EFFECT OF USING SWRT TECHNOLOGY ON SOME PHYSICAL PROPERTES OF SOIL PLANTED WITH POTATO CROP UNDER DRIP IRRIGATION SYSTEM

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Abstract : **A field experiment was carried out in the field of College of Agriculture / University of Wasit, located on longitude 45° 50'33.5^o East and latitude 32° 29° 49.8^o North, in the spring agricultural season 2019. The experiment was designed according to Randomized Complete Block Design (RCBD) with three replication and four treatments that include each of the SWRT treatment (use of plastic films under plant root area in an engineering style) treatment of vegetal fertilizer (using Petmos), organic fertilizer (sheep manure), and control treatment. The bulk density values of soil profile for the season increased compared to their values before planting. It is noticed that the values of bulk density of soil increased with depth, ranging between 1.22 - 1.27 Mg m^{-3} for SWRT treatment and between 1.28 - 1.31 Mg m^{-3} for plant fertilizer treatment and between 1.22 - 1.32 Mg m^{-3} for animal manure treatment and between 1.29-1.34 Mg m^{-3} for control treatment. The values of saturated hydraulic conductivity of soil decreased with depth after the end of the season ranged between 0.41-0.47 cm / hour for SWRT treatment and between 0.21 -0.24 cm / hour for petmos treatment and between 0.14-0.2 cm / hour for animal manure treatment and between 0.17-0.2 cm / hour for control treatment. The rate of infiltration rate and accumulative infiltration decreased for all treatments after the end of potato growth season compared to their value before planting, and the SWRT treatment gave the highest values compared to the rest treatments.**
KEYWORDS: SWRT, Bulk density,Saturated Hydraulic conductivity,Porosity Rate of infiltration.

I.   INTRODUCTION

In arid and semi-arid regions due to its prevailing climatic conditions from high temperatures and less rainfall, needs to be irrigated to secure water requirements for production of different crops. Therefore, water users and researchers should put the possible measures to legalize the use of irrigation water and secure it for the areas to be cultivated permanently, therefore, it is preferable to use all required scientific methods to reduce wasting water and reduce water losses such as deep percolation and runoff in addition to reducing evaporation as much as possible, as a result of these activities, a high efficiency of water use is achieved to check the highest possible production for unit quantity of water [1]. In developed countries, farmers have directed the use of modern irrigation methods in recent years. This is because modern methods of irrigation of crops lead to increase the ability of soil to retain water, increase its permeability, reduce water lost by runoff, and also secure plants water requirements. Drip irrigation is one of the appropriate methods for irrigation in arid and semi-arid regions, because it provides control over irrigation water and equips water near the root zone of plant. This is regarded as high level of control and it performs to increase crop productivity [2].

Modern technologies have been developed that use natural hydrological processes to retain the largest amount of water in the soil for a longer period, thus reducing water deficits for plants in arid and semi-arid regions. Among these modern technological are subsurface water retention technology (SWRT), in which plastic membrane are placed below the root growth zone with specific engineering methods, that aimed to improving the physical and hydrologic properties, minimizing water losses and increasing the productivity of these soils. Through field studies and agriculture in green houses, it was observed to increase the capacity of soil to preserve water and improve the root environment through preserving water

and nutrients, thus improving the water qualities of soil and its productivity by using modern technology. These environmental and hyrological effects of SWRT technology increase the quantity and quality of both vegetable and cereal crops with using low amount of water and fertilizer. Experiences at the University of Michigan showed that erecting polyethylene films at a depth of 0.2m increase the water capacity of root zone by twice compared to not using it [3,4]. Therefore, this study aims to know the effect of SWRT technology on the physical properties of soil related to the movement of water in soil profile.

II. Materials and methods

Afield experiment was carried out in the field of College of Agriculture/ Waist University at the spring agricultural season 2019. Random samples were taken from several separate sites from the field soil and from three layers (0-15,15-30,30-45)cm. Each sample was mixed together and obtained a representative compound sample. The soil samples were air dried, then pulverized and sieved through 2mm diameter sieve. These samples were used to estimate the physical and chemical properties of the soil before planting, as following, a particles size analysis was carried out to find the texture by using the hydrometer method according to [5]. The bulk density of soil and particle density were estimated by core sample method and pycnometer method respectively according to methods mentioned by [5]. The total porosity calculated by the relationship between bluk density and particle density according to[5] by the following equation:

$$f = 1 - \rho b / \rho s * 100 \quad \ldots\ldots\ldots\ldots(1)$$

as that

f : porosity(%)

ρb : Bulk density of soil (Mg m^{-3})

ρs : Particle density of soil (Mg m^{-3})

The soil saturated hydraulic conductivity was estimated using the constant water column method according to [6] by the following equation:

$$K = \frac{V\ L}{At\ \Delta H} \quad \ldots\ldots\ldots\ldots(2)$$

as that:

K : Saturated hydraulic conductivity(cm hr^{-1})

V : The volume of accumulated water out let of soil column (cm^3)

L: The length of the soil column (cm)

A : Cross section area of soil column (cm^2)

t: Water collection time (hr)

ΔH: The change of hydraulic head between intel and outlet of water to soil column (cm)

The accumulative infiltration and infiltration rate estimated by using the double ring infiltrometer, according to [7] as shown in the table below:

Table (1) physical properties of the field soil before conducting the experiment.

Soil property	Unit	Soil depth(cm)		
		0-15	15-30	30-45
Sand	G kg^{-1}	492	522	491
Silt		496	471	493
Clay		12	7	16
Texture class		Sandy Loam		
Bulk density	Mg m^{-3}	1.2	1.24	1.27
Particle density		2.61	2.59	2.60
Porosity	%	54	52	51
Hydric conductivity	Cm/hr	0.65	0.6	0.58
Infiltration rate		0.7		

Soil moisture characteristic curve was estimated by taking the moisture content values at different tension values, where the soil has been saturated with water for 24 hours and different tension values (0-

15 bar) have been used by tension plate and pressure membrane where the volumetric moisture content has been calculated at each level of tension according to method (22), the data showed at fig.1 .
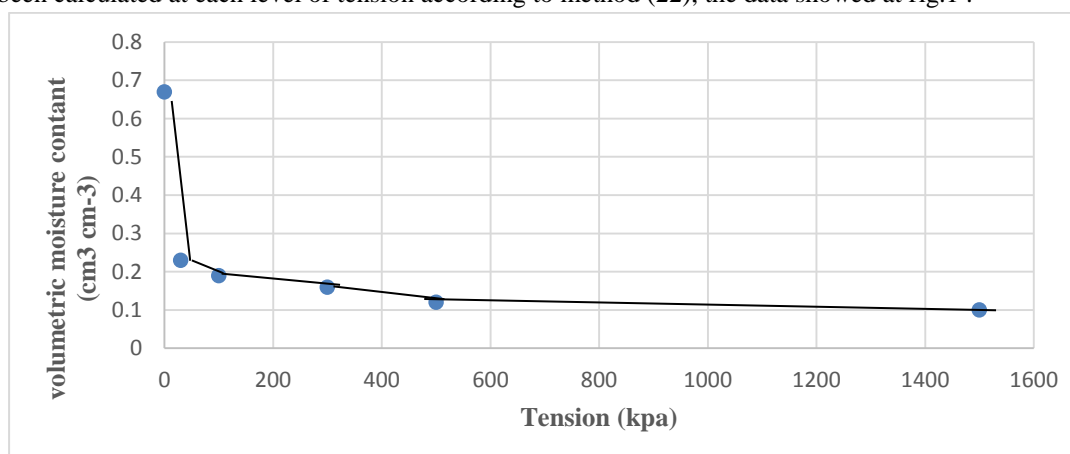

Fig.1 : soil moisture characteristic curve for soil depth(0-30cm)

The experiment includes four experimental treatments and three replicates, by using randomized complete block design and the treatments are:

1- SWRT treatment

To apply this treatment required the use of transparent plastic films and was used to ditch trench with dimensions (0.5m ,0.5m ,10m) depth, width and length for each experimental unit, where these films were placed with a depth (0.5m) and a side slope of (1:1) and width (30cm) at the bottom two trenches for each experimental unit were ditched. After that, the excavated soil was restored to its previous depth before digging as possible, as shown in fig.2 .
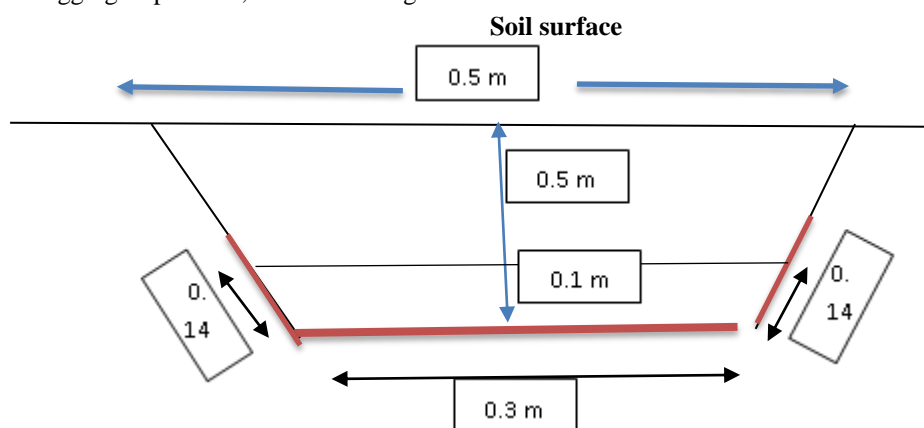
Soil surface

Fig.2 :A diagram showing the dimensions of the plastic film used in the experiment

2- plant fertilizer treatment : Plant fertilizer was used (ptmos) and two trenches were ditched with dimensions(0.5m ,0.5m,10m) depth, width and length for the experimental unit, and fertilizer was added at 44kg terrace[-1],i.e.22 kg trench[-1] according to the fertilizer recommendation 73-75 m^3 hectare[-1] [8].

3- Animal manure treatment: Animal manure was used as sheep waste(Al-Daman), and it was used to ditch two trenches were ditched with dimensions(0.5m ,0.5m,10m) depth, width and length for the experimental unit, and fertilizer was added at 44kg terrace[-1],i.e.22 kg trench[-1] according to the fertilizer recommendation 73-75 m^3 hectare[-1] [8].

4- Comparison treatment: (without using SWRT or adding plant and animal manure)

Preparing the field soil to planting: The field soil is prepared by plowing the field soil with the moldboard plow, and it was smoothed by using the rodivatour and leveling by using the landplane, the dimensions of the field(10.75m*50m), the experiment field was divided into terraces, as the length of the terrace was 10m, width 2.25m and height 0.10m and the distance between the terrace and another 2.0 m , each block divided into four terraces with four treatments, and a distance of 2m was left longitudinally and

transversely to prevent interaction between irrigation treatments. The number of experimental units reached twelve experimental units.

Installing the drip irrigation system: Drip irrigation system has been installed in the field of experiment, which consists of the following parts: water tank with dimensions of 6*4*2m, gas pump 2 inch*2inch, fertilizer, filter, pressure gauge, control switches, main tube diameter of 2 inch, 4 semi-main pipes with a diameter of 2 inch, twenty four field tubes with a diameter of 16 mm, the distance between a side line and another 0.75m and the distance between emitter and another 25cm , each field tube contains 40 emitter. The system was examined and calibrated before planting, where emitters discharge and distribution uniformity were measured by the lowest quarter method by selecting four field-tubes, the first located at the beginning of the main line and the second and third located in the second and third quarters of the main line and the fourth is located in the last quarter of the line and four sites were selected in each field-line is distributed over the four quarter, and the system was operate and put the glass beakers at the bottom of the chosen emitters, fix the time(2 minutes) for measurement, the discharge rate(liter/hour) and distribution uniformity (%) calculated as shown in table(2), remeasured after two days, and the discharge rate was approved for the used emitters is 5 L/hr.

Table(2) the mean discharge emitters (L/hr) and distribution uniformity(%)

Field tube location on semi-main tube	Emitters location on field tube				
	beginning of field tube	second quarter of field tube	third quarter of field tube	End of field tube	The average
beginning of semi-main tube	5.18	5.34	5.46	5.04	5.26
Second of semi-main tube	5.15	5.09	5.26	5.1	5.15
third quarter of semi-main tube	5.29	5.39	5.25	5.03	5.24
End of semi-main tube	5.41	5.11	5.05	5.27	5.21
The average	5.26	5.23	5.25	5.11	5.21

Discharge rate(the lowest quarter) = 5.11 L/h

General discharge rate = 5.21 L/h

Distribution uniformity =5.11/5.21 * 100 =98.08%

Agriculture: The potato tubers (Solanum tubersoum L.) Burin cultivar for a spring season were planted at (10/2/2019) at a depth of 5-10 cm and an average of 80 tuber for every terrace, a distance of 25 cm between one tuber and another [9].

Fertilization: Urea fertilizer was used at a rate of 240 kg/ha in three batches at planting, stage of vegetative growth and the stage of tubers filling, and mono ammonium phosphate fertilizer (21% phosphorus and 11% nitrogen) at a rate of 120 kg/ha added at one batch at cultivation and potassium sulfate fertilizer (41.5% k) at a rate of 400 kg/ha added in two batches at planting and during the development tuber stage ,according to fertilizer recommendations by [3].

Control and Weeding: The weeding process of weeds in the field tookplace over the period of the crop growth during the season, and the control process was not carried out because no pathological injuries occurred during the stages of crop growth.

Irrigation: The irrigation process was carried out after the depletion of 50% of the available water, where the depth of the water needed to reach the soil moisture to the field capacity limits based on the data of soil moisture characteristic curve (as shown in table 3) where the content of the available water in the soil is estimated by the difference between the field capacity (Volumetric moisture content at a tension of 0.3 bar) and a permanent wilt point (volumetric moisture content at a tension of 15 bar) according to the following formula proposed from (1) :

$$d =(\theta_{f.c}- \theta_w)*D   ......……..(3)$$

d: added water depth(cm) $\theta_{f.c}$: Volumetric moisture content at field capacity (cm^3 cm^{-3}) θ_w: Volumetric moisture content before subsequent irrigation (cm^3 cm^{-3})   D: Depth of soil (cm) where a depth of 15 cm was used for the germination and vegetative stage , then increased to 30cm in the stage of emergence of tubers.

Based on the measurements of the irrigation water depth calculated in the above equation, the irrigation time is calculated for each emitter according to the equation given in (4) [10] :

$$T=d*Ae / Q   \quad.....………..(4)$$

Ae: Wetted area (m^2)   d: depth of irrigation water (m)   Q: emitter discharge (m^3/h)   T: Irrigation time (hour).

Table (3) Moisture content and soil characteristics used in scheduling irrigation of experiment.

Property	Unit	Value
Volumetric moisture content ☐ at saturation		0.67
Volumetric moisture content ☐ at field capacity 0.3 bar		0.23
Volumetric moisture content ☐ at wilting point 15 bar	Cm^3 cm^{-3}	0.1
Available water		0.13
Volumetric moisture content ☐ at depletion 50% of available water		0.165
Gravimetric moisture content pw at field capacity		18.7
Gravimetric moisture content pw at depletion 50% of available water	%	13.41
Mean bulk density of soil to a depth of 0-30 cm	Mg m^{-3}	1.23

Estimation of physical properties of the field soil after the end of growing season:

-The bulk density and particle density were estimated by the Core Sampler method and by the Pycnometer method respectively, according to the method mentioned in [5].

-The total porosity was calculated from the relationship between bulk density and particle density according to [5] as given in equation (1).

-The saturated aqueous conductivity in non-disturbed soil samples was estimated at the end of the field experiment using the constant water column method [6] , as described in equation (2).

-The accumulative infiltration and rate infiltration was also estimated by using Double- ring infiltrometer , according to method [11].

III. Result and discussion

The bulk density of the field soil after the end of growing season of potato:

Fig.3 shows the values of bulk density of the studied treatments after the end of the season for potato for the depths of soil 0-15, 15-30, 30-45 cm. It is observed that the values of bulk density of soil increase in depth, ranging between 1.22-1.27 Mg m^{-3} for SWRT treatment and between 1.28-1.31 Mg m^{-3} for plant fertilizer treatment ,between 1.22-1.32 Mg m^{-3} for animal manure treatment, and 1.29-1.34 Mg m^{-3} for comparison treatment, and when comparing these values with the values of bulk density of field soil before planting at spring season (Table 1).It has been noted that the bulk density values for the three depths above were 1.2 ,1.24 ,1.27 Mg m^{-3} respectively, While the average bulk density of the studied treatments SWRT , plant fertilizer, animal fertilizer and comparison increase by 0.81%, 3.04%, 2.42%, 5.65% respectively, compared to the average bulk density of soil depth 0-45cm before planting. The reason of this is due to the effect of tillage operations, the weight of the agriculture tractor and the equipment attached to it when preparing soil of field for planting at spring season, where the agricultural tractor and the attached equipments were passed three times for the season, which leads to compaction soil layers for the agriculture season, in addition to the effect of irrigation operations, whether it happened by irrigation water or rain, in the movement of fine soil particles and their precipitation inside the pores of the soil, which leads to a decrease in the total porosity and an increase in their bulk density, where the number of irrigation for the studies treatments in the season ranged between 21-24 irrigations throughout the season in addition to the falling rain on the site of the experiment during the season, which was 77.6mm,

which leads to the break down and collapse of soil aggregates and the movement of its particles by increasing the amount of irrigation water and its sedimentation inside the pores, which causes reduced pore volumes and increasing in the bulk density of the soil, and this is agreed with what was indicated by [12] that the increase in the amount of irrigation water and wetting changes shapes and sizes of soil pores, which causes an increase in its bulk density.
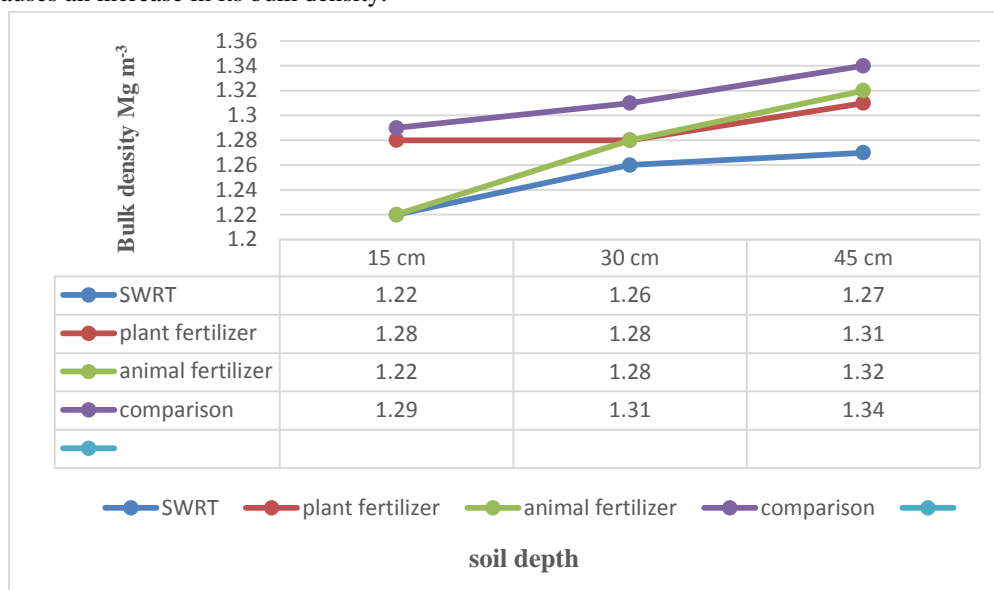

	15 cm	30 cm	45 cm
SWRT	1.22	1.26	1.27
plant fertilizer	1.28	1.28	1.31
animal fertilizer	1.22	1.28	1.32
comparison	1.29	1.31	1.34

Fig.3 :values of bulk density of field soil after the end of crop growth.

The particle density of soil

Fig.4 shows the values of the particle soil density after the end of the growing season. It was found that the particle soil density for the study treatments SWRT, plant fertilizer, animal fertilizer and comparison after the end of season is closed to what it was before planting where it was 2.60, 2.58, 2.61, 2.57 Mg m^{-3} for depth 15 cm for SWRT, plant fertilizer, animal fertilizer and comparison respectively. The results of particle density of all treatments for all three depths after the end of season of crop have ranged between 2.56 ,2.61 Mg m^{-3} , it may be due to the fact that the particle density is not affected by arrangement or coordination of soil grains or their structure, but rather is affected by the mineral soil composition [13].
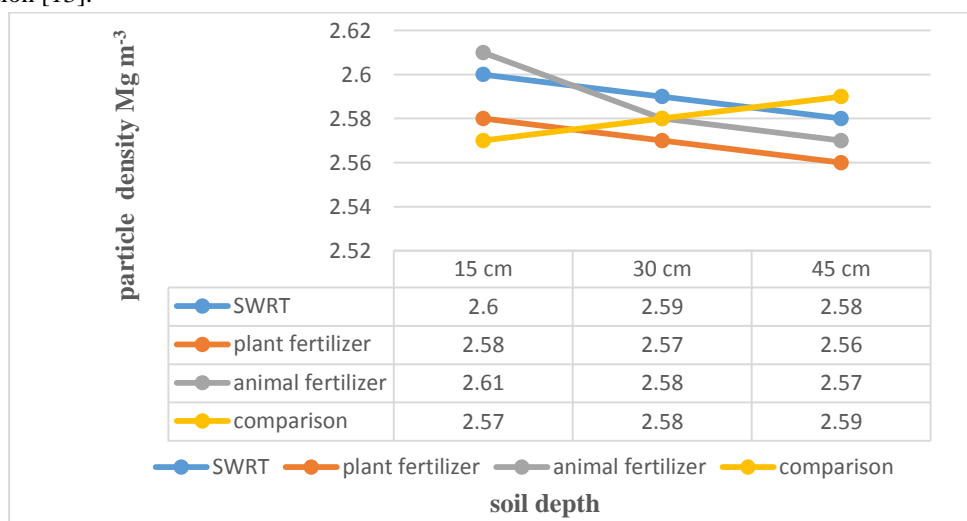

	15 cm	30 cm	45 cm
SWRT	2.6	2.59	2.58
plant fertilizer	2.58	2.57	2.56
animal fertilizer	2.61	2.58	2.57
comparison	2.57	2.58	2.59

Fig.4 : values of particle density of field soil after the end of crop growth season.
Porosity of soil (%)

Fig.5 shows the soil porosity of the study treatments after the end of crop growth season. It was found that the porosity values were slightly lower than it was before planting, so the porosity value for the depth

15cm before planting was 0.54 while the porosity value was 0.5, 0.51, 0.54, 0.53 for treatments SWRT, plant fertilizer, animal fertilizer and comparison respectively for the same depth, this is due to the increase of bulk density with depth and for all experiment treatments after the end of growing season fig.3 . The reason for this is due to the role of irrigation water when it leaches fine soil particles downward and fill the voids in the lower layers of soil profile, this leads to increase the bulk density of soil and to reduce the total porosity of soil and vice versa, and this is what it was found by [14] , also increasing the depth leads to a decrease in the total porosity because of the increased bulk density of the soil, which reduce the percentage of pores present in the soil. This is supported by [15].
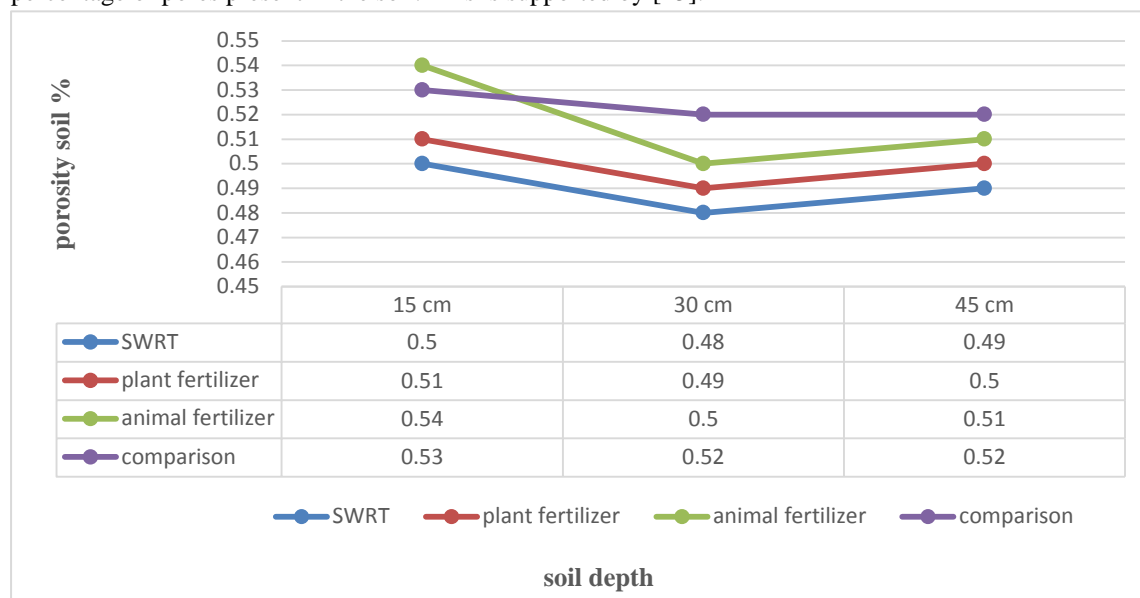
	15 cm	30 cm	45 cm
SWRT	0.5	0.48	0.49
plant fertilizer	0.51	0.49	0.5
animal fertilizer	0.54	0.5	0.51
comparison	0.53	0.52	0.52

Fig.5 : values of porosity of field soil after the end of crop growth season.

The saturated hydraulic conductivity of the field soil after the end of crop growth season

values of the field soil before planting table (1), it has been noted that the values of saturated hydraulic conductivity for the three depths above were 0.65, 0.6, 0.58 cm/hour respectively. It has been noted that the average of hydraulic conductivity of the three depths of studied treatments SWRT, plant fertilizer, animal manure and comparison decreased by 27.78%, 62.3%, 72.135, 70.5% respectively comparatively with average of hydraulic conductivity of soil depth 0-45 cm before planting. The reason for this is due to the high values of bulk density of the studied treatments with depth after the end of growing season. As it has been mentioned previously, the saturated hydraulic conductivity depends on the soil structure, its total porosity and distribution of its pore sizes, this is indicated by[16].

When comparing the studied treatments of the saturated hydraulic conductivity values, it has been noticed that the average hydraulic conductivity of soil profile for SWRT treatment was the highest values, it reached 0.44 cm/hour then it followed by plant fertilizer which was 0.23cm/hour, then comparison treatment was 0.18 cm/hour, then animal manure treatment was 0.17 cm/hour, with percentage decreased from the SWRT treatment 47.52%, 59.1%, 61.36% respectively. This is attributed to the role of the plastic barrier for the treatment of SWRT in increasing the area and volume of wetting soil by reserving irrigation and rain water within the soil profile, which leads to an increase the spread of root system, which contributed to improving soil structure by reducing its bulk density and increasing its hydraulic conductivity compared to other treatments.
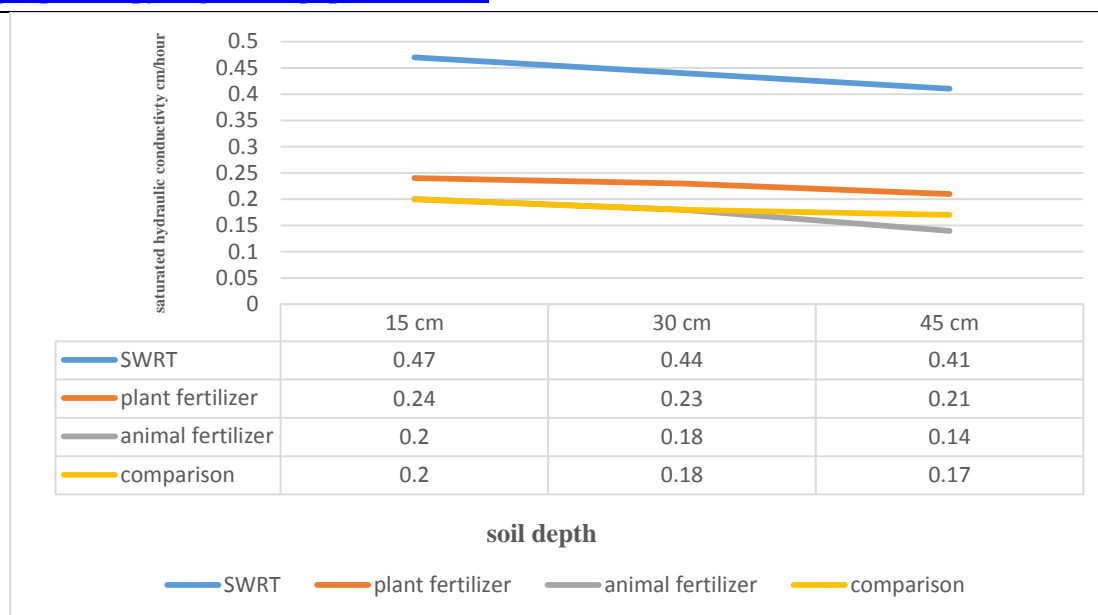
soil depth	15 cm	30 cm	45 cm
SWRT	0.47	0.44	0.41
plant fertilizer	0.24	0.23	0.21
animal fertilizer	0.2	0.18	0.14
comparison	0.2	0.18	0.17

Fig.6 : values of saturated hydraulic conductivity of field soil after the end of crop growth season.

The infiltration rate and accumulative infiltration of the field soil after the end of growing season of potato

Fig.7 shows the relationship of both the accumulative infiltration (cm) and the infiltration rate (cm/hour) with time for soil of study site before planting potato for spring season. The result showed that the infiltration rate and accumulative infiltration of soil were high at the beginning of measurement (during the first five minutes) when the accumulative infiltration was by 9.3cm and the infiltration rate was 111.6 cm/hour. Then the infiltration rate and accumulative infiltration began to decrease with the advance of measurement time. For example, during the second five minutes, the depth of infiltrate water became 5.7cm and the infiltration rate was 68.4 cm/hour, and this decrease continues until the end of measurement time 300 minutes (5 hour), the accumulative infiltration arrived 26.9 cm and the infiltration rate was 0.7 cm/hour at the end of the measurement period. As it has been indicated previously, the forces responsible for the infiltration at the beginning of measurement were the tension forces, especially when the soil is drier. This leads to rise of the accumulative infiltration and infiltration rate at the short first time of beginning of measurement period. As the measurement period progresses, soil becomes close to the state of saturation and gravitational forces becomes the most effective of water infiltration, which was confirmed by [17,18].

It has been observed increasing the infiltration rate and accumulative infiltration of the field soil before planting potato. This is due to decrease of the bulk density and increase of porosity and hydraulic conductivity as shown in (Table 1). This is all due to what was previously explained that the water infiltration increases with well-structure soils which do not contain a thin crust (low permeability layer) at the surface resulting from the movement and precipitation of soil particles in the inter-pores of the soil aggregates as mentioned by [19]. The result showed that the infiltration rate of field soil pre-planting was 0.7 cm/hour and was closed to the rate of saturated hydraulic conductivity of the soil profile of 0.61 cm/hour, the difference between them 0.09 and this was due to what has been mentioned previously because the soil texture and its structure are not consistent with the depth of water. This leads to differences in the moisture distribution in the layers of soil profile during and after the entry and movement of water in it [20].

In fig.7 , the results illustrate the values of accumulative infiltration and the infiltration rate of the studied treatments after the end of the agriculture season, the results showed decreasing of accumulative infiltration and infiltration rate for all treatments compared to their value before planting, where their

values were as follows 20.7cm, 0.5 cm/hour for SWRT and 17.9cm,0.3cm/hour for plant fertilizer and 16.5cm, 0.2 cm/hour for animal fertilizer and 16.8 cm, 0.2cm/hour for comparison treatment.

The percentage decrease in accumulative infiltration of the studied treatments compared to its value before planting the crop was as follows: 23.05% for SWRT treatment, 33.46% for plant treatment, 38.66% for the animal manure treatment, 37.55% for comparison treatment. As for the percentages of decrease in infiltration rate of studied treatments compared to their value before planting, they were as follows: 28.57% for SWRT , 57.14% for the treatment of plant fertilizer, 71.43% for treatment of animal manure and 71.43% for comparison treatment. This decrease of the accumulative infiltration and infiltration rate values of studied treatments after the end of season is attributed to increase the bulk density of the soil profile after the end of season. Finally, this leads to a decrease in the sorptivity of the soil aggregates because of the low percentage of pores, especially large ones, which causes a reduction in the area of the flow section, this is consistent with what is found by [21].

The result of the infiltration rate for the studied treatments showed that they approach the average values of saturated hydraulic conductivity of the soil for each treatment. For example, the infiltration rate for the plant fertilizer treatment was 0.3 cm/hour, while the saturated hydraulic conductivity average for the soil profile was 0.23cm/hour, and the difference between them is 0.07 and this has been interpreted and indicated by [20].
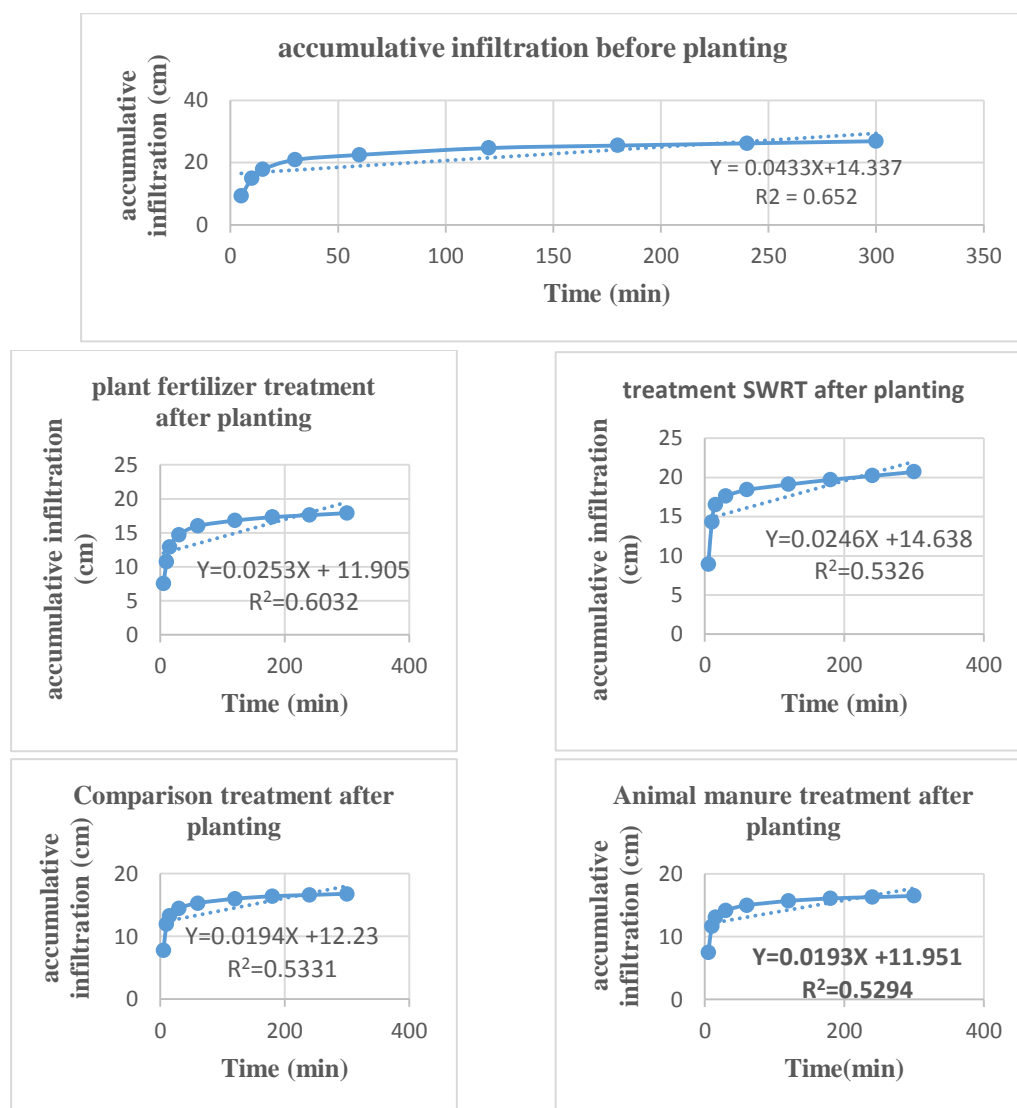
Fig.7 :values of accumulative infiltration of the field soil before planting and after the end of crop growth season

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