Reclamative response of various texture salt-affected soils for salt leaching getting good quality canal water

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Abstract

A lysimeter experiment was conducted to compare the leaching behavior of varying texture salt-affected soils for salt leaching when irrigated with diverse volumes of good quality water. Lysimeters consisted of PVC (polyvinyl chloride) columns with length of 50 centimeter and diameter of about 11 centimeter. Each lysimeter was filled with 3.0 kg of processed soil. Four treatments of pore volume (T_1 = 1.0, T_2 = 1.5, T_3 = 2.0 and T_4 = 2.5) with canal water. The results revealed that leachate volume increased with increasing pore volume and it decreased significantly with time. More volume was collected from silt loam soil than that from loam soil. The quantity of salts removed in initial leachates was higher which exhibited decreasing trend consecutively within all the treatments from both soils. Maximum salt leaching was noted with 2.0 PV. Soil texture significantly affected the removal of carbonates and more carbonates passed through loam than those from silt loam soil. The leaching pattern of bicarbonates was similar as that of carbonates. The effect of treatments on the removal of Ca^{2+} + Mg^{2+} in leachates was statistically non-significant. Soil texture differed significantly for the removal of Ca^{2+} + Mg^{2+} and more Ca^{2+} + Mg^{2+} leached from silt loam than that from loam soil. The SAR of third leachate was significantly higher than leachates 1,2, and 4. Effect of soil texture was statistically significant and maximum SAR was recorded in leachates from loam compared to that from silt loam soil. Data regarding post soil analysis showed that both the soils responded significantly for the reduction in TSS after leaching of 4 PV of water. The behaviour of both soil textures was different as in loam soil, CO_3^{2-} concentration decreased whereas it increased in silt loam soil during the study period.

After leaching of 4 PV, the soil response for SAR was statistically significant, being maximum for silt loam as compared to loam soil.

Keywords: Reclamation, soil texture, salt leaching, pore volume.

1. Introduction

In Pakistan, about 16 mha is irrigated through canal and tube well water out of 21.87 mha cultivated area. About 25 percent and 38 percent of the irrigated area have been badly affected by different degrees of salinity and sodicity respectively (Maqsood and Qamar, 2004). Out of total salt- affected soils, 2.11 mha are in Sindh, 2.67 mha in the Punjab, 1.35 mha in Balochistan and 0.05 mha in Khyber Pakhtun Khah (Anon, 2004; Ansari *et al*., 2007). Major part of Pakistan's soils are dominantly loamy/ clayey (slit loam, silty clay, clay loam, silty clay loam) followed by sandy and sandy loam soils (Rafiq, 2001). Arid as well as semi-arid conditions, the rainfall is not enough for leaching salts beyond root zone, leading to their accumulation in soil profile with sodium being dominant cation after the precipitation of Calcium and magnesium.By affecting the distribution and removal of soluble salts from soil profiles and preventing their accumulation in the root zone, leaching of soluble salts from the root zone is crucial to maintaining irrigated soil productivity.

Salts leaching reported by various scientists, ranged from 0.30 centimeter to 4.43 centimeter of water per centimeter depth of soil and it varies with the types (texture) of soil (Singh and Kundu, 2000; Kuligod *et al*., 2002; Mostafazadeh-Fard *et al*., 2008). Therefore, it is essential to identify the response of soils (salt-affected) of varying textured for salt leaching of applying different quantities of irrigation to find out the best combination of soil texture as well as the volume of water to be used (LR) in order to control accumulation of salt in dry regions.

2. Materials and Methods

2.1. Soil of Experimental Site

The experiment was carried out in D.G.Khan. For this study, samples of three dissimilar textures (loam, silt loam and clay loam) were collected from 0-15 cm depth of soil of canal irrigated farmer fields in the district D.G.Khan. These fields were already salt-affected over time. The samples were processed as per standard protocol for further analysis.

2.2. Preparation of Soil Columns

Polyvinyl chloride Lysimeters with 50 centimeter length and 11 centimeter diameter were used. The Covered the lower ending of lysimeter with wire gauze and strongly bandaged with the thread and rubber band and after that placed vertically on iron stands. About 1.00 centimeter coating of wool was placed on the wire gauze and A layer of 2.0 cm of sand was spread on it to check the movement of fine particles into leachate. Plastic bottles fixed with funnels, were placed beneath the lysimeters for receiving the leachates. Filled each lysimeter was with 3.0 kilogram soil. The soil was poured into lysimeter with funnel in order to avoid the sorting of particles of soil during the soil fall from top to bottom of lysimeters.

2.3. Treatments

For this experiment, 36 soil columns in PVC pipe lysimeter were prepared, i.e. 4 treatment for all soil texture with three repeats in Completely Randomized Design (CRD). The treatments were:

T1= 1.0 PV
T2= 1.5 PV
T3= 2.0 PV
T4= 2.5 PV

Saturated the lysimeters were with water of canal with saturation paste (75%), and allowed for 3 weeks for equilibrate for with recycling the leachate, if any.

2.4. Leaching from soil columns

Subsequent to the preparation of soil columns, started leaching by adding canal water (EC = 0.32 dSm^{-1}, SAR = 1.78) at the surface of the soil and maintained 5 centimeter water head during the period of leaching. Every the soil column was leached in the same way and at same interval of time. Collect Four leachates throughout the experimental period and each leachate was collected in separate plastic bottle mounted below the lysimeter.

2.5. Soil sampling and analysis

Soil sample were taken in lysimeters, and analyzed for physic-chemical properties of the soil (Table 1) prior to the treatments. The particle size was measured by using Bouyoucos method of Hydrometer (Bouyoucos, 1962). Determination of pH_s, EC_e and soluble ions (Ca^{++}, Mg^{++}, Na^+, K^+, CO_3^{--}, HCO_3^-, and Cl^-), CEC, organic matter and lime contents was done adopting of U.S. Salinity Lab. Staff (1954). Calculated the volume of Pore through bulk density and saturation percentage (Jury *et* *al.*, 1991). The leachates were collected after infiltrating each pore volume and were analyzed for EC, soluble Ca^{++}, Mg^{++}, Na^{+}, K^{+}, CO_3^{--}, HCO_3^{-}, and Cl^{-} ions. Soils were analyzed again for pH_s, EC_e and soluble ions (Ca^{2+}, Mg^{2+}, Na^{+}, K^{+}, CO_3^{2-}, HCO_3^{-}, and Cl^{-}) after the termination of experiment. The data was analyzed statistically following complete randomized design and LSD test (Steel and Torrie, 1997) was applied to differentiate the effectiveness of treatments.

Table 1. Physico-chemical Properties of soil before experiment

Characteristics	**Unit**	**Value**		
		Soil 1	**Soil 2**	**Soil 3**
Sand	%	36	23	29
Silt	%	45	46	53
Clay	%	16	31	18
Textural class	-	Loam	Clay loam	Silt loam
Saturation percentage		29.09	29.91	29.23
pH_s	-	7.77	8.25	7.65
EC_e	dS m^{-1}	10.82	23.28	4.67
Saturation Extract Analysis				
Ca^{2+}+ Mg^{2+}	$mmol_c$ L^{-1}	17.8	14.0	4.4
Na^{+}	″	102.92	190.14	50.31
K^{+}	″	0.08	0.10	0.08
CO_3^{2-}	″	1.2	1.0	0.4
HCO_3^{-}	″	5.8	7.2	4.4
Cl^{-}	″	21	87	22
SO_4 (By difference)	″	102	114.8	28.2
SAR	$(mmol\ L^{-1})^{1/2}$	34.49	71.87	33.92
Exchangeable cations				
Na^{+}	$cmol_c$ kg^{-1}	4.00	5.35	4.55
K^{+}	″	0.30	0.55	0.34
Ca^{2+}+ Mg^{2+} (By difference)	″	1.18	0.5	0.86
CEC	″	5.48	6.4	5.75
Exchangeable Sodium	%	33.05	51.16	32.78
Organic matter	″	0.79	0.59	0.82
Lime	″	10.5	13	8
Pore volume of columns	mL	874	919	884

3. Results and Discussion

Results regarding two soils (silt loam and loam) were presented as only two PV water could infiltrate through the third soil (clay loam) and later leaching practically stopped.

3.1. Leachate volume

The leachate volume is an important feature for salts movement inside and outside of soils, i.e. in general the infiltration of more water through soils will have to transport much more salts. The leachate volume (Table 2) increased with increase in the water volume. There was a decrease in leachate volume as the experiment progressed. This is because of more elimination of soluble salts than the adsorbed sodium (Na^+) which resulted in deflocculation of soils (Ghafoor and Salam, 1993; Kahlon *et al*., 2013). Leachate volume differed significantly between different textures of soils. More volume was collected from silt loam soil in contrast to loam soil partially because of more PV of silt loam than the loam soil which was 874 and 884 mL, respectively. More volume from silt loam than that from loam soil indicates perhaps higher clay contents of the former soil which resulted decrease in the infiltration of water as a result of clay dispersion (Ghafoor *et al*., 2001).

Table 2. Volume of leachates (mL) collected from silt loam and loam soils during studies

Treatment	L_1		L_2		L_3		L_4		Treatment mean
	S_1	S_2	S_1	S_2	S_1	S_2	S_1	S_2	
T_1	598.3 ij	676.7 hj	621.7 ij	698.33 gi	415.0 j	645.0 ij	563.3 ij	620.0 ij	604.8 D
T_2	645.0 ij	1070.3 ce	615.0 ij	1023.3 cf	666.7 ij	940.0 eh	775.0 fi	946.7 eg	835.3 C
T_3	1063.3 ce	1255.0 ac	1126.7 be	1340.0 ab	1010.0 cf	1260.0 ac	943.3 eg	1242.3 ad	1155.0 B
T_4	1146.7 be	1473.3 a	1151.7 be	1506.7 a	1176.7 be	1391.7 ab	976.7 df	1476.7 a	1287.5 A
L × S mean	863.3 A	1118. 8 A	878.8 B	1142.1 A	817.08 B	1059.17 A	814.6 B	1071.4 A	
leachate mean	991.08		1010.42		938.13		943.00		
soil mean	843.44 (S_1)		1097.88 (S_2)						

T×L	T_1L_1	T_1L_2	T_1L_3	T_1L_4	T_2L_1	T_2L_2	T_2L_3	T_2L_4	T_3L_1	T_3L_2	T_3L_3	T_3L_4	T_4L1	T_4L_2	T_4L_3	T_4L_4
Mean T×L	637.5 ef	660.0 ef	530.0 f	591.7 f	857.7 d	819.2 de	803.3 de	860.8 d	1159.2 ac	1233.3 ac	1135.0 bc	1092.8 c	1310.0 ab	1329.2 a	1284.2 ab	226.7 ac

Values sharing the same letter in mean columns or rows are statistically similar at P= 5%.

L = Leachate; S_1 = Loam; S_2 = Silt loam.

SE: Treatments = 33.3065^{**}; Soils = 23.5513^{**}; Leachates = 33.3065^{NS}; L × S= 47.1025^{NS}; S × T= 47.1025^{NS}; L × T= 66.6130^{NS} S × T × L = 94.205^{NS}.

* = Significant, ** = Highly Significant, NS = Non-significant.

3.2. Leaching of Total soluble salts

The salts quantity removed in initial leachates was higher (Table 3) which exhibited decreasing trend successively in alI treatments from both the soils. The treatments differed significantly for the removal of salts from soils. However, maximum salt leaching was observed with T_4 followed by T_3, T_2 and T_1. The difference among treatments for removing salts appear due to higher water potential being helpful for dissolving and carrying salts downward. Our findings are in line with the findings of Ghafoor *et al*. (1989) and Singh (1996). The impact of soil texture was statistically non-significant for the removal of salts, however, more salts leached from loam than those from silt loam soil owing to higher EC_e of the former than that of the later soil (Table 1). Leachate also differed significantly for the removal of salts. Maximum salts were removed in L_4 (80.88%) followed by L_3 (70.24%), L_2 (53.94%) and L_1 (48.96%) in loam soil while in case of silt loam soil maximum salts were removed with L_4 (83.10%) followed by L_3 (81.42%), L_1 (73.97%) and L_2 (71.19%). It might be due to reduction of total soluble salts in soils with the passage of time. Similar results were reported by Ali *et al*. (1994), resulted more salts leaching throughout the first two leachates than with the following leachates. The salt removal from soil due to water is natural phenomina and depends on the quantity of salts existing in soil. High initial electrical conductivity of soils alongwith sluggish water flow due to comparatively higher SAR resulted more salts exclusion in the initial leachates (Ghafoor *et al*., 1998).

Table 3. Total Soluble Salts (mmol$_c$ L^{-1}) removed in leachates for silt loam and loam soils during studies

Treatment	L_1		L_2		L_3		L_4		Treat. mean
	S_1	S_2	S_1	S_2	S_1	S_2	S_1	S_2	
T_1	51.56 eg	41.48 fh	52.88 ef	36.24 hk	28.27 hm	26.84 im	29.17 hm	21.46 m	35.99 C
T_2	58.80 ce	57.33 de	53.24 ef	58.94 ce	35.07 hm	38.74 gj	22.22 lm	26.19 jm	43.82 B
T_3	83.42 a	62.96 be	74.17 ab	70.11 ad	55.38 e	40.05 fi	23.78 km	35.62 hl	55.69 A
T_4	71.63 ac	56.91 de	59.19 ce	76.73 a	36.06 hk	50.40 eg	24.27 km	58.74 ce	54.24 A
L × S Mean	66.35 A	54.67 B	59.87 AB	60.50 AB	38.69 C	39.01 C	24.86 D	35.50 C	
Leachate mean	60.51 A		60.19 A		38.85 B		30.18 C		
Soil mean	47.44 (S_1)		47.41(S_2)						

T×L	T_1L_1	T_1L_2	T_1L_3	T_1L_4	T_2L_1	T_2L_2	T_2L_3	T_2L_4	T_3L_1	T_3L_2	T_3L_3	T_3L_4	T_4L1	T_4L_2	T_4L_3	T_4L_4
Mean T×L	46.52 ce	44.56 de	27.56 fg	25.32 g	58.07 b	56.09 bc	36.90 ef	24.20 g	73.19 a	72.14 a	47.72 cd	29.70 fg	64.27 ab	67.96 a	43.23 de	41.50 de

Values sharing same letter (s) in mean columns or rows are statistically similar at P = 5%.

L = Leachate, S_1 = Loam, S_2 = Silt loam

SE: Treatments = 1.7184**; Soils = 1.2151^{NS}; Leachates = 1.7184**; L × S= 2.4301*; S × T=2.4301**; L × T=3.4367*; S × T × L = 860*

* = Significant, ** = Highly Significant, NS = Non-significant

3.2.1. Leaching of carbonates (CO_3^{2-})

The effect of treatments on the removal of carbonates in leachates was statistically significant (Table 4). The leaching of carbonates was higher in leachates with T_4 followed by T_3, T_2 and T_1 for both the soils. The carbonates removal was directly proportional to the volume of water which wasapplied as with an increase in pore volume of applied water, carbonate removal also increased. Significantly the highest amount of carbonates leached from soils with L_3 followed by L_4, L_2 and L_1. Soil texture affected significantly the removal of carbonates and significantly more carbonates passed through loam than those from silt loam soil. The slow rate of carbonate displacement from fine textured soil (silt loam) may be caused by the more efficient leaching through mixing of the water applied with the soil before its displacement (Das, 1995). In general, about 70% or more soluble salts that are initially present in medium textured salt-affected soil, which can be removed with a water depth which is equivalent soil depth to be reclaimed when continuously water is ponded on the surface of soil (Hoffman, 1986).

Table 4. CO_3^{2-} concentration (mmol$_c$ L^{-1}) removed in leachates for silt loam and loam soils during studies

Treatment	L_1		L_2		L_3		L_4		Treat. mean
	S_1	S_2	S_1	S_2	S_1	S_2	S_1	S_2	
T_1	0.71 no	0.54 o	1.25 io	0.51 hn	2.47 cf	1.04 ko	2.92 bd	1.63 gm	1.38 B
T_2	0.81 mo	1.21 jo	1.63 gm	0.88 lo	2.67 ce	2.16 dh	2.07 ei	2.46 cg	1.74 A
T_3	2.18 dh	1.26 io	2.15 dh	1.17 jo	4.40 a	1.77 fk	0.79 no	1.90 ej	1.95 A
T_4	1.64 fm	1.51 hn	1.70 fl	1.51 hn	3.63 ab	3.08 bc	0.52 o	2.05 ei	1.96 A
L × S Mean	1.34 CD	1.13 D	1.68 BC	1.02 D	3.29 A	2.01 B	1.57 C	2.01 B	
Leachate mean	1.23 C		1.35 C		2.65 A		1.79 B		
Soil mean	1.97 (S_1)		1.54(S_2)						

T×L	T_1L_1	T_1L_2	T_1L_3	T_1L_4	T_2L_1	T_2L_2	T_2L_3	T_2L_4	T_3L_1	T_3L_2	T_3L_3	T_3L_4	T_4L1	T_4L_2	T_4L_3	T_4L_4
Mean T×L	0.622 g	0.877 fg	1.755 cd	2.273 bc	1.010 eg	1.255 df	2.418 b	2.267 bc	1.717 cd	1.662 d	3.082 a	1.342 df	1.575 de	1.603 d	3.355 a	1.287 df

Values sharing same letter (s) in mean columns or rows are statistically similar at P = 5%.

L = Leachate; S_1 = Loam; S_2 = Silt loam.

SE: Treatment= 0.1042*; Soil= 0.0737*; Leachate= 0.1042**; L × S=-0.1474**; S × T= 0.1474*; L × T= 0.2085**; S×L×T = 0.2948*.

* = Significant, ** = Highly Significant, NS = Non-significant

3.2.2. Leaching of Bicarbonates (HCO_3^-)

The amount of bicarbonates in leachates as affected by pore volumes of applied water (Table 5) revealed that removal of HCO_3^- from both soils with all the treatments remained statistically different, being highest with T_4 which is followed by T_3, T_2 and T_1. The leaching pattern of bicarbonates was similar as that of carbonates. There was no significant difference between the two soils. However, bicarbonates leaching was more from loam than that from silt loam soil. The bicarbonates removal was significantly higher in L_4 followed by L_3, L_1 and L_2 from both the soils. The interactions of soils and leachate with treatments were statistically similar. However, maximum concentration of bicarbonates was recorded in leachate for T_4L_1 and was minimum for T_1L_3 combination. The interaction of soils with leachates was statistically significant and maximum bicarbonate leached with L_4S_1 and minimum with L_2S_2 combination. In terms of pore volume, 1.5-2.0 PV of water passing through soil caused a decrease in salt concentration by more than 70%. These results are in conformity with those presented by Rhoades and Loveday (1990).

3.2.3. Leaching of Ca^{2+}+Mg^{2+}

The effect of treatments on the removal of Ca^{2+} + Mg^{2+} in leachates was statistically non-significant (Table 6). However, the highest amount of Ca^{2+} + Mg^{2+} leached with T_3 followed by T_4, T_2 and T_1. Soil texture differed significantly for the removal of Ca^{2+} + Mg^{2+} and significantly more Ca^{2+} + Mg^{2+} leached from silt loam than that from loam soil. It appears because of lower SAR of silt loam compared to that of loam soil due to which little Ca^{2+} was consumed in Na^+- Ca^{2+} exchange to maintain a steady equilibrium between the Ca^{2+} + Mg^{2+} on exchange site and in soil solution consequently more removal of Ca^{2+} + Mg^{2+} from silt loam than that from loam soil occurred. Similar results were reported by Ghafoor and Salam(1993). The interactive effect of leachates with soil was significant. Maximum amount of Ca^{2+} + Mg^{2+} leached with L_2S_2 while was minimum for L_4S_1 combination. The interaction of treatment and leachate was non-significant. Similarly interaction effect of leachate with treatment was also non-significant. However, maximum removal of Ca^{2+} + Mg^{2+}

was recorded with T_3L_2 and it was minimum with T_1L_4 combination. The effect of interaction soil × treatments × leachates remained significant for leaching Ca^{2+} + Mg^{2+}, being maximum for $S_2T_3L_2$ and was minimum for $S_1T_1L_4$ combination. It was concluded that concentration of Ca^{2+} + Mg^{2+} was more in the first two leachates and then gradually decreased with time. These Findings are parallel to those presented by Ali et al. (1994). In the earlier leachates, Ca^{2+} + Mg^{2+} could not affect complete Na^+ desorption since Na^+ ions in soil solution and that are p[resent in exchange complex has to remain in equilibrium and owing to high Na^+ in these saline-sodic soil solutions, considerable amount of Na^+ has to remain adsorbed causing Ca^{2+} + Mg^{2+} leaching higher in earlier leachates. It can be concluded that lower Ca^{2+} ions in irrigation water or in the soil solution will improve the Na^+- Ca^{2+} exchange efficiency, however, longer time will be required to achieve the desired level of reclamation of saline-sodic and sodic soils.

Table 5. Removal of HCO_3^- (mmol$_c$ L^{-1}) in leachates from loam and silt loam soils

Treatment	L_1		L_2		L_3		L_4		Treat. mean
	S_1	S_2	S_1	S_2	S_1	S_2	S_1	S_2	
T_1	5.25 gk	4.48 ik	3.51 k	4.34 jk	5.89 fk	7.18 dk	8.99 bj	6.56 ek	5.78 C
T_2	4.28 jk	7.65 ck	4.04 jk	4.67 hk	9.74 ag	8.75 bj	12.23 ac	9.53 ah	7.61 B
T_3	8.74 bj	9.43 ai	11.83 ad	6.67 ek	11.70 ad	10.63 af	12.17 ac	8.03 ck	9.90 A
T_4	7.16 dk	10.98 ae	14.09 a	8.53 bj	10.10 ag	13.44 ab	10.14 ag	9.90 ag	10.54 A
L × S Mean	6.36 c	8.14 bc	8.37 bc	6.05 c	9.36 ab	10.00 ab	10.88 a	8.51 ac	
Leachate mean	7.25 B		7.21 B		9.68 A		9.70 A		
Soil mean	8.74 (S_1)		8.17 (S_2)						

T×L	T_1L_1	T_1L_2	T_1L_3	T_1L_4	T_2L_1	T_2L_2	T_2L_3	T_2L_4	T_3L_1	T_3L_2	T_3L_3	T_3L_4	T_4L1	T_4L_2	T_4L_3	T_4L_4
Mean T×L	4.87 ef	3.93 f	6.54 cf	7.78 be	5.97 df	4.36 ef	9.24 ad	10.88 ab	9.09 ad	9.25 ad	11.16 ab	10.10 ab	9.07 ad	11.31 a	11.78 a	10.02 ac

Values sharing same letter (s) in mean columns or rows are statistically similar at P = 5%.

L = Leachate; S_1 = Loam; S_2 = Silt loam.

SE: Soil= 0.4396^{NS}; Treatment= 0.6217^{**}; Leachate=0.6217^{*}; L × S= 0.8793^{*}; S × T= 0.8793^{NS}; L × T= 1.2435^{NS}; S×T×L=1.7585

* = Significant, ** = Highly Significant, NS = Non-significant

SAR of soil

SAR of leachates as affected by different pore volumes of applied water showed (Table 7) that treatment effect was significant for both the soils. The SAR of leachates was highest in T_3 which was followed by in T_4, T_2 and T_1. Similar pattern of SAR was reported by Murtaza *et al* (1998) while studying of medium textur saline-sodic soils reclamation. The SAR of third leachate was significantly higher than that of L_4, L_2 or L_1. Effect of soil texture was statistical and maximum SAR was recorded in leachates from loam compared to that from silt loam soil. Ghafoor *et al*. (2001) reported that decrease in EC_e and SAR of fine textured soil (loamy clay) was lower than that of coarse textured soil (clay loam). The interactive effects of soil with leachate and treatment with leachate remained non-significant. The interaction of soil and treatment statistically affected the SAR and highest the SAR was recorded with T_3S_1 while it was the lowest with T_1S_2 combination.

Table 6. Removal of $Ca^{2+} + Mg^{2+}$ ($mmol_c L^{-1}$) in leachates from loam and silt loam soils

Treatment	L_1		L_2		L_3		L_4		Treat. mean
	S_1	S_2	S_1	S_2	S_1	S_2	S_1	S_2	
T_1	4.10 bd	5.52 b	3.84 cd	3.87 cd	0.96 g	1.51 eg	0.67 g	0.73 g	2.65
T_2	4.77 bc	3.53 cd	3.75 cd	5.62 b	1.01 g	1.49 eg	0.69 g	1.13 g	2.75
T_3	4.93 bc	3.75 cd	2.99 df	7.29 a	1.26 g	1.17 g	0.87 g	1.38 g	2.96
T_4	4.98 bc	4.71 bc	3.02 de	5.61b	1.15 g	1.39 fg	0.71 g	1.60 eg	2.90
L × S Mean	4.69 B	4.38 B	3.40 C	5.60 A	1.10 D	1.39 D	0.73 D	1.21 D	
Leachate mean	4.53 A		4.50 A		1.24 B		0.98 B		
Soil mean	2.48 (S_1)		3.15 (S_2)						

T×L	T_1L_1	T_1L_2	T_1L_3	T_1L_4	T_2L_1	T_2L_2	T_2L_3	T_2L_4	T_3L_1	T_3L_2	T_3L_3	T_3L_4	T_4L1	T_4L_2	T_4L_3	T_4L_4
Mean T×L	4.81 ab	3.86 b	1.24 c	0.70 c	4.15 ab	4.69 ab	1.25 c	0.91 c	4.33 ab	5.14 a	1.21 c	1.12 c	4.84 ab	4.31 ab	1.27 c	1.16 c

Values sharing same letter (s) in mean columns or rows are statistically similar at P = 5%.

L = Leachate; S_1 = Loam; S_2 = Silt loam.

SE: Treatment= 0.2015^{NS}; Soil= 0.1425^{*}; Leachate= 0.2015^{**}; L × S= 0.2849^{*}; S × T = 0.2849^{NS}; L × T = 0.4030^{NS}; S×T×L= 10.5699^{*}.

* = Significant, ** = Highly Significant, NS = Non-significant

Table 7. Sodium Adsorption Ratio of leachates

Treatment	L_1		L_2		L_3		L_4		Treat. mean
	S_1	S_2	S_1	S_2	S_1	S_2	S_1	S_2	
T_1	33.78 di	21.55 i	34.14 di	23.06 hi	44.31 cg	29.49 gi	50.48 bd	33.28 di	33.76 B
T_2	33.58 di	39.76 ch	36.55 di	31.96 ei	46.33 bg	41.57 cg	43.02 cg	32.99 di	38.22 B
T_3	49.75 be	41.40 cg	57.40 ac	31.37 fi	74.30 a	49.11 bf	41.33 cg	41.28 cg	48.24 A
T_4	41.83 cg	33.44 di	45.66 bg	40.99 ch	41.21 cg	57.69 ac	38.83 di	62.66 ab	45.29 A
L × S Mean	39.74 BD	34.04 CD	43.44 AB	31.84 D	51.54 A	44.46 AB	43.42 AB	42.56 AC	
Leachate mean	36.88 B		37.64 B		48.00 A		42.99 AB		
Soil mean	44.53 (S_1)		38.23 (S_2)						

T×L	T_1L_1	T_1L_2	T_1L_3	T_1L_4	T_2L_1	T_2L_2	T_2L_3	T_2L_4	T_3L_1	T_3L_2	T_3L_3	T_3L_4	T_4L1	T_4L_2	T_4L_3	T_4L_4
Mean T×L	27.67 f	28.60 ef	36.90 cf	41.88 bd	36.67 df	34.26 df	43.95 bd	38.01 bf	45.58 bd	44.38 bd	61.71 a	41.31 be	37.64 cf	43.33 bd	49.45 ac	50.75 ab

Values sharing same letter (s) in mean columns or rows are statistically similar at P = 5%.

L = Leachate; S_1 = Loam; S_2 = Silt loam.

SE: Treatment= 2.2546*; Soil= 1.5943*; Leachate= 2.2546*; L × S= 3.1885^{NS}; S × T= 3.1885*; L × T= 4.5093^{NS}; S×T×L=6.3771^{NS}.

* = Significant, ** = Highly Significant, NS = Non-significant

Soil Reclamation

Soil Salinity (TSS)

Soil analysis performed after the termination of experiment showed (Table 8) that both the soils responded significantly for the reduction of TSS after leaching of 4 PV of water. The decrease in TSS was more in loam soil (83.52%) than that of silt loam soil (54.76%).There was non-significant differences among treatments in reducing the TSS of soils, however, reduction was more with T_2 (75.71%) and T_4 (75.38%) compared to that with T_1 (73%) and T_3 (71.64%). There was more leaching of salts and hence more reduction in TSS was observed from coarse textured soil (loam) than that of fine textured soil (silt loam). Singh and Kundu (2000) also reported more leaching of salts from coarse textured soil and resultantly their more amelioration.

Table 8. The TSS ($mmol_cL^{-1}$) of the soils after the termination of experiment

Soil	Treatment				
	T1	T2	T3	T4	Soil mean
S_1	22.39	22.44	21.62	19.24	21.42 B
S_2	30.26	24.91	33.67	28.77	29.40 A
Treatment mean	26.33	23.68	27.65	24.01	

Values sharing same letter (s) in mean columns or rows are statistically similar at P = 5%.

S_1 = Loam, S_2 = Silt loam

SE: Treatment = 2.1022^{NS}, Soil = 1.4865^{*}, S × T= 2.9730^{NS}

* = Significant, ** = Highly Significant, NS = Non-significant

After the infiltration of four pore volumes of leaching water through loam and silt loam soils, ECe reduced to less than 4 dS m^{-1} (40 mmolc L^{-1}) which is regard as as the critical limit for saline soils (US Salinity Lab. Staff, 1954).

Carbonates (CO_3^{2-}) in Soils

The effect of treatments on CO_3^{2-} contents of soil remained statistically similar (Table 9). However, all the treatments resulted in low concentration of CO_3^{2-} in loam soil but in silt loam soil, CO_3^{2-} concentration increased with all the treatments. Soil texture did not differ significantly but the behaviour of both the textures was different as in loam soil, CO_3^{2-} concentration decreased whereas in case of silt loam soil, it increased during the study period. The interactive effect of soils with treatments was also non-significant, however, maximum concentration was observed in S_1T_3 and was minimum with S_1T_4 combination.

Table 9. CO_3^{2-} ($mmol_cL^{-1}$) of soil after the termination of experiment

Soil	Treatment				
	T1	T2	T3	T4	Soil mean
S_1	0.61 AB	0.54 B	0.47 B	0.66 AB	0.58
S_2	0.87 A	0.61 AB	0.67 AB	0.50 B	0.66
Treatment mean	0.73	0.57	0.57	0.58	

Values sharing same letter (s) in mean columns or rows are statistically similar at P = 5%.

S_1 = Loam, S_2 = Silt loam

SE: Treatment = 0.0702^{NS}, Soil = 0.0497^{NS}, S × T= 0.0993^{NS}

* = Significant, ** = Highly Significant, NS = Non-significant

Bicarbonates (HCO_3^-) in Soils

The data regarding the HCO_3^- contents in soil is given in table 10. The impacts of different treatments on HCO_3^- contents of soils was statistically non-significant. An increase in HCO_3^- contents of soils was observed with all the treatments during the study perhaps through the dissolution of native lime leading to formation of $CaHCO_3^+$ ion pairs. In case of loam soil, maximum increase was exhibited with T_4 that was follow by T_1, T_2 and T_3 whereas in case of silt loam soil, maximum increase in HCO_3^- concentration was noted in T_1 that was followed by T_4, T_2 & T_3. Soil texture behaviour was similar for increasing the HCO_3^- concentration but there was non-significant difference between the two soils. However, increase in HCO_3^- concentration was less in loam than that in silt loam soil.

Table 10. HCO_3^- ($mmol_cL^{-1}$) of the soil after the termination of experiment

Soil	Treatment				
	T1	T2	T3	T4	Soil mean
S_1	6.33	6.20	6.07	7.27	6.47
S_2	9.33	6.90	6.93	7.20	7.59
Treatment mean	7.83	6.55	6.50	7.23	

Values sharing same letter (s) in mean columns or rows are statistically similar at P = 5%

S_1 = Loam, S_2 = Silt loam

SE: Treatment = 0.7772^{NS}, Soil = 0.5496^{NS}, S × T= 1.0992^{NS}

* = Significant, ** = Highly Significant, NS = Non-significant

This increase might be due to differences in initial lime contents which were high in loam than that in silt loam soil. These differences could also be due to differential leaching of HCO_3^- from soils, i.e. more HCO_3^- leached from loam than that from silt loam soil. The interactive effect of soils with treatments was non-significant during the study period.

Ca^{2+}+Mg^{2+} in Soils

The impact of treatments on the concentration of Ca^{2+}+Mg^{2+} was on statistical basiswas non-significant. However, in all the treatments Ca^{2+}+Mg^{2+} concentration decreased in both the soils compared to their initial contents (Table 11). The Ca^{2+}+Mg^{2+} concentration remained more with T_2 and T_4 than that with T_1 and T_3. The effect of soil texture was statistically non-significant, however, maximum in Ca^{2+}+Mg^{2+} was observed in loam (75.45%) than that of silt loam (31.14%) soil. The interaction between soils and treatments was also non-significant, however, Ca^{2+}+Mg^{2+} concentration was maximum with S_2T_2 and minimum with S_1T_3 combination.

Table 11. Ca^{2+}+Mg^{2+} ($mmol_cL^{-1}$) of soil after the termination of experiment

Soil	Treatment				
	T1	T2	T3	T4	Soil mean
S_1	3.27	4.47	5.33	4.40	4.37
S_2	3.87	1.40 b	4.47	2.40	3.03
Treatment mean	3.57	2.93	4.90	3.40	

Values with same letter in the columns of mean or in the rows are statistically same at P = 5%.

S_1 = Loam, S_2 = Silt loam

SE: Treatment = 0.9254^{NS}, Soil = 0.6544^{NS}, S × T= 1.3087^{NS}

* = Significant, ** = Highly Significant, NS = Non-significant

Na^+ in Soils

The treatments effect over the concentration of Na was statistically non-significant. However, all the treatments decreased the Na concentration in both the soils compared to their initial contents. The reduction in Na concentration remained more with T_4 and T_2 than that of T_3 and T_1 (Table 12). The effect of soil texture was statistically significant and maximum concentration of Na (83.87%)

removed from loam than that of silt loam soil (48.29%), as expected, might be due to coarse texture of loam compared to silt loam soil. The interactive effect of soils with treatments was non-significant, however, reduction in Na concentration was maximum with S_1T_4 while it was minimum with S_2T_2 combination.

Table 12. Na^+ ($mmol_cL^{-1}$) of soil after the termination of experiment

Soil	Treatment				
	T1	T2	T3	T4	Soil mean
S_1	18.77	17.33	15.87	14.43	16.60 B
S_2	26.03	23.27	28.77	26.00	26.02 A
Treatment mean	22.40	20.30	22.32	20.22	

Values sharing same letter (s) in mean columns or rows are statistically similar at P = 5%.
S_1 = Loam, S_2 = Silt loam
SE: Treatment = 1.8260^{NS}, Soil = 1.2912*; S × T= 2.5824^{NS}
* = Significant, ** = Highly Significant, NS = Non-significant

Soil sodicity (SAR)

Sodium adsorption ratio indicates the sodicity danger of soils. For minimizing the Sodium Adsorption Ration (SAR), substitution of exchangeable Na^+ from clay colloids following its removal from soils is necessary. Analysis of soil samples, taken after leaching of 4 PV, indicated that the soil response was statistically significant, SAR being maximum for silt loam compared to that of the loam soil (Table 13). The high SAR of silt loam appear due to higher Na^+ concentration in solution due to high quantity of the adsorbed Na^+ as counter ions in higher CEC silt loam as compared to loam soils. A decrease in SAR of loam soil in overall all the treatments remain more in comparison to silt loam soil due to its little clay content and therefore low CEC. The effect of treatments on soil SAR was non-significant. Nevertheless, decline in SAR was higher with T_4 that was followed by T_3, T_1 and T_2. On Sodium Adsorption Ratio (SAR) basis the decrease in, treatments T_3 & T_4 found better for loam as compared to T_2 and T_1. Treatments T_2, T_3 and T_4 decreased the SAR in loam soil to below 13 being critical level for sodic soils (US Salinity Lab. Staff, 1954). Furthermore, decline in SAR for loam might be because of "valence dilution" as reported earlier by Reeve and Bower (1960) for reclamation of sodic soil. In a soil water system somewhere monovalent

(Na^+) and divalent cations (Ca^{++}, Mg^{++}) are in equilibrium in the solution with the adsorbed cations, the water addition in the system causes alteration in equilibrium condition. Diluting the soil solution favors divalent cations adsorption of Ca^{2+} at the cost of monovalent cations (i.e Na^+). The reverse is factual when the soil solution get concentrated because of evapotranspiration (Eaton and Sokoloff, 1935).

Table 13. The SAR of soil after the termination of experiment

Soil	Treatment				
	T1	T2	T3	T4	Soil mean
S_1	15.58	12.22	9.63	9.91	11.83 B
S_2	21.91	28.07	26.24	24.12	25.08 A
Treatment mean	18.74	20.15	17.93	17.01	

Values sharing same letter (s) in mean columns or rows are statistically similar at P = 5%.
S_1 = Loam, S_2 = Silt loam
SE: Treatment = 2.6463^{NS}; Soil = 1.8712^{*}; S × T= 3.7425^{NS}.
* = Significant, ** = Highly Significant, NS = Non-significant

4. Conclusions

The salts removal was found correlated positively with the volume of applied water and it was higher in initial leachates and reduced increasingly with time. Removal of salts was also dependent on the texture of soil and salt removal was more from loam soil than that from silt loam soil. The carbonate and bicarbonate salts followed the same trend and their removal was more in loam than that of silt loam soil. The slow rate of their displacement from silt loam soil might be caused due to the more efficient leaching through mixing of the water applied with the soil before their displacement. The effect of initial SAR of soil played a significant role in the leaching of $Ca^{2+}+Mg^{2+}$ from the soils. The removal of $Ca^{2+}+Mg^{2+}$ was more in silt loam soil having low initial SAR as little Ca^{2+} was consumed in Na^+- Ca^{2+} exchange to maintain the steady equilibrium between the $Ca^{2+}+Mg^{2+}$ on exchange site and the soil solution. It was also concluded that lower Ca^{++} in irrigation water or soil solution will improve the Na^+- Ca^{2+} exchange efficiency. However, longer time will be required to achieve the desired level of reclamation of saline sodic & sodic soils.

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