sodic soils, with high effectively gypsum solubility.

Electrical conductivity

The Electrical conductivity for different soil depths i.e. 0-6, 6-12, 12-18, 18-24 inches was significantly (P≤0.05) affected by different treatments of gypsum application after leaching (Table 2). Among the treatments, T_5 was more effective in reducing the EC of the soil as compared to the other treatments. The possible reason may be the soil deep plowing with chisel plow which improve in

Table 2. Percent change in ECe during 11 weeks of leaching a saline-sodic soil under different treatments of gypsum application for different soil depths.

Treatment	Initial ECe	Final ECe	Initial ECe	Final ECe	Initial ECe	Final ECe	Initial ECe	Final ECe
	dS/m		dS/m		dS/m		dS/m	
	Soil Depth (0-6 Inches)		Soil Depth (6-12 Inches)		Soil Depth (12-18 Inches)		Soil Depth (18-24 Inches)	
I		8.20a		8.62a		8.46a		8.05a
II		5.64b		5.92b		5.81b		5.53b
III	8.72	5.31c	9.15	5.58c	8.98	5.47c	8.54	5.20c
IV		4.64d		4.87d		4.78d		4.55d
V		4.15e		4.36e		4.27e		4.07e
One – Way ANOVA (F-Statistics)		1019.51**		1070.47**		1050.08**		999.11**
CV (%)		1.46		1.53		1.50		1.43

Values followed by dissimilar letters in the same column are significant at P≤0.05 according to Fischer LSD. (** = P≤ 0.01. I = Control for which no gypsum was added; II = 25% gypsum requirement (G.R) of the soil; III = 50% gypsum requirement (G.R) of the soil; IV = 75% gypsum requirement (G.R) of the soil; V = 100% gypsum requirement (G.R) of the soil.

Table 3. Percent change in SAR during 11 weeks of leaching a saline-sodic soil under different treatments of gypsum application for different soil depths.

Treatment	Initial SAR	Final SAR	Initial SAR	Final SAR	Initial SAR	Final SAR	Initial SAR	Final SAR
	Soil Depth (0-6 Inches)		Soil Depth (6-12 Inches)		Soil Depth (12-18 Inches)		Soil Depth (18-24 Inches)	
I		11.39a		11.95a		11.77a		11.12a
II		5.93b		6.25b		6.19b		5.84b
III	12.53	5.18c	13.15	5.49c	12.99	5.34c	12.24	5.04c
IV		4.53d		4.75d		4.69d		4.44d
V		2.75e		2.85e		2.85e		2.65e
One – Way ANOVA (F-Statistics)		40856.71**		42899.35**		42082.40**		40039.56**
CV (%)		2.59		2.75		2.66		2.52

Values followed by dissimilar letters in the same column are significant at P≤0.05 according to Fischer LSD. (** = P≤ 0.01. I = Control for which no gypsum was added; II = 25% gypsum requirement (G.R) of the soil; III = 50% gypsum requirement (G.R) of the soil; IV = 75% gypsum requirement (G.R) of the soil; V = 100% gypsum requirement (G.R) of the soil.

porosity and breaks the hardness of soil, which resulted in enhancing the leaching of salts. The overall reduction of ECe after leaching were 4.11 dS/m to 8.20 dS/m for 0-6 inch soil depth, 4.36 dS/m to 8.62 dS/m for 6-12 inch soil depth, 4.27 dS/m to 8.46 dS/m for 12-18 inch soil depth, and 4.07 dS/m to 8.05 dS/m for 18-24 inch soil depth for T_5 treatment respectively. Once again treatment T_5 showed same results in reducing maximum EC which is an evident that 100% gypsum requirement (G.R) for the soil is an optimum dose for reclaiming saline-sodic soils. However, the treatment T1 showed minimum reduction results for EC reduction for different soil depths. These results are in agreement with Mishra A, Sharma SD, Khan GH (2003), who suggested that as compared to other doses 100% gypsum requirement dose will reduced the maximum EC.

Sodium adsorption ratio (SAR)

Statistically remarkable results obtained for sodium absorption ratio (SAR) which showed significant (P≤0.05)

Table 4. Percent change in ESP during 11 weeks of leaching a saline-sodic soil under different treatments of gypsum application for different soil depths.

Treatment	Initial ESP	Final ESP	Initial ESP	Final ESP	Initial ESP	Final ESP	Initial ESP	Final ESP
	Soil Depth (0-6 Inches)		Soil Depth (6-12 Inches)		Soil Depth (12-18 Inches)		Soil Depth (18-24 Inches)	
I		14.66a		15.33a		15.98a		14.38a
II		14.26b		14.93b		14.78b		13.98b
III	17.21	13.96c	18.05	14.68c	17.73	14.88c	16.88	13.68c
IV		13.97c		14.55d		14.31d		13.66c
V		12.79d		13.45e		13.17e		12.52d
One – Way ANOVA (F-Statistics)		389.6**		409.08**		401.28**		381.88**
CV (%)		1.16		1.28		1.19		1.13

Values followed by dissimilar letters in the same column are significant at $P \leq 0.05$ according to Fischer LSD. (** = $P \leq 0.01$. I = Control for which no gypsum was added; II = 25% gypsum requirement (G.R) of the soil; III = 50% gypsum requirement (G.R) of the soil; IV = 75% gypsum requirement (G.R) of the soil; V = 100% gypsum requirement (G.R) of the soil.

reduction in all treatments of gypsum application as compared with control after leaching (Table 3). The decrease in SAR is due to increase in divalent cations (Ca^{2+} and Mg^{2+}), and decrease in monovalent cation (Na^{+}). The obtained data indicated that Na+ decreased while Ca^{2+} increased in the exchangeable complex after the application of gypsum followed by leaching. The maximum reduction of SAR after leaching were 2.75 to 11.39 for 0-6 inch soil depth, 2.85 to 11.95 for 6-12 inch soil depth, 2.85 to 11.77 for 12-18 inch soil depth, and 2.65 to 11.12 for 18-24 inch soil depth for T_5 treatment respectively. Hence, the obtained results once again indicated that treatment T_5 was superior in changing SAR compared with other treatments. Similar findings were obtained by Mace JE and Amrhein C (2001), who concluded that the reduction in SAR could be due to replacement of Na as monovalent on the exchange complex by Ca^{2+} from the soil solution by using gypsum as an amendment.

Exchangeable sodium percentage (ESP)

Exchangeable sodium percentage (ESP) was significantly ($P \leq 0.05$) lowered from 17.21 (initial) to 12.79 for 0-6 inch soil depth for treatment T_5. Likewise, for 6-12, 12-18, 18-24 inches soil depth the maximum reduction found to be 13.45, 13.17 and 12.52 for the same T_5 treatment respectively (Table 4). The data indicated that due to well mixing of gypsum with soil by using cultivator and by using 100% gypsum dose for soil reclamation the soil ESP reduced and was rated as superior to other doses. However, control plots showed un-satisfactory results. Similar results were reported by Raza ZI, Rafiq MS, Abdur R (2001), who concluded that reduction in ESP imply greater effective solubility of gypsum since the cation exchange in the thoroughly mixed treatment acted as sink, thus, encouraging further dissolution to the satisfaction of their solubility product.

CONCLUSIONS

The present research study was conducted at Zulfiqar Farms in Jacobabad district to compare the different doses of gypsum in a sandy clay loam saline-sodic soil for different soil depths i.e. 0-6, 6-12, 12-18, 18-24 inches. The following five treatments were kept in study: T_1 = Control (without gypsum application), T_2 = 25% gypsum requirement (G.R) of the soil, T_3 = 50% gypsum requirement (G.R) of the soil, T_4 = 75% gypsum requirement (G.R) of the soil, and T_5 = 100% gypsum requirement (G.R) of the soil respectively. The outcome of the research study tantamount that the gypsum application with different treatments brought a positive effect in reducing soil pH, ECe, SAR and ESP. Amongst different treatments, T_5 – 100% gypsum requirement of the soil was observed to be more suitable dose as it reduces soil pH 7.23 for 0-6 inch soil depth, 7.59 for 6-12 inch soil depth, 7.44 for 12-18 inch soil depth, and 7.38 for 18-24 inch soil depth after leaching respectively. Furthermore, the ECe after leaching were 4.11 dS/m to 8.20 dS/m for 0-6 inch soil depth, 4.36 dS/m to 8.62 dS/m for 6-12 inch soil depth, 4.27 dS/m to 8.46 dS/m for 12-18 inch soil depth, and 4.07 dS/m to 8.05 dS/m for 18-24 inch soil depth for the same treatment T_5 respectively. The reduction in soil EC is due to the soil deep ploughing with chisel plough which improves in porosity and breaks the hardness of soil, which resulted in enhancing the leaching of salts.

The maximum reduction of SAR after leaching found to be 2.75 to 11.39 for 0-6 inch soil depth, 2.85 to 11.95 for 6-12 inch soil depth, 2.85 to 11.77 for 12-18 inch soil depth, and 2.65 to 11.12 for 18-24 inch soil depth for T_5 treatment respectively. The decrease in SAR is due to increase in divalent cations (Ca^{2+} and Mg^{2+}), and decrease in monovalent cation (Na^{+}). The obtained data indicated that Na+ decreased while Ca^{2+} increased in the exchangeable complex after the application of gypsum followed by leaching. Likewise, for 0-6, 6-12, 12-18, 18-24 inches soil depth the maximum reduction in ESP found to be 12.79, 13.45, 13.17 and 12.52 for T_5 treatment respectively. The ESP reduce due to well mixing of gypsum with soil by using cultivator and by using 100% gypsum dose for soil reclamation the soil ESP reduced and was rated as superior to other doses. Hence, gypsum application improved the soil chemical properties by reducing the soil pH, EC, SAR and ESP with maximum reduction attained by T_5 treatment in all cases. However, control plots showed un-satisfactory results regarding all the parameters. Application of 100% gypsum requirement of the soil seems to be an economical and optimum dose to reclaim saline-sodic soil. By applying 100% gypsum dose maximum reduction in soil pH, ECe, SAR and ESP can be achieved. Since the soil of experimental plots was sandy clay loam in texture, therefore these suggestions are applicable for only sandy clay loam soils while the results may vary for other types of soil.

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REFERENCES

Al-Busaidi AS, Cooksen P (2003). Salinity-pH relationships in calcareous soils. Agri Marine Sci 8: 41-46 FFC Pakistan (2015). "Salt affected soil sand their Reclamation". http://www.ffc.com.pk/kdesk/kdesk_docs/colour_salt.pdf

Gharaibeh MA, Eltai NI, Shunnar OF (2009). Leaching and reclamation of calcareous saline-sodic soil by moderately saline and moderate-SAR water uses gypsum and calcium chloride. J. Plant. Nutr. Soil. Sci. 172: 713-719

Joachim HJR, Makoi, Hubert V (2010). "Effect of gypsum placement on the physical chemical properties of a saline sandy loam soil" Austrailian Journal of Crop Science AJCS 4(7): 556-563 (2010).

Mace JE, Amrhein C (2001). Leaching and reclamation of a soil with moderate SAR waters. Soil Sci Soc Am J 65: 199-204

Makoi JHJR, Ndakidemi PA (2007). Reclamation of sodic soils in Rundugai village, Hai District, Kilimanjaro Region, Tanzania, using locally available organic and inorganic resources. Afr J Biotechnol 6(16): 1926-1931

Mishra A, Sharma SD, Khan GH (2003). Improvement in physical and chemical properties of sodic soil by 3, 6, and 9 years old plantation of Eucalyptus tereticonis biorejuvenation of sodic soil. Forest Ecol Manage 184: 115-124

Raza ZI, Rafiq MS, Abdur R (2001). Gypsum application in slots for reclamation of saline sodic soils. Inter J Agric Biol 3(3): 281-285

Sahin U, Oztas T, Anapali O (2003). Effects of consecutive applications of gypsum in equal, increasing, and decreasing quantities on soil hydraulic conductivity of a saline-sodic soil. J Plant Nutr Soil Sci 166(5): 621-624 USDA-NRCS (2002). Soil conservationists. Salinity Management Guide Salt management. Available at http://launionsweb.org/salinity.htm.2002.