# Impact of Time Scheduling of Intermittent Leaching on the Solubility and Movement of Soil Salts

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**Abstract**
Two types of leaching water with different salinity values (river water and well water) were used, with electrical conductivity values of (1.81 and 10.12) $dS/m^{-1}$, respectively, and ionic strengths of (0.023 and 0.132) $mol\ L^{-1}$, The purpose of studying their effect on the leaching of salts from some salt-affected soils in Babil, with varying soil textures, was to determine the pore size of the soil columns during the experiment. Microsoft Excel was used to plot the intermittent leaching curves for these salt-affected soils. The results showed a clear decrease in soil salinity for all treatments following leaching with water of different ionic strengths. However, the well water treatment was superior to the river water treatment in terms of its content of divalent ions $Ca^{2+}$, $Mg^{2+}$, which are capable of replacing monovalent ions Dispersing soil particles on the surfaces of ion exchange sites, forming aggregates and improving soil structure, The effect of intermittent of leaching water on the release of ions present on the surfaces of ion exchange sites is evident in the figures, where an increase in ion release can be observed continuously by allowing a period for salts to reform and then be released by the used wash water, whether it is well water or river water.

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**Keywords:** Salt-Affected Soils, Soil Leaching, Soil Salinity, Intermittent Leaching, Leaching Water Quality

## Introduction

Soil is the primary source of human food and animal feed. However, its ability to provide basic life necessities can be affected by several natural factors, including soil salinity. The central and southern provinces of Iraq suffer from high soil salinity due to water scarcity resulting from a limited water allocation and a shortage of dams. This has led farmers in some rural areas to rely on well water, which has high salinity levels due to leaching. The soil is irrigated to meet the needs of economic or fodder crops without considering the negative effects of this water on the soil in the short and long term. This has led to the gradual accumulation of salts in the soil, causing the salinity problem to worsen. The high summer temperatures in Iraq affect the evaporation of water containing these salts, leaving salts to accumulate on the soil surface. Furthermore, the chemical and physical properties of the soil contribute to the development and exacerbation of the salinity problem (Saleh, 2020; Lei, 2022) [2, 5]. Therefore, the study aims to use saline and non-saline water to leaching these soils and calculate the aggregate concentration of leached salts with leaching water affected by gravity, which gives an indication of the diversity and concentration of salts causing the salinity problem in these soils and the role of intermittent of leaching.

## Materials and Work Methods

### Study Location

The study was conducted during the summer using a randomized complete block design (RCBD). Undisturbed soils were brought from the academic year (2024). These samples represent types of salt-affected soils from different locations in Babylon Governorate. The soils of the selected locations are characterized by different textures, and most of them are characterized by a high percentage of clay in them, exceeding 41%. This has an effect on the adsorption of ions on the surfaces of mineral soil particles. Increasing the surface area of the particles will lead to an increase in the surface's ability to attract ions present in the soil solution and exchange them with the ions present on the surface of the particles. Chemical and physical analyses were carried out in the method mentioned in (page *et al*., 1982), the total percentage of dissolved salts in the soil was calculated as shown in (Richards, 1954) in Table No. (2), and the water used has the following specifications as shown in Table (1).

### The Leaching Process and Displacement of Ions from the Soil Column

The leaching method intermittently every week and using well water, which is symbolized by the symbol W1, as well as using river water, which is symbolized by the symbol W2, leaching comparison samples of sites affected by soil salts, as in Figure (2), which shows the field inspection of sites where chloride salts are dominant and their chemical characteristics are determined as in Table No. 2, for a specific period of time every week for a period of 42 days using a well, by adding leaching water according to the volume that is determined based on the weight of the soil column and determining the moisture content. The addition period is every week, and the leachate is collected weekly for (6) weeks, In each leaching process, the leachate is collected for the purpose of conducting chemical analyses on it to determine the quality of this water.

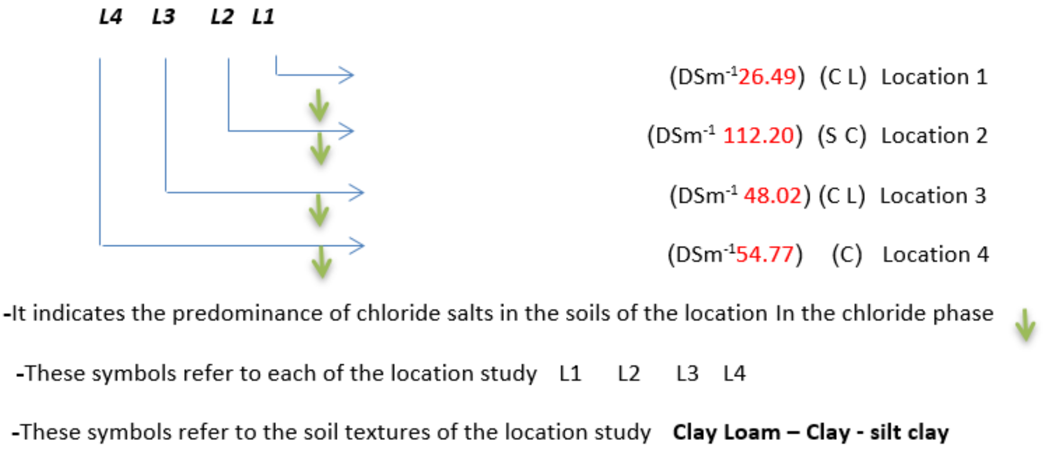

**Fig 1:** Provides a graphical illustration of location symbols and soil textures

**Fig 2:** Inspection of salt-affected soil

**Table 1:** Represents the chemical and physical properties of used leaching water.

| Character | Unit | Leaching Water for Saline Soils | |
|---|---|---|---|
| | | $W_1$ | $W_2$ |
| EC | Ds $m^{-1}$ | 10.12 | 1.81 |
| PH | - | 7.26 | 7.88 |
| Ionic strength (I) | mol $l^{-1}$ | 0.132 | 0.023 |
| $Ca^{+2}$ | mmol $l^{-1}$ | 11.00 | 2.75 |
| $Mg^{+2}$ | mmol $l^{-1}$ | 23.02 | 6.05 |
| $Na^{+}$ | mmol $l^{-1}$ | 20.34 | 4.12 |
| $K^{+}$ | mmol $l^{-1}$ | 0.27 | 0.13 |
| $Cl^{-}$ | mmol $l^{-1}$ | 35.68 | 12.16 |
| $SO_4^{-2}$ | mmol $l^{-1}$ | 11.72 | 7.24 |
| $HCO_3^{-}$ | mmol $l^{-1}$ | 1.50 | 0.61 |
| Sodium adsorption ratio (SAR) | mmol charger $^{-1}$ | 7.33 | 2.23 |
| Classification of leaching water according to Ayers و (Westcot, 1985) | | C1-s1 | C2-s1 |

## Results and discussion

**Chemical Characteristics of Some Study location:** The results in Table 2 indicate some of the chemical characteristics of soil samples from the study sites. The electrical conductivity values of the saturated soil paste extract ranged from 26.49 to 112.20 dS/m⁻¹. The use of leaching water reduced soil salinity to levels close to that of the leaching water, which is consistent with the findings of (Al-Asadi, 2018) [3]. The lowest electrical conductivity value was found in the soil sample from the first site, L1, which is uncultivated soil characterized by a groundwater level close to the surface, with a depth of approximately 100 cm, contributing to salinization. The highest soil salinity value was found in the third site sample within the geographical area. Examination of the groundwater depth revealed it to be close to the soil surface, at a depth of 80 cm. This strongly suggests the contribution of groundwater to soil salinization through capillary action during periods of drought, causing water to evaporate and leave salts accumulating on the soil surface. These values are consistent with the soil pH values, which ranged between 7.11 and 7.80. The lowest pH value was found in the soil of the second site, while the highest was in the soil of the first site. The first is that the scientific explanation for the decrease in the degree of soil reactivity with the increase in salinity is that the increase in salinity will affect the electrical double layer, as the increase in the concentration of dissolved salts (cations) exchanges with the hydrogen ion adsorbed on the surface of the soil particles, and this leads to the separation of hydrogen ions and an increase in their concentration in the solution, and this results in a decrease in the degree of soil reactivity. This phenomenon is called the dilution effect. As for the electrical double layer, it is compressed as a result of the increase in concentration in the solution, which leads to the exit of a portion of the hydrogen exchanged in this layer into the soil solution so that its concentration inside the electrical double layer remains constant (Shafiq *et al*, 1990).

**Table 2:** Some chemical properties of some soil location studied before leaching

| $Cl^-$ | $SO_4^{2-}$ | $HCO_3^-$ | $CO_3^{2-}$ | $K^+$ | $Na^+$ | $Mg^{2+}$ | $Ca^{2+}$ | CEC Smol ch. $^{-1}$ | Soil texture | SAR SAR m mol -1 | ECe Ds m-1 | pH | location |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 210.22 | 35.6 | 5.00 | nill | 0.47 | 299.70 | 17.00 | 18.00 | 18.89 | Clay loam | 71.64 | 26.49 | 7.80 | L1 |
| 1301.15 | 34.05 | 2.70 | nill | 3.90 | 622.18 | 385.50 | 50.10 | 14.82 | Silt clay | 42.15 | 112.20 | 7.11 | L2 |
| 30.705 | 371.60 | 1.73 | nill | 14.40 | 177.40 | 162.59 | 72.00 | 15.78 | clay loam | 16.37 | 48.02 | 7.20 | L3 |
| 571.34 | 31.20 | 2.55 | nill | 1.52 | 290.72 | 4.60 | 42.10 | 20.15 | clay | 60.16 | 54.77 | 7.44 | L4 |

**Physical Characteristics of Some Soils in the Study Location:** The results in Table 2 indicate, the values of the soil texture percentages ranged between (clay loam, silt clay, clay). The reason for this in most of the soils of these areas affected by salts or suffering from a problem of high soil salinity, after conducting physical analyses of the soil separators, is that they are of the (clay loam, silt clay, clay) type. Most of them are characterized by a high percentage of clay in them exceeding 41%, and this has an effect on the adsorption of ions on the surfaces of mineral soil particles. Increasing the surface area of the particles will lead to an increase in the surface's ability to attract ions present in the soil solution and exchange them with the ions present on the surface of the particles.

**Table 3:** shows the concentration of positive and negative ions at the first location.

| Dissolved ions mmol l-1 | | | | | | | | Soil PH | EC Ds m$^{-1}$ | /TIME | The quality of leaching water |
|---|---|---|---|---|---|---|---|---|---|---|---|
| $Cl^-$ | $SO_4^{2-}$ | $HCO_3^-$ | $CO_3^{2-}$ | $K^+$ | $Na^+$ | $Mg^{2+}$ | $Ca^{2+}$ | | | | |
| L1 | | | | | | | | | | | River water |
| 200.60 | 25.6 | 6.00 | nill | 0.47 | 289.28 | 16.00 | 14.00 | 7.73 | 20.3 | 7 | |
| 104.75 | 52.64 | 3.00 | Nill | 5.34 | 91.56 | 15.00 | 15.50 | 8.10 | 16.04 | 14 | |
| 79.90 | 41.80 | 1.50 | Nill | 0.47 | 93.30 | 6.16 | 11.33 | 7.90 | 12.32 | 21 | |
| 44.20 | 69.00 | 2.00 | Nill | 2.58 | 68.40 | 10.20 | 16.68 | 8.10 | 11.89 | 28 | |
| 61.43 | 52.56 | 1.20 | Nill | 0.73 | 91.02 | 3.81 | 6.82 | 7.80 | 11.52 | 35 | |
| 61.96 | 27.03 | 1.60 | Nill | 0.52 | 34.26 | 31.60 | 35.60 | 8.35 | 9.06 | 42 | |

**Table 4:** Shows the concentration of positive and negative ions at the second location.

| Dissolved ions mmol l-1 | | | | | | | | Soil PH | EC Ds m$^{-1}$ | /TIME | The quality of leaching water |
|---|---|---|---|---|---|---|---|---|---|---|---|
| $Cl^-$ | $SO_4^{2-}$ | $HCO_3^-$ | $CO_3^{2-}$ | $K^+$ | $Na^+$ | $Mg^{2+}$ | $Ca^{2+}$ | | | | |
| L2 | | | | | | | | | | | River water |
| 1100.05 | 35.55 | 1.50 | nill | 2.93 | 679.18 | 385.50 | 51.00 | 7.84 | 112.20 | 7 | |
| 347.42 | 247.57 | 9.50 | Nill | 2.96 | 205.67 | 291.00 | 30.00 | 7.93 | 60.45 | 14 | |
| 708.90 | 242.60 | 1.50 | Nill | 2.74 | 716.13 | 219.83 | 37.66 | 7.73 | 95.30 | 21 | |
| 521.90 | 327.60 | 3.50 | Nill | 5.47 | 715.22 | 221.50 | 44.58 | 7.93 | 85.30 | 28 | |
| 397.05 | 454.74 | 1.20 | Nill | 5.78 | 458.78 | 90.75 | 41.16 | 7.63 | 85.39 | 35 | |
| 230.11 | 189.28 | 1.60 | Nill | 3.95 | 54.51 | 121.60 | 71.20 | 8.41 | 42.10 | 42 | |

**Table 5:** Shows the concentration of positive and negative ions at the third location.

| Dissolved ions mmol l-1 | | | | | | | | Soil PH | EC Ds $m^{-1}$ | /TIME | The quality of leaching water |
|---|---|---|---|---|---|---|---|---|---|---|---|
| $Cl^-$ | $SO_4^{2-}$ | $HCO_3^-$ | $CO_3^{2-}$ | $K^+$ | $Na^+$ | $Mg^{2+}$ | $Ca^{2+}$ | | | | |
| L3 | | | | | | | | | | | Well water |
| 32.70 | 461.50 | 1.50 | nill | 12.76 | 147.21 | 143.50 | 67.00 | 7.90 | 46.23 | 7 | |
| 108.19 | 216.40 | 2.50 | Nill | 0.36 | 28.45 | 73.50 | 17.00 | 8.01 | 32.71 | 14 | |
| 85.60 | 130.90 | 1.50 | Nill | 6.59 | 128.91 | 57.00 | 14.00 | 8.41 | 21.80 | 21 | |
| 38.00 | 103.70 | 2.50 | Nill | 3.71 | 57.87 | 49.16 | 12.30 | 7.50 | 14.42 | 28 | |
| 105.73 | 77.26 | 1.20 | Nill | 3.78 | 91.38 | 22.11 | 10.30 | 7.82 | 18.42 | 35 | |
| 35.10 | 109.59 | 0.80 | Nill | 3.87 | 60.99 | 44.00 | 26.00 | 8.15 | 14.55 | 42 | |

**Table 6:** shows the concentration of positive and negative ions at the fourth location

| Dissolved ions mmol l-1 | | | | | | | | Soil PH | EC Ds $m^{-1}$ | /TIME | The quality of leaching water |
|---|---|---|---|---|---|---|---|---|---|---|---|
| $Cl^-$ | $SO_4^{2-}$ | $HCO_3^-$ | $CO_3^{2-}$ | $K^+$ | $Na^+$ | $Mg^{2+}$ | $Ca^{2+}$ | | | | |
| L4 | | | | | | | | | | | Well water |
| 451.20 | 20.3 | 3.50 | nill | 1.84 | 258.62 | 3.50 | 43.00 | 7.92 | 47.50 | 7 | |
| 373.8 | 13.8 | 4.00 | Nill | 1.82 | 178.45 | 43.00 | 25.00 | 8.46 | 37.70 | 14 | |
| 239.70 | 39.80 | 1.50 | Nill | 1.95 | 164.38 | 26.33 | 22.66 | 7.81 | 28.10 | 21 | |
| 207.40 | 76.70 | 2.00 | Nill | 2.09 | 204.06 | 4.60 | 24.12 | 8.03 | 28.61 | 28 | |
| 156.79 | 126.90 | 2.40 | Nill | 1.65 | 212.30 | 6.20 | 21.60 | 7.73 | 28.40 | 35 | |
| 94.75 | 32.14 | 2.00 | Nill | 1.25 | 48.82 | 17.20 | 33.60 | 8.36 | 12.89 | 42 | |

**The Aggregate Concentration of Salts and Cation Concentrations of the Soil at the Study Location:** The results in Table 6 show the difference in the aggregate concentration values of dissolved salts (TDS) and the aggregate concentration of calcium, magnesium, sodium, and potassium ions during the leaching process of the soil at the sites. The results in the tables above show that the aggregate concentration values of dissolved salts (TDS) during the process ranged between 860.63 - 1452.22 mg $L^{-1}$, with the lowest value being in the soil of site L1 during leaching with river water, and the highest value for dissolved solid salts. It is in the soil of site L3 during the leaching process with high ionic strength water. As for the aggregate concentration of calcium, magnesium, sodium and potassium ions during the leaching process with water of different ionic strength and concentration, the aggregate concentration values of calcium ions ranged between 99.93 – 275.6 mmol L-1, as the lowest value was in the soil of L1, the highest value was in the soil of site L2. The results also showed that the aggregate concentration values of magnesium ions ranged between 82.77 – 1330.18 mmol L-1, while the aggregate concentration of sodium ions ranged between 662.02 – 2829.49.

**Table 7:** shows the aggregate concentration of salts and cations.

| concentration of ions in mmol 1 | | | | The combined concentration of ions in mmol 1 | ECe Ds m-1 | time day |
|---|---|---|---|---|---|---|
| $K^{1+}$ | $Na^{1+}$ | $Mg^{2+}$ | $Ca^{2+}$ | | | |
| L1 | | | | | | |
| 0.47 | 289.28 | 16 | 14 | 319.75 | 20.30 | 7 |
| 5.81 | 380.84 | 31 | 29.5 | 447.15 | 16.04 | 14 |
| 6.28 | 474.14 | 37.16 | 40.83 | 558.41 | 12.32 | 21 |
| 8.86 | 542.54 | 47.36 | 57.51 | 656.27 | 11.89 | 28 |
| 9.59 | 633.56 | 51.17 | 64.33 | 758.65 | 11.52 | 35 |
| 10.11 | 667.82 | 82.77 | 99.93 | 860.63 | 9.06 | 42 |
| L2 | | | | | | |
| 2.93 | 679.18 | 385.5 | 51 | 1118.61 | 112.20 | 7 |
| 5.89 | 884.85 | 676.5 | 81 | 1648.24 | 60.45 | 14 |
| 8.63 | 1600.98 | 896.33 | 118.66 | 2624.6 | 95.30 | 21 |
| 14.1 | 2316.2 | 1117.83 | 163.24 | 3611.37 | 85.30 | 28 |
| 19.88 | 2774.98 | 1208.58 | 204.4 | 4207.84 | 85.39 | 35 |
| 23.83 | 2829.49 | 1330.18 | 275.6 | 4459.1 | 42.10 | 42 |
| L3 | | | | | | |
| 13.12 | 175.66 | 217 | 84 | 489.78 | 46.23 | 7 |
| 19.71 | 304.57 | 274 | 98 | 696.28 | 32.71 | 14 |
| 23.42 | 362.44 | 323.16 | 110.3 | 819.32 | 21.80 | 21 |
| 27.2 | 453.82 | 345.27 | 120.6 | 946.89 | 14.42 | 28 |
| 31.07 | 514.81 | 389.27 | 146.6 | 1081.75 | 18.42 | 35 |
| 43.83 | 662.02 | 532.77 | 213.6 | 1452.22 | 14.55 | 42 |
| L4 | | | | | | |
| 1.84 | 258.62 | 3.50 | 43.00 | 306.96 | 47.50 | 7 |
| 3.66 | 437.07 | 46.5 | 68.00 | 555.23 | 37.70 | 14 |
| 5.61 | 601.45 | 72.83 | 90.66 | 770.55 | 28.10 | 21 |
| 7.70 | 805.51 | 77.43 | 114.78 | 1005.42 | 28.61 | 28 |
| 9.35 | 1017.81 | 83.63 | 136.38 | 1247.17 | 28.40 | 35 |
| 10.60 | 1066.63 | 100.83 | 169.98 | 1348.04 | 12.89 | 42 |

**Calcium ion release curves, cumulative over time, for soil samples from salt-affected of location**

Fig. 3, 4, 5, and 6 show the release curves of dissolved calcium and sodium in the leaching water for all selected salt-affected soil sites under intermittent leaching. The behavior of these curves reveals a cumulative release of calcium and sodium over a period of 42 days. However, the concentration of these ions decreased linearly over time for all soil samples from the study location, we observe from the leaching curves that the ions initially followed a straight line during the first week of leaching. As the leaching period increased, the dissolved ions began to follow a straight line at certain points, indicating a decrease in the amount of ions released during the leaching process, In the final stages, the concentration of ions released and dissolved by the leaching process equals the concentration of ions introduced by the used leaching water. It is also observed that there is a similarity in the behavior of some sites, although they differed in the accumulation of this ion,From this, it is noted from the figures that the highest R2 value for the calcium ion was 0.995 during intermittent washing for sites washed with well water, compared to sites washed with river water. This is attributed to the ion exchange that occurs during the intermittent leaching process with water containing a high ionic strength. The ions then influence solubility through the sodium adsorption ratio also plays a role; increasing it leads to increased release of calcium ions from ion exchange sites on the surfaces of clay particles. The intermittent leaching of the leaching water affects the release of ions present on the surfaces of ion exchange sites. As shown in the figures, there is a continuous increase in ion release by allowing the salts a period to reform and then be released by the leaching water used, whether well water or river water (as a control treatment). This is due to the active movement of ions through diffusion. This is consistent with what (Al-Hashemi, 2020) [4] concluded, as he indicated that during intermittent leaching, the diffusion phenomenon will be activated in addition to the mass flow due to the difference in concentration from one area to another within the soil column. As a result, the dissolved salts in these waters are released, and diffusion is considered the controlling factor in the process of salt dissolution between mineral layers. Consequently, the ions associated with the salt are leach through the use of irrigation water, and the groundwater level is lowered to reduce the accumulation of salts in the soil (Al-Hassan *et al*., 2022) [7].

The results show the effect of intermittent leaching of the leaching water on the release of ions present on the surfaces of the ion exchange sites. Through the figures, it can be observed that there is an increase in the release of ions continuously by giving a period for the salts to reform and then be released by the leaching water used, whether it is drainage water, well water, or river water. River water is also used as a control treatment. This is due to the activity of the phenomenon of ion movement by diffusion (AL-Hassani, 2007 and Al-Hashemi, 2020) [9, 4].

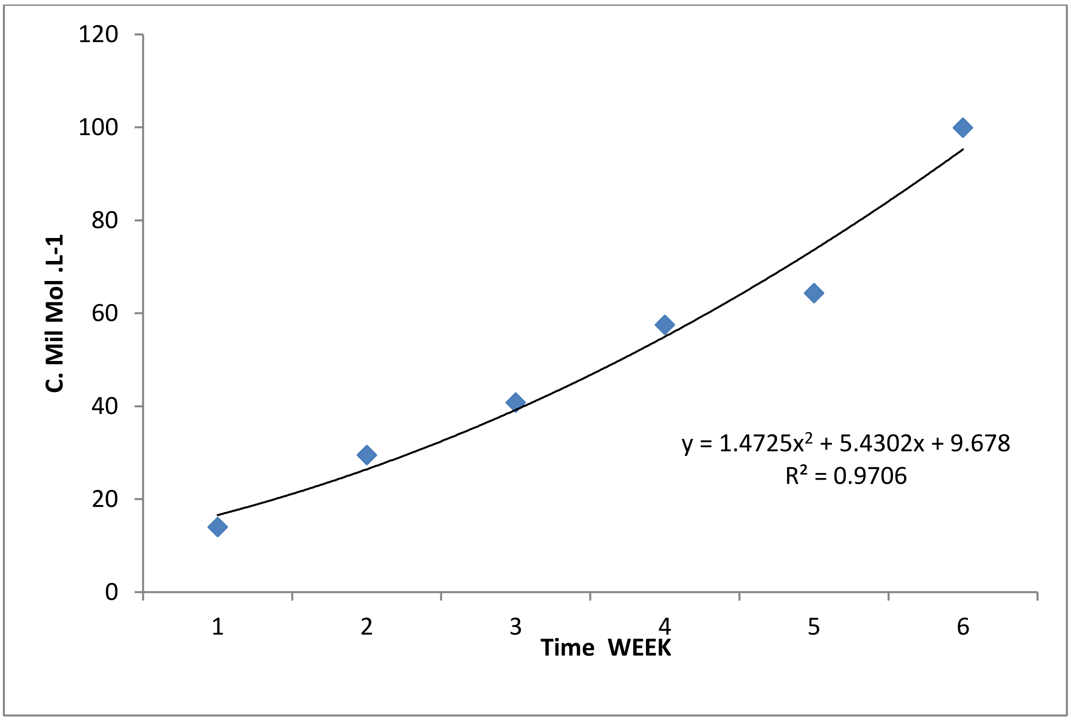

**Fig 3:** Intermittent washing of the combined liberated calcium ion over time (L2)

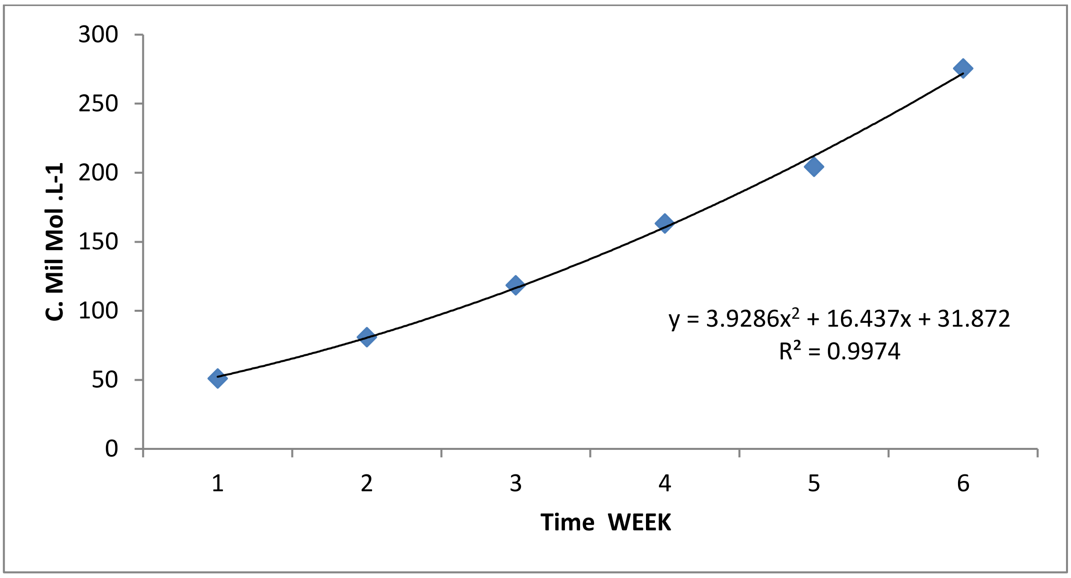

**Fig 4:** Intermittent washing of the combined liberated calcium ion over time (L2)

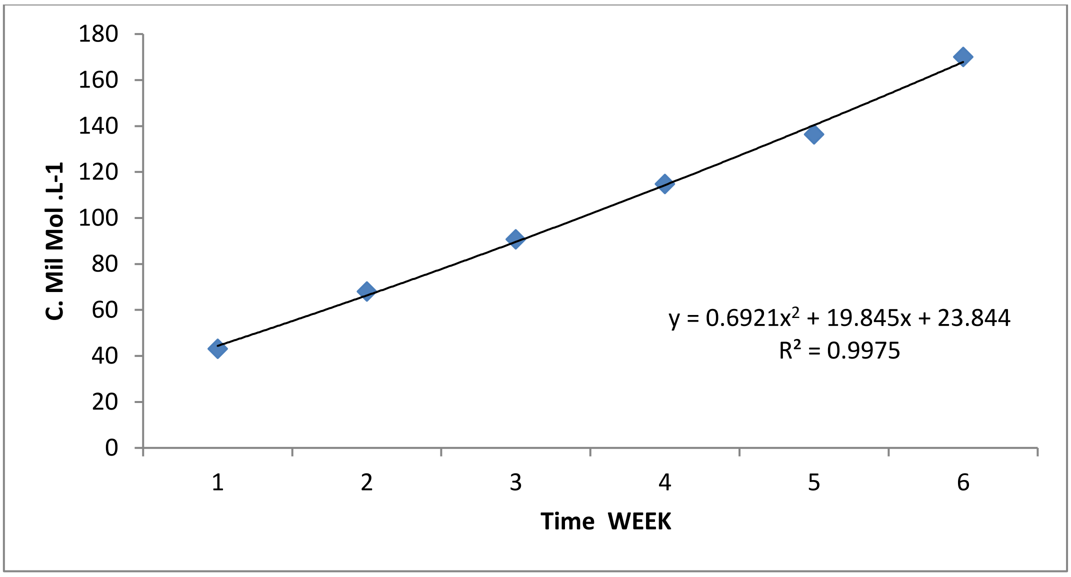

**Fig 5:** Intermittent washing of the combined liberated calcium ion over time (L4)

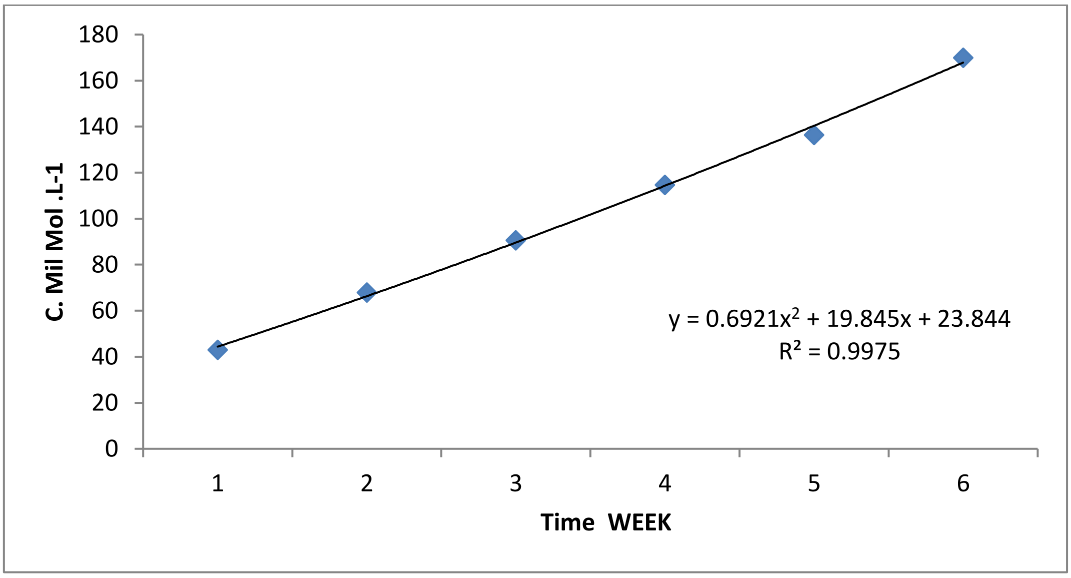

**Fig 6:** Intermittent washing of the combined liberated calcium ion over time (L3)

## Conclusion

The study results, as shown leaching in the tables and graphs of the leaching process, indicate a difference in the solubility behavior of salts present in the soils of the study sites during the leaching process, depending on the type of leaching water used and the phase sequence of the intermittent leaching process. It was concluded that the salts with the highest solubility were rapidly displaced from the ion exchange sites in the leached filtrate collected during the 42-day, Depending on the type of salts prevalent in these soils, where sodium salts were dominant over magnesium, calcium, and potassium salts respectively in the leachate, the dissolution and leaching of salts outside the soil surface caused a decrease in soil salinity to levels that allow for the cultivation of salt-tolerant economic crops.

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