



The Effect of Washing Water Quality and Some Amendments (Gypsum and Organic Matter) on Salt Dynamics and Improvement of Saline Soil Properties

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Abstract

Soil salinity is one of the major problems affecting the development of agriculture in arid and semi-arid areas because of the impact of salt on the physicochemical characteristics of the soil and its low productivity. This research was carried out with the aim of studying the effect of applying different washing waters combined with some amendments such as agricultural gypsum and organic material on salt movement through a saline loamy soil. It was done through a pot experiment according to a Completely Randomized Design (CRD) with three replications for each treatment consisting of five treatments as follows. The results indicated a significant reduction in the salinity of the soil since there was a considerable reduction in the EC_e values from 8.50 to 3.10 dS/m for the gypsum treatment (T4). Similarly, there was a considerable reduction in the SAR values from 12.0 to 4.2, as well as a significant reduction in the ESP values from 18.0% to 7.8%. The filtered water (T2) had a significant reduction in EC_e values to 4.20 dS/m, whereas the saline water (T3) had the least effective rate of reducing soil salinity with values at 7.05 dS/m. There was also a significant reduction in the EC_e values to 4.90 dS/m with an improvement in the physical characteristics of the soil in the organic matter treatment (T5).

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Keywords: Soil salinity, soil leaching, gypsum, organic matter, electrolyte balance, SAR (sodium adsorption ratio), ESP (exchangeable sodium percentage)

Introduction

Soil salinity is one of the most prevalent problems that have been posed against agriculture in the arid and semi-arid areas, with a significant impact on agricultural productivity and sustainability of natural resources. As documented by the Food and Agriculture Organization, huge stretches of agricultural land around the world are exposed to soil salinity because of mismanagement and unfriendly climate.

Salinity in the soil is a result of the accumulation of soluble salts, such as sodium chloride and its sulfates, in the soil where plants have their roots as a consequence of lower precipitation and higher rates of evaporation. This results in increasing the osmotic pressure of the soil and decreasing the plant's capability to absorb water, as well as the ions' balance in the plant itself (Hussain *et al.*, 2021)^[5]. The issue of salinization is rather complicated, since it impacts both the physical and chemical properties of the soil; the high amount of exchangeable sodium causes soil particles to be dispersed and unstable (Singh, 2022)^[10].

Leaching is among the most effective approaches in the management of saline soils, as the method involves the washing away of salt from the root zone by using enough volumes of water. But the success of this approach strongly depends on the quality of washing water, as well as its chemistry. In addition, there is an influence of soil characteristics on the effectiveness of leaching. For instance, the efficiency of salt removal by leaching will be higher in case of using water with low salinity content (Elshaikh *et al.*, 2023)^[4].

Agricultural amendments are considered crucial to increase the effectiveness of saline soil reclamation processes. Among other

agricultural amendments, agricultural gypsum is frequently used for its contribution to the formation of an optimal ionic ratio through calcium addition that will take place of sodium ions at the exchange complex (Abdel-Fattah, 2021) ^[1]. Organic matter is another key amendment that affects the physical structure and the porosity level of soils. Moreover, organic amendments are responsible for increasing biological activity and affecting plants' growth positively (Al-Wabel *et al.*, 2022) ^[2]. In view of the growing problems of water scarcity and its deterioration, it becomes essential to investigate the impact of the quality of washing water with different amendments on salts dynamic in soils.

Materials and Methods

The test was performed in the 2025 season, where the plants were grown in saline loam soil in plastic containers. Five different treatments were used:

- **T1:** Washing with river water (EC ~ 1.2 dS/m).
- **T2:** Washing with filtered water (EC ~ 0.4 dS/m).
- **T3:** Washing with relatively saline water (EC ~ 5.0 dS/m).
- **T4:** Addition of gypsum to the soil (5 t/ha) + washing with river water.
- **T5:** Addition of organic matter to the soil (2% w/w) + washing with river water.

Washing was performed using a 2:1 leaching ratio (double the field capacity), adding water gradually to ensure the movement of salts below the root zone. Soil samples were collected before and after 7 days of washing at the soil layer of 0-30 cm to measure EC_e, SAR, ESP, and ions concentration. The data was analyzed by SPSS and LSD test with a 0.05 probability level.

Results and Discussion

Table 1: Dissolved Ion Concentrations in Soil Solution (mmol L⁻¹).

Treatments	Na+	Ca ²⁺	Mg ²⁺	K+	Cl-	SO ₄ ²⁻	HCO ₃ ⁻
Pre-washing	18.0	3.0	2.5	1.0	15.0	5.0	5.0
T1	11.5	2.75	2.4	0.8	9.5	3.5	3.5
T2	8.0	2.9	2.5	0.7	6.5	2.75	3.0
T3	15.5	2.6	2.3	0.9	13.0	4.5	4.2
T4	6.2	3.8	2.7	0.8	5.5	3.0	2.8
T5	9.5	2.85	2.6	0.85	7.5	3.2	3.2
LSD	1.2	0.35	0.25	0.15	1.1	0.8	0.75

The results show a definitive drop in the concentration of ions when the samples were washed. T4 performed best when it came to lowering the concentration of sodium ions, thanks to calcium ions' ability to replace sodium ions in the soil

exchange complex, thus enhancing their leachability. Additionally, organic matter (T5) improved water flow, hence lowering the concentration of salts. This concurs with the results presented by Daba (2025) ^[3].

Table 2: Impact of Washing on Chemical Characteristics of Soil.

Treatments	EC _e (dS/m)	SAR	ESP (%)	Texture	O.M. (%)
Pre-washing	8.5	12.0	18.0	Loam	1.2
T1	5.65	8.2	13.3	Loam	1.1
T2	4.2	6.1	10.5	Loam	1.05
T3	7.05	10.8	16.2	Loam	1.15
T4	3.1	4.2	7.8	Loam	1.08
T5	4.9	7.5	12.5	Loam	1.35
LSD	0.6	0.85	1.0	-	-

There was a considerable reduction in EC_e, SAR, and ESP, where T4 had the lowest value. This is because gypsum was highly effective in decreasing sodicity. The improvement in

the physical characteristics of T5 indicated a positive wash. The findings support those of Qadir *et al.* (2021) ^[7], who noted that chemical treatments decreased ESP and SAR.

Table 3: Ion Balance and Couples in Soils.

Treatments	Na/Ca	Na/Mg	(Ca+Mg)/Na	Assessment
Pre-washing	6.0	7.2	0.31	High
T1	4.18	4.79	0.45	Moderate
T2	2.76	3.2	0.68	Low
T3	5.96	6.74	0.32	High
T4	1.63	2.29	1.05	Balanced
T5	3.33	3.65	0.58	Moderate

The ion balance was greatly improved by washing, which led to a decrease in the ratios of Na/Ca and Na/Mg while increasing (Ca + Mg)/Na, particularly in treatment 4, suggesting less dominance of sodium. Treatment 5 exhibited

moderate effects. This concurs with findings by Rengasamy (2020) [8] that an increase in calcium minimizes sodium effects.

Table 4: % Changes (%) in Ion Concentrations.

Treatments	Na+	Ca ²⁺	Mg ²⁺	Cl-	SO ₄ ²⁻	HCO ₃ ⁻
T1	-36.1	-8.3	-4.0	-36.7	-30.0	-30.0
T2	-55.6	-3.3	0.0	-56.7	-45.0	-40.0
T3	-13.9	-13.3	-8.0	-13.3	-10.0	-16.0
T4	-65.5	26.7	8.0	-63.3	-40.0	-44.0
T5	-47.2	-5.0	4.0	-50.0	-36.0	-36.0

Monovalent ions (Na⁺, Cl⁻) exhibited higher mobility compared to divalent ions, having the highest reduction percentages, especially in T4. Organic matter enhanced water

movement. This result is consistent with Zhang *et al.* (2024) [11] who posited that monovalent ions have higher mobility.

Table 5: Ion Mobility Sequence in Soils.

Treatments	Ion Mobility Order
T1	Mg ²⁺ <Ca ²⁺ <HCO ₃ ⁻ <SO ₄ ²⁻ <Na ⁺ <Cl ⁻
T2	Mg ²⁺ =Ca ²⁺ <HCO ₃ ⁻ <SO ₄ ²⁻ <Na ⁺ <Cl ⁻
T3	Mg ²⁺ <Ca ²⁺ <SO ₄ ²⁻ <HCO ₃ ⁻ <Na ⁺ =Cl ⁻
T4	Ca ²⁺ <Mg ²⁺ <SO ₄ ²⁻ <HCO ₃ ⁻ <Na ⁺ <Cl ⁻
T5	Ca ²⁺ <Mg ²⁺ <HCO ₃ ⁻ <SO ₄ ²⁻ <Na ⁺ <Cl ⁻

Monovalent ions (Cl⁻, Na⁺) dominated in speed in the mobility order, whereas divalent ions (Ca²⁺, Mg²⁺) were less mobile because of particle attachment in the soil. The treatments made more ions mobile, with gypsum being effective. This is consistent with Li *et al.* (2023), since monovalent ions possess greater mobility.

Conclusion

1. Leaching greatly reduced salinity.
2. Gypsum (T4) performed better in chemical modification.
3. Organic matter (T5) increased soil structure.
4. Water quality affected efficiency (T2 > T1 > T3).
5. Ion balance improved with gypsum.
6. Monovalent ions moved faster.
7. Chemical modifications are more efficient for salt removal.

Recommendations

1. Gypsum should be applied to reclaim saline/sodic soils.
2. Low salinity water is preferred.
3. Organic material can be added to improve structure.
4. Saline water is not suitable for leaching.
5. Conduct combined amendment studies in the future.
6. Move towards advanced simulation/detection approaches.

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