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The Effect of Irrgation Water Quality of Furrow Irrgation System on The Soil Properties in ABU Gharib District

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Abstract

a field experiment was conducted at the soil research department station (Agricultural Research Office), located in Abu Ghraib district (20 kilometers west of Baghdad) during the spring season for year (2016) to study the effect of irrigation water quality of furrow irrigation system on chemical and physical properties of the Soil.
The field study carried out by using three types of saline irrigation water: (tap water) with (0.6 ds/m), two wells water with (3.0 ds/m) and (5.1 ds/m), and the alternating irrigation method through the continuation of irrigation to the end of the agricultural season using one irrigate of tap water followed by one irrigate of water well with (5.1 ds/m). The results showed increasing of EC_S and SAR values if salinity water used as ($S_2 > S_3 > S_1$), respectively for the depths (20-30, and 30-45cm) more than the depths (0-10, and 10-20 cm) and decreasing of EC_S and SAR values at the depths (0-10, 10-20, and 20-30 cm) when the tap water (S_0) is used. Also, increasing of the physical properties of the soil when the irrigation used by tap water (S_0), and, decreasing of the physical properties of the soil when the irrigation used by water salinity ($S_2 > S_3 > S_1$), respectively, at the depth (15-30) more than the depth (0-15 cm).

Keywords: surface irrigation, Sodium Adsorption Ratio, Mean Weight Diameter, saturated hydraulic conductivity, bulk density.

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1. Introduction

The quality of irrigation water is the most important factor in the soil sustainability and production improving. In Iraq, irrigation became more important in arid and semi-arid areas because of inadequate quantity of rainfall for crops growth, specifically, in the central and southern parts of Iraq due to high evaporation values, which cause the loss of most rainfall water. So, Iraq depends in providing its food on irrigated agriculture. Saline irrigation water is considered one of the alternatives to meet irrigation requirements of agricultural because of significant shortage in the amount of high quality water for cultivation. Saline irrigation water considers as the most dangerous sources of salinity in the soil, as a result its contains a mixture of naturally causing salts. The soil becomes salinized when the salt concentration increased in the root zone of optimum plant growth (osmotic and specific toxic ions effects), the plant yield is decreases, moreover, the soil properties (physical, chemical, biological) are deterioration.

2. Literature Review

Salinity irrigation water effects multiple properties of the soil, where, it was observed that, it is the electrical conductivity (EC_s), it is the chemical property affected most of soil by saline irrigation water because of the salt concentration in irrigation water is the main factor and the specific of added salts amount to the soil, which would be responsible for determining salinity soil, where, it has observed [1] that the increase in irrigation water salinity (Abu Ghraib River water =1.4 dS/m, a mixture of river water with water well =3.0 dS/m, and well water = 4.5 dS/m) led to a significant increase in soil salinity rates (5.15, 6.34, and 8 dS/m), respectively, as well, showed [2] that, electrical conductivity of soil had been significantly increased (3.02, 3.67, 4.56 and 5.52 dS/m) for soil depth (0-20) cm, and (3.44, 4.43, 5.56 and 6.40 dS/m) for depth (20-40 cm), and (3.10, 3.35, 4.13 and 4.29 dS/m) for depth (40-60 cm), with increased of irrigation water salinity levels (1.39, 4, 6 and 7.15 dS/m), respectively. As well, it was observed that the ionic composition of irrigation water can affect the concentration of the ions prevailing in the soil solution depending on the concentration of these ions in the irrigation water, where, the use of water with a high concentration of a calcium or magnesium or sodium ions can lead to the rule of this the ions on the exchange sites of soil particles, thus, this causes increase or decrease of Sodium Adsorption Ratio (SAR) [3], where, it has observed [1] that salinity irrigation water (1.4, 3.0, and 4.5 dS/m) caused significant increase of dissolved sodium ion (10.50, 15.94, and 22.29 $\mathrm{mmol/L}$), dissolved calcium ion (11.26, 15.72, and 18.11 $\mathrm{mmol/L}$), dissolved magnesium ion (6.83, 9.39, and 12.27 $\mathrm{mmol/L}$), dissolved chloride ion (10.04, 13.76, and 16.58 $\mathrm{mmol/L}$), sulfate ion (14.46, 18.77, and 27.84 $\mathrm{mmol/L}$), and sodium adsorbed ratio (SAR) (2.47, 3.18, and 3.99$(\mathrm{mmol/L})^{1/2}$), as well, it has showed by [2], that, the values of sodium adsorption ratio (SAR) had been significantly increased (2.75, 4.40, 5.24 and 6.45 $(\mathrm{mmol/L})^{1/2}$)) with increased of irrigation water salinity levels (1.39, 4, 6 and 7.15 dS/m), respectively.

Also, salinity irrigation water has negative effects on the physical properties of soil, particularly, when the increase of sodium ion in the irrigation water, which causes the increase of the percentage of exchangeable sodium in the soil, which in turn can exerts an adverse effect on the physical properties of soil through the occurrence of the dispersion and swelling processes, particularly, when Ca^{2+}ion concentration in the soil solution decreases, these processes works on the release of individual soil particles from aggregates, and the movement with the water down the soil profile and deposition of the particles into soil pores, thus, it causes plugging of soil pores, reducing for each of porosity, hydraulic conductivity(K_{sat}), infiltration, and increasing for each of surface crusting, soil erosion in streams and waterlogging, in addition to, increasing the bulk density of the soil [4], therefore, it has observed through laboratory experiment was carried out by [5] that, bulk density was increased linearly as the salinity level of irrigation water increased, while, hydraulic conductivity (K_s), and Mean weight diameter (MWD) values were decreased as the salinity of irrigation water increased, also, [6] was observed that saline water only reduced the mean weight dimeter significantly by (42%) as compared with river water, as well, he noted that there was no significant difference in bulk density for (0-20) cm among treatments, as well, showed [7] that saline water caused significant decrease for hydraulic conductivity about (14.8%) for (0-20)cm depth as compared with river water.

There many of effective scientific ways for using and management salinity irrigation water, these ways reduce the accumulation of salt in soil and it contribute to mitigate the negative effects of saline irrigation water on soil properties. Form these successful mothed, it is alternating irrigation method through using low salinity water alternating with the high salinity water, where, it was found [8] that all each of MWD, saturated hydraulic conductivity, and porosity decreased less through alternate irrigation method (1.202 mm, 2.12 cm/hr, 0.511) compared with irrigation by saline water (0.5 mm, 1.11 cm/hr, 0.508) also, he observed that, the EC_e and bulk density of soil increased by saline water (4.82 dS/m, and 1.30 Mg /m^3) more than alternate irrigation method (3.86 dS/m, and 1.29 Mg /m^3).

3. Experimental Work

The experimental work included the following activities:

3.1. The Preparation of Field

A land plot with area (26 m x 26 m) is chosen to conduct the field work. This land has been plowed by the mold board plow, then the soil is softened by disk harrows, and flooded with water for purpose of salts leaching. It left for a period of two weeks before plowing again. Main furrows excavated by using furrows machine, and radfiator machine to furrow and divide the land into major sectors and plots.

The land divided into four major sectors with dimensions for each sector of (4 m x 26 m) and leaving a comma space between each two sectors (2 m) in order to controll the movement of water and salts between the sectors and carry out irrigation operation, easily. Each single sector was divided to four experimental units (replicates), the total number of experimental units was 16 plots, the area of each experimental unit was 16 m^2 (4 m x 4 m). Canals were excavated with identifying the plots by shoulders with height of (20 cm) to ensure the homogeneity of the irrigation water distribution. The experimental unit (plot) consists of five furrows and six terraces. The distance between each two furrows (0.75 m) and the length, width, and depth of each furrow are (4, 0.5, and 0.2 m), respectively. The furrows and terraces were arranged in longitudinal direction of the field.

3.2. Experimental Scenarios

To simulate the effect of irrigation water salinity on the soil properties, the following scenarios are used:

A- Tap water (S_0) (0.6 ds/m), **B-** Well Water No.1 (S_1) (3.0 ds/m), **C-** Well Water No.2 (S_2) (5.1 ds/m), and **D-** Alternating irrigation (S_3) through using one irrigate of tap water followed by one irrigate of well water No.2.

The total number of experimental units was 16 experimental units in four sectors, [(4 water levels) × (4 replications)]. Table 1 illustrates the used scenarios in the experiment. The experimental data analyzed by using, variance statistical analysis program (GenStat).

Table 1 The experimental scenarios.

Scenarios	Code	Details
S1	S_0	The irrigation by tap water to the end of the season.
S2	S_1	The irrigation by well water (No.1) to the end of the season.
S3	S_2	The irrigation by well water (No.2) to the end of the season.
S4	S_3 (S_0:S_2)	The alternating irrigation using tap water followed well water (No.2).

3.3. Irrigation Aspects

A. Surface Irrigation System (Furrows): Surface irrigation system (furrows) included the following parts:

1- Plastic pipe for suppling the water to field with entering control gate valve, **2- Discharge Gauge (Flow Meter)** to calculate the quantity of water used in irrigation, and **3- Drain Pipe** to dispose the remaining water after each irrigation process, and ensuring that the mixing process is not occur with the water inflowed seniors. Figure 1 shows the components of furrows irrigation system.

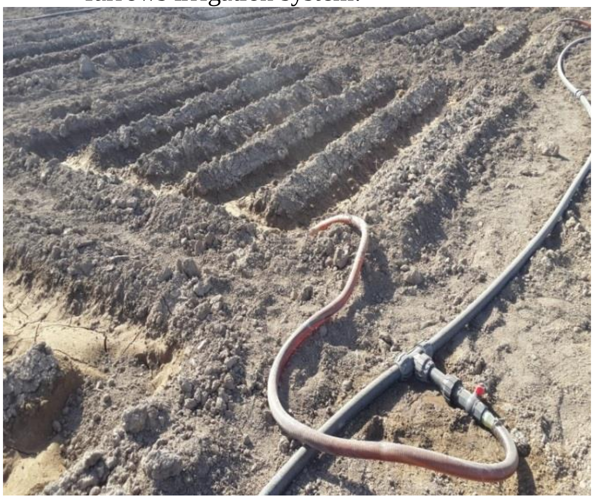

Figure 1: The components of furrows irrigation system

B. Calculation of Crop Water Requirements: The values for each of actual evapotranspiration of the crop (ET_a), and gross irrigation requirement (IR_g) when agriculture of the maize crop as reference plant, it was calculated according to the Equations 1 and 2, respectively, [9 & 10]:

$$ET_a = ET_o x K_c \quad (1)$$

Where: ET_a = Actual evapotranspiration of the crop (L/T).

ET_o = Reference evapotranspiration (L/T), it has been estimated by using empirical equation (Penman- Monteith)

K_c =Crop coefficient.

$$IR_g = \frac{ET_a}{E_a} - (P_e + LR) \quad (2)$$

Where: IR_g = Gross irrigation requirement (mm/day).

ET_a = Actual evapotranspiration of the crop (L/T).

P_e= The effective rainfall (L/T).

LR = Leaching requirement (L/T), (not used leaching requirement during irrigation process).

E_a= Field application efficiency (irrigation efficiency) (%).

C. Irrigation Scheduling: irrigation processes are carryed out depending on attrition moisture basis for the root zone depth when the moisture depletion reaches 50% of available water (initial moisture) through the using of the gravimetric method and through follow-up development of roots depth of the plants. It is based on three stages (the beginning of agriculture, the vegetative growth stage, and the flowering stage until the end of the physiological maturity stage)**.** The calculation of the added water depth to compensation moisture depletion from the field capacity is conducted by using the following Equation, [11]:

$$d = (\theta_{F.c} - \theta_{bi}) x D \quad (3)$$

Where: d= The added water depth (L).

$\theta_{F.c}$=The volumetric moisture content at field capacity (%).

θ_{bi}= The volumetric moisture content before the irrigation (%).

D = Soil depth required at the effective root system (L).

And, for calculation the irrigation time, it is depended on the volumes of added water and the pump discharge according to the following Equation:

$$t = \frac{A \ x \ d}{Q} \quad (4)$$

Where:

t= Irrigation time (T).

A = Irrigated area (L^2)

d= The added water depth (L).

Q= The discharge (pump discharge)(L^3/T).

3.4. Laboratory Work

It is included the implementation of the following activities

A. Water Samples

The water samples are collected from the water sources used in the irrigation process at the field. The samples are analyzed at three-time intervals (before planting, after one month of the planting, and at the end of the agricultural season)). Table 2 shows the chemical characteristics of the types used irrigation water.

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Table 2 The Chemical Characteristics of Irrigation Water.

Well water (No.2)			Well water (No.1)			Municipal water			Water source	
Sampling intervals										
June	Apr	Mar	June	Apr	Mar	June	Apr	Mar	Chemical characteristics	
7.7	7.8	7.4	7.6	7.5	7.3	7.5	7.45	7.2	pH	
5.6	5.4	4.9	2.7	2.65	2.45	0.68	0.63	0.65	(EC_{iw}) (dS/m)	
16.6	15	15.6	5.5	5.2	5.2	5	4.7	4.3	Calcium (Ca^{+2})	Positive ions
21.4	18.8	19.3	12.5	11.2	12.4	3.2	2.8	2.9	Magnesium (Mg^{+2})	
23.9	22.1	23.6	11.84	11.26	11.4	1.9	1.9	1.7	Sodium (Na^{+})	
28	29.1	28.4	14	14.2	16	5	5.2	4.6	Sulphates (SO_4^{2-})	Negative ions (mmol/L)
23.6	23.8	20.5	10	7.5	8	2.5	2.9	2.5	Chlorides (Cl^{-})	
1	1.2	0.8	1	0.8	1	0.8	0.6	0.65	Carbonates (CO_3^{-2})	
3.3	3.7	4.1	2.2	2.4	2.1	1.2	1.5	1.3	Bicarbonate (HCO_3^{-})	
7.45	8.5	7.63	5.5	5.6	5.6	2.8	3.1	3.3	Nitrates (NO_3^{-})(ppm)	
5.48	5.37	5.65	3.94	3.93	3.84	0.93	0.98	0.89	SAR $(mmol/L)^{1/2}$	

B. Soil Samples

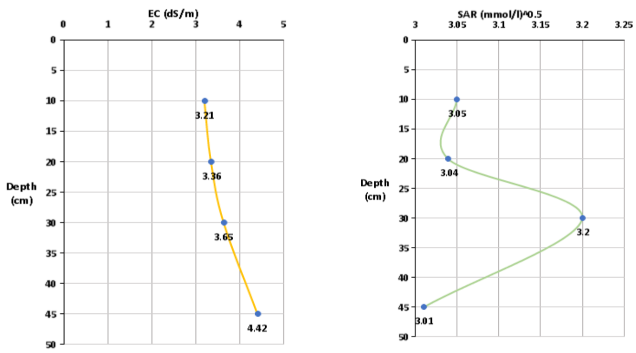
Before agricultural, representative soil samples of the field (disturbed soil samples) were collected from four depths (0-10, 10-20, 20-30, and 30-45 cm) randomly at several points distributed in the field through the selection of eight points in the experiment site (six points surrounding the field, and two points inside the field). Soil samples are taken by using Auger, and dried aerobically, then grinded by a wooden hammer to pass through (2 mm diameter) sieve. Three composite samples are chosen from each depth for the chemical analysis. Also, undisturbed and disturbed soil samples are taken from two depths (0-15, and 15-30 cm) at the same locations of the points to determine the physical properties of the soil. Tables 3, and 4 show the chemical and physical characteristics of the field soil, respectively, before agricultural. Figure 2 shows the chemical characteristics (EC_S, and SAR) of the field soil before agricultural. The chemical and physical analysis of soil samples were conducted from same depths at the end of the agricultural season for knowing the changes in the chemical properties, which included (salinity (EC_S), sodicity (SAR) at depths (0-10, 10-20, 20-30 and 30-45 cm) of soil, Figures 3, and the physical properties, which included (mean weight diameter (MWD), saturated hydraulic conductivity (K_{sat}), total porosity (f), and bulk density (ρb)) at depths (0-15 and 15-30 cm) of soil, Figures 4.

Table 3 The chemical characteristics of the field soil before agricultural.

30-45	20-30	10-20	0-10	Soil depths (cm) Chemical characteristics	
7.51	7.5	7.48	7.56	pH	
4.42	3.65	3.36	3.21	(EC_{se}) (dS/m)	
16.5	12.4	12.6	12.3	Calcium (Ca^{+2})	Positive ions (Cation) mmol/L
12.38	10.15	10.06	10.01	magnesium (Mg^{+2})	
11.45	10.75	10.25	10.2	Sodium (Na^{+})	
8.2	8.8	7.9	6.7	Sulphates (SO_4^{2-})	Negative ions (anions) mmol/L
21.9	20.6	21.5	21.8	Chlorides (Cl^{-})	
Nill	Nill	Nill	Nill	Carbonates (CO_3^{-2})	
2.5	2.3	2.2	1.9	Bicarbonate (HCO_3^{-})	
3.01	3.20	3.04	3.05	SAR $(mmol/L)^{1/2}$	
23.13	22.2	20.3	20.13	cation exchange capacity (CEC) (Meq/100gm soil)	
1.71	1.96	1.94	2.13	Organic matter (OM)	(%)
0.29	0.15	0.12	0.11	Gypsum ($CaSO_4$)	
23.67	22	26.83	22.83	Lime ($CaCO_3$)	
7.32	8.83	10.71	9.98	Available phosphorus (P)	N P K (available) (ppm)
434	454.67	484.67	507.34	Available potassium(K)	
.033	2.33	28.0	31.5	Nitrates (NO_3) (N)	
42.0	7.40	42.0	38.5	Ammonium (NH_4) (N)	

Table 4 The physical characteristics of the field soil before agricultural.

30-45	20-30	10-20	0-10	Soil depths (cm) Physical characteristics		
7.6	8.0	10.0	7.6	Sand		Size distribution %
42.8	44.0	42.4	44.8	Silt		
49.6	48.0	47.6	47.6	Clay		
Slit clay loam	Slit clay loam	Slit clay loam	Slit clay loam	Texture		
66.45	751.6	62.25	65.24	0	Tensile moisture (bar)	Gravimetric moisture content (%)
4.772	24.24	13.52	25.46	0.33		
.8612	21.49	21.80	.6202	1		
18.73	18.68	17.22	17.40	5		
15.29	16.58	15.53	15.33	10		
5513.	13.73	61.31	13.04	15		
11.22	10.51	5112.	12.42	Available Water (AW)		
5.61	5.25	076.	6.21	depletion (50 %) of AW		
15-30		0-15		Soil depths		
0.52		0.51		Mean Weight Diameter (MWD) (mm)		
3.57		3.82		Hydraulic Conductivity (K_{sat}) (cm/hr.)		
1.36		1.33		Bulk Density (ρb) (Mg/m³)		
2.65		2.65		Particle density (Mg/m³)		
0.486		0.498		Total Porosity (f)		



A. The average values of (EC_S) in the soil B. The average values (SAR) in the soil

Figure 2: The average values of EC_S and SAR of soil before agriculture

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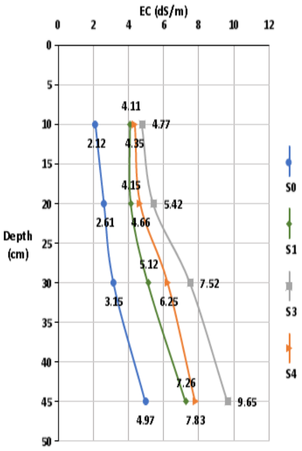
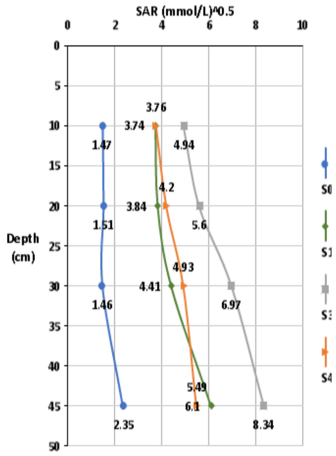
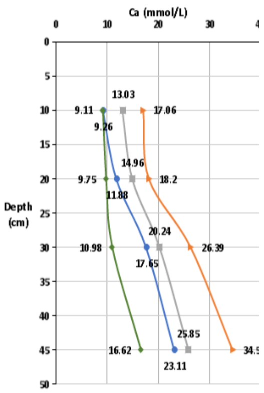
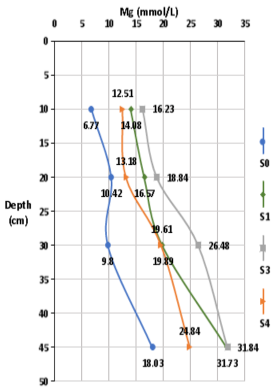


A. The average values of (EC_S) in the soil



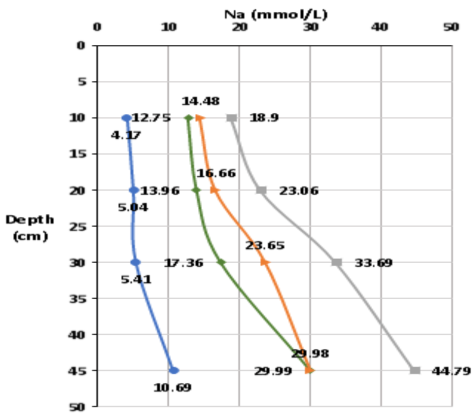
B. The average values (SAR) in the soil





C. The average values of (Ca^{2+}) in the soil

D. The average values of (Mg^{2+}) in the soil



E. The average values of (Na^{+}) in the soil

Figure 3: The average values of the chemical properties of soil after agriculture.

4. Results and Discussion

In terms of the effect of using saline irrigation water on the chemical properties of the soil. It is observed that, the soil salinity (EC_S) and soil sodicity (SAR) at the depths (0-10, 10-20, and 20-30 cm) gradually decreased to the lowest possible values at the end of the agriculture season when the use of tap water (S_0) with slightly increasing in EC_Sat the depth of (30-45 cm) (Figure 3-A, B) compared with the values of EC_S and SAR of soil before the agriculture (Figure 2-A, B). The reason for this is due to use furrow irrigation system which is characterized by rapid moisturizing process and its ability to leach the salts in larger quantities from these depths. Particularly, when low salinity water (tap water) used, which causes increasing of calcium ion ratios and decreasing sodium ion ratios in soil, as, it contains a small percentage of sodium ion versus a high percentage of calcium ion, thereby, this causes the declination of SAR in the soil, in addition to improving the hydraulic properties of the soil.

At the same depths, it has been observed when the use of water (S_2) that the values of (EC_S) were larger than the values of (EC_S) when the use of water (S_1, and S_3) (Figure 3-A), as it characterized by high salts concentrations compared with the medium salinity water (S_1) or in case alternately irrigation method (S_3). Also, it has observed that the salts are collected significantly in the depths (20-30, and 30-45 cm), especially, when irrigation by water (S_3) due to the nature of the furrow irrigation system to leach the salts from surface depths to these depth, in addition to the rapid moisturizing and drying processes which caused internal air explosions in these depths and the closure of soil pores and decline of water conductivity, for this reason salts concentrated and accumulated significantly in these depths in larger quantities and decreasing the leaching from these depths to the lower depths.

The values of SAR at the depths (0-10, 10-20, 20-30, and 30-45 cm) with water (S_2) were more than the values when the use of water (S_1, and S_3), (figure 3-B), as, water (S_2) contains high proportions of sodium ion compared with the calcium and magnesium ions, this helped to increased its concentration in the soil more than calcium ion and magnesium ion, (Figure 3-C, D, E), thus the sodic index of soil (SAR) is increasing, while, it has observed that, the irrigation water (S_1) contains on proportions magnesium ion higher somewhat than proportions ion sodium, and alternately irrigation method (S_3) contains also on high levels of calcium ion through the irrigation by tap water and high salinity water (S_2), this caused an increase concentrations calcium and magnesium ions in soil compared sodium ion and increase their impact in competing with sodium ion on exchange surface of soil particles (Figure 3-C, D, E), thereby, reducing the effect of the sodium ion and declining the values of sodic indicator

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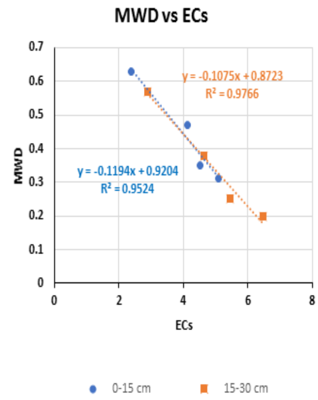
(SAR). Also, it has observed the occurrence of a sharp rise of SAR in the depth (30-45 cm), especially, when irrigation by water (S_3) because rapid moisturizing process by furrow irrigation system and leaching of the salts from depths (0-30 cm) to this depth, especially, sodium ion, in addition to, this depth contains on high concentrations of sodium ion before the agricultural.

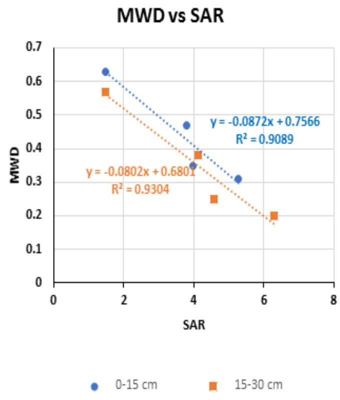
In terms of the effect of saline irrigation water on the physical properties of the soil and through reviewing the linear equations and the strength of correlation between values of EC_s and SAR with the physical properties (R-squared value). At the depths (0-15, 15-30 cm), it has observed when the use of tap water (S_0) that the physical characteristics increased (Figure 4) compared with the physical properties of the soil before planting (table 2) due to using the tap water (S_0), which is characterized by low levels of salinity and it contains on small concentration of sodium ion and high concentration of calcium ion, this helped on increases calcium ion ratios and decreases sodium ion ratio, thus, improving the hydraulic properties of the soil with the declination of bulk density, (Figure 4- E, F).

At the depths same, it has observed that the physical characteristics values (MWD, porosity, and hydraulic conductivity) were smaller with water (S_2) more than the values when the use of water (S_1, and S_3), (figure4) due to irrigation water (S_2) contains high proportions of sodium ion compared with the calcium and magnesium ions, this helped to increased its concentration in soil with observation the decrease of the values was larger in the depth (15-30 cm) because the high efficiency of leaching sodium ion in the furrow irrigation system from (0-15 cm) to this depth, therefore, the deterioration of the soil aggregates stability is happening and the decline of physical characteristics values in this depth was larger. This the deterioration through dispersion and decrease of porosity and hydraulic conductivity caused the increase of bulk density also, (Figure 4- E, F).

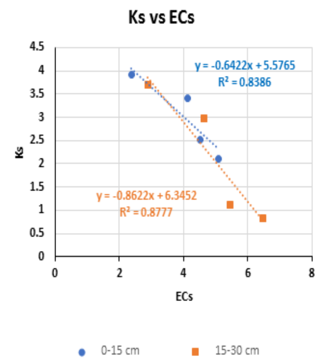
Also, it has observed when using irrigation water (S_1) and the alternately irrigation method (S_3), that the values of (MWD, porosity, and hydraulic conductivity), respectively, were more than the values when irrigation by water (S_2) for the depths (0-15, and 15-30 cm), respectively, (Figure 4) due to the irrigation water (S_1) contains high levels of magnesium ion, and, the alternately irrigation method (S_3) by each of municipal water and high salinity water contains on high levels of calcium, this caused an increase their concentrations in soil compared sodium ion, thereby, reducing the effect of the sodium ion and the deterioration of physical characteristics in lesser extent compared with (S_2).



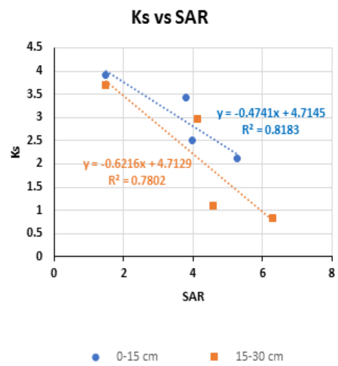
A. The average values of MWD vs EC_S



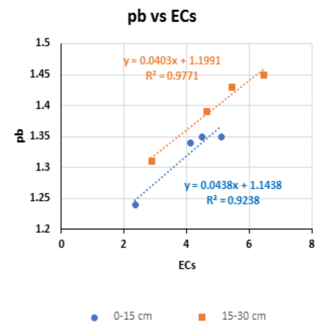
B. The average values of MWD vs SAR



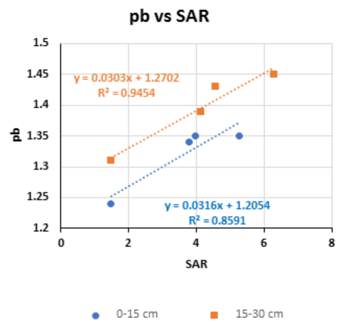
C. The average values of K_{sat} vs EC_S



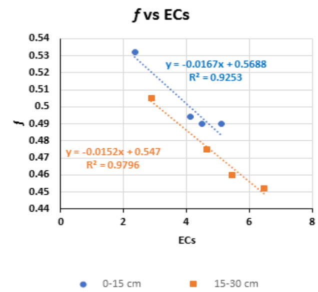
D. The average values of K_{sat} vs SAR



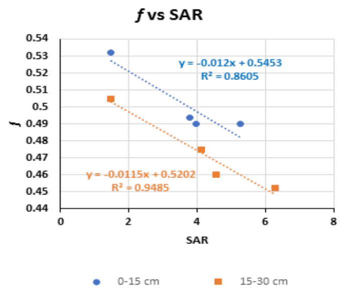
E. The average values of ρb vs EC_S



F. The average values of ρb vs SAR



G. The average values of *f* vs EC_S



H. The average values of *f* vs SAR

Figure. 4 The average values of the physical properties of soil after agriculture.

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5. Conclusions

From the results and the dissection, the points following can be concluded: -

1- Both of EC_S and SAR values are increased by increasing the depth form (10 to 45 cm) for irrigation scenarios (S_1, S_2, and S_3).

2- Both of EC_S and SAR values are decreased at the depths (0-10, 10-20, and 20-30 cm) the tap water (S_0) is used.

3- All of MWD, porosity, and hydraulic conductivity are decreased, while, the bulk density is increased by increasing the depths form (10 to 30 cm) for irrigation scenarios (S_1, S_2, and S_3).

4- All of MWD, porosity, and hydraulic conductivity are increased, while, the bulk density is decreased by increasing the depths form (10 to 30 cm) for irrigation scenario (S_0).

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