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# Effect of Gravel-Sand Mole Drains on Soil Electrical Conductivity and Exchanged Sodium Percentage

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**Abstract:** A field study was conducted to evaluate the effects of the mole drains in the corn crop (*zea mayes* L.) field during the season of 2019; this study was carried out at the Agricultural research station, University of Basrah, where the soil was silty clay loam. The results showed that the treatments of mole drains filled with gravel and sand mixture (S+G) and filled with gravel and sand layers (S/G) affected the decrease of the electrical conductivity (EC), and the exchanged sodium percentage (ESP) compared to W.M. treatment. The S/G drain gave lower values compared to the S+G drain. As well as, the values of EC decreased by the increase of the depth of the mole drain. Also, the treatments of mole drains distances of 2 m decreased the values of EC and ESP compared to the distance of 4 m. The S/G with depth of 60 cm and distance of 2m gave the lower values of EC and ESP, while the W.M. treatment gave higher values. Soil depths of 0-10 and 10-20 cm reached the lower values of EC and ESP; however depths of 50-60 cm gave the higher values. The treatment of S/G, with mole drain depth of 50 cm, and soil depth of 20-30 cm gave a lower value of EC; while, S+G, with mole drain depth of 50 cm, and soil depth of 50-60 cm gave a higher value. Finally, the ESP was decreased in the end of the growing season compared to the middle of the season.

**Keywords**: Soil chemical properties, Soil drainage, Soil Salinity.

## Introduction

The soils of southern Iraq are distinguished by the increase of the percentage of salts that has been classified as a soil saline or affected by salinity (Buringh, 1960). 70% of the irrigated lands of Iraq became threatened by salinization (Schoup *et al*., 2005). Salinization is one of the main factors leading to the degradation of the agricultural land, and it consequently results in a decline in agricultural production.

Salinity contributes to the degradation of natural wealth and water resources, along with the latest natural factors, due to excessive temperatures and lack of water (Saleh *et al*., 2019).

Soil salinization usually occurs when concentrations of sodium, calcium and magnesium ions or their dissolved salts in the ground water near the soil surface, especially in dry areas with a climate that allows for an increase in the intensity of evaporation (USDA, 1998). The sodium ion is in concentrations, it competes with calcium and magnesium ions, and then increases its exchange ratio in the soil, which increases the risks of chemical deterioration. Therefore, the study of chemical degradation of soil should not be limited to measuring the electrical conductivity only, but also measuring the exchanged sodium percentage, as they are both essential indicators for characterizing the state of chemical degradation (Darwish *et al*., 2013).

The mole drains provide a cheap solution to the problem of high soil salinity and to get rid of soluble salts such as sodium salts. The mole drains are pipeless drains that are formed with a mole plough. The mole plough consists of a cylindrical foot attached to a narrow leg connected to the back of the foot is a slightly larger diameter cylindrical expander which forms the drainage channel as the implement is drawn through the soil and the leg leaves a slot and associated fissures, these fissures extend from the surface and laterally out into the soil, any surplus water above moling depth can therefore move rapidly through these fissures into the mole channel (Dhakad *et al*., 2014). Aiad (2014) found that the mole drains affected the decrease of the electrical conductivity by 19.11, 14.33 and 11.25% for the distance between mole drains 2, 4 and 6 m respectively at the end of the wheat season (first season), while the increase was 22.87, 18.33 and 16.74% for above distance between mole drains respectively at the end of the sunflower season (second season). El-Sanat *et al.* (2017) found that the electrical conductivity decreased from 6.82 to 6.37 and 5.07 ds $m^{-1}$ with the increase tillage depth from 15 to 30 and 60 cm respectively, while the exchanged sodium percentage decreased from 14.15 to 13.77 and 12.06% for this tillage depths respectively. The results that was found by Aday *et al.* (2017) showed that the electrical conductivity decreased from 17.24 to 15.81 and 15.72 dS $m^{-1}$ with the increase of the tillage depth from 30 to 40 and 50 cm respectively. Bayoumi (2019) represented that the electrical conductivity and the exchanged sodium percentage have decreased after installed mole drains, whereas the values of these properties of the mole drains at depth 30cm and the distance between them 2m was lower than of its depth 50cm with the same distance between them after the end of the sunflower season.

The results which found by Jassim (2015) clarified that the increase soil depth from 0-30 cm to 30-60 cm leading to increase the electrical conductivity by 30.93% and increase the exchanged sodium percentage by 17.95%.

The aim of this research is study the effect of filling the mole drains by gravel and sand on a mixed and layered on the soil electrical conductivity and the exchanged sodium percentage under cultivation corn crop conditions.

## Materials & Methods

An implement of gravel-sand mole drains was designed and manufactured locally at the department of al machine and equipment, College of Agriculture, University of Basrah. This implementation consists of a farm installed on it a box which is divided into two parts: the front is to the gravel and the rear is to the sand; the capacity of each part is 1.45 and 1.81 ton respectively. Mechanism feeding gravel and sand to filling moles (mixing or layering) was installed at the bottom of the box. Mole plow was installed under the farm which supplied by cylindrical foot. This foot contains in its rear part two holes to installed the lower part of mechanism feeding. As shown in the fig. (1 A and B).

A field experiment was carried out in one of the Agricultural research stations, which is located at the University of Basrah, Garmit Ali campus. The soil was silty clay loam and the corn crop was utilized in this experiment during autumn season 2019. The Randomized Completely Block Design (RCBD) with factorial experiment was used to analyze the results. The experimental treatments were: three drain types {without mole drains (W.M.), the implement of mole constriction with mechanism feeding mole drain by mixed gravel and sand (S+G) and with mechanism feeding mole drain by layering gravel and sand (S/G)}, three drain depths {40 cm (D1), 50 cm (D2), and 60 cm (D3)}, two distances between drains {2 m (L1) and 4 m (L2)}, six soil depths {0-10 cm (d1), 10-20 cm (d2), 20-30 cm (d3), 30-40 cm (d4), 40-50 cm (d5) and 50-60 cm (d6)} and three replicates with each experimental treatment. The growth periods had been compared between them by using T-test on probability level 0.05. The results were statistically analysed by the SPSS program by using the RLSD test to compare between the means on probability level 0.05 to evaluate the implement effect on the electrical conductivity (EC) and the exchanged sodium percentage (ESP).

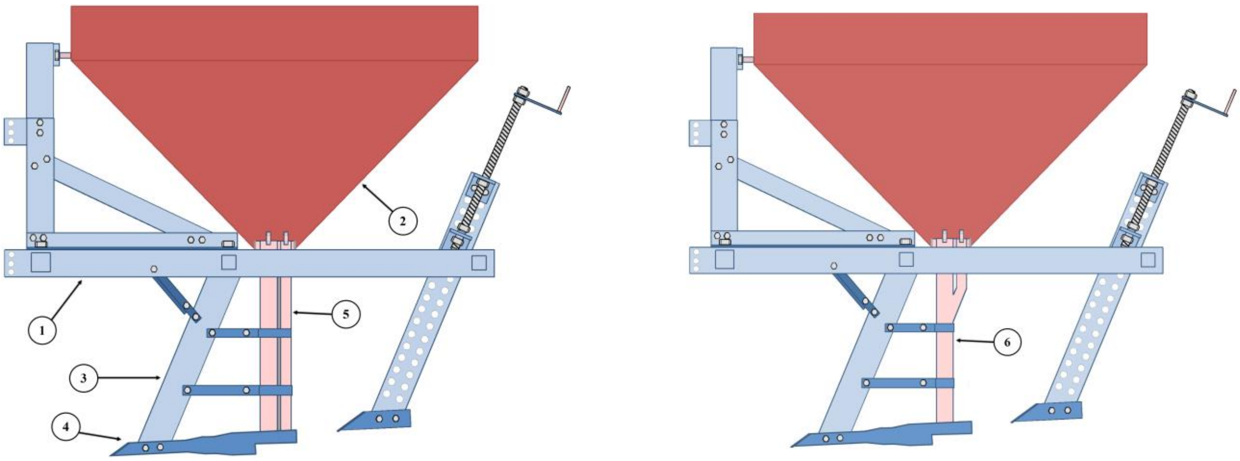

**Fig. (1): The implement of gravel-sand mole drains**
**A: With mechanism feeding of Layered gravel-sand (Left) B: with mechanism feeding of mixed gravel-sand (right) 1. The frame, 2. Gravel and sand box, 3. Mole plow, 4. Cylindrical foot, 5. Mechanism feeding of layered gravel-sand, 6. Mechanism feeding of mixed gravel-sand.**

The implement calibrated to filling the mole canal by gravel for the lower half from the size of the canal while the upper half filling by the sand with layered method, as well as, the implement calibrated to filling all the mole canal size by gravel while the sand filling the pores of the gravel in this canal with mixed method. After the construction of mole drains and soil tilled by mouldboard plow on depth 20 cm; the crop planted on a lines, the chemical fertilizer was depending on fertilizer recommendation with three batches: at the crop planting in 6/8/2019, during the middle of the season and at the flowering time. The crop irrigated by flooding after depletion 70% from filed capacity with addition 20% leaching requirement from field capacity. The harvesting has conducted after 94 days from planting. Before the construction of mole drains and soil farming, the soil samples were taken to the depths 10-20, 20-30, 30-40, 40-50 and 50-60 to determinate some of soil properties as shown in table (1).

**Table (1): Some of physical and chemical soil properties for depths (0-10), (10-20), (20-30), (30-40), (40-50) and (50-60) cm, water irrigation salinity, groundwater salinity and their depth.**

| Properties | Units | Depth (cm) | | | | | |
|---|---|---|---|---|---|---|---|
| | | 0-10 | 10-20 | 20-30 | 30-40 | 40-50 | 50-60 |
| Sand | $g\ kg^{-1}$ | 35.29 | 38.63 | 36.88 | 13.50 | 9.20 | 9.26 |
| Silt | $g\ kg^{-1}$ | 546.54 | 650.83 | 683.31 | 693.76 | 711.34 | 665.28 |
| Clay | $g\ kg^{-1}$ | 418.17 | 310.54 | 279.81 | 292.74 | 279.46 | 325.46 |
| Texture | | Silty Clay | Silty Clay Loam | Silty Clay Loam | Silty Clay Loam | Silty Clay Loam | Silty Clay Loam |
| Particle density | $Mg.m^{-3}$ | 2.67 | 2.67 | 2.69 | 2.70 | 2.70 | 2.73 |
| Bulk density | $Mg.m^{-3}$ | 1.32 | 1.33 | 1.37 | 1.38 | 1.41 | 1.45 |
| Total porosity | % | 50.67 | 50.28 | 49.26 | 48.97 | 47.76 | 46.96 |
| Soil penetration resistance | $kN\ m^{-2}$ | 3702.50 | 4398.00 | 4400.00 | 4452.50 | 4516.25 | 4662.08 |
| Cohesion | $kN\ m^{-2}$ | 245.97 | 343.96 | 361.02 | 365.78 | 386.81 | 376.89 |
| Moisture content | % | 8.75 | 15.67 | 16.92 | 21.49 | 27.52 | 25.66 |
| Field capacity | % | 31.43 | 32.26 | 32.24 | 31.27 | 31.40 | 31.48 |
| Organic matter | $g\ kg^{-1}$ | 8.79 | 8.13 | 8.06 | 4.72 | 3.77 | 1.08 |
| Total carbonate | $g\ kg^{-1}$ | 338.73 | 331.07 | 316.48 | 295.41 | 289.56 | 279.67 |
| CEC | $cmol\ kg^{-1}$ | 28.36 | 28.91 | 29.11 | 28.41 | 26.38 | 26.18 |
| The soluble ions: $Ca^{+2}$ | $Mmol\ L^{-1}$ | 39.42 | 39.22 | 37.02 | 35.51 | 35.85 | 33.21 |
| The soluble ions: $Mg^{+2}$ | $Mmol\ L^{-1}$ | 32.67 | 30.34 | 30.93 | 28.01 | 29.97 | 28.46 |
| The soluble ions: $Na^{+1}$ | $Mmol\ L^{-1}$ | 76.05 | 75.13 | 74.52 | 71.43 | 68.39 | 65.76 |
| The soluble ions: $K^{+1}$ | $Mmol\ L^{-1}$ | 4.56 | 3.28 | 5.84 | 2.86 | 6.27 | 3.71 |
| The soluble ions: $CO_3^{-2}$ | $Mmol\ L^{-1}$ | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| The soluble ions: $HCO_3^{-1}$ | $Mmol\ L^{-1}$ | 1.06 | 1.03 | 1.23 | 1.19 | 0.48 | 0.37 |
| The soluble ions: $Cl^{-1}$ | $Mmol\ L^{-1}$ | 156.07 | 157.12 | 142.59 | 125.82 | 145.33 | 137.89 |
| The soluble ions: $SO_4^{-2}$ | $Mmol\ L^{-1}$ | 10.32 | 10.06 | 8.85 | 5.67 | 8.01 | 4.42 |
| SAR | $(mmol\ L^{-1})^{0.5}$ | 12.67 | 12.74 | 12.78 | 12.68 | 11.92 | 11.82 |
| ESP | % | 14.84 | 14.92 | 14.96 | 14.85 | 14.03 | 13.93 |
| EC | $dS\ m^{-1}$ | 17.15 | 16.97 | 15.18 | 12.80 | 15.32 | 14.95 |
| pH | | 7.50 | 7.32 | 7.44 | 7.37 | 7.32 | 7.26 |
| Irrigation water salinity | $dS.m^{-1}$ | 4.30 | | | | | |
| Groundwater salinity | $dS.m^{-1}$ | 41.81 | | | | | |
| Groundwater depth | cm | 100.54 | | | | | |

Soil penetration resistance measured by pentrologer which made in Holland by Eijkelkamp Agrisearch Equipment. This pentrologer gives a reading each 1 cm of the soil depth. A penetration angle of the cone was 30° and its base area 1cm$^2$.

The soil texture determined by volumetric pipet, pycnometercore samplers. As well as, tequation (1) as these were represented in Black *et al*. (1983).

$$f = \left(1 - \frac{\rho_b}{\rho_s}\right) \times 100 \quad \text{..........(1)}$$

Whereas;

$f$: Total porosity (%).

$\rho$b: Bulk density (Mg m$^{-3}$).

$\rho$s: particle density (Mg m$^{-3}$).

The organic matter was determined by using Walkey-Black's method, the total carbonate, cations, anions and pH were determined, as these were represented in Sparks *et al*. (1996).

The cation exchange capacity, potassium, sodium, soluble sulfuric and electrical conductivity determined in the seepage 1:1 (soil: water) as a represented in Richards (1954).

The soluble carbonate and bicarbonate ions determined, Sodium adsorption ratio measured from equation (2) and the exchanged sodium percentage was measured from equation (3), as these were represented in Page *et al*. (1982).

$$\text{SAR} = \text{Na} / \sqrt{(\text{Ca} + \text{Mg})/2} \quad \text{.......(2)}$$

$$\text{ESP} = \frac{100(-0.0126+0.01475\ \text{SAR})}{1+(-0.0126+0.01475\ \text{SAR})} \quad \text{.....(3)}$$

## Results & Discussion

### Effect of the mole drains type on the EC and the ESP

The results in table (2) showed that the high significantly effects of the mole drain type on the EC and the ESP at the middle and the end of the season. The results in table (3) showed that the EC decreased by 15.18 and 26.87% and the ESP decreased by 29.59 and 48.02% at the middle of the season when used S+G and S/G mole drains compared with the W. M. treatment, respectively. While at the end of the season the EC decreased by 19.09 and 33.06% and the ESP decreased by 24.22 and 42.71% for above mole drains respectively. The installed mole drains have been leading to great cracks from depth to soil surface and this causes the increase water leaching movement and dissolving salts that are soluble in water and contains sodium salts. This is consistent with his findings Abd El-Aziz (2013).

As a result the efficiency of the S/G mole drain compared the S+G mole drain to soil drainage. The S/G mole drain led to a decrease in the EC by 13.78 and 17.27% and in the ESP by 26.20 and 24.41% compared with the S+G mole drain at the middle and at the end of the season, respectively. The filled mole drains by gravel layer under sand layer have been leading to decrease the amount of soil particles where movement to the drain and cumulated in it's the porosity of the sand layer while the gravel porosity have remained active to a longer time. While, the filled mole drains by the mixed of gravel-sand have been leading to cumulate soil particles in the porosity of gravel-sand and this means the soil particles have closed almost porosity and this reduces its ability to absorb drainage water.

### Effect of the Mole drains depth on EC

The results in table (2) showed that the effects of the mole drains depth is significant on EC at the middle of the season, but it was of a high significant effect at the end of the season. The results in table (4) represented that the EC decreased by 5.79 and 5.65% at the middle of the season as well as. It decreased by 5.35 and

9.91% at the end of the season when the mole drains depth was increased to D2 and D3 compared with D1, respectively. This is due to the increase of the soil cracks in addition to the increase of the mole drains depth which encourages the movement of water and electrolytes to the soil depths which is far from the surface towards the drains (El-Sanat *et al.*, 2017).

**Effect of the distance between mole drains on EC and ESP**

The results of the statistical analysis of the data showed that the effects of the distance of mole drains were significant on the ESP only at the middle of the season while this effect was high significance on EC and ESP at the end of the season (Table 2).

**Table (2): The statically analysis of F and T test for EC and ESP at the middle and at the end of the season.**

| Source of Variation (S.O.V.) | df | EC | | ESP | |
|---|---|---|---|---|---|
| | | Middle Season | End Season | Middle Season | End Season |
| A | 2 | 87.611** | 78.628** | 88.087** | 76.987** |
| B | 2 | 4.270* | 5.315** | 2.821 n.s. | 1.104n.s. |
| C | 1 | 2.090 n.s. | 6.781** | 6.600* | 7.804** |
| D | 5 | 19.634** | 12.561** | 23.204** | 4.689** |
| A×B | 4 | 3.786** | 3.063* | 1.204 n.s. | 1.526n.s. |
| A×C | 2 | 2.937 n.s. | 3.145* | 5.635 ** | 4.221* |
| A×D | 10 | 5.810** | 5.784** | 7.594** | 3.030** |
| B×C | 2 | 3.317* | 4.451* | 6.452** | 5.342** |
| B×D | 10 | 2.798** | 0.156 n.s | 0.455 n.s. | 0.286n.s. |
| C×D | 5 | 0.309 n.s. | 0.216 n.s | 0.442 n.s. | 0.768 n.s. |
| A×B×C | 4 | 1.775 n.s. | 11.654** | 1.871 n.s. | 6.972** |
| A×B×D | 20 | 2.731** | 0.276 n.s | 0.802 n.s. | 0.691 n.s. |
| A×C×D | 10 | 0.520 n.s. | 0.216 n.s | 0.761 n.s. | 1.241 n.s. |
| B×C×D | 10 | 1.192 n.s. | 0.172 n.s | 0.421 n.s. | 0.822 n.s. |
| A×B×C×D | 20 | 0.878 n.s. | 0.362 n.s | 1.097 n.s. | 1.577n.s. |
| **T-test** | **323** | **0.460n.s.** | | **1.232*.** | |

A: mole drain type, B: mole drain depth, C: the distance between the mole drains, D: soil depth.
*: significant, **: high significant, n.s.: no significant.

**Table (3): Effect of the mole drains type on EC and ESP at the middle and at the end of the season.**

| Mole drains type | EC (dS $m^{-1}$) | | ESP (%) | |
|---|---|---|---|---|
| | Middle season | End Season | Middle Season | End Season |
| W.M. | 8.30c ±0.940 | 8.59c ±3.200 | 16.91c ±3.688 | 15.03c ±3.581 |
| S+G | 7.04b±2.260 | 6.95b ±2.171 | 11.91b ±4.968 | 11.39b ±5.318 |
| S/G | 6.07a ±1.673 | 5.75a ±1.337 | 8.79a ±5.683 | 8.61a ±2.751 |

**Table (4): Effect of the Mole drains depth on EC at the middle and at the end of the season.**

| Mole drains depth | EC (dS $m^{-1}$) |
|---|---|

| | Middle season | End Season |
|---|---|---|
| D1 | 7.43[b] ±2.673 | 7.47[b] ±2.673 |
| D2 | 7.00[a] ±2.694 | 7.07[a] ±2.694 |
| D3 | 7.01[a] ±2.482 | 6.73[a] ±2.498 |

The results of table (5) showed that the decrease of the distance between mole drains from L2 to L1 had led to the increase of the ESP by 8.72% at the middle of the season. a highly interaction for the soil distribution volume of the parallel drains caused by decreasing the distance between them from L2 to L1 that leading to increase the movement of water through extra soil pores and decrease ability of water to dissolving sodium salt.

At the end of the season, the values decreased by 6.68 and 10.39% for the EC and ESP respectively. Attributed toper filed water leaching on it due to increase the leaching water ability to s and move it toward mole drains. This was consistent with these findings Aiad (2014), Balusamy *et al*. (2019) and Bayoumi (2019).

**Table (5): Effect of the distance between the mole drains on EC at the end of the season and ESP at the middle and at the end of the season.**

| Distance between mole drains | EC (dS $m^{-1}$) | ESP (%) | |
|---|---|---|---|
| | | Middle Season | End Season |
| L1 | 6.85[a] ±2.708 | 13.09[b]±5.435 | 11.04[a]±4.796 |
| L2 | 7.34[b] ±2.530 | 12.04[a]±5.986 | 12.32[b]±4.542 |

**Effect of the soil depth on EC and ESP**

The results represented that the effects of the soil depth had a high significance on the EC and ESP at the middle and at the end of the season (Table 2). Overall, the results in table (6) showed that the increase in the soil depth led to the increase in the EC and ESP. The lower values were d2 reached to 6.51 dS $m^{-1}$ and 9.53% for EC and ESP respectively at the middle of the season. While the EC gave a lower value in d2 which reached 6.46 dS $m^{-1}$ but the ESP gave a lower value in d1 which reached 9.88% by non-significant difference with d2 at the end of the season.

However a higher value was d6 reached 8.57 dS $m^{-1}$ and 17.39% for EC and ESP respectively at the middle of the season. But the EC gave a higher value in d6 which reached 8.55 dS $m^{-1}$ while the ESP gave a higher value in d5 which reached 13.04% by non-significant difference with d6 at the end of the season. These {what do you mean by these, you should mention them} were at deep depths, and also of near it from. These were confirmed by Jassim (2015) and Abd El-Aziz (2013).

**Table (6): Effect of the soil depth on EC and ESP at the middle and at the end of the season.**

| Soil depth | EC (dS m$^{-1}$) | | ESP (%) | |
|---|---|---|---|---|
| | Middle season | End Season | Middle Season | End Season |
| d1 | 6.62$^{ab}$ ±1.619 | 7.06$^{abc}$ ±1.931 | 9.71$^{a}$ ±4.094 | 9.88$^{a}$ ±5.703 |
| d2 | 6.51$^{a}$ ±1.369 | 6.46$^{a}$ ±1.684 | 9.53$^{a}$ ±4.533 | 10.50$^{a}$ ±3.801 |
| d3 | 6.88$^{abc}$±1.646 | 6.55$^{a}$ ±2.075 | 10.55$^{a}$ ±7.672 | 11.27$^{ab}$ ±4.456 |
| d4 | 7.04$^{bcd}$ ±1.571 | 6.53$^{a}$ ±2.013 | 12.31$^{b}$ ±7.422 | 12.48$^{bc}$ ±4.052 |
| d5 | 7.29$^{cd}$ ±1.705 | 7.42$^{bc}$ ±2.949 | 15.89$^{c}$ ±2.778 | 13.04$^{c}$ ±4.320 |
| d6 | 8.57$^{d}$ ±2.722 | 8.55$^{c}$ ±3.893 | 17.39$^{c}$ ±3.382 | 12.90$^{c}$ ±5.350 |

**Effect of the interaction between the mole drains type and its depth on the EC**

The statistical analysis showed that the effects of the interaction between the mole drains type and its depth was highly significant and significant on the EC at the middle and at the end of the season (Table 2).

The results in table (7) showed that the lower values of the EC was in the S/G, D2 and S/G, D3 treatments without significant differences between them at the middle and at the end of the season. While the W.M. treatment reached the higher values of the EC at the middle and at the end of the season. The decrease value in the EC of this treatment was attributed to S/G drain efficiency to provide more effective pores and increase the soil crack in crescent failure with increasing mole drains depth led to increase of the movement of the leaching water to the drains, while the soil bulk for the W.M. treatment was stay distributed only the soil surface depths which was did not exceed 20 cm had led to cumulated irrigation water salts in the soil.

**Table (7): Effect of the interaction between the mole drains type and its depth on EC at the middle and at the end of the season.**

| Mole drains type | Mole drains depth | EC (dS m$^{-1}$) | |
|---|---|---|---|
| | | Middle season | End Season |
| W.M. | - | 8.30$^{c}$ ±0.949 | 8.59$^{c}$ ±3.277 |
| S+G | D1 | 7.11$^{b}$ ±1.980 | 7.11$^{b}$ ±2.615 |
| | D2 | 7.08$^{b}$ ±3.021 | 7.04$^{b}$ ±2.498 |
| | D3 | 7.03$^{b}$ ±1.604 | 6.70$^{b}$ ±1.114 |
| S/G | D1 | 6.89$^{b}$ ±2.358 | 6.73$^{b}$ ±1.609 |
| | D2 | 5.62$^{a}$ ±1.135 | 5.60$^{a}$ ±0.966 |
| | D3 | 5.70$^{a}$ ±0.815 | 4.91$^{a}$ ±0.466 |

**Effect of the interaction between the mole drains type and the distance between them on the EC and ESP**

The results in the table (2) clarified that the effect of the interaction between the mole drains was not significant for the EC and highly significant on ESP at the middle of the season, while it's significant for EC and ESP at the end of the season. The results in table (8) indicated that the S/G, L1 treatment gave a lower ESP amount to 8.72% at the middle of the season as well as, 5.19 dS m$^{-1}$ and 7.24%

for the EC and ESP respectively at the end of the season. The lower distance between mole drains to L1 caused to distribute the leaching water on lower soil volume. It also assisted to dissolving higher amount from the salts, corresponding to it the efficiency of S/G drain to absorb the drainage water so that the values of EC and ESP decreased for this treatment. While the W.M. treatment was of a higher ESP amount to 16.99% at the middle of the season, as well as a higher values at the end of the season which reached 8.59 dS.m$^{-1}$ and 15.03% for the EC and ESP respectively at the end of the season. The increase values of EC and ESP of the W.M. treatment because the irrigation water salts accumulated in soil which resulted from the low of the internal drainage of this treatment and did not drains in it.

**Table (8): Effect of the interaction between the mole drains type and the distance between them on EC at the end of the season and ESP at the middle and at the end of the season.**

| Mole drains depth | Mole drains Type | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | EC (dS m$^{-1}$) | | | ESP (%) | | | | | |
| | | | | Middle season | | | End Season | | |
| | W.M. | S+G | S/G | W.M. | S+G | S/G | W.M. | S+G | S/G |
| L1 | 8.59$^{d}$ ± 3.200 | 6.78$^{b}$± 2.345 | 5.19$^{a}$ ± 0.752 | 16.99$^{d}$± 5.683 | 13.56$^{c}$± 4.834 | 8.72$^{a}$ ± 2.543 | 15.03$^{d}$± 2.751 | 10.84$^{cb}$ ±4.458 | 7.24$^{a}$± 3.249 |
| L2 | 8.59$^{d}$ ± 3.200 | 7.12$^{c}$± 1.990 | 6.30$^{b}$ ± 1.554 | 16.99$^{d}$± 5.683 | 10.26$^{b}$± 4.867 | 8.86$^{ab}$ ± 4.579 | 15.03$^{d}$± 2.751 | 11.94$^{c}$± 6.076 | 9.97$^{b}$± 2.896 |

**Effect of the interaction between the mole drains type and the soil depth on the EC and ESP**

The results in the table (2) indicated that the effects of the interaction between the mole drains type and the soil depth were highly significant for the EC and ESP at the middle and at the end of the season. The results in table (9) showed that the S/G, d4 treatment gave a lower EC at the middle of the season while the S/G, d3 treatment gave a Lower EC at the end of the season. As well as, the S/G, d3 treatment recorded a lower value of the ESP at the middle of the season, while the S/G, d1 treatment gave a lower value at the end of the season.

**Table (9): Effect of the interaction between the mole drains type and the soil depth on EC and ESP at the middle and at the end of the season.**

| Mole drains type | Soil depth | EC (dS m$^{-1}$) | | ESP (%) | |
|---|---|---|---|---|---|
| | | Middle season | End Season | Middle season | End Season |
| W.M. | d1 | 7.34$^{a}$ ±0.001 | 7.84$^{ij}$ ±1.845 | 10.07$^{bc}$ ±0.770 | 11.09$^{cdef}$ ±1.972 |
| | d2 | 7.93$^{a}$ ±0.001 | 7.10$^{defghi}$ ±1.807 | 11.10$^{c}$ ±3.384 | 12.89$^{defg}$ ±1.370 |
| | d3 | 8.05$^{a}$ ±0.001 | 7.44$^{fghi}$ ±1.990 | 13.95$^{d}$ ±6.244 | 14.28$^{ghi}$ ±2.989 |
| | d4 | 8.03$^{a}$ ±0.001 | 7.67$^{ghi}$ ±2.482 | 16.11$^{de}$ ±6.038 | 15.65$^{ghi}$ ±0.597 |
| | d5 | 8.16$^{a}$ ±0.001 | 9.53$^{j}$ ±3.437 | 25.21$^{f}$ ±1.676 | 16.39$^{i}$ ±0.067 |
| | d6 | 10.31$^{c}$ ±0.001 | 11.95$^{k}$ ±4.212 | 25.48$^{f}$ ±2.282 | 19.91$^{j}$ ±0.270 |
| S+G | d1 | 6.07$^{a}$ ±1.067 | 7.12$^{defghi}$ ±2.289 | 9.52$^{abc}$ ±3.671 | 10.57$^{bcde}$ ±8.815 |
| | d2 | 5.77$^{a}$ ±0.883 | 6.65$^{cde}$ ±1.829 | 9.11$^{abc}$ ±3.632 | 10.34$^{abcd}$ ±3.949 |
| | d3 | 6.69$^{a}$ ±1.650 | 6.84$^{def}$ ±2.466 | 10.13$^{bc}$ ±5.464 | 10.91$^{cde}$ ±4.772 |
| | d4 | 7.38$^{a}$ ±1.882 | 6.37$^{bcd}$ ±1.484 | 11.42$^{c}$ ±6.752 | 13.04$^{efg}$ ±3.675 |
| | d5 | 7.33$^{a}$ ±2.162 | 6.96$^{defg}$ ±2.135 | 14.64$^{de}$ ±3.369 | 13.47$^{gf}$ ±4.024 |

| | | | | | |
|---|---|---|---|---|---|
| | d6 | 9.23[b] ±3.345 | 7.76[hi] ±2.654 | 16.62[e] ±3.031 | 10.01[abc] ±5.033 |
| | d1 | 6.45 [a] ±2.477 | 6.22[abcd] ±1.056 | 9.53[abc] ±4.107 | 7.98[a] ±3.684 |
| S/G | d2 | 5.83 [a] ±1.356 | 5.64[ab] ±0.885 | 8.36[ab] ±4.605 | 8.27[ab] ±4.060 |
| | d3 | 5.90 [a] ±1.795 | 5.37[a] ±0.276 | 7.56[a] ±2.821 | 8.61[abc] ±3.347 |
| | d4 | 5.70 [a] ±1.050 | 5.54[a] ±0.361 | 9.40[abc] ±4.018 | 8.74[abc] ±3.361 |
| | d5 | 6.38 [a] ±1.642 | 5.78[ab] ±0.430 | 7.81[ab] ±2.516 | 9.25[abc] ±3.677 |
| | d6 | 6.16 [a] ±1.453 | 5.94[abc] ±0.480 | 10.08[bc] ±3.269 | 8.78[abc] ±3.741 |

The reason of decreasing the EC and ESP values before planting on this depths corresponding to the higher soil cracks when installed the S/G drain is of higher efficiency to absorb the drainage water as showed in table (3). While the W.M.,d6 treatment reached the higher values on the EC and ESP at the middle and at the end of the season because of the cohesiveness of the soil bulk for W.M. leading to accumulated the salts on the subsurface depths (d6) as well as this soil depth was near groundwater.

**Effect of the interaction between the mole drains depth and the distance between them on the EC and ESP**

The statistical analysis of the results clarified that the effect of the interaction between the mole drains depth and the distance between them was significant for the EC at the middle and at the end of the season while this effect on the ESP was higher significance at the middle and at the end of the season (Table 2). The results in table (10) indicated that the D3, L2 treatment of a lower value of the EC by 11.30% compared with D1, L1 treatment at the middle of the season, this is happened because of higher soil disruption when installing the mole drains on D3 and increasing the distance between the mole drains to L2 gives a higher area to distributed leaching water due to higher dissolving for the salts. The mole drain on D1 have worked to rid the upper soil of its depth (0-40 cm) only from the salts while the depths under its depth remained keeping the salt as well as accumulated the salts of water irrigation which has distributed on lower soil area with the decreases of the distance between mole drains to L1 assisted to accumulate the salts on the depths are under this drain depth. The D2, L1 treatment reached lower ESP by 22.43% compared with D1, L1 treatment at the middle of the season, Attributed to the middle site for the drain on D2 where the water can move by easy to this drain compared the drain on D3, and at the same time the decrease of the distance between mole drains to L1 leading to increase the interaction of the distribution soil volume of the parallel drains which was a higher than from the drains on D1.

The D2, L1 treatment reached lower EC and ESP at the end of the season by 16.23 and 21.56% compared with the D2, L2 treatment which reached higher EC and ESP respectively at the end of the season. The higher distribution of soil where installing mole drains on D2 and decreased the distance between them to L1 caused to leaching the salts from a higher soil volume to the drain which was characterized by a middle site whom can received the leaching water by easy.

**Effect of the interaction between the mole drains depth and the soil depth on the EC and ESP**

The results in table (2) showed that the effect of the interaction between the mole drains depth and the soil depth was highly significant for the EC at the middle of the season. While it was not significant in the EC at the end of the season, and in the ESP at the middle and at the end of the season. The results in table (11) showed that the D2, d2 treatment was reached a lower EC by 33.98% compared with D2, d6 which reached a higher value. It attributed to the surface tillage on the depth 20 cm which represent the half depth of the higher soil distributed to installed mole drains on D2 which assisted to leaching the salt from the surface depth (d2) and accumulated it at the subsurface depth (d6).

**Table (10): Effect of the mole drains depth and the distance between them on EC and ESP at the middle and at the end of the season.**

| Mole drains depth | Distance between mole drains | EC ($dS.\ m^{-1}$) | | ESP (%) | |
|---|---|---|---|---|---|
| | | Middle season | End Season | Middle season | End Season |
| D1 | L1 | $7.70^{b} \pm 1.859$ | $7.48^{b} \pm 2.943$ | $14.67^{c} \pm 4.919$ | $11.94^{bcd} \pm 4.195$ |
| | L2 | $7.17^{ab} \pm 2.010$ | $7.47^{b} \pm 2.401$ | $11.89^{ab} \pm 5.916$ | $12.22^{cd} \pm 6.298$ |
| D2 | L1 | $7.15^{ab} \pm 2.448$ | $6.45^{a} \pm 2.562$ | $11.38^{a} \pm 5.840$ | $10.37^{a} \pm 5.391$ |
| | L2 | $7.15^{ab} \pm 1.970$ | $7.70^{b} \pm 2.700$ | $12.70^{ab} \pm 6.072$ | $13.22^{d} \pm 2.858$ |
| D3 | L1 | $7.20^{ab} \pm 1.746$ | $6.63^{a} \pm 2.567$ | $13.22^{b} \pm 5.120$ | $10.80^{ab} \pm 4.520$ |
| | L2 | $6.83^{a} \pm 1.386$ | $6.84^{a} \pm 2.446$ | $11.51^{a} \pm 5.960$ | $11.51^{abc} \pm 3.556$ |

**Table (11): Effect of the interaction between the mole drains depth and the soil depth on EC ($dS\ m^{-1}$) at the middle of the season.**

| Soil depth | Mole drains depth | | |
|---|---|---|---|
| | D1 | D2 | D3 |
| d1 | $6.99^{abc} \pm 2.368$ | $6.16^{a} \pm 1.184$ | $6.70^{abc} \pm 0.889$ |
| d2 | $6.81^{abc} \pm 1.432$ | $6.14^{a} \pm 1.378$ | $6.57^{ab} \pm 1.281$ |
| d3 | $7.41^{bc} \pm 1.712$ | $6.20^{a} \pm 1.484$ | $7.03^{abc} \pm 1.582$ |
| d4 | $7.01^{abc} \pm 1.387$ | $7.11^{bc} \pm 1.687$ | $6.99^{abc} \pm 1.708$ |
| d5 | $7.53^{c} \pm 1.851$ | $7.10^{bc} \pm 1.628$ | $7.24^{bc} \pm 1.697$ |
| d6 | $8.85^{d} \pm 2.224$ | $9.30^{d} \pm 3.474$ | $7.54^{c} \pm 2.077$ |

**Effect of the interaction between the mole drains type, its depth and the distance between them on the EC and ESP**

The results clarified that the interaction between the mole drains type, its depth and the distance between them did not have significantly effect for the EC and ESP at the middle of the season. But it has a highly significance effect at the end of the season on these properties (Table 2). The results in table (12) represented that the S/G, D3, L1 treatment reached a lower EC and ESP compared with the W.M. treatment which reached the higher values. It was because the higher efficiency of the S/G mole drains to absorb the drainage water. Moreover, the higher soil cracks of crescent failure which formed when installed of the drains on D3 and the distance between mole drains L1 assisted to restriction the leaching water distribution on a limited volume of soil. Therefor the salts dissolved and get rid of soil which leading to decrease the EC and ESP of this treatment.

**Effect of the interaction between the mole drains type, its depth and the soil depth on the EC**

The results clarified that the effect of the interaction between the mole drains type, its depth and the distance between them was a highly significance by EC at the middle of the season only (Table 2). The results in table (13) indicted that the S/G, D2, d3 treatment gave a lower EC reached 5.15 dS $m^{-1}$ which was low by 56.80% compared to the S+G, D2, d6 treatment which had given a higher value reached 11.92 dS $m^{-1}$ which was not significant different from W.M.d6 which its value was 10.31 $ds.m^{-1}$.

**Table (12): Effect of the interaction between the mole drains type, its depth and the distance between them on EC and ESP at the end of the season.**

| Mole drains depth | Distance between mole drains | Mole drains Type | | | | | |
|---|---|---|---|---|---|---|---|
| | | EC (dS. $m^{-1}$) | | | ESP (%) | | |
| | | W.M. | S+G | S/G | W.M. | S+G | S/G |
| D1 | L1 | $8.59^{f}$ ±3.200 | $8.34^{f}$ ±3.099 | $5.52^{abc}$ ±0.718 | $15.03^{h}$ ±2.751 | $13.27^{gh}$ ±3.803 | $7.51^{ab}$ ±1.260 |
| | L2 | $8.59^{f}$ ±3.200 | $5.87^{bc}$ ±1.116 | $7.93^{ef}$ ±1.319 | $15.03^{h}$ ±2.751 | $9.53^{bcde}$ ±9.365 | $12.09^{fg}$ ±2.900 |
| D2 | L1 | $8.59^{f}$ ±3.200 | $5.61^{abc}$ ±1.189 | $5.15^{ab}$ ±0.960 | $15.03^{h}$ ±2.751 | $8.63^{abcd}$ ±4.226 | $7.45^{ab}$ ±4.684 |
| | L2 | $8.59^{f}$ ±3.200 | $8.46^{f}$ ±2.667 | $6.06^{bcd}$ ±0.750 | $15.03^{h}$ ±2.751 | $14.57^{h}$ ±2.687 | $10.04^{cdef}$ ±0.924 |
| D3 | L1 | $8.59^{f}$ ±3.200 | $6.39^{cd}$ ±1.388 | $4.90^{a}$ ±0.348 | $15.03^{h}$ ±2.751 | $10.62^{def}$ ±3.708 | $6.76^{a}$ ±2.857 |
| | L2 | $8.59^{f}$ ±3.200 | $7.02^{de}$ ±0.647 | $7.92^{ef}$ ±0.571 | $15.03^{a}$ ±2.751 | $11.72^{efg}$ ±1.795 | $7.78^{abc}$ ±1.295 |

**Table (13): Effect of the interaction between the mole drains type, its depth and the soil depth on EC ($dS.m^{-1}$) at the middle of the season.**

| Mole drains depth | Soil depth | Mole drains Type | | |
|---|---|---|---|---|
| | | W.M. | S+G | S/G |
| D1 | d1 | $7.34^{fghijk}$ ±0.001 | $5.72^{abcd}$ ±0.460 | $7.92^{ij}$ ±3.968 |
| | d2 | $7.93^{a}$ ±0.001 | $5.83^{abcdef}$ ±0.381 | $6.69^{abcdefghijk}$ ±2.036 |
| | d3 | $8.05^{jk}$ ±0.001 | $7.27^{efghijk}$ ±1.604 | $6.91^{cdefghijk}$ ±2.565 |
| | d4 | $8.03^{jk}$ ±0.001 | $7.02^{defghijk}$ ±1.380 | $5.99^{abcdefg}$ ±1.463 |
| | d5 | $8.16^{jk}$ ±0.001 | $7.57^{hijk}$ ±2.722 | $6.85^{cdefghijk}$ ±1.791 |
| | d6 | $10.31^{l}$ ±0.001 | $9.24^{kl}$ ±2.267 | $6.99^{defghijk}$ ±2.189 |
| D2 | d1 | $7.34^{fghijk}$ ±0.001 | $5.71^{abcd}$ ±1.373 | $5.44^{abc}$ ±0.589 |
| | d2 | $7.93^{a}$ ±0.001 | $5.20^{a}$ ±0689 | $5.29^{ab}$ ±0.455 |

| | | | | |
|---|---|---|---|---|
| | d3 | 8.05$^{jk}$ ±0.001 | 5.39$^{abc}$ ±0.822 | 5.15$^{a}$ ±0.775 |
| | d4 | 8.03$^{jk}$ ±0.001 | 7.63$^{ijk}$ ±2.251 | 5.67$^{abcd}$ ±0.884 |
| | d5 | 8.16$^{jk}$ ±0.001 | 6.64$^{abcdefghij}$ ±1.410 | 6.50$^{abcdefghij}$ ±0.223 |
| | d6 | 10.31$^{l}$ ±0.001 | 11.92$^{m}$ ±3.896 | 5.68$^{abcd}$ ±0.841 |
| D3 | d1 | 7.34$^{fghijk}$ ±0.001 | 6.76$^{bcdefghijk}$ ±0.947 | 6.01$^{abcdefg}$ ±0.849 |
| | d2 | 7.93$^{a}$ ±0.001 | 6.26$^{abcdefgh}$ ±1.162 | 5.51$^{abcd}$ ±0.735 |
| | d3 | 8.05$^{jk}$ ±0.001 | 7.40$^{ghijk}$ ±1.724 | 5.64$^{abcd}$ ±0.338 |
| | d4 | 8.03$^{jk}$ ±0.001 | 7.48$^{hijk}$ ±2.196 | 5.45$^{abc}$ ±0.806 |
| | d5 | 8.16$^{jk}$ ±0.001 | 7.77$^{ijk}$ ±2.372 | 5.78$^{abcde}$ ±0.500 |
| | d6 | 10.31$^{l}$ ±0.001 | 6.51$^{abcdefghij}$ ±0.418 | 5.81$^{abcdef}$ ±0.661 |

The lower EC value of the S/G, D2, d3 treatment was because of the higher efficiency of the S/G mole drain to absorb leaching water as well as affected d3 by the compaction which was generated from mouldboard plow to tillage soil on 20 cm due to the decrease of slow water movement on this soil depth and that caused in dissolving almost the salts from this depth and drainage this salts to the mole drain which was on depth (D2) near to the d3. While the higher EC of S+G,D2,d6 treatment attribute to leaching the salts from soil surface depths and accumulated it under mole drain which was on D2 upper d6 as well as the efficiency of this mole drain was lower than S/G mole drain to absorb drainage water due to its components.

**Effect of the growth period on ESP**

The results clarified that the ESP was significantly affected by the growth period (Table 2). The results in fig. (1) indicated that the ESP decreased from 12.56 to 11.68% by advance the growth period from the middle season to the end season respectively. The soil extra pores is closed at the end season while the middle and small pores is activity, so that the movement of leaching water decreased in soil and its leading to dissolved almost the sodium salts.

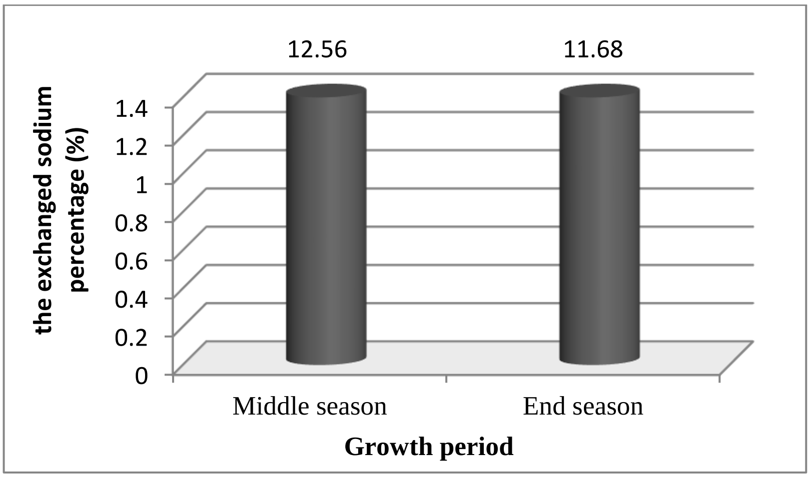


**Fig. (1): Effect of the growth period on ESP.**

## Conclusions

The S+G and S/G mole drains instilled leading to decrease the electrical conductivity and the exchanged sodium percentage but this decrease was the S/G drains higher than the S+G drains. Moreover, these soil chemical properties decreased with increased of the depth of the drains, the soil depth and lowered the distance between the drains So that, the treatment of S/G, D3, L1 reached a lower values for the electrical conductivity and the exchanged sodium percentage.

## Contributions of authors

**D. S. Ashour :** Wrote the paper, collected the data and performed the analysis.

**S.H. Aday & K.A.H. Al-Mosawi**: Presented idea of the article.

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## Conflict of interest

As for the requirements of the publishing policy, there is no potential conflict of interest for the authors.

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## تأثير المبازل المولية الحصوية – الرملية في التوصيل الكهربائي للتربة والنسبة المئوية للصوديوم المتبادل

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**المستخلص:** نفذت تجربة حقلية في احد الحقول التابعة الى كلية الزراعة – جامعة البصرة في موقع كرمة علي في تربة مزيجة طينية غرينية. اذ تم زراعة محصول الذرة الصفراء (*Zea Mays* L.) للموسم الخريفي 2019 لتقييم تأثير نوع المبازل المولية. اظهرت النتائج ان انشاء المبازل المولية ادى الى خفض قيم التوصيل الكهربائي للتربة (EC) والنسبة المئوية للصوديوم المتبادل (ESP) مقارنة بالمعاملة من دون مبازل مولية (W.M. ) وكانت نسبة الانخفاض المبازل المولية المملؤة بالحصى والرمل على شكل طبقات( S/G )اعلى منها والمبازل المولية المملؤة بالحصى والرمل المخلوطين( S+G )، وكذلك انخفضت القيم بزيادة عمق المبازل المولية وكانت اقل القيم عند العمق المبزل 60 سم. كما انخفضت قيمة الـEC والـESP بتقليل المسافة بين المبازل المولية من 4 الى 2 م. اذ حققت المعاملة S/G عند العمق 60 سم والمسافة بين المبازل 2 م اقل قيمة للـEC والـESP ،بينما اعطت المعاملة W.M. اعلى القيم. كما سجل عمقي التربة 0-10 و10-20 سم اقل القيم للـEC ، بينما كانت اعلى قيمة عند العمق التربة 50-60 سم. اذ سجلت المعاملة S/G عند العمق 50 سم وعمق التربة 20-30 سم اقل القيم، وكانت اعلاها عند المعاملة S+G عند العمق 50 سم وعمق التربة 50-60 سم. وادى تقدم نمو المحصول من منصف الى نهاية الموسم الى انخفاض قيم الـESP.

**الكلمات المفتاحية:** الصفات الكيميائية للتربة، بزل التربة، ملوحة التربة.