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ARTICLE

Effects of Amendment Type and Leaching Requirement on Salinity and Soluble Ions in Different Textured Soils under Tomato Cultivation (*Solanum lycopersicum* L.)

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ABSTRACT

A pot experiment was conducted in 2024 under lath house conditions at the Department of Soil and Water Resources, College of Agriculture, University of Basrah (Karma-Ali site), to investigate the effect of adding soil amendments and different leaching requirements on the salinity of soils with varying textures and the concentrations of selected soluble ions in the soil solution of tomato-planted soils. Two soil textures were used—clay loam (north of Basrah) and sandy loam—along (west of Basrah) with two types of organic amendments (compost and cattle manure) in addition to a control treatment (no amendment). Two levels of leaching requirement (10% and 20% above field capacity) were also applied. The amendments were thoroughly mixed (2% w/w) with the surface layer of the soil before planting tomato seedlings (*Solanum lycopersicum* L.), and soil moisture was maintained at field capacity throughout the experiment. The experiment was conducted using a factorial design with three factors. Standard agronomic practices, including irrigation and fertilization, were carried out according to the treatment design. After 60 days of growth, the plants were harvested, and soil samples were collected to determine electrical conductivity (E.C.) and the concentrations of sodium (Na^+) and chloride (Cl^-) soluble ions in the soil solution. The results showed that the application of organic amendments significantly ($P > 0.05$) reduced soil electrical conductivity at the end of the experiment, from 6.11 and 1.88 dSm^{-1} to 4.18 and 1.66 dSm^{-1} for the clay loam and sandy loam soils, respectively. The reduction was more pronounced with compost compared to cattle manure. Furthermore, the 20% leaching requirement was more effective in reducing soil E.C., reaching a minimum value of 2.63 dSm^{-1}. Sodium and chloride ion concentrations in the soil leaching also decreased with amendment application, with the compost treatment combined with 20% leaching in sandy loam soil achieving the lowest concentrations of 37.6 and 99.0 mmol L^{-1} for Na^+ and Cl^-, respectively. This study concludes that suggest compost combined with a 20% leaching requirement can be effectively used in the reclamation of saline-affected soils and in improving their physical and chemical properties to create a more favorable environment for plant growth.

Keywords: *Amendments; Compost; Leaching Requirement; Soil Texture; Soil Salinity.*

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INTRODUCTION

Soils in arid and semi-arid regions are generally characterized by low organic matter content due to limited rainfall, sparse natural vegetation, and high temperatures. In addition, improper land use and poor irrigation management often contribute to the degradation of soil properties, which in turn negatively affects crop productivity. Among soil characteristics, physical properties play a critical role in agricultural use due to their influence on chemical and biological soil behavior, there by necessitating their improvement (Ouédraogo `*et al*., 2001). Soil amendments are commonly used to enhance physical properties, contributing to better water and nutrient retention, which promotes plant growth (Kranz et. al., 2020). A wide range of materials have been employed as soil conditioners, including organic sources such as compost, as well as inorganic materials like perlite. The application of organic amendments is considered an effective strategy to mitigate the adverse effects of irrigation water salinity and to enhance plant tolerance to saline conditions. Organic amendments improve soil pore distribution, thereby increasing water-holding capacity and aeration. They also stimulate root exudation of organic acids, which regulate soil pH and reduce the toxic effects of salts in the soil solution (El-Dardiry, 2007). Moreover, these amendments accelerate sodium leaching; reduce exchangeable sodium percentage (ESP), and lower electrical conductivity (EC) (Walker and Bernal, 2008). Additionally, they contribute to nutrient balance in soils by counteracting the dominance of certain ions at the expense of essential nutrients, and they improve soil aeration and oxygen diffusion, thereby enhancing microbial activity and nutrient availability (Lakhdar `*et al*., 2010).

The application of leaching requirements and net leaching water movement is essential for removing excess salts from the root zone to prevent their accumulation to levels that exceed plant tolerance, which could adversely affect plant growth and productivity. Efficient leaching of salts and improvement of soil physical and chemical properties depend on multiple factors, including irrigation methods, the salinity and volume of the applied water, the time interval between irrigations, soil properties, and other related factors (Kamel and Bakry, 2009).Therefore, the aim of this study was to evaluate the effects of organic soil amendments and leaching requirements on the salinity of soils with different textures and on selected soluble ions in the leaching of tomato-cultivated soil.

MATERIALS AND METHODS

The experiment was conducted in 2024 under lath house conditions at the Department of Soil and Water Resources, College of Agriculture, University of Basrah (Karmatt-Ali, southern Iraq). Surface soil samples (0–30 cm) were collected from two locations: a clay loam soil from the Karmatt-Ali site and a sandy loam soil from the Al-Burjesia area, south of Basrah province. The study aimed to investigate the interactive effects of organic amendments and leaching requirements on soil salinity and the concentrations of soluble sodium and chloride ions in the soil leaching water under tomato cultivation. The soil samples were air-dried and sieved through a 4 mm mesh. Physical and chemical properties of the soils were determined using standard methods, and the results are presented in Table 1. Soil texture was determined according to Blacke (1965), while calcium, magnesium, sodium, potassium, chloride, carbonate, bicarbonate, and sulfate ions were measured in a (1:1) soil: water extract following the procedures outlined by Richards (1954). Other soil parameters were analyzed according to methods described in Page `*et al*. (1982). Sufficient quantities of compost used in the experiment were obtained from a local, well-prepared source. Cattle manure was collected from nearby livestock farms in the vicinity of the study site. Foreign materials were manually removed, and the manure was thoroughly mixed and sieved through a 1 mm mesh to ensure uniformity. The organic amendments were mixed with air-dried soil at a rate of 2% (w/w) based on the dry weight of the soil, with each pot filled with 5 kg of soil.

The experiment was conducted using a factorial design with three factors:

1. Type of organic amendment: compost, cattle manure, and a control treatment (no amendment).
2. Leaching requirement: 10% and 20% above field capacity.
3. Soil texture: clay loam and sandy loam.

Three replicates per each f*actorial interaction* treatment were used in the experience. The organic amendments were incorporated into the soil prior to transplanting tomato seedlings (*Solanum lycopersicum* L.). Soil moisture was maintained at field capacity throughout the experiment. Three tomato seedlings were transplanted into each pot, and after one week, thinning was carried out to leave one healthy plant per pot. Crop management practices, including irrigation and fertilization, were conducted following the protocol of Al-Abedi (2011).

The fertilizer regime included:

Diammonium phosphate (DAP) (14:12:10) at a rate of 2.5 g pot^{-1}. A compound fertilizer (18:10:18) applied at a rate equivalent to 80 kg K ha^{-1} before planting, to compensate for potassium. Nitrogen fertilizer was applied in the form of urea (46% N) at a rate of 1 g pot^{-1}, split into two equal doses: the first at 10 days after transplanting and the second at 30 days. After 60 days of growth, the plants were harvested to assess soil salinity and concentrations of soluble ions. Irrigation was conducted based on the experimental treatments. The amount of irrigation water required was calculated using the following formula from Kovda (1973):

$$\mathbf{d = (w_{f.c.} - w_{i.w.}) * P\mathit{b} * D * A} \quad \ldots\ldots (1)$$

Where:

d = amount of irrigation water (cm^3), $w_{f.c.}$ = gravimetric soil moisture content before the next irrigation (%), $w_{i.w.}$ = gravimetric soil moisture content in the previous irrigation (%), Pb = soil bulk density (g cm-^{3}), D = soil depth (cm), A = pot surface area (cm^2)

It was also maintaining a constant weight at the field capacity of each pot. The calculated irrigation water (4dSm^{-1}) was then multiplied by the leaching requirement (10% or 20%, depending on treatment). The total amount of irrigation water applied per pot was 2.39 and 2.54 liters for the 10% and 20% leaching requirement treatments, respectively. At the end of the experiment (60 days after transplanting), the soil leaching was collected and analyzed for electrical conductivity (EC),soluble sodium (Na^+), and chloride (Cl^-) concentrations using a 1:1 (soil :water) extract, following the methods described by Richards (1954). The experimental data were analyzed statistically using a factorial experiment with three factors in a randomized complete block design (RCBD) and three replicates (3 × 2 × 2 × 3: amendment type × leaching requirement × soil texture × replicates). The statistical analysis was performed using SPSS software. Analysis of variance (ANOVA) was conducted, and treatment means were compared using the Least Significant Difference (L.S.D) test at a 5% probability level (Al-Rawi and Khalaf-Allah, 2000).

Table (1) Primary physical and chemical properties of the studied soils

Parameters	Depth (0-30 cm)		Unit
	North of Basrah (Karma-Ali site)	**West of Basrah (Al-Burjesia site)**	
PH	7.77	8.15	-------
E.C	6.11	1.88	dsm^{-1}
CEC	13.88	5.40	cmol$^+$ kg^{-1}
available N	4.22	0.99	
available P	11.01	0.13	mg kg^{-1}
available K	114.88	0.12	
Total N	0.41	0.10	
Organic Carbon	2.32	0.93	g kg^{-1}
Organic mater	3.80	1.02	
Ca	9.5	3.71	
Mg^{++}	7.77	1.89	
Na^+	36.1	7.89	
K^+	1.62	1.05	
HCO_3^-	5.42	2.54	mmol L^{-1}
CO_3^{--}	0.00	0.00	
Cl^-	34.41	5.91	
SO_4^{--}	13.30	6.02	
Particle Density	2.64	2.65	Mg gm^{-3}
Bulk Density	1.31	1.22	
Porosity	35.00	38.86	%
Sand	110	827.10	
Silt	434	38.14	g kg^{-1}
Clay	456	134.76	
Texture & location	Clay Loam	Sandy Loam	

RESULTS AND DISCUSSION

Table (2) illustrates the effect of organic amendment type on the efficiency of salt leaching throughout the experiment. Significant differences were observed in the electrical conductivity (E.C.) of the soil leaching among the treatments with different amendments. The application of compost significantly reduced the E.C. values, recording the lowest value of 2.58 dSm^{-1} compared to cattle manure and the control treatment (no amendment), which recorded values of 3.18 and 3.01 dSm^{-1}, respectively.

The superiority of compost in reducing soil salinity is attributed to its positive impact on the physical properties of the soil. The addition of compost decreased the soil bulk density, consistent with the findings of Brown and Cotton (2011), who reported that soil bulk density decreases with compost application, and this reduction becomes more pronounced with increasing amendment rates. Furthermore, compost inherently has a low bulk density and its incorporation into soil results in a reduction of soil density and an increase in soil porosity. This, in turn, enhances saturated hydraulic conductivity, improving water movement through the soil, thereby facilitating greater salt leaching and reducing soil salinity (Lee `*et al*., 2014).

Table (2) The effect of experimental factors on the average of electrical conductivity of soil solution (dSm^{-1})

Texture	L.R.	Amendment: cont. (none)	cattle res.	com.
Clay loam	10	4.73	4.51	3.97
Clay loam	20	4.45	3.86	3.59
Sandy loam	10	1.65	2.65	1.78
Sandy loam	20	1.22	1.69	0.97
		n.s.		

Texture \ Amendment	cont. (none)	cattle res.	com.
Clay loam	4.59	4.18	3.78
Sandy loam	1.44	2.17	1.37
L.S.D.$_{0.05,6}$= 0.99			

Texture * L.R. (Texture \ L.R.)	10	20
Clay loam	4.40	3.96
Sandy loam	2.03	1.29
n.s.		

L.R. * Amendment (Amendment \ L.R.)	10	20
cont. (none)	3.19	2.83
cattle res.	3.58	2.77
com.	2.87	2.28
n.s.		

Texture	Clay loam	Sandy loam
	4.18	1.66
	*	

L.R.	10	20
	3.21	2.63
	*	

Amendment	cont. (none)	cattle res.	com.
	3.01	3.18	2.58
	L.S.D.$_{0.05,12}$= 0.70		

ns = Non significant ($p > 0.05$)

Table illustrates the decline in electrical conductivity (E.C.) values as a result of the leaching processes, showing a continuous decrease in soil E.C. throughout successive leaching stages until the end of the experiment. The highest leaching efficiency was recorded in the treatment with a 20% leaching requirement (2.63 dSm^{-1}) compared to the 10% leaching treatment, which had an E.C. value of 3.21 dSm^{-1}. This significant reduction in E.C. values with increased irrigation water is attributed to the removal of a larger quantity of salts from the soil matrix, as well as the high initial concentration of highly soluble salts at the beginning of leaching, which tend to concentrate in the larger soil pores through which leaching flows. This phenomenon promotes downward water movement and is enhanced by the short interval (5 days) between leaching events, which supports alternating wetting and drying cycles, thereby increasing the diffusion of salts between small and large pores through which percolation water moves (Javadi `*et al*., 2019).

Additionally, the availability of extra water due to repeated leaching stages increases soil moisture, improving salt leaching and ion mobility, including the possible removal of sodium salts that negatively impact soil properties and reduce permeability. Lu `*et al*. (2019) reported a positive correlation between leaching efficiency and the amount of leaching water applied. Their study also showed that the highest salt leaching efficiency occurred at a 6-day rest interval.

Table 2 also reveals a significant effect of soil texture on the E.C. values of soil leaching with increasing leaching requirements. A significant reduction in soil salinity was observed across all treatments, with sandy loam soil exhibiting the lowest E.C. value (1.66 dSm^{-1}), which was significantly lower than that of clay loam soil (4.18 dSm^{-1}). Additionally, the soils after treatment showed improved salinity reduction compared to initial salinity levels (1.88 and 6.11 dSm^{-1} for sandy loam and clay loam, respectively).This outcome can be explained by differences in pore size distribution and connectivity between soil textures, as well as the negative effect of monovalent cations such as sodium on the hydraulic properties of fine-textured soils. Sodium causes swelling of clay particles and dispersion of fine particles from larger aggregates, slowing water movement and reducing soil hydraulic conductivity. The limited leaching effect in clay soils is not only due to diffusion constraints but also to inadequate water flow through large pores, which are more prevalent in coarse-textured soils. Consequently, sandy soils exhibit relatively higher percolation rates (Kahlon `*et al.*, 2013). Who further demonstrated that salt leaching depends on soil structure, water infiltration rate, soil depth, initial salinity concentration, and salt type. They emphasized that soil texture influences the volume of irrigation water needed during leaching of sodic saline soils. Their findings showed that leaching positively affects the quantity of salts removed, with the highest salt removal recorded in soils with sandy loam texture compared to sandy and silty clay loam soils. Clay soils tend to retain more water and dissolved salts within their aggregates compared to sandy soils.

The interaction between amendment type and soil texture on salt leaching efficiency and E.C. of the soil leaching (Table 2) showed a significant reduction in E.C. when compost was applied to sandy loam soil, resulting in the lowest E.C. value of 1.37 dSm^{-1} among all treatments. This effect is likely due to the improvement in soil physical properties induced by compost addition. Compost enhances soil water retention capacity owing to its colloidal nature, which allows it to absorb 10 to 100 times more water than the soil itself (Seker and Manirakiza, 2020). Moreover, the initial physical properties of sandy loam soil were superior to those of clay loam soil, characterized by higher porosity and lower bulk density (Table 1). In contrast, no significant interactions were found between soil texture and leaching requirement (Texture × L.R.), leaching requirement and amendment (L.R. × Amendment), nor the three-way interaction (Texture × L.R. × Amendment) regarding soil leaching E.C. (Table 2).

Tables (3) and 4 indicate that compost significantly reduced the concentrations of soluble sodium and chloride ions in soil solution (112.6 and 160.4 $mmolL^{-1}$, respectively) compared to other amendments. The control treatment (no amendment) showed the highest sodium and chloride concentrations at the end of the experiment, with values of 160.5 and 226.2 $mmolL^{-1}$, respectively. The superior performance of compost is attributed to its capacity to improve soil physical properties compared to other amendments (Markoska `*et al.*, 2018), as well as the lower E.C. values observed in the compost-amended soils (Table 2).

Table (3) The effect of experimental factors on the average of soluble sodium in soil solution (mm l^{-1})

Texture	L.R.	Amendment			Texture * L.R.			Texture		
		cont. (none)	cattle res.	com.	L.R. / Texture	10	20	Clay loam	Sandy loam	
Clay loam	10	239.1	245.0	187.4	**Clay loam**	223.9	165.1	194.5	89.1	
	20	199.4	164.5	131.3	**Sandy loam**	121.1	57.1	*		
Sandy loam	10	135.9	133.4	94.0	n.s.			**L.R.**		
	20	67.5	66.3	37.6				**10**	**20**	
		n.s.			**L.R. * Amendment**			172.5	111.1	
Amendment / Texture		**cont. (none)**	**cattle res.**	**com.**	L.R / Amendment	**10**	**20**	*		
					cont. (none)	187.5	133.5	**Amendment**		
Clay loam		219.3	204.8	159.4	**cattle res.**	189.2	115.4	**cont. (none)**	cattle res.	com.
Sandy loam		101.7	99.9	65.8	**com.**	140.7	84.4	**160.5**	152.3	112.6
L.S.D.$_{0.05\ .6}$= 32.48					n.s.			L.S.D.$_{0.05\ .12}$= 22.96		

ns = Non significant ($p> 0.05$)

Tables (3) and (4) demonstrate a significant effect of soil texture on the mean concentrations of soluble sodium and chloride ions in soil solution with increasing leaching requirements. A significant reduction in sodium and chloride concentrations was observed across all treatments, with sandy loam texture outperforming by recording the lowest values of 89.1 and 157.4 mmolL⁻¹, respectively, which were significantly lower than those of clay loam texture (194.5 and 240.3 mmolL⁻¹, respectively). This superiority of sandy loam texture is attributed to the easier movement of water through the soil matrix due to the higher sand particle content and lower bulk density, resulting in higher saturated hydraulic conductivity compared to clay loam (Table 1).

Table (4) The effect of experimental factors on the average of soluble chloride in soil solution (mm l^{-1})

Texture	L.R.	Amendment			Texture * L.R.			Texture		
		cont. (none)	cattle res.	com.	L.R. / Texture	10	20	Clay loam		Sandy loam
Clay loam	10	283.3	266.7	228.3	Clay loam	259.4	221.1	240.3		157.4
	20	266.7	233.3	163.3	Sandy loam	172.1	142.8		*	
Sandy loam	10	186.7	178.7	151.0	n.s.				L.R.	
	20	168.3	161.0	99.0				10		20
		n.s.			L.R. * Amendment			172.5		111.1
Amendment / Texture		cont. (none)	cattle res.	com.	L.R / Amendment	10	20		*	
					cont. (none)	235.0	217.5		Amendment	
Clay loam		275.0	250.0	195.8	cattle res.	222.7	197.2	cont. (none)	cattle res.	com.
Sandy loam		177.5	169.8	125.0	com.	189.7	131.2	226.2	209.9	160.4
L.S.D.$_{0.05\ .6}$= 22.82					L.S.D.$_{0.05.6}$ = 22.82			L.S.D.$_{0.05\ .12}$= 16.14		

ns = Non significant (*p> 0.05*)

Similarly, the leaching requirement factor followed the same trend as electrical conductivity in reducing the soluble ion concentrations. Tables (3) and (4) show a significant decrease in the average concentrations of sodium and chloride ions at the 20% leaching requirement level (111.1 and 181.9 mmolL⁻¹, respectively), whereas the 10% leaching requirement treatment recorded higher concentrations (172.5 and 215.8 mmolL⁻¹, respectively). The superior performance of the higher leaching requirement in reducing soluble ion concentrations is due to the availability of sufficient water to dissolve salts and ions in the soil solution, in addition to enhanced movement of leaching water toward groundwater resulting from increased water volume added to the soil (Hoshan, 2021).

Regarding the interaction between organic amendment type and leaching requirement on chloride ion concentration in soil solution, Table (4) shows a significant effect of the interaction between compost amendment and 20% leaching requirement, which recorded the lowest chloride concentration of 131.2 mmolL⁻¹, outperforming other treatments. The highest value (235.0 mmolL⁻¹) was observed in the control treatment (no amendment) with a10% leaching requirement. The reduction in chloride concentration under the compost and 20% leaching treatment is attributed to improved soil physical properties, reduced bulk density, increased porosity (Arthur `*et al.,* 2012), and the relatively high volume of leaching water sufficient to remove percolating water below the soil profile (Hoshan, 2024). No significant interaction was observed between amendment type and leaching requirement on sodium ion concentration in soil leaching (Table 3).

Tables (3) and (4) also reveal significant differences at the 0.05 level due to the interaction between amendment type and soil texture on the mean concentrations of soluble ions in soil solution. The compost treatment with sandy loam texture recorded the lowest values of sodium and chloride ions at 65.8 and 125.0mmolL⁻¹, respectively, while the highest concentrations were observed in the control treatment (no amendment) with clay loam texture, recording 219.3 and 275.0 mmolL⁻¹ for sodium and chloride ions, respectively. The superiority of the compost and sandy loam combination in reducing soluble ion concentrations is linked to the texture's facilitation of water movement within the soil and compost's water retention capacity, which enhances ion dissolution and diffusion (Seker and Manirakiza, 2020). No significant interactions were found between soil texture and leaching requirement(Texture × L.R.) or the three-way interaction(Texture × L.R. × Amendment) on sodium and chloride ion concentrations in soil leaching (Tables 3 and 4).

CONCLUSIONS

The results demonstrated the effectiveness of compost amendment and a 20% leaching requirement in reducing electrical conductivity and concentrations of some soluble ions in the soil solution, improving soil properties and plant growth conditions in saline-affected soils of the study area.

RECOMMENDATIONS

1. The use of organic amendments such as compost is recommended for reclamation of saline-affected soils.
2. Applying a 20% leaching requirement is advised to reduce soil salinity and create a suitable environment for plant growth in saline soils.
3. In clay loam soils with an EC value exceeding 6 dSm^{-1}, it is recommended to apply compost at a rate of 2% (w/w), together with a leaching requirement of 20%.

DEDICATION

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