# The efficiency of intermittent and continuous leaching of salt affected soils

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## ABSTRACT

In this study the efficiency of intermittent and continuous leaching methods of two types of soil, saline soil (S1) and saline sodic soil (S2) from Taworgha Agricultural Project were investigated. Two different pore volumes of good water quality (EC 0.029 mmhos / cm at 25C, PH 6.6) and the concentration of soluble cations for $Na^+$, $K^+$, $Ca^{+2}$, $Mg^{+2,}$ $Cl^-$ were (0.060, 0.001, 0.050, 0.225 and 0.325 meq /l respectively). This water quality was used in 2 and 6 PV. The experiments were carried out by using leaching columns. The results indicated that the efficiency of intermittent leaching was higher compared to continuous one. These results may be attributed to the replacement of soluble calcium ions in place of exchangeable sodium ions in soils under study.

Key Words: - Intermittent leaching, continuous leaching, leaching columns. exchangeable sodium. leaching methods, Leaching efficiency.

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**المستخلص باللغة العربية:-**

فى هذه الدراسة تم الكشف عن كفاءة طرق الغسيل المتقطع والمستمر لنوعين من الترب،

تربة ملحية (S1) وتربة ملحية صودية (S2) من مشروع تاورغاء الزراعي باستخدام حجمين مختلفين (6 PV & 2 PV) من مياه ذات جودة عالية ( جدول ـ 3) وقد أجريت التجارب باستخدام أعمدة غسيل التربة، وأشارت النتائج المتحصل عليها إلى أن كفاءة طريقة الغسيل المتقطع كانت أعلى مقارنة بكفاءة طريقة الغسيل المستمر ، ويمكن أن تعزى هذه النتائج إلى أحلال أيونات الكالسيوم القابلة للذوبان في التربة محل أيونات الصوديوم القابلة للتبادل.

الكلمات المفتاحية: - االغسيل المتقطع، االغسيل المستمر ، أعمدة الغسيل، الصوديوم المتبادل، طرق الغسيل، كفاءة الغسيل.

# INTRODUCTION

It is well known fact that in most of the countries which characterised by arid to semi-arid climates where evaporation exceeds precipitation, the migration of salts in water, accumulation through and deposition are responsible for Salinization of soils. In Libya, Taworgha spring, with a dissolved solids content of about 3000 ppm which is the main source of irrigation water in Taworgha Agricultural Project. Salts influence directly or indirectly in irrigated soil properties, given rise to saline soils. Salinity is one of the major factors reducing plant growth and productivity worldwide, and affects about 7% of the world's total land area (Flowers *et al*., 1997). The percentage of cultivated land affected by salt is even greater, with 23% of the cultivated land being saline and 20% of the irrigated land suffering from secondary salinization. Furthermore, there is also a dangerous trend of a 10% per year increase in the saline area throughout the world (Ponnamieruma, 1984). Libya is one of the countries that suffering from severe salinity problems. The processes which result in an increase in the exchangeable sodium and sodium carbonate in the soil led to the alkalization process. Miller *et al*. (1965) reported that intermittent application of a total 60 cms of water produced leaching effect which was significantly superior over 90 cms of water applied by continuous ponding. Oster et al. (1972) compared sprinkling ponding and intermittent ponding and found that each could achieve the same extent of leaching using different amount of water. A repeated leaching with shallow depth was found to be more efficient in leaching than permanent ponding (Bower, 1964). Doerping *et al* (1965) found that in continuous ponding, the depth of leaching was approximately equal to the depth of water applied.

Elgabaly (1970) studied some soils having 2.3 % of salt content in the UAR and found that for leaching the salts during summer, it requires more quantity of water compared to winter season. Furthermore, he observed that a minimum of 8000 $m^3$ of water per hectare was needed to leach salts from a depth of 1.5 meters. Khailah *et al* (2022) indicated that the soil improvement program under the treatment of adding rice straw and gypsum improved the physicochemical properties of the heavily saline soil in the newly reclaimed coastal area where gypsum and rice straw treatment turned out to be the best where salinity (EC), sodium adsorption ratio (SAR), and exchangeable sodium percentage (ESP) dropped to 3.61%, 5.04%, and 8.14%, respectively. These values reached the safe limit of salinity-sodicity (EC $\leq$ 4dS $m^{-1}$, ESP $\leq$ 15%). In addition, the incorporation of rice-straw with gypsum affects the ability to increase the removal of sodium and thus enhance salt-leaching efficiency.

Leaching with fresh water tended to increase the soil PH, and the rate of downward movement decreased due to soil dispersion under high PH (Soil Conservation Service, 1973). In an experiment conducted at U.S. Salinity Laboratory, it was observed that leaching effectively removed salts and boron, the rate of removal of salts was comparatively more than boron. In addition, it was found that with continuous ponding, the depth of leaching was approximately equal to the depth of water applied (Reeve *et al.*, 1955). Sahakyan *et al.*, (2024) reported that the efficiency of acoustic oscillations in expediting reclamation processes, reducing leaching water requirements, enhancing soil fertility, and facilitating integration into agricultural cycle. In a reclamation experiment conducted in a saline alkali soil in Antalya, Turkey, it has been found that intermittent leaching was better in lowering of ESP. In addition, in another field experiment, it was reported that the lowering of ESP was due to the removal of exchangeable sodium (Ozdemier&Beyce, 1972). Tagar *et al* (2010) suggested that continuous leaching is the suitable method of leaching when time for leaching is a limiting factor. However, for better results for long duration (up to five months) intermittent leaching methods is more efficient. The mean objective of this study was to investigate the leaching efficiency of saline and saline sodic soils on removal of exchangeable soil cations.

In an experiment, it was observed that leaching of the soil columns with the simulated acid rain in south China, the impacts of the simulated acid rain on cation leaching depended not only on the simulated acid rain pH but also on the original soil pH (Jia – EnZhang *et al*., 2007). Nesrin and Al- Mansori (2018) reported that in both continuous and intermittent leaching processes, all parameters tested decreased with time and when comparing continuous leaching with intermittent leaching, it can be noticed that the two heads, increasing the head size results in a faster decrease across all parameters ph., Total soluble salts (TSS), Cl, $CaCO_3$, salinity (EC) in both continuous and intermittent leaching processes.

Recently, many studies have been done to evaluate the use of different levels of water application intensity and irrigation amount of microsprinkler irrigation in coastal region with very strongly saline silt soil (Chu *et al*., 2014, 2015). The greater water application intensity and irrigation amount values were having more advantageous under unsaturated flow conditions, as they cause better water movement in the soil (Chu *et al*., 2016.). In addition, they have found that after leaching, due to microsprinkler irrigation soil was gradually changed to a moderately saline soil.

Abd Al-Kader *et al*., 2022 found, a high correlation between time flow and release capacity. In addition, the amount of calcium and magnesium release with increase of porosity volumes numbers and discontinuous leaching appeared a higher release of calcium and magnesium (0.81, 1.18 mole.kg$^{-1}$) in comparison with that in continuous leaching (0.73, 1.02 mole.kg$^{-1}$). Satar Boroujen *et al* (2022) reported that both intermittent and permanent leaching methods were reduced soil salinity but this reduction is more frequent in intermittent leaching, therefore intermittent leaching is more efficient than permanent leaching.

Russo (1985) shown that with the higher levels of leaching, the excess chloride was essentially removed, whereas considerable sulphate concentration was maintained as a result of gypsum dissolution in a gypsiferous desert soil. Leaching is more uniform for saturated than for unsaturated flow was concluded (Philip, 1984). Shaviv *et al* (1986) found that the salts leached from column-packed soil – manu re mixtures were significantly less than the total salt inputs. The loss of cations, was greater for calcium and potassium than for magnesium and sodium, which was attributed to reversible $K^+$ fixation and precipitation of $Ca^{+2}$ salts from solution. Beng *et al*. (2012) reported that without evaporation, intermittent infiltration significantly raised the average infiltration rate as well as drainage rate. With limited irrigation frequencies, it raised the solute leaching rate without influencing the final leaching efficiency. Moreover, measured $K^+$ fixation was greater in pulse- irrigated than in continuously irrigated columns. Zikri & El Sawaby, 1979 indicated that the salt content of soils was decreased with the increase of the age of leaching and it is more effective if the permeability of the layer which extends from a depth of 40 to 90 cm below land surface increases by sub soiling or by drying with the addition of adequate amount of gypsum and also reported that the soil productivity increases with increase of the age of leaching. Chi XU Wen *et al* (2015) indicated that soil texture, irrigation amount per time and irrigation application frequency had significant effect on salt and nitrate nitrogen ($NO_3$–-N) storage of 0-40 cm depth soil in intermittent irrigation while only soil texture affected soil water storage obviously. Cote *et al* (2000) stated that leaching efficiency in unsaturated methods was higher than permanent waterlogging due to unsaturated conditions and water passes through fine pores. Many studies have found positive changes that can enhance leaching efficiency, such as improved electrical conductivity, significant removal of exchangeable sodium, reduced sodium adsorption ratio, increased soil permeability (Salah *et al*., 2015), reduced bulk density (Chaganti *et.al*., 2015).

Two sandy loam surface soil samples, saline sodic (S1) and saline soil (S2) were collected from Tawergha Agricultural project, located about 300 km east of Tripoli / Libya.
The objective of this study was to see the effect of method and quantity of water application on the leaching efficiency of salt affected soils.

## MATERIALS AND METHODS

-Soil sampling: -

Composite soil samples were collected from 0-30cm depth, air dried, sieved using a 2 mm sieve and analyzed for Physical and chemical characteristics before leaching (Table 1, 2). The chemical composition of water used for leaching is presented in Table (3).

**Table 1- Physical characteristics of soil samples before leaching.**

| Parameters | Soil-1 | Soil-2 |
|---|---|---|
| bulk density ($g/cm^3$) | 1.50 | 1.48 |
| particle density ($g/cm^3$) | 2.56 | 2.39 |
| pore volume (%) | 41.00 | 38.00 |
| sand (%) | 73.00 | 57.00 |
| silt (%) | 18.00 | 40.00 |
| clay (%) | 9.00 | 3.00 |
| Soil texture | Sandy loam | Sandy loam |
| Saturation percent | 36.50 | 32.00 |

**Table 2- Chemical composition of soil samples before leaching.**

| Constituents | Soil-1 | Soil-2 |
|---|---|---|
| Soluble cations (meq/l) | | |
| $Na^+$ | 60.21 | 46.73 |
| $K^+$ | 3.99 | 1.92 |
| $Ca^{\|+2}$ | 60.00 | 50.00 |
| $Mg^{+2}$ | 49.00 | 40.00 |
| Soluble anions (meq/l) $Cl^-$ | 80.00 | 57.25 |
| Calcium carbonate (%) | 9.25 | 7.87 |
| Calcium sulphate (meq/100g) | 38.00 | 34.00 |
| EC (mmhos/cm at 25 °C ) | 10.82 | 8.82 |
| $P^H$ ( 1: 2.5) Ratio | 7.40 | 7.58 |

**Table 3- chemical composition of water used for leaching**

| Constituents | |
|---|---|
| Soluble cations (meq/L) | |
| $Na^+$ | 0.060 |
| $K^+$ | 0.001 |
| $Ca^{+2}$ | 0.050 |
| $Mg^{+2}$ | 0.225 |
| Soluble anions (meq/L) $Cl^-$ | 0.325 |
| EC (mmhos/cm at 25 C° ) | 0.029 |
| $P^H$ | 6.6 |

**-leaching columns**

A glass soil leaching columns 30 cm long and 10 cm diameter were used. Each soil column had a provision of 5 cm in addition to its absolute height to pour in water. At the base of columns, a thin layer of glass wool and an 11 cm diameter of schwarzband filer paper No. 5891 was placed to protect the draining down of soil particles.

The weight of soil to fill the columns was calculated on the basis of the soil bulk density, the weight of soil for each column was 3639 grams for soil-1 and 3591 grams for soil-2.

These soil samples were leached through thirty-two leaching soil columns were used to cover all the experiment combinations, the weight of soil to fill the columns were calculated on the basis of the bulk density. Based on the soil weight, the percent pore space for each soil type was calculated according to the method described by Brady (1974) based to the specific equations and they were 41 % for S1 and 38 % for S2. This lead to the estimation of exact pore volume (PV) of the water for leaching.

$$\% \textbf{ of solid space} = \frac{\textbf{bulk density}}{\textbf{particle density}} * \textbf{100}$$

**Since**

$$\% \textbf{ pore space} + \% \textbf{ solid space} = \textbf{100}$$

**and**

$$\% \textbf{ pore space} = \textbf{100} - \% \textbf{ solid space}$$

**Then**

$$\% \textbf{ pore space} = \mathbf{100} - \frac{\textbf{bulk density}}{\textbf{partical density}!} * \mathbf{100}$$

**-Preparation of columns**

Thirty-two glass soil leaching columns were used in this experiment to cover all experimental combinations, 3 and 6 pour volumes were used as V1, V2, two different methods of water pouring, intermittent and continuous one were used as M1, M2 respectively for each soil type.

In the intermittent method, each pour volume was divided in to two halves, half of the dose was poured or applied at the beginning of the study and the second half was added exactly 20 days after the first application. The duration of 20 days was allowed to bring the soil to an apparent dry condition. In the other set of columns, the (PV) was added continuously without allowing the soil to dry.

Soil samples were also analyzed before and after leaching processes for exchangeable cations ($Na^{+}$, $K^{+}$, $Ca^{+2}$, $Mg^{+2}$) and cation exchange capacity (CEC) in meq/100 g dry soil which used to determine exchangeable sodium percent (ESP) using the formula listed below.

$$\textbf{ESP} = \frac{\textit{Exchangeable Na+}}{\textit{Cation Exchange Capacity}} * \mathbf{100}$$

Where all concentrations in meq/100 g dry soil

In the intermittent method, each pour volume was divided equally to two halves, half of the dose was applied at the beginning of the study and the second half was added exactly 20 days after the first application. In the continuous method, the (PV) was added continuously without allowing the soil to dry. At the end of the leaching process, the soil from each column was air dried separately, sieved using a 2mm sieve and stored for some chemical analysis.

## RESULTS AND DISCUSSIONS

All treatments combinations used in this study had a significant effect on the exchangeable cations (Tables 4 – 8). The concentrations of three cations, $Na^{+}$, $K^{+}$ and $Mg^{+2}$ decreased under all treatments. However, the concentration of exchangeable $Ca^{+2}$ under all treatments showed a trend of increase. Since those soils contain 38, 34 meq/100-gram soil calcium sulphate for saline sodic and saline soil respectively, calcium dissolves during leaching process and the replacement of exchangeable sodium by calcium takes place (Soil Conservation Service, 1973).

All treatment combinations showed a significant decrease in the ESP (Table 8). However, the decrease was high in the first soil type as compared to the second one in all leaching treatments. These findings are also in accordance with those obtained by Ozdemir&Beyce (1972) who reported that lowering of ESP was due to the removal of exchangeable sodium.

## Table 4. Results of proposed procedures of exchangeable Na* (meq / 100-gram soil) **

| | | Continuous leaching | | | Intermittent Leaching | | |
|---|---|---|---|---|---|---|---|
| sample | volume | Concentration meq/100g soil | | Recovery % | Concentration meq/100g soil | | Recovery % |
| | | Before | After | | Before | After | |
| S1 | V1 | 1.41 | 0.28 | 80.32 | 1.41 | 0.30 | 70.90 |
| | | | | | | | |
| S1 | V2 | 1.41 | 0.35 | 75.53 | 1.41 | 0.24 | 82.97 |
| | | | | | | | |
| S2 | V1 | 0.99 | 0.43 | 57.05 | 0.99 | 0.41 | 58.26 |
| | | | | | | | |
| S2 | V2 | 0.99 | 0.44 | 55.90 | 0.99 | 0.41 | 58.54 |

## Table 4. 1. Means for two way interactions

| | S x V | | | S x M | | | V x M | |
|---|---|---|---|---|---|---|---|---|
| | V1 | V2 | | M1 | M2 | | M1 | M2 |
| S1 | 75.61 (0.29) | 79.25 (0.30) | S1 | 77.93 (0.32) | 76.94 (0.27) | V1 | 68.69 (0.36) | 64.58 (0.36) |
| S2 | 57.66 (0.42) | 57.22 (0.43) | S2 | 56.48 (0.44) | 58.40 (0.41) | V2 | 65.72 (0.40) | 70.76 (0.33) |

**Table 4.2. Means for main effects**

| SOIL TYPE | | | POUR VOLUME | | | METHODS | |
|---|---|---|---|---|---|---|---|
| S1 | S2 | | V1 | V2 | | M1 | M2 |
| 77.43 (0.30) | 57.44 (0.43) | | 66.64 (0.36) | 68.24 (0.37) | | 67.21 (0.38) | 67.67 (0.34) |

** S×V×M highly significant at 1% level, LSD 5% for different methods under same soil and pour volume - 1.00, for different pour volume under same soil and method - 1.10, for different soils for same pour volume and methods -1.21.

**Table 5. Results of proposed procedures of exchangeable $K^+$ (meq / 100-gram soil)**

| sample | volume | Continuous leaching | | | Intermittent Leaching | | |
|---|---|---|---|---|---|---|---|
| | | Concentration meq/100g soil | | Recovery % | Concentration meq/100g soil | | Recovery % |
| | | Before | After | | Before | After | |
| S1 | V1 | 0.74 | 0.59 | 20.90 | 0.74 | 0.54 | 27.30 |
| S1 | V2 | 0.74 | 0.42 | 43.40 | 0.74 | 0.38 | 48.60 |
| S2 | V1 | 0.28 | 0.24 | 18.70 | 0.28 | 0.22 | 22.30 |
| S2 | V2 | 0.28 | 0.19 | 32.60 | 0.28 | 0.20 | 28.50 |

**Table 5.1. Means for two way interactions**

| | S x V ( a ) | | | S x M ( b ) | | | V x M (C) | |
|---|---|---|---|---|---|---|---|---|
| | V1 | V2 | | M1 | M2 | | M1 | M2 |
| S1 | 24.10 (0.57) | 46.00 (0.40) | S1 | 32.20 (0.51) | 38.00 (0.46) | V1 | 19.80 (0.42) | 24.80 (0.38) |
| S2 | 20.50 (0.23) | 30.60 (0.20) | S2 | 25.70 (0.22) | 25.40 (0.21) | V2 | 38.00 (0.31) | 38.60 (0.29) |

**Table 5.2. Means for main effects**

| SOIL TYPE (d) | | | POUR VOLUME (e) | | | METHODS (f ) | |
|---|---|---|---|---|---|---|---|
| S1 | S2 | | V1 | V2 | | M1 | M2 |
| 35.10 (0.49) | 25.60 (0.22) | | 22.30 (0.40) | 38.30 (0.30) | | 28.90 (0.37) | 31.70 (0.34) |

**( a ) Significant at 1 % level, LSD, 5 % for different pour volume for same soil - 0.30, for different soil for same pour volume - 3.50.**

**( b ) Significant at 1 % level, LSD, 5 % for different methods for same soil - 2.90, for different soils for same method - 2.80.**

**( c ) Significant at 1 % level, LSD, 5 % for different methods for same pour volume - 2.90, for different pour volume for same soil - 2.00.**

**( d ), ( e ), ( f ), Significant at 1 % level, LSD, 5 % for soil - 2.40, for pour volume - 0.20, for method - 2.90.**

## Table 6. Results of proposed procedures of exchangeable $Ca^{+2}$ (meq / 100-gram soil)

| sample | volume | Intermittent Leaching | | | Continuous leaching | | |
|---|---|---|---|---|---|---|---|
| | | Concentratio meq/100g so | Recovery % | | Concentration meq/100g soil | Recovery % | |
| | | **Before** | **Change %** | **After** | **Before** | **Change %** | After |
| S1 | **V1** | **3.10** | **4.73** | **52.73** | **3.10** | **49.59** | (4.63) |
| | | | | | | | |
| S1 | **V2** | **3.10** | **4.66** | **50.31** | **3.10** | **55.80** | (4.83) |
| | | | | | | | |
| S2 | **V1** | **3.35** | **4.45** | **33.05** | **3.35** | **30.74** | (4.38) |
| | | | | | | | |
| S2 | V2 | 3.35 | 4.33 | 29.47 | 3.35 | 32.16 | (4.42) |

## Table 6.1. Means for two way interactions

| | S x V | | | S x M | | | V x M ( a ) | |
|---|---|---|---|---|---|---|---|---|
| | **V1** | **V2** | | **M1** | **M2** | | **M1** | M2 |
| S1 | **51.16 (4.68)** | **53.05 (4.74)** | **S1** | **51.52 (4.69.)** | **52.69 (4.73)** | **V1** | **42.89 (4.59)** | 40.16 (4.50) |
| S2 | 31.89 (4.41) | 30.81 (4.37.) | S2 | 31.26 (4.39) | 31.45 (4.40) | V2 | 39.89 (4.49) | 43.98 (4.62) |

## Table 6.2. Means for main effects

| SOIL TYPE ( b ) | | | POUR VOLUME | | | METHODS | |
|---|---|---|---|---|---|---|---|
| S1 | **S2** | | **V1** | **V2** | | **M1** | M2 |
| 52.10 (4.71) | 31.35 (4.39) | | 41.52 (4.54.) | 41.93 (4.56) | | 41.39 (4.54) | 42.07 (4.56) |

**( a ) Significant at 1 % level, LSD, 5 % for different methods for same pour volume - 4.04.**

**( b ) Significant at 1 % level, LSD, 5 % for soil - 0.89.**

## Table 7. Results of proposed procedures of exchangeable $Mg^{+2}$ (meq / 100-gram soil)

| sample | volume | Continuous leaching | | | Intermittent Leachin | | |
|---|---|---|---|---|---|---|---|
| | | Concentratio meq/100g so | Recovery % | Recovery % | Concentration meq/100g soil | | |
| | | **Before** | **Change %** | **After** | **Before** | **Change %** | After |
| S1 | **V1** | **2.50** | **13.90** | **(2.15)** | **2.50** | **9.00** | (2.27) |
| | | | | | | | |
| S1 | **V2** | **2.50** | **7.00** | **(2.32)** | **2.50** | **8.00** | (2.30) |
| | | | | | | | |
| S2 | **V1** | **2.66** | **18.13** | **(2.17)** | **2.66** | **14.47** | (2.27) |
| | | | | | | | |
| S2 | V2 | 2.66 | 12.59 | 2.32) | 2.66 | 15.41 | (2.25) |

**Table 7.1. Means for two way interactions**

| | S x V | | | S x M | | | V x M | |
|---|---|---|---|---|---|---|---|---|
| | **V1** | **V2** | | **M1** | **M2** | | **M1** | M2 |
| S1 | **11.45 (2.21)** | **7.50 (2.31)** | **S1** | **10.45 (2.23)** | **(8.50) (2.28)** | **V1** | **16.01 (2.16)** | 11.73 (2.27) |
| S2 | 16.30 (2.22) | 14.00 (2.28) | S2 | 15.36 (2.24) | 14.94 (2.26) | V2 | 9.79 (2.32) | 11.70 (2.27) |

**Table 7.2. Means for main effects**

| SOIL TYPE ( a ) | | | POUR VOLUME ( b ) | | | METHODS | |
|---|---|---|---|---|---|---|---|
| S1 | **S2** | | **V1** | **V2** | | **M1** | M2 |
| 9.47 (2.26) | 15.15 (2.25) | | 13.87 (2.21) | 10.75 (2.29) | | 12.90 (2.24) | 11.72 (2.27) |

**( a ) Significant at 1 % level, LSD, 5 % for soil - 0.71.**

**( b ) Significant at 5 % level, LSD, 5 % for pour volume - 2.90.**

**Table 8. Results of proposed procedures of exchangeable sodium percent (ESP)**

| sample | volume | Continuous leaching | | | Intermittent Leaching | | |
|---|---|---|---|---|---|---|---|
| | | Concentration meq/100g soil | | Recovery % | Concentratio meq/100g so | | Recovery % |
| | | **Before** | **After** | **Change %** | **Before** | **After** | Change % |
| S1 | **V1** | **18.18** | **3.57** | **80.31** | **18.18** | **3.83** | 78.88 |
| | | | | | | | |
| S1 | **V2** | **18,18** | **4.44** | **75.54** | **18.18** | **3.09** | 83.00 |
| | | | | | | | |
| S2 | **V1** | **13.55** | **5.83** | **56.95** | **13.55** | **5.66** | 58.18 |
| | | | | | | | |
| S2 | V2 | 13.55 | 5.98 | 55.80 | 13.55 | 5.62 | 58.46 |

**Table 8.1. Means for two way interactions**

| | S x V | | | S x M | | | V x M | |
|---|---|---|---|---|---|---|---|---|
| | **V1** | **V2** | | **M1** | **M2** | | **M1** | M2 |
| S1 | **79.59** **(3.70)** | **79.27** **(3.76)** | **S1** | **77.92** **(4.00)** | **80.94** **(3.46 )** | **V1** | **68.63** **(4.70)** | 68.53 (4.74) |
| S2 | 57.56 (5.74) | 57.13 (5.80) | S2 | 56.37 (5.90) | 58.32 (5.64.) | V2 | 65.67 (5.21) | 70.73 (4.35) |

**Table 8.2. Means for main effects**

| SOIL TYPE | | | POUR VOLUME | | | METHODS | |
|---|---|---|---|---|---|---|---|
| S1 | **S2** | | **V1** | **V2** | | **M1** | M2 |
| 79.43<br>(3.73) | 57.34<br>(5.77) | | 68.58<br>(4.72) | 68.20<br>(4.78) | | 67.15<br>(4.95) | 69.63<br>(4.55) |

**** S×V×M interaction are highly significant at 1 % level, LSD 5 % for different methods for same soil, pour volume - 0.97, for different pour volume for same soil and methods - 1.29, for different soil for same pour volume and methods - 2.88.**

**DATA ANALYSIS: -**

Data from the experiment were prepared, tabulated in Excel and statistically analyzed by double split design using procedure described by Thomas & Little (1975).

The double split design is often quite useful for a three factor experiment (as in the current study). In this experiment the split- split design is desirable. Least significant difference (LSD) used to test the statistical significance of the difference between two means. the great advantage of LSD is that it is easy to calculate and provides a single figure for making comparisons where: -

$LSD_{0.05} = t_{0.05} \sqrt{\frac{2S2}{r}}$ where $S^2$ is the mean square for error, r is the number of replications, and t is the tabular t value for degree of freedom ( d f ).

From table No 4. There was highly significant (P≤0.01) interaction between soil type, method of irrigation and water pore volume in the concentration of exchangeable sodium in the soils under study, at LSD, 5% for different methods under same soil and pour volume - 1.00. 1.10 for different pore volume under same soil and method and -1.21 for different soils for same pour volume and methods. For exchangeable potassium concentration as shown in table 5, the effect for two way interactions was highly significant (P≤0.01), at LSD, 5% for different pour volume for same soil - 0.30, for different soil for same pour volume - 3.50. for different methods for same soil – 2.90, for different soils for same method – 2.8. For main effects, the effect was highly significant (P≤ 0.01), at LSD, 5% for soils – 2.40, for pour volumes – 0.20 and for methods – 2.90.

For exchangeable calcium concentration as shown in tables 6. For main effects in exchangeable calcium, the effect was highly significant (P≤ 0.01), at LSD, 5% for different methods for same pour volume - 4.04. for soil - 0.89. For exchangeable magnesium concentrations, soil - 0.89. pour volumes – 0.20 and for methods – 2.90. For main effects in exchangeable magnesium concentrations (Table 7), the effect was highly significant (P≤ 0.01), at LSD, 5% for soil - 0.71 while the effect was significant (P≤ 0.05), at LSD, 5% for pour volume - 2.90.

From table No 8. There was highly significant effect ($P \leq 0.01$) interaction between experimental factors, soil type, method of irrigation and water pore volume in exchangeable sodium percent of soils at LSD, 5% for different methods for same soil, pour volume – 0.97, for different pour volume for same soil and methods – 1.29 and for different soil for same pour volume and methods – 2.88.

In summary, it can be concluded that the composite analysis data of the various soil parameters indicated that since these soils under study containing calcium sulphate (gypsum ), by 38, 34 meq /100 g soil for soil 1 and soil 2 respectively, when leached, calcium dissolves and the replacement of exchangeable sodium by calcium takes place concurrently with the removal of excess salts which tends to increase the rate of hydrolysis of exchangeable sodium and often causes a rise of the pH reading of the soil (Soil Conservation Service, 1973). However, the rise in soil pH reading under these study treatments from 7.4 to 7.5 for Soil 1 and from 7.5-7.7 for Soil 2 does not indicate the possibility of evolution to alkalinity in these soils.

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