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INTERACTION EFFECTS OF LEACHING, SALINITY, SULFUR, AND ORGANIC MATTER ON PHYSICAL PROPERTIES OF SOIL PLANTED WITH MAIZE CROP

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SUMMARY

A pot experiment in a plastic house proceeded in 2022 at the Karma Ali site of the Agricultural Research Station, College of Agriculture, University of Basrah, Iraq. The experiment aimed to investigate the impact of mineral sulfur and organic matter addition, leaching requirements, and irrigation water salinity on the physical properties of soil cultivated with *Zea mays* L. (maize) plants. This study administered two organic residues (cow and alfalfa), three levels of mineral sulfur (0%, 0.8%, and 1.6%), three levels of leaching needs (15%, 25%, and 35%) more than the field capacity, and two levels of irrigation water salinity (4 dSm^{-1} and 8 dSm^{-1}). The organic residues and mineral sulfur mixture with the soil incurred incubation for 60 days. Yellow maize (*Zea mays* L.) planting followed incubation, maintaining the soil moisture at field capacity fertilization, and carrying out irrigation operations according to the above treatments. Soil bulk density and mean weighted diameter measuring ensued at the end of the experiment. The results showed the ability of organic residues to reduce bulk density and increase soil stability (mean weighted diameter). The decrease in bulk density was more evident in the alfalfa residues, which amounted to 1.25 µg m^{-3} soil and 0.62 mm, respectively. The leaching requirement level of 35% exceeded in reducing the bulk density of soil compared with the other two levels, which amounted to 1.25 µgm-^{3} soil. The 1.6% sulfur and irrigation water salinity of 4 dSm^{-1} reduced the soil's bulk density and increased the mean weighted diameter of the soil (1.31 μgm^{-3} soil and 0.79 mm, respectively).

Keywords: Organic residues, leaching requirements, mineral sulfur, soil bulk density, mean weighted diameter, salinity

Key findings: Using organic residues, leaching requirements of 35%, mineral sulfur addition of 1.6%, water salinity of 4 dSm^{-1}, and the interactions between these factors in improving the soil's physical properties proved possible. Alfalfa residue and sulfur excelled in reducing soil bulk density and increasing soil stability compared with cow residue. Moreover, mineral sulfur enhanced the physical properties of the soil.

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INTRODUCTION

Irrigated soils in arid and semi-arid regions are prone to salt accumulation due to insufficient leaching water utilized to remove salts introduced through irrigation. This issue, further exacerbated by the disruption of the water balance, causes groundwater movement toward the soil surface through capillary action, primarily driven by evaporation during the summer; consequently, salt accumulation is particularly prominent in the root zone and soil surface. Likewise, incorrect irrigation systems, the deterioration of water quality, and the lack of efficient drainage systems can worsen salinity problems in irrigated croplands (Ismail, 2000).

The concept of leaching soil from salts to improve its physical and chemical properties depends on several factors, including the leaching method components: the quality and quantity of water added during the leaching process, the period for leaching, soil characteristics, and other factors. Chu *et al*. (2016) indicated that increasing the amount of water and periods causes leaching to rejuvenate the soil's physical properties and reduce the electrical conductivity of the soil solution, especially in unsaturated soil conditions.

Sulfur is one of the compounds used as soil conditioners, as the addition of agricultural sulfur to the soil reduces the pH degree due to its oxidation and the formation of sulfuric acid, lowering the soil pH level and affecting the concentration of available forms of nutrients, thus increases soil fertility (Souza *et al*., 2015). Sulfur occurs in large quantities in nature and is incidental to the oil industry. Hence, several researchers employ the addition of sulfur as a means of soil management and reclamation, given that sulfur is one of the macronutrients plants need vital for their processes. However, a small part of this product is only consumable compared with its produced quantity (Shaker and Rahi, 2002).

Sulfur is crucial in agricultural advancement, particularly in calcareous soils. These soils are prevalent in Iraq, characteristic of a significant presence of calcium carbonate (Kovda and Hangun, 1973). This high calcium carbonate content affects various soil properties that influence plant growth. These properties include physical aspects, such as soil-water relations and the occurring surface crust issues, as well as chemical factors, i.e., the high degree of soil pH, which affects plant nutrient availability (Hassan *et al.,* 2021). Therefore, sulfur contributes to the reclamation of alkaline soils through its acidic properties, which increase the availability of the elements, water conductivity, and porosity, improving drainage and soil structure.

Adding organic residues is one of the effective strategies to reduce irrigation water salinity's damages and increase plant tolerance, as it improves the distribution of soil pores. In turn, the ability to hold water aeration increases and improves root secretions, such as organic acids that regulate the soil pH and lessen salts' harmful effects in the soil solution (El-Dardiry, 2007). Organic residues are crucial in sodium ion leaching and reducing the ratio of exchange sodium and electrical conductivity (Walker and Bernal, 2008). Similarly, organic residues work on the nutritional balance in the soil disturbed by an increase in specific ions at the expense of essential nutrients, improving ventilation conditions and the movement of oxygen for soil organisms raising the biological activity and available nutrients (Lakhdar *et al*., 2010).

Hao *et al*. (2008) indicated that adding organic residues to the soil improves its physical properties related to permeability, porosity, air, and water movement. Moreover, the organic materials added to the soil from different sources play an essential role in the soil, as these materials directly affect the improvement of soil structure and increase the stability of the aggregates. It came through its work in binding soil particles according to a transparent structural system due to decomposing products. It also leads to an increase in the ability of the soil to keep moisture and preserve its surface from erosion by forming aggregates through the adhesion of soil particles to each other, as it acts as a binder, and thus, the difficulty of its disintegration and drift, whether by water or wind (Tarchitzky and Chen, 2002).

Table 1. Some initial physical and chemical properties of the studied soil.

Parameters	Depth (0–30 cm)	Unit
PH	8.12	-------
ECe.	6.11	dS m^{-1}
CEC	13.88	$Cmol^{+}$ gm^{-1}
available N	4.22	
available P	11.01	mg kg^{-1}
available K	114.88	
Total N	0.41	
Organic Carbon	2.32	gm kg^{-1}
Organic metal	3.80	
Ca^{++}	9.5	
Mg^{++}	7.77	
Na^{+}	36.1	
K^{+}	1.62	mmol l^{-1}
HCO_3^{-}	5.42	
CO_3^{--}	0.00	
Cl^{-}	34.41	
SO_4^{-2}	13.30	
Particle Density	2.64	µg m^{-3}soil
Bulk Density	1.39	
Porosity	35	%
Sand	110	
Silt	434	gm kg^{-1}
Clay	456	
Texture	Silty clay	

This study aimed to demonstrate the effect of adding mineral sulfur, organic matter, leaching requirements, and irrigation water salinity on some soil physical properties (bulk density and mean weighted diameter) of soil planted with maize plants.

MATERIALS AND METHODS

The experiment began in a plastic house at the Agricultural Research Station, University of Basrah, Iraq, in 2022 on a surface soil sample (0–30 cm) brought from the same site to study the interference effect of leaching requirements, irrigation water salinity, and organic residues, with sulfur levels added on soil properties planted with maize plants (*Zea mays* L.). The soil, air-dried first, incurred sifting through a 4 mm sieve. Its physical and chemical properties appear in Table 1, with estimations according to the approved standard methods. The soil texture estimates used the guide according to what Black (1965) reported, and the soluble ions of calcium, magnesium, sodium, potassium, chloride, carbonates, bicarbonates, and sulfates in a soil extract: water (1:1), according to the method reported by Richards (1954). The rest of the characteristics assessment relied on the technique mentioned in Page *et al*. (1982).

Collected alfalfa plants from one of the agricultural research station fields underwent washing, drying, and sifting through a 1 mm sieve. The cow's residues in required quantities came from animal fields near the study area. Mixing foreign materials continued to sift through a 1 mm sieve. The organic residue mixed with the dry soil of each pot of 5 kg soil had a rate of 2% (weight: weight).

The studied interactions of four factors were as follow:

1- The type of organic residues, including cow and alfalfa,
2- The percentage of added mineral sulfur (0%, 0.8%, and 1.6%),
3- Irrigation water salinity (4 and 8 dS m^{-1}), and
4- Leaching requirements (15%, 25%, and 35%) more than the field capacity.

Organic residues and mineral sulfur combination with the soil continued to incubating for 60 days before planting the yellow corn plant while maintaining the soil moisture at the field capacity with three replications. After incubating, sowing seeds of maize plants (*Zea mays* L.) variety Baghdad 3 ensued, and after germination and seedlings' emergence, a thinning process followed to obtain one plant in each pot. Fertilization and crop service operations depended on the method according to Al-Abedi (2011), in two additions: the first, after 10 days of planting and the second, after 30 days. After 60 days of planting, estimation of some of the soil's physical properties progressed. Irrigation was also according to the previous treatments. Determining the amount of water required for rinsing relied on the wet moisture of the soil before each irrigation and according to the following equation:

$$d = (w_{f.c.} - w_{i.w.}) \times Pb \times D \times A \text{ (Kovda, 1973)}$$

Where:
d = the amount of water needed for irrigation (cm^3),
$W_{f.c.}$ = Weight moisture percentage before subsequent watering (%),
$w_{i.w.}$ = Weight moisture percentage at the previous watering (%),
Pb = bulk density of soil (μg gm^{-3}),
D = soil depth (cm), and
A = area of the pot (cm^2).

Then, multiplying the result of the equation by the percentage of leaching requirements and according to the above transactions, adding the outcomes continued to the total amount of water, with the amount of water added to each pot at 2.39, 2.54, and 2.75 liters for leaching requirements of 15%, 25%, and 35%, respectively. After 60 days of maize plant growth, some physical soil properties (bulk density and mean weighted diameter of the soil) received measuring.

Statistical analysis

Statistically analyzing the trials followed the design of the factorial experiments with four factors and three replications, 3 * 2 * 3 * 2 * 3 (leaching requirements * irrigation water quality * percentage of added mineral sulfur * type of organic matter * replicate), using sectors design. The data analyzed statistically used the SPSS program and analysis of variance, and the F-test employing the rate of least significant difference (RLSD) to compare the means of the studied treatments (AL-Rawi and Khalaf-Allah, 2000).

RESULTS AND DISCUSSION

Interaction effects

The bulk density of the soil

The results in Figure 1 showed a highly significant effect of leaching requirements at the end of the experiment on the bulk density values (Pb) of the soil 35% omit treatment was significantly superior over the rest of the leaching requirements' treatments in reducing the Pb values. It gave the lowest value (1.25 μg m^{-3}), while the other two treatments of leaching requirements, 25% and 15%, had higher values at 1.30 and 1.39 μg m^{-3}, respectively. It may be due to the effect of large amounts of leaching water causing better leaching of salts from the soil body and a decrease in sodium ions; plus, the use of leached water at a rate of 35% leads to preserving the soil structure and preventing cracks formation because of drought due to the increase in moisture content in the soil (Hoshan, 2021). Zeng *et al.* (2013) indicated that the amount of leaching water from 10 to 20 cm increased soil water storage significantly.

Figure 2 presents outcomes of a highly significant effect of the added sulfur level at the end of the experiment on the Pb values of the soil, with the lowest value (1.23 μg m^{-3}) recorded for the 1.6% addition treatment. It was significantly superior to the rest of the addition levels (1.31 and 1.40 μg m^{-3} for the two addition treatments of 0.8% and 0%, respectively). The changes in the bulk density due to adding sulfur can refer to the contribution of sulfur in reducing the soil pH by

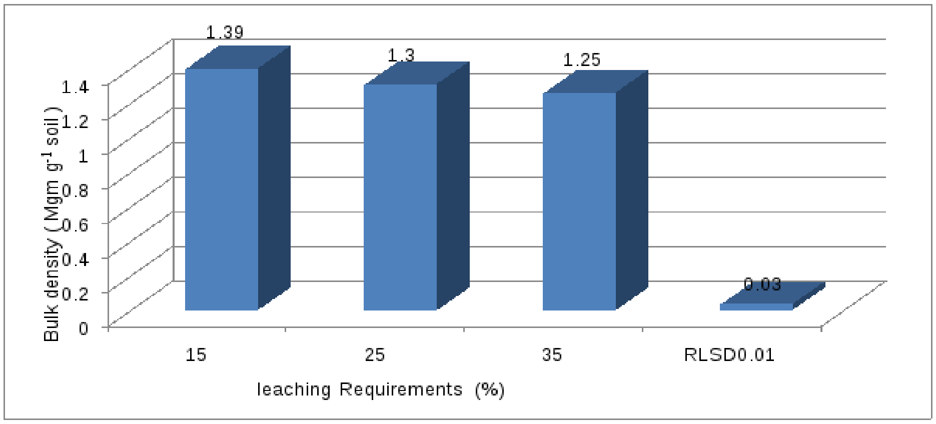

Figure 1. The effect of leaching requirements on soil bulk density values at the end of the experiment (μg m^{-3}soil).

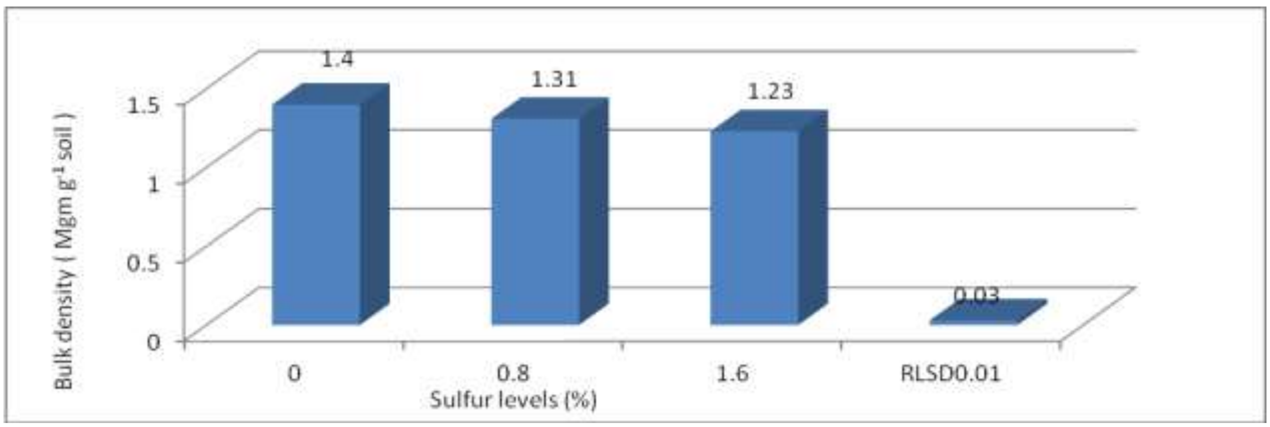

Figure 2. The effect of the added sulfur level on the soil bulk density values at the end of the experiment (μg m^{-3}soil).

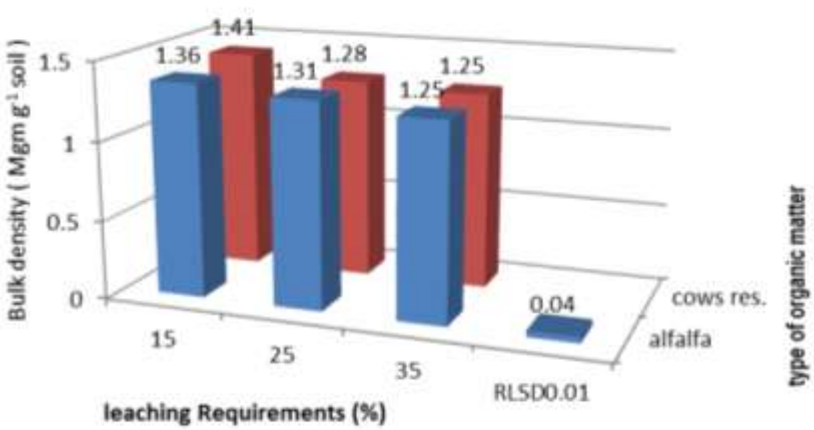

Figure 3. The effect of the type of organic matter and leaching requirements on the bulk density values of the soil at the end of the experiment (μg m^{-3}soil).

transforming sulfur into sulfuric acid. It also contributes to increasing the solubility of calcium carbonate available in the soil, raising the proportion of calcium ions, and replacing them with other cations that have a dispersing effect on soil building, such as sodium or decomposing organic matter (Ibrahim *et al*., 2015).

It is notable from the soil's bulk density results shown in Figure 3 that a highly significant effect of the interaction between the type of organic matter and the leaching requirements existed on the Pb values of the soil at the end of the experiment. The lowest value (1.25 µg m^{-3}soil) emerged for the 35% leaching requirements for both types of organic residues compared with the bulk density of soil before leaching (1.39 µg m^{-3} soil). It significantly outperformed the rest of the treatments, and higher significant values were 1.36 and 1.41 µg m^{-3} soil obtained for the 15% leaching requirements with alfalfa and cow residues, respectively. The reason for the leaching requirements of 35% excess may be due to the increase in soil moisture storage in this period, compared with the 25% and 15% addition rates (Chozin *et al*., 2017; Salih *et al*., 2022). It leads to an increase in the activity of soil microorganisms, and thus, an increase in the decomposition of organic residues together with the secretions of microorganisms, increasing the formation of soil aggregates, therefore, reducing the soil's bulk density (Hoshan, 2021; Kudaibergenova *et al*., 2023). AL-Hadithiy and AL-Heety (2010) indicated that adding organic matter to the soil at a level of 2% reduced the bulk density from 1.50, 1.60, and 1.63 µg m^{-3} to 1.44, 1.50, and 1.60 µg m^{-3} for depths 0–10, 10–25, and 25–40 cm, respectively, referring to the organic matter's role in improving soil structure and increasing its porosity.

The effect of the interaction between the irrigation water salinity and the type of organic matter on the Pb values of the soil at the end of the experiment occurs in Figure 4. A significant difference appeared for the irrigation water salinity treatment of 4 dSm^{-1} with alfalfa residues, recording the lowest values (1.30 µg m^{-3} soil) compared with other treatments. The maximum value was 1.32 µg m^{-3} soil for the irrigation water salinity treatment of 8 dSm^{-1} with cow residues. The better value of alfalfa residues with low irrigation water salinity may be due to the rapid decomposition of alfalfa deposits compared with cow residues. Thus, the available nutrients for microorganisms contributed to forming soil agglomerations, increasing porosity, and reducing the bulk density of the soil, in addition to the effect of leached salts in developing pseudo-building and poor properties of the physical soil due to the decrease in soil permeability as the irrigation process progresses with the increase in electrical conductivity of the added leaching water (Hoshan, 2021).

Considering the interaction between the type of organic matter, leaching requirements, and irrigation water salinity on the bulk density values of the soil at the end of the experiment, Figure 5 shows a high significance of alfalfa residue, water salinity (4 dSm^{-1}), and 35% leaching requirement, recording the lowest values compared with other factors (1.24 µg m^{-3}soil). It indicated the role of alfalfa residue (Figure 3), low electrical conductivity (Figure 4), and high leaching requirements (Figure 1) in improving soil structure, forming aggregates, increasing porosity, and, thus, reducing the apparent density of the soil.

From Table 2, no significant effect occurred from the factors (type of organic matter and salinity of irrigation water); the interaction between (type of organic matter and percentage of added sulfur), (leaching requirements and salinity of irrigation water), (leaching requirements and percentage of added sulfur), (irrigation water salinity and the percentage of added sulfur); the interaction between (type of organic matter, leaching requirements, and added sulfur), (type of organic matter, irrigation water salinity, and added sulfur), (leaching requirements, irrigation water salinity, and added sulfur), and the interaction between the (type of organic matter, leaching requirements, added sulfur, and salinity of irrigation water) in the soil bulk density values after the end of the experiment.

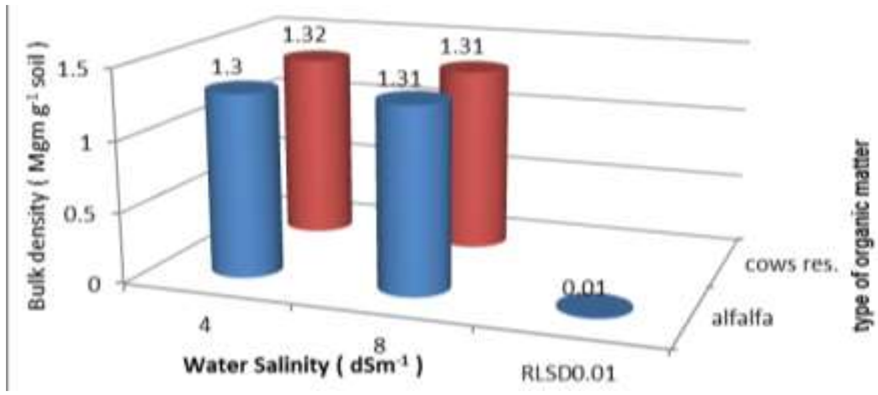

Figure 4. The effect of the type of organic matter and the salinity of the irrigation water on the bulk density values of the soil at the end of the experiment (μg m^{-3}soil).

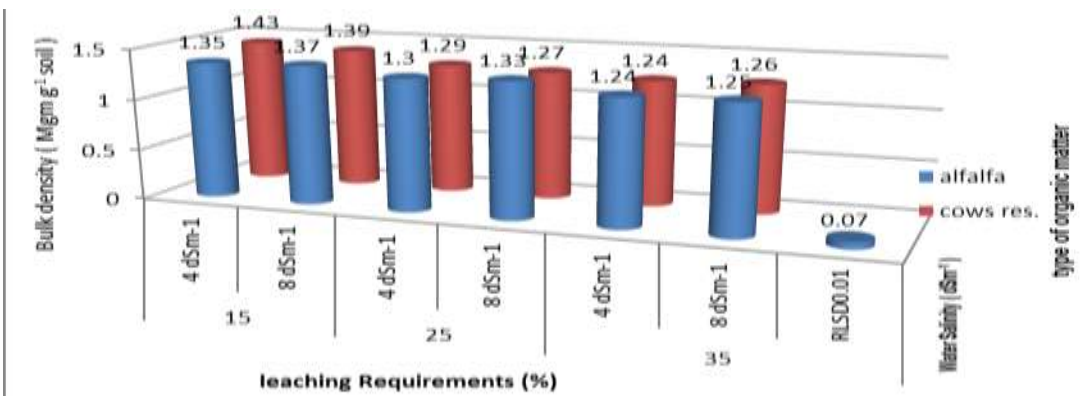

Figure 5. The effect of the type of organic matter, leaching requirements, and irrigation water salinity on soil bulk density values at the end of the experiment (μg m^{-3}soil)

Mean weighted diameter of the soil

The treatment of alfalfa residues (Figure 6) was superior in giving the most significant value (0.62 mm) of MWD compared with the treatment of cow residues, which amounted to 0.49 mm. Also a Figure 7 shows the same affected, where the treatment 35% leaching requirements give the most significant value (0.69 mm) of MWD compared with the other treatments. The superiority of the alfalfa residues may be due to the speed of its decomposition compared with the residues of cows. Abdel-Hamza (2010) obtained an increased decomposition rate of dried alfalfa compared with cow wastes due to the decrease in the C / N ratio in the dried alfalfa. Thus, it increases the effectiveness of soil microorganisms, which improves the distribution of soil pores and increases the ability to hold moisture and aeration of the soil improving roots' secretion (Hassan and Moatasim, 2012; AL-Sultani *et al*., 2022).

Considering the change in the MWD values according to the percentage of added sulfur, the results in Figure 8 show a significant effect of this factor at the end of the experiment. It gave the highest significant MWD value (0.79 mm) at the addition rate of 1.6%, compared with the rest of the additives. The results also showed noteworthy differences between the rest of the addition rates, which gave values of 0.53 and 0.35 mm at the addition rates of 25% and 15%, respectively. Root products can form soil aggregates, which improve soil structure (Hassan *et al*., 2021).

Table 2. The effect of the treatments on the bulk density of the soil at the end of the experiment (μg m^{-3}soil).

LR	EC-water	S %	Organic matter type		Organic matter type * S %
			Alfalfa	Cow	
15	4	0	1.46	1.50	1.48
		0.8	1.39	1.43	1.41
		1.6	1.21	1.35	1.28
	8	0	1.47	1.49	1.48
		0.8	1.36	1.39	1.38
		1.6	1.28	1.29	1.29
25	4	0	1.35	1.39	1.37
		0.8	1.30	1.28	1.29
		1.6	1.25	1.21	1.23
	8	0	1.36	1.41	1.39
		0.8	1.36	1.20	1.28
		1.6	1.26	1.19	1.23
35	4	0	1.34	1.35	1.35
		0.8	1.20	1.22	1.21
		1.6	1.19	1.16	1.18
	8	0	1.32	1.31	1.32
		0.8	1.26	1.29	1.28
		1.6	1.16	1.19	1.18
Organic matter type			1.31	1.31	
					LR * S %
Organic matter type * LR * S %	15	0	1.47	1.50	1.48
		0.8	1.38	1.41	1.39
		1.6	1.25	1.32	1.28
	25	0	1.36	1.40	1.38
		0.8	1.33	1.24	1.29
		1.6	1.26	1.20	1.23
	35	0	1.33	1.33	1.33
		0.8	1.23	1.26	1.24
		1.6	1.18	1.18	1.18
					EC-water * S %
Organic matter type * EC-water * S %	4	0	1.38	1.41	1.40
		0.8	1.30	1.31	1.30
		1.6	1.22	1.24	1.23
	8	0	1.38	1.40	1.39
		0.8	1.33	1.29	1.31
		1.6	1.23	1.22	1.23
S %	0		1.38	1.41	
	0.8		1.31	1.30	
	1.6		1.23	1.23	
EC-water	4		1.31		
	8		1.31		
			4	8	
LR * EC-water	15		1.39	1.38	
	25		1.30	1.30	
	35		1.24	1.26	

Note: There are no significant differences between the coefficients within the table below the probability level of 0.01.

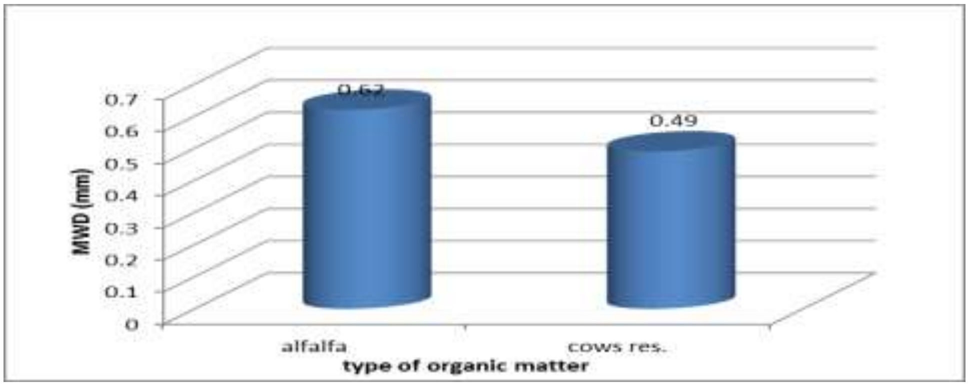

Figure 6. The effect of the type of organic matter on the values of the mean weighted diameter of the soil at the end of the experiment (mm).

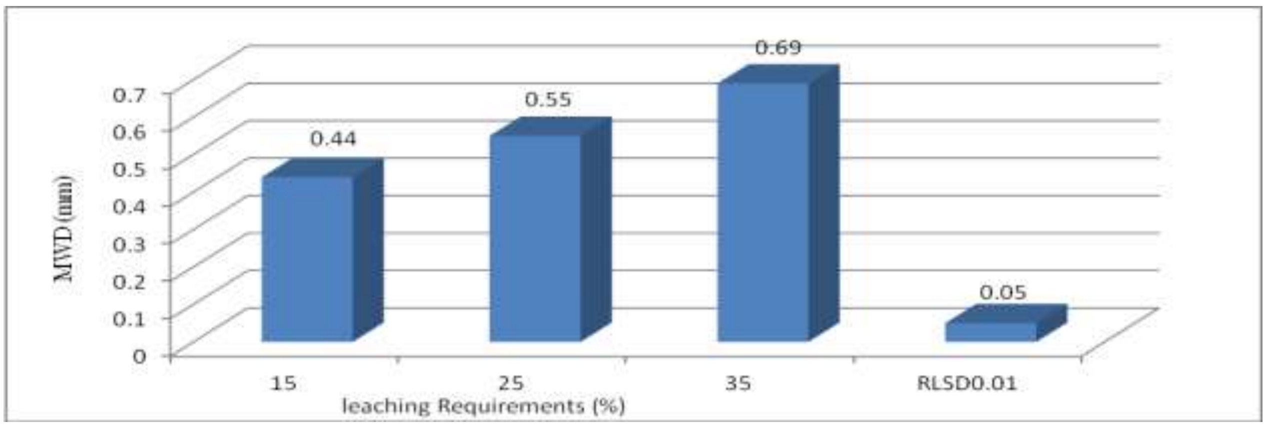

Figure 7. The effect of leaching requirements on the values of the mean weighted diameter of the soil at the end of the experiment (mm).

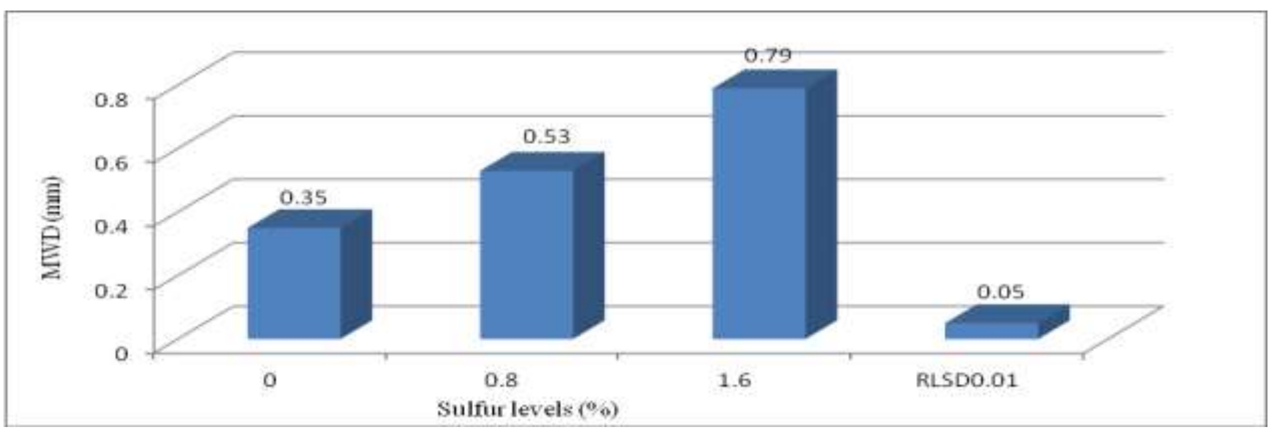

Figure 8. The effect of the level of added sulfur on the values of the mean weighted diameter of the soil at the end of the experiment (mm).

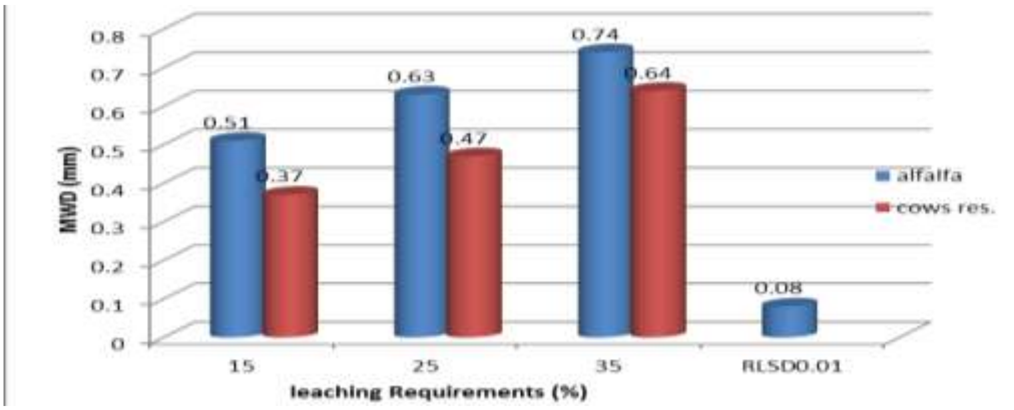

Figure 9. The effect of the type of organic matter and leaching requirements on the values of the mean weighted diameter of the soil at the end of the experiment (mm).

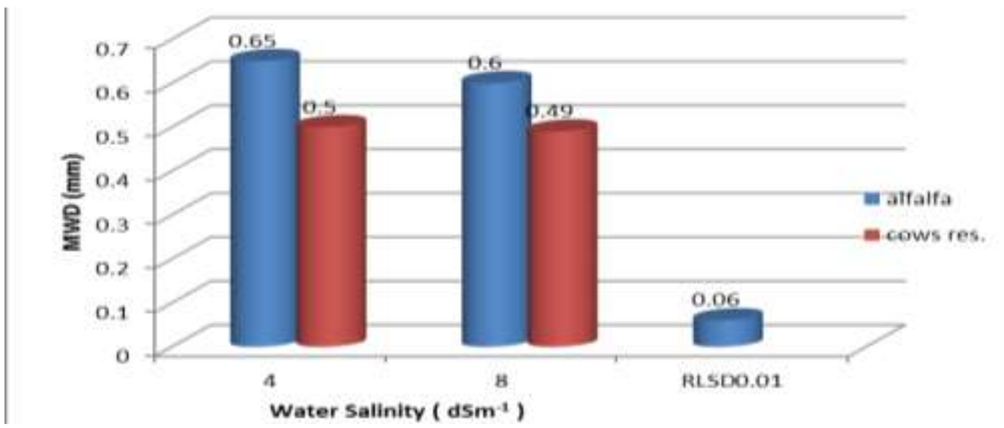

Figure 10. The effect of the type of organic matter and the salinity of the irrigation water on the values of the mean weighted diameter of the soil at the end of the experiment (mm).

Ibrahim *et al*. (2015) found that adding sulfur at different levels to calcareous soil improved some of its physical and water properties, as the sulfur addition increased the porous volume of the soil and decreased bulk density.

Figure 9 details the substantial effect of the interaction of quality water and leaching requirements on the MWD values of the soil. The 35% leaching requirements treatment gave the highest values (0.74 and 0.64 mm for alfalfa and cow residues, respectively), significantly superior to the other treatments. The 15% leaching requirements treatment recorded the lowest values, which amounted to 0.51 and 0.37 mm for alfalfa and cow residues, respectively. The reason for exceeding the leaching requirements of 35% is due to the effect of high water quantities and the available nutrients on increasing the activity of soil microorganisms, eventually raising the decomposition of organic matter mixed with soil, which contributes to improving the formation of soil aggregates and maintaining soil structure (Abd-Al-Hseen *et al*., 2020). Tefaij (2020) confirmed that treating the soil with organic residues (alfalfa and cows) and urea fertilizer enhanced the effectiveness of soil microorganisms, as the results indicated that urea fertilizer and alfalfa residues were superior to cow waste in intensifying the activity of microorganisms, the amount of ammonium liberated, and the nitrates formed for all transactions.

Table 3. The effect of the treatments on the mean weighted diameter of the soil at the end of the experiment (mm).

LR	EC-water	S %	Organic matter type		Organic matter type*S %
			Alfalfa	Cow	
15	4	0	0.21	0.22	0.22
		0.8	0.53	0.28	0.41
		1.6	0.65	0.59	0.62
	8	0	0.26	0.16	0.21
		0.8	0.52	0.34	0.43
		1.6	0.88	0.63	0.76
25	4	0	0.58	0.31	0.45
		0.8	0.68	0.45	0.57
		1.6	0.89	0.69	0.79
	8	0	0.27	0.23	0.25
		0.8	0.57	0.40	0.49
		1.6	0.76	0.71	0.74
35	4	0	0.60	0.47	0.54
		0.8	0.74	0.61	0.68
		1.6	0.93	0.86	0.90
	8	0	0.52	0.42	0.47
		0.8	0.67	0.59	0.63
		1.6	0.95	0.89	0.92
EC-water		4	0.57		
		8	0.54		
					LR * EC-water
Organic matter type * LR * EC-water	15	4	0.46	0.36	0.41
		8	0.55	0.38	0.47
	25	4	0.72	0.48	0.60
		8	0.53	0.45	0.49
	35	4	0.76	0.65	0.70
		8	0.71	0.63	0.67
					LR * S %
Organic matter type * LR * S %	15	0	0.24	0.19	0.21
		0.8	0.53	0.31	0.42
		1.6	0.77	0.61	0.69
	25	0	0.43	0.27	0.35
		0.8	0.63	0.43	0.53
		1.6	0.83	0.70	0.76
	35	0	0.56	0.45	0.50
		0.8	0.71	0.60	0.65
		1.6	0.94	0.88	0.91
					EC-water * S %
Organic matter type * EC-water * S %	4	0	0.46	0.33	0.40
		0.8	0.65	0.45	0.55
		1.6	0.82	0.71	0.77
	8	0	0.35	0.27	0.31
		0.8	0.59	0.44	0.52
		1.6	0.86	0.74	0.80
S %	0		0.41	0.30	
	0.8		0.62	0.45	
	1.6		0.84	0.73	

Note: There are no significant differences between the coefficients within the table below the probability level of 0.01.

Regarding the effect of the interaction between the type of organic matter and the salinity of the irrigation water at the end of the experiment on the soil's MWD, it appears from Figure 10 that the interaction of the treatment of alfalfa residues with an irrigation water salinity of 4 dSm^{-1} was significantly superior to the rest of the treatments, giving the maximum value (0.65 mm). In comparison, the lowest value of the mean weighted diameter was 0.49 mm, recorded when treating cow residues with a salinity of irrigation water 8 dSm^{-1}. It is also evident from the results that alfalfa residue treatments were markedly superior to cow residues for both levels of salinity of the irrigation water under study. It may be due to the effect of the rapid decomposing of alfalfa residues and the high quality of irrigation water with electrical conductivity on increasing soil microorganism activity, speeding the decomposition of organic matter mixed with soil during the growing season, enhancing the formation of soil agglomerations and maintaining soil structure (Figure 4).

Table 3 points out no significant effect of the irrigation water salinity factor and the interaction between the following: type of organic matter and added sulfur; leaching requirements and irrigation water salinity; leaching requirements and added sulfur; irrigation water salinity and added sulfur; type of organic matter, leaching requirements, and irrigation water salinity; type of organic matter, leaching requirements, and added sulfur; type of organic matter, irrigation water salinity, and added sulfur; leaching requirements, irrigation water salinity, and added sulfur; type of organic matter and leaching requirements, and irrigation water salinity and added sulfur in the soil MWD values after the end of the experiment.

CONCLUSIONS

The results showed the ability of the alfalfa residues, the percentage of added sulfur of 1.6%, and the leaching requirements of 35% with an irrigation water quality of 4 dSm^{-1} to reduce the bulk density of the soil and increase the stability (MWD) and, thus, improving the soil properties and plant growth conditions in the study soil.

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