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DIFFERENTIAL RESPONSE OF SOIL TEXTURE FOR LEACHING OF SALTS RECEIVING DIFFERENT PORE VOLUMES OF WATER IN SALINE-SODIC SOIL COLUMN

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This study examined the leaching requirement of three saline-sodic soils in polyvinyl chloride (PVC) columns of 50 cm long and 11 cm internal diameter. Air-dried soils were packed in PVC lysimeters receiving different pore volume (PV) of water (EC 0.89 dS m^{-1}, SAR 1.55, RSC 1.02 $mmol_c$ L^{-1}). Leaching with 2.5 PV of water removed 94 % of soluble salts and decreased EC_e from 33.9 to 5.9 dS m^{-1} in 0-25 cm layer of sandy clay loam soil. For lowering EC_e to < 4 dS m^{-1} in loamy sand up to 0-25 cm soil layer, 2.0 PV water removed 67 % soluble salts. In silty clay loam soil, 2.5 PV water lowered EC_e to < 4 dS m^{-1} only up to 0-10 cm depth with 83 % removal of salts. Relationships between EC/EC_0 and D_w/D_s established were for the soils as $EC/EC_0 = 0.329 (D_w/D_s)^{-2.12}$ with r= 0.87 for loamy sand; $EC/EC_0 = 0.167 (D_w/D_s)^{-0.60}$ with r=0.89 for silty clay loam and $EC/EC_0 = 0.06 (D_w/D_s)^{0.78}$ with r=0.98 for sandy clay loam soil. These relationships leads to conclude that reduction in salinity of loamy sand, silty clay loam and sandy clay loam soil was 67, 83 and 94 % when leached with 1.88, 2.72 and 2.67 cm of water, respectively.

Keywords: Leaching, saline-sodic soils, texture, pore volume, reclamation

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INTRODUCTION

In arid and semi-arid regions, irrigation water of poor quality coupled with the limited scarce rainfall and high evapotranspiration often increases soil salinity and sodicity. The presence of salts in soil deteriorates soil physical conditions; impair plant growth and decrease crop yields (Ayers and Westcot, 1989). Therefore, desalinization and desodication of soils help to sustain irrigated agriculture. In dry regions, there is high evaporation which causes salt accumulation in the upper soil layers (Sadiq *et al*., 2002; Makoi and Ndakidemi, 2007; Rashid *et al*., 2009).

Texture is very useful indicator of physical properties like soil porosity and bulk density. It influences air and water movement and is important for irrigation management and soil salinity and sodicity. Texture is strongly correlated with permeability and infiltration, available water holding capacity, and adsorption-desorption of ions (Miller and Donahue, 1995; Shainberg *et al*., 2001; Ghafoor *et al*., 2004; Mostafazadeh-Fard *et al*., 2008). Saline soils are usually reclaimed by pounding water on soils to leach salts. But reclaiming saline-sodic soils requires removal of sodium (Na^+) from soil cation exchange sites, usually with addition of calcium (Ca^{2+}) followed by leaching of the replaced Na^+ out of the root zone. Gypsum is the most extensively used agent in reclamation of saline-sodic soils, because of its low cost, general availability and safe handling by farmers (Murtaza *et al*., 2009; Ghafoor *et al*., 2010).

Chemical amendments can resolve the problem in two ways. Firstly, gypsum or calcium chloride applications supply soluble Ca^{2+} directly. Secondly in calcareous soils, acid and acid formers (H_2SO_4, HCl, HNO_3) convert native $CaCO_3$ to more soluble salts like $CaSO_4$, $Ca(HCO_3)_2$, $Ca(NO_3)_2$ or $CaCl_2$ (Ghafoor *et al*., 2004). However, the initial cost of these amendments restricts their use, especially by farmers with limited resources (Mirza and Zia, 2006; Makoi and Ndakidemi, 2007; López-Aguirre *et al*., 2007; Ghafoor *et al*., 2010).

The amount of leaching water and the time required to reclaim a soil will depend on the depth of soil to be reclaimed, the initial salinity, the type of salts present and soil characteristics such as texture, structure, infiltration and permeability. Leaching requirement (LR) to sustain productive soil has been determined earlier by several workers which ranged from 0.30 to 4.43 cm of water per cm of soil depth and that varied with soil types (Singh, 1996; Singh and Bhargava, 1995; Singh and Kundu, 2000; Kuligod *et al*., 2002; Mostafazadeh-Fard *et al*., 2008). It seems therefore, necessary to know the response of different textured salt-affected soils for leaching salts with a given amount of irrigation water to determine the most effective interactions of soil texture and volume of irrigation (LR indirectly) for the control of salt accumulation in soils. Considerable work has been done on leaching of salts in saline soils but limited literature is available on leaching under saline-sodic soil conditions. The specific objective of this study was to determine leaching requirement of different textured saline-sodic soils and establishing relationships between volume of water applied and salt removal from soils to achieve reclamation.

MATERIALS AND METHODS

This experiment was conducted in zero-tension filled-in lysimeter (lysimeter with free draining leachate containing homogenized test material) using three different textured calcareous saline-sodic soils in the wire house, Institute of Soil and Environmental Sciences, University of Agriculture, Faisalabad during 2008. The bulk soil samples were collected from the upper 15 cm of three different fields located at village Dheroki, District Toba Tek Singh. Bulk soil samples were air-dried, ground to pass through a 2 mm sieve and mixed thoroughly. Physical and chemical characteristics of soils were determined by methods given in hand book No. 60 (U.S. Salinity Lab. Staff, 1954) and methods of soil analysis (Page *et al*., 1982). Soil particle-size distribution was measured using the hydrometer method (Bouyoucos, 1962). Soil bulk density was measured by drawing 0.050 m × 0.072 m cores from lysimeters (Blake and Hartge, 1986). Pore volume was calculated with the help of saturation percentage and bulk density using the formula PV (cm^3) = $\theta_v \pi r^2 l$ (Jury *et al*., 1991). The physical and chemical characteristics of soils are given in Table 1.

Lysimeters used in this study were made of PVC and had 50 cm length and 11 cm internal diameter. Each column was fitted with PVC net at the bottom. The bottom of each column was padded with 3 cm gravel and then sand to facilitate leaching. In each soil column, 3.5 kg soil was added in small increments to obtain uniform packing. Soil was packed to a height of 27 cm, making soil column of 24 cm. Soil columns were placed vertically on iron stands. To check evaporation loss, top of each column was covered with polythene sheet following application of water. Storage bottles were placed underneath columns to collect leachate. Four treatments were replicated three times in Complete Randomized Design in all three soils. For leaching cycles, with tap water having EC = 0.89 dS m^{-1}, SAR = 1.55 and RSC = 1.02 $mmol_c\ L^{-1}$ was applied. Treatments were: T_1 = 1.0 PV (application of 1.0 PV water), T_2 = 1.5 PV (application of 1.5 PV water), T_3 = 2.0 PV (application of 2.0 PV water), T_4 = 2.5 PV (application of 2.5 PV water). During leaching of columns, water equal to designed PV was allowed to infiltrate consecutively and four leachates (L_1, L_2, L_3, $L_{4)}$ were collected after every 15 days. The water was allowed to infiltrate till there was no dripping of water. Leachates volume was measured and analyzed for electrical conductivity (EC). The salts removed were computed with the following formula:

Salt removal (mg $leachate^{-1}$) = EC of leachate (dS m^{-1}) × 640 × {vol.of leachate (mL) /PV (mL)}

At the end of leaching treatments, soils from top to bottom

Table 1. Physical and chemical properties of soils

Soil Parameter	Unit	Value		
		LS (S_1)	**SiCL (S_2)**	**SCL (S_3)**
Sand	%	77.4	19.7	55.6
Silt	%	7.70	43.6	18.6
Clay	%	14.9	36.7	25.8
Textural class	-	Loamy sand	Silty clay loam	Sandy clay loam
pH_s		8.88	8.97	9.15
EC_e	dS m^{-1}	8.19	23.9	33.9
$Ca^{2+} + Mg^{2+}$	$mmol_c\ L^{-1}$	7.63	14.6	18.2
Na^+	"	84.5	286	430
K^+	"	5.62	6.82	7.00
CO_3^{2-}	"	1.40	1.00	1.62
HCO_3^-	"	4.83	6.54	9.68
Cl^-	"	32.0	58.4	105
SO_4^{2-}	"	60.0	250	351
SAR	$(mmol\ L^{-1})^{1/2}$	43.3	106	142
Organic matter (OM)	%	0.58	0.61	0.53
Bulk density (BD)	Mg m^{-3}	1.08	1.01	1.03
Saturation percentage	(%)	26.9	31.4	30.5
Pore volume (PV)	mL	944	1097	1067

LS (S_1) = Loamy sand; SiCL (S_2) = Silty clay loam; SCL (S_3)= Sandy clay loam of each column at 5 cm increments (D_1 = 0-5 cm, D_2 = 5-10 cm, D_3 = 10-15 cm, D_4 = 15-20, D_5 = 20-25 cm) were sampled, air-dried and ground to pass through a 2 mm sieve. Saturation extract of the soil samples were collected and their EC_e and concentration of soluble cations and anions was determined following methods of the U.S. Salinity Lab. Staff (1954). Sodium adsorption ratio (SAR) was calculated by using the following equation:

$$SAR = Na^+/(Ca^{2+} + Mg^{2+}/2)^{1/2}$$

Empirical relationships between EC/EC_0 and D_w/D_s were drawn in Microsoft Excel for all the three soils using (EC_0 and EC are electrical conductivity of saturation extracts of the soil before and after leaching, D_w is the depth of water and D_s is the depth of soil).

RESULTS AND DISCUSSION

Leaching fraction: The downward flow of water, carrying excess soluble salts and Na^+ through soils is essential for successful reclamation of saline-sodic soils. The Leaching fraction is a key factor for the movement of salts within and out of soils. Soil texture, pore volume, and their interactions differed statistically for leaching fraction (LF) (Fig. 1, 2, 3). Mean leaching fraction for soil, treatment and leachates was in order as: Soil [LS (0.75) > SCL (0.59) > SiCL (0.55)], treatments [T_2 (0.69) > T_3 (0.64) > T_1 (0.61) > T_4 (0.60)] and leachates [L_1 (0.72) > L_2 (0.67) > L_3 (0.60) > L_4 (0.54)]. The interactive effects of soil × leachate (S×L), soil × treatment (S×T) and treatment × leachate (T×L) remained statistically significant (Figs. 1, 2, 3) for leaching fraction. Highest leaching fraction was recorded for S_1L_1 (0.83) and the lowest with S_2L_4 (0.44). The highest Leaching fraction was obtained for S_1T_2 (0.82) and lowest with S_2T_1 (0.48), and highest LF was collected for T_2L_1 (0.78) and the lowest with T_1L_4 (0.49). Decrease in leachate volume over time could be due to fast leaching of soluble salts leading to increase proportion of exchangeable Na^+ particularly without the application of an external source of Ca^{2+}. Accumulation of exchangeable Na^+ caused deflocculation of soils and thus decreased hydraulic conductivity of soils, hence leachate volume decreased (Quirk and Schofield, 1955; Ghafoor and Salam, 1993).

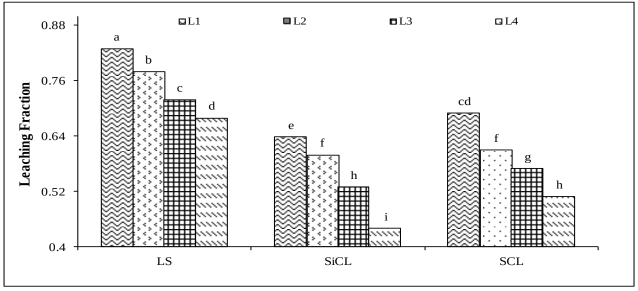

Figure 1. Treatment×leachate effects on leaching fraction in different soils. LS: Loamy sand; SiCl: Silty clay loam; SCL: Sandy clay loam

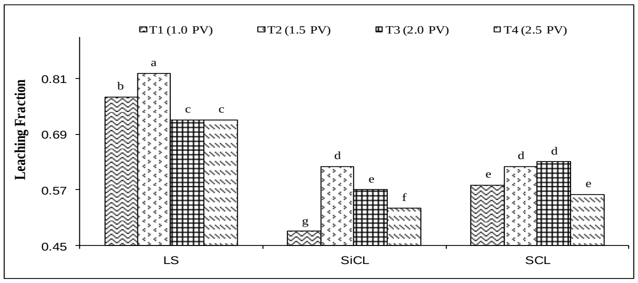

Figure 2. Soil×treatment effects on leaching fraction in different soils. LS: Loamy sand; SiCl: Silty clay loam; SCL: Sandy clay loam

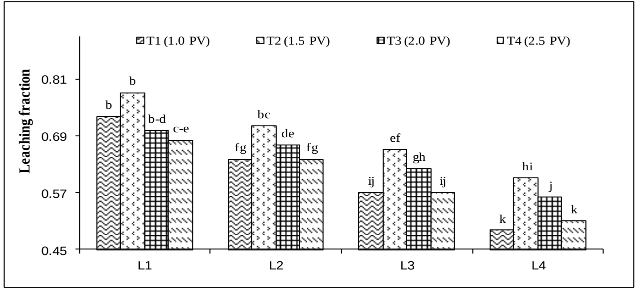

Figure3. Treatment×leachate effects on leaching fraction. Leachates (L_1, L_2, L_3 and L_4) collected after every 15 days.

Amount of salts removed: Soil texture, treatment and their interactions differed significantly for the amount of salts removed from leachates. For better understanding, data regarding salt removal was converted from mg leachate^{-1} into kg ha^{-1} as shown in (Figs. 4, 5, 6). Highest salt removal (kg ha^{-1}) was observed with T_3 followed by T_2, T_4 and T_1 with values as 670, 568, 562 and 405. Salt removal was the highest in L_1 followed by L_2, L_3 and L_4 having values as 845, 632, 630 and 310. The interactive effect of S×L was significant, being highest for S_1L_3 (1155 kg ha^{-1}) and lowest with S_3L_3 (280 kg ha^{-1}) interaction. The interactive effect of S×T was significant, being highest for S_3T_3 (962 kg ha^{-1}) and lowest with S_1T_1 (390 kg ha^{-1}). The T×L interaction also differed significantly, removal (kg ha^{-1}) being highest for T_3L_1 (1014) and lowest with T_1L_4 (188).

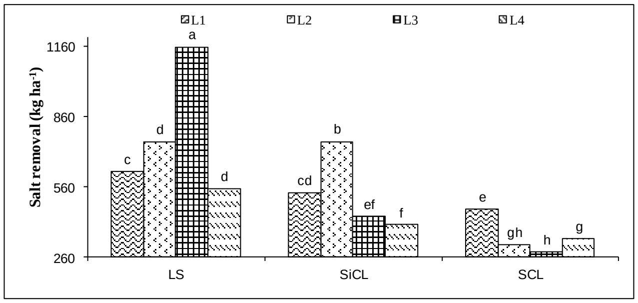

Figure 4. Treatment×leachate effects on salt removal in different soils. LS: Loamy sand; SiCl: Silty clay loam; SCL: Sandy clay loam

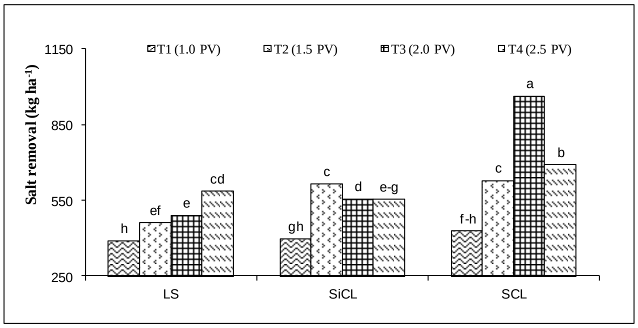

Figure 5. Soil×treatment effects on salt removal in different soils. LS: Loamy sand; SiCl: Silty clay loam; SCL: Sandy clay loam

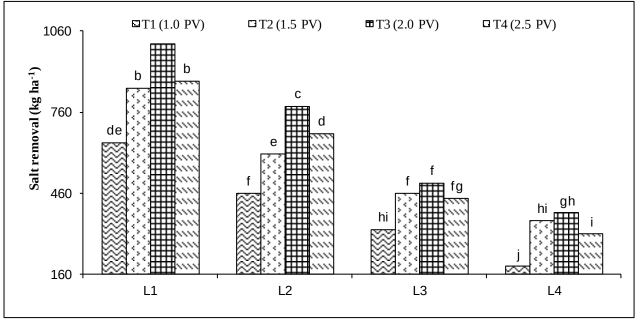

Figure 6. Treatment×leachate effects on salt removal. Leachates (L_1, L_2, L_3 and L_4) collected after every 15 days.

In general, it was concluded that after application of four irrigations of different pore volume, highest leaching fraction (0.75) for LS removed 481 kg ha^{-1} salts. After application of four irrigations of different pore volume with T_2, T_3, T_4 and $T_{1,}$ having LF of 0.69, 0.64, 0.61, and 0.60 could remove salts (kg ha^{-1}) with values as 568, 670, 562 and 405, respectively.

In 1st, 2nd, 3rd and 4th irrigation with LF = 0.72, 0.67, 0.60 and 0.54 removed 846, 632, 430 and 310 kg ha^{-1} salts. In S×L interactions, salt removal (kg ha^{-1}) was highest with loamy sand in third leachate having LF = 0.32 and the lowest with sandy clay loam soil with LF = 0.20. For S×T interactions, highest salt removal in sandy clay loam soil was observed with 2.0 PV having LF = 0.63 and lowest being with loamy sand with 1PV with LF = 0.77. With T×L interactions, highest salt removal was noted with 2.0 PV having LF =0.70 and lowest for with 2.5PV with LF = 0.51.

Salt removal with water from soil is a function of nature and amount of salts present, time for solute interaction with solvent and volume of water passed through soil. High initial EC$_e$ of soils along with slow flow rate of water due to relatively high SAR caused more salt removal in the initial leachates. Assuming water flow is a simple piston flow, the initial solute can be replaced completely after 1PV of water application. However, water flow in soil is not ideal, 5-30% of initial soluble salts remained in soil profile following leaching with 1PV. This seems due to the fact that in soils there are two types of pores distinguished by their pore size as micro-pores within and between aggregates, and macro-pores between aggregates. Coarse textured soils (LS) have relatively low total porosity but possess mostly macrospores' that is why higher volume of leachate and thus salt removal occurred. Fine textured soil (SiCL) contain relatively high total pore space, mainly micro pores which remained filled with water for a considerable period of time, so relatively less volume of leachate and salt removal was observed (Mirza and Zia, 2006; Kolahchi and Jalali, 2007; Mostafazadeh-Fard *et al*., 2008).

Post-Experiment Soil Characteristics

Soil salinity (EC$_e$): The soil EC$_e$ differed statistically for soil textures, treatment and their interactions at different soil depths. The highest EC$_e$ was recorded in SiCL followed by SCL and LS. Mean values of EC remained the highest for T_1 (6.8 dS m^{-1}) followed by T_2 (5.5), T_3 (3.9) and T_4 (2.7 dS m^{-1}), while EC$_e$ in different soil layers were the highest at D_5 soil depth followed by D_4, D_3, D_2 and D_1 with values as 6.8, 5.6, 4.3, 3.7 and 3.2 dS m-^{1}, respectively. The interactive effects of soil × treatment (S×T), soil × depth (S×D) and treatment × depth (T×D) remained statistically significant (Fig. 7, 8, 9). The EC$_e$ for the interaction of S_2T_1 (9.9 dS m^{-1}) was highest but lowest with S_1T_4 (1.9 dS m^{-1}). For EC$_e$ for the interaction of S_2D_5 (9.4 dS m^{-1}) was highest but lowest with S_1D_1 (2.0 dS m^{-1}) and it was highest (8.0 dS m^{-1}) with T_2D_5 and lowest (1.9 dS m^{-1}) for T_4D_1.

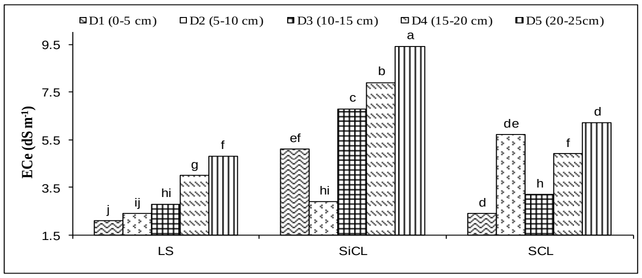

Figure 7. Variation in EC$_e$ of soil profile in different soils. LS: Loamy sand; SiCl: Silty clay loam; SCL: Sandy clay loam

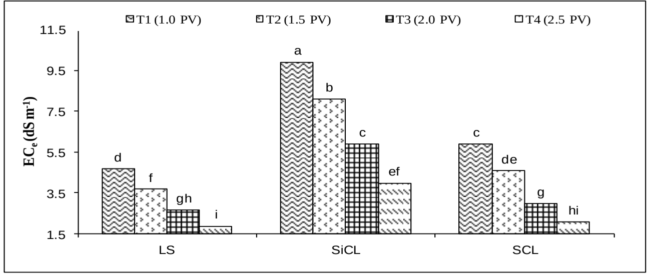

Figure 8. Effect of treatments on EC$_e$ of different soils. LS: Loamy sand; SiCl: Silty clay loam; SCL: Sandy clay loam

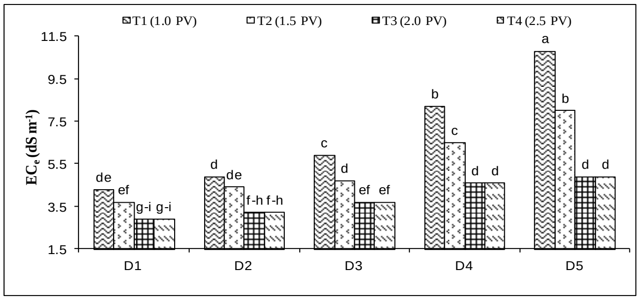

Figure 9. Effect of treatments on EC_e of soil at different depths. D_1: 0-5 cm; D_2: 5-10 cm; D_3: 10-15 cm; D_4: 15-20 cm; D_5: 20-25 cm

The initial EC_e (dS m^{-1}) of LS, SiCL and SCL was 8.2, 23.9 and 33.9 in the 0-25 cm soil column. In LS, EC_e after leaching with 1PV (1PV = 944 mL = 0.94 cm), it decreased to 2.9, 3.5, 4.1, 5.6 and 7.6 dS m^{-1} at 0-5, 5-10, 10-15, 15-20 and 20-24 cm soil depth, respectively, with mean value of 4.7 dS m^{-1}. For SiCL, EC_e after leaching with 1PV (1PV = 1097 mL = 1.09 cm) decreased to 6.7, 7.5, 9.6, 11.2 and 14.6 dS m^{-1} at 0-5, 5-10, 10-15, 15-20 and 20-25 cm soil depth, respectively, with mean value of 9.9 dS m^{-1}, while in SCL, EC_e after leaching with 1PV (1PV = 1067 mL = 1.06 cm) decreased to 3.3, 3.8, 4.1, 7.8 and 10.6 dS m^{-1} at 0-5, 5-10, 10-15, 15-20 and 20-25 cm soil depth, respectively, with an average EC_e of 5.9 dS m^{-1}.

The average (EC_e) in 0-25 cm layer decreased from 8.2 to < 4 dS m^{-1} in LS with 2.0 PV (1.88 cm) of water and from 33.9 to < 4 dS m^{-1} in SCL with 2.5 PV (2.67 cm) of water). While 2.5 PV (2.72 cm) of water could not lower average EC_e of 0-25 cm layer of SiCL from 23.9 to < 4 dS m^{-1}. The said leaching treatment lowered EC_e to < 4 dS m^{-1} only in 0-10 cm top soil layer. It is the fact that leaching is likely to carry salts down to the lower soil layers, in resulting salt accumulation in the lower layers. Under any leaching conditions, column EC is affected by EC of irrigation water and the salt concentration in the lower depth increase significantly (Hoffman, 1990; Smets *et al*., 1997; Odemis and Kanber, 2005).

Soil sodicity (SAR): The SAR is a measure of sodicity hazard of soils (≥13.2) and waters (≥10). For lowering the soil SAR, replacement of adsorbed Na^+ from soil colloids followed by its removal through leaching is necessary (Ghafoor *et al*., 2004). Soil SAR differed statistically for soil textures, treatment and their interactions at different soil depths (Fig. 10, 11, 12). At the termination of leaching, soil SAR was the highest (37.3) for SiCL followed by SCL (31.8) and LS (24.6). The higher SAR of SiCL seems because of high concentration of Na^+ in solution owing to higher amount of adsorbed Na^+ in high cation exchange capacity (CEC) of SiCL than that in SCL and LS. A decrease in SAR of LS with all the treatments remained more than SiCL and SCL because of its low clay contents and thus low CEC (López-Aguirre *et al*., 2007). The effect of treatments on soil SAR was significant. However, decrease in SAR was the highest with T_4 (13.7) followed by T_3, T_2 and T_1 (57.6). The SAR was highest at D_5 soil depth followed by D_4, D_3, D_2 and D_1 with values as 49.3, 39.8, 25.6, 22.4 and 18.7, respectively. The SAR remained higher with S_3T_1 (65.39) and lower with S_1T_4. It was maximum for S_3D_5 (56.0) and minimum for S_1D_1. The highest SAR was recorded for T_1D_5 (103.42) and lowest with T_4D_1. The effect of applied treatments (PV) remained significant on soil SAR but did not decrease SAR below 13 which is a critical limit for sodic/saline-sodic soils (U.S. Salinity Lab. Staff, 1954). Moreover, decrease in SAR for LS with simple leaching could be due to "valence dilution" (Reeve and Bower, 1960). This dilution of soil solution favors the adsorption of divalent cations like Ca^{2+} at the cost of monovalent like Na^+. The reverse is true when soil solution is concentrated due to evapo-transpiration (Eaton and Sokoloff, 1935). Application of 2.5 PV decreased SAR to < 13 for LS, SiCL and SCL up to 0-20 cm, 0-10 cm and 0-15 cm soil depths, respectively. Overall it is concluded that application of 2.5 pore volume of water is essential to decrease SAR to < 13 in LS up to 0-20 cm depth, For SiCL soil, this much water application did so up to 0-10 cm soil depth and for SCL soil up to 0-15 cm soil depth.

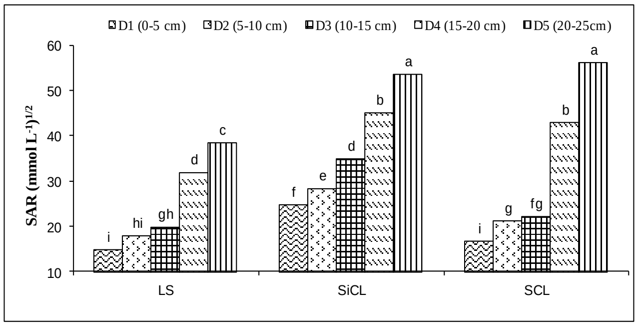

Figure 10. Variation in SAR of soil profile in different soils. LS: Loamy sand; SiCl: Silty clay loam; SCL: Sandy clay loam

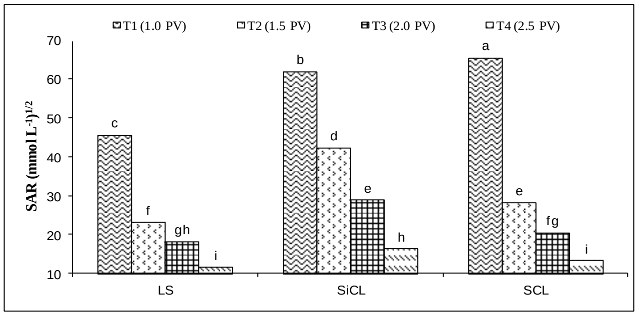

Figure 11. Effect of treatment on SAR of different soils. LS: Loamy sand; SiCl: Silty clay loam; SCL: Sandy clay loam

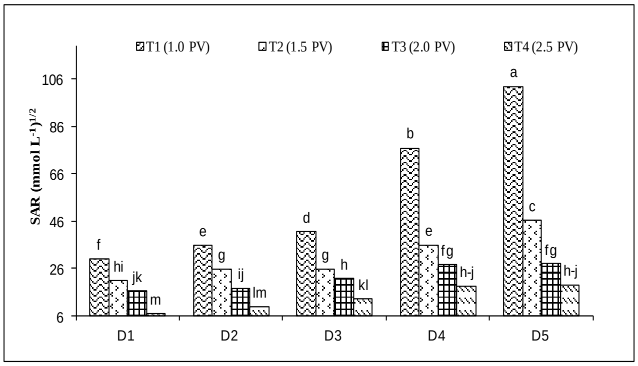

Figure 12. Effect of treatments on SAR of soil at different depths. D_1: 0-5 cm; D_2: 5-10 cm; D_3: 10-15 cm; D_4: 15-20 cm; D_5: 20-25 cm

Leaching of salts: The data on fractions of salts moved out of different soil layers with different degree of leaching are presented in Figs. 13, 14, 15. Mean fraction of salts removed from soils, treatment, soil depths and their interactions were significant in decreasing order as: Soil (SCL > SiCL > LS), treatments ($T_4 > T_3 > T_2 > T_1$) and soil depths ($D_1 > D_2 > D_3 > D_4 > D_5$). The fraction of salts removed was the highest with S_3T_4 and the lowest with S_1T_1. It was the highest for S_3D_1 (0.93) and the lowest for S_1D_5. The highest salt fractions removed was recorded for T_4D_1 (0.89) and the lowest with T_1D_5. In LS with 1.0 PV (0.94 cm), fraction of salts removed ranged from 0.64 to 0.13 at 0-25 cm soil layer with average of 0.43. For SiCL with 1.0 PV (1.09 cm), removal ranged from 0.72 to 0.39 at 0-25 cm soil layer with an average of 0.58. In SCL 1.0 PV (1.06 cm), removal ranged from 0.90 to 0.69 in 0-25 cm soil layer with an average of 0.82.

Over all, it may be concluded that mean fraction of salts removed from 0-25 cm soil column by leaching with 2.0 PV (1.88 cm) water to decrease EC_e to < 4 dS m^{-1} was 0.67 in LS, 0.94 in SCL with application of 2.5 PV (2.67 cm), while in SiCL it was 0.83 but it does not decreased EC_e below 4.0 dS m^{-1}.

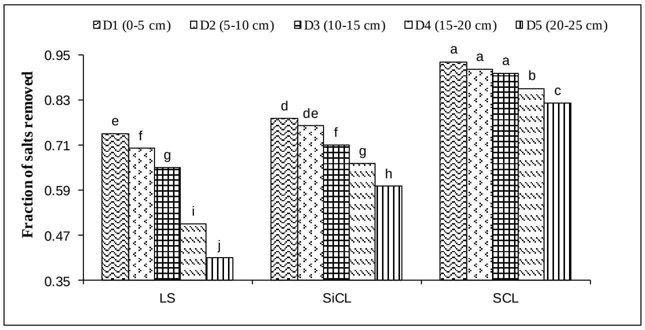

Figure 13. Fraction of salts removed at different depths in soils. LS: Loamy sand; SiCl: Silty clay loam; SCL: Sandy clay loam

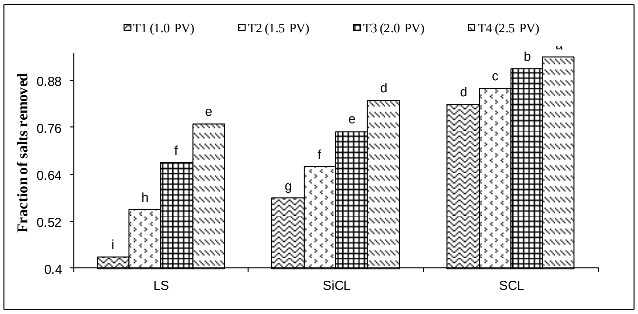

Figure 14. Effect of treatments on fraction of salts removed in different soils. LS: Loamy sand; SiCl: Silty clay loam; SCL: Sandy clay loam

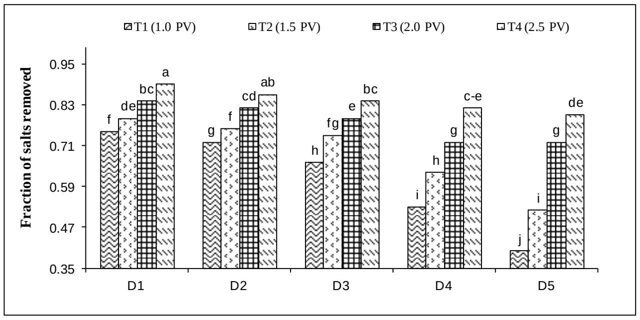

Figure 15. Effect of treatments on fraction of salts removed at different depths. D_1: 0-5 cm; D_2: 5-10 cm; D_3: 10-15 cm; D_4: 15-20 cm; D_5: 20-25 cm

Relationship between EC/EC_0 and D_w/D_s: The relationship between EC/EC_0 (electrical conductivity of saturation extracts of soils before and after leaching, respectively) and D_w/D_s (depth of water and soil, respectively) with respect to desalinization of 0-25 cm layers for all the three soils were worked out. The relationships observed were as follows:

Soil			
Treatment	LS (S_1)	SiCL (S_2)	SCL (S_3)
T_1 (1.0 PV)	$Y=0.573X^{-3.92}$ r =0.93	$Y=0.414X^{-3.24}$ r=0.78	$Y=0.174X^{-2.02}$ r=0.89
T_2 (1.5 PV)	$Y=0.451X^{-2.99}$ r= 0.94	$Y=0.339X^{-2.36}$ r=0.90	$Y=0.136X^{-1.08}$ r=0.92
T_3 (2.0 PV)	$Y=0.329X^{-2.12}$ r =0.87	$Y=0.247X^{-1.49}$ r=0.96	$Y=0.09X^{-0.05}$ r=0.94
T_4 (2.5 PV)	$Y=0.232X^{-1.29}$ r = 0.98	$Y=0.167X^{-0.60}$ r= 0.89	$Y=0.06X^{-0.78}$ r = 0.98

LS (S_1) = Loamy sand, SiCL (S_2) = Silty clay loam and SCL (S_3) = Sandy clay loam

$Y = EC/EC_0$ and $X = D_w/D_s$

These relationships suggest that in LS with application of 1PV, 1.5PV, 2.0PV and 2.5PV, the decrease in EC_e of 0-25 cm soil column was 43%, 55%, 67% and 77%, respectively. For SiCL, application of 1PV, 1.5PV, 2.0PV and 2.5PV, the decrease in EC_e of 0-25 cm soil column was 58%, 66%, 75% and 83%, respectively. For SCL, application of 1PV, 1.5PV, 2.0PV and 2.5PV, the decrease in EC_e in 0-25 cm soil was 82%, 86%, 91% and 94%, respectively. Similar equations have been developed by different workers (Singh and Kundu, 2000; Kuligod *et al*., 2002) for leaching of salts.

Conclusions: The highest amount of salts was removed from SCL soil (677 kg ha^{-1}) with LF = 0.59 with the application of four PV water. The decreasing order of treatments for salt removal was $T_3 > T_2 > T_4 > T_1$ with LF = 0.69, 0.64, 0.61, 0.60, respectively. It was concluded that salt removal was highest in initial leachates and decreased progressively with time for all the soil and treatments. It was found that leaching of soluble slats does occur with simple addition of water of any quality in different textured saline-sodic soils but could convert these into sodic soils. The relationship between PV of water applied and amount of salts leached from soil columns indicated that leaching had a positive effect on amount of salts leached. The equations established were as $EC/EC_0 = 0.329\ (D_w/D_s)^{-2.12}$ with r= 0.90 for loamy sand; $EC/EC_0 = 0.167\ (D_w/D_s)^{-0.60}$ with r=0.93 for silty clay loam and $EC/EC_0 = 0.06\ (D_w/D_s)^{0.78}$, r=0.98 for sandy clay loam soil. These relationships suggest decrease in EC of LS, SiCL and SCL soils was 67, 83 and 94 percent when leached with 1.88, 2.72 and 2.67 cm of water, respectively. These equations could be modified in accordance with specific soil texture for determining leaching requirement of soils to grow a given crop provided its salt tolerance limit and effective rooting depth are pre-decided. It is suggested, that without application of amendments, reclamation of saline-sodic soils is slow. Hence the economical and cost-effective reclamation need an external source of Ca^{2+}.

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