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RESEARCH ARTICLE

The effect of using subsurface water retention technology on the available content of soil nutrients under subsurface drip irrigation system

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ABSTRACT

To evaluate the effect of using subsurface water retention technology (SWRT) in rationing added irrigation water and in the growth and yield of *Zea mays* L., Field experiments were conducted under the subsurface drip irrigation system in two locations: one in the Palm Tissue Research Station affiliated to the Ministry of Agriculture in Najaf Governorate. The second location of the experiment was conducted in the research fields of the College of Agriculture in Al-Jadriya, affiliated to the University of Baghdad, for two seasons, spring and autumn of 2016. The study included four treatments: SWRT, organic matter, tillage, and no tillage. The treatments were distributed according to a randomized complete block design (RCBD) with four replicates. *Zea mays* L. seeds were planted and the date and amount of irrigation water were determined for each irrigation after draining 50% of the available water based on the moisture data of GS3-Soil Moisture Sensor to monitor the volumetric moisture content at depths of 15, 30 and 45 cm using Data Logger devices to store and represent the data every four hours and throughout the growing season. The results showed that the use of SWRT technology increased the availability of nutrients in the soil as well as increased the concentration of nutrients in the plant, as the SWRT treatment was superior in increasing the concentration of nitrogen, phosphorus and potassium in the vegetative group, as the concentration of nitrogen increased by 26.37%, phosphorus by 43.33% and potassium by 33.33% compared to the plowing treatment in the first season of cultivation for the Baghdad location, and the percentage of increase in the concentration of nitrogen was 35.19%, phosphorus by 32.14% and potassium by 30.32% compared to the plowing treatment for the Najaf location.

Keywords: *Irrigation scheduling, subsurface drip irrigation, organic matter, field capacity, soil nutrients.*
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INTRODUCTION

Iraq is geographically located within the driest belt in the world, which means that Iraqi agriculture depends on surface and groundwater resources to provide irrigation water for sustainable agriculture. These resources are limited and shared with other countries neighboring Iraq, in addition to the clear deterioration in the efficiency of water use and the lack of protection and maintenance. The available alternatives to fill the Iraqi water deficit are mainly represented in raising the efficiency of use and protecting and maintaining resources. Therefore, protecting and maintaining water resources in terms of quantity and quality become available solutions for Iraqi water resources and exerting more effort in planning and awareness of the technology of rational water use (Al-Azzawi and Khalaf, 2015). Water resources are an important determinant of the agricultural development program in Iraq and one of its most important foundations and one of the most important determinants of the exploitation pattern of agricultural lands and the possibility of expanding them vertically and horizontally. The Tigris and Euphrates rivers and border-rivers with Iran constitute the main source of water resources in the Iraq. Rain comes in second place in meeting the need for water uses, especially for agricultural purposes, while groundwater occupies third place, as it constitutes a small percentage and most of its uses are limited to drinking purposes, especially in desert areas (Al-Badri and Nasser, 2012).

Water resources in Iraq are largely linked to the amount of rainfall in the main river basins (Tigris, its tributaries and Euphrates) as well as to the policy of operating dams and reservoirs built in the upper reaches of the shared rivers in Turkey, Syria and Iran. There is no international agreement to share water with Iraq, in addition to the expansion of the development of storage and irrigation projects by the aforementioned countries, which has currently negatively affected (quantity and quality) the imports entering Iraqi territory, and this effect will increase in the future to threaten life. Agriculture is also the largest consumer of fresh water and consumes about 58% of the fresh water used in Iraq (Al-Azzawi and Khalaf, 2015). Good water management controls water and uses it to obtain food or crops and fodder in their ideal form. This management is represented by using and employing all natural, chemical, biological and social resources to provide crops with their water needs to obtain food and fodder to achieve pre-determined goals without harming the environment. The amount of water needed and the timing of irrigation depend on the prevailing climatic conditions, the type of crop and its degree of growth. Soil properties also affect the irrigation process, the water needs of plants, and the amount of water lost by evaporation-transpiration because it affects the movement of water in the soil towards the surface, which determines the amount of water consumed by the plant (Al-Amir, 2010). SWRT technology is defined as a system for retaining water under the surface of sandy soil to improve its physical and water properties, reduce losses to the minimum possible, and increase the productivity of these soils. SWRT technology was developed to maintain the volumetric moisture content in the root zone of plants (Smucker et al., 2011). Field and greenhouse studies have proven that using this technology leads to doubling the soil's capacity to retain water (Aoda, 2012). SWRT technology improves the root environment by conserving water and nutrients, thus improving soil hydrological properties and productivity. These multiple environmental and hydrological effects of SWRT technology can increase the quantity and quality of both vegetable and grain crops while using less water and fertilizer. Experiments at the University of Michigan have shown that installing polyethylene membranes at a depth of 30 cm increased the root zone water capacity by two times compared to not using this technology (Smucker *et al*., 2011).

MATERIALS AND METHODS

Field experiments were conducted in two locations one was at the Palm Tissue Research Station of the Ministry of Agriculture in Najaf Governorate (Najaf Desert Island) during the spring season of 2016. This location is located at latitude 37.80'''0732º north and longitude 44.7" 19' 44º east. The field soil was classified as sandy with a sandy mixture texture (Sandy loam; moderate medium, Typic, Torripsamments). The second location of the experiment was conducted in the research fields of the College of Agriculture in Al-Jadriya, affiliated with the University of Baghdad, for two seasons, spring and autumn of 2016. This location is located at latitude 32º 16' 06" north, and longitude 2.2" 23' 44º east. The field soil was classified as having a clay loam texture (Clay loam; Strong fine, Typic, Torrifluvents) according to (Soil Survey Staff, 2012). Random samples were taken from several scattered locations of the soil of the two locations at three depths of 0-0.30, 0.30-0.60, and 0.60-0.90 m. Then, the samples of each depth were mixed and a representative composite sample was obtained. The soil samples were air dried, then ground and sieved with a sieve with a hole diameter of 2 mm. These samples were used to estimate the physical and chemical properties of the soil before planting, as shown in Tables 1 and 2.

Table (1) Some physical properties of field soil before planting for the two study locations

Location	Soil separators		Soil Depth (m)		
			0.0 – 0.3	0.3 – 0.6	0.6 – 0.9
Najaf	**Sand**	**gm kg^{-1}**	**673**	**734**	**785**
	Silt		**242**	**234**	**193**
	Clay		**85**	**33**	**22**
Class of Texture			**Sandy Loam**	**Loamy Sand**	
Baghdad	**Sand**	**gm kg^{-1}**	**182**	**230**	**245**
	Silt		**470**	**455**	**389**
	Clay		**348**	**315**	**365**
Class of Texture			**Clay Loam**		**Silt Clay Loam**

Other Physical Characteristics			
Location	**soil Particles density**	**soil Bulk density**	**Total porosity**
	Mg m^{-3}		
Najaf	**2.72**	**1.61**	**0.41**
Baghdad	**2.65**	**1.48**	**0.44**

Property	Location	
	Najaf	**Baghdad**
Field capacity	**0.30**	**0.30**
Permanent wilting point	**0.10**	**0.11**
Available water	**0.20**	**0.19**

Table (2) Some chemical properties of field soil before planting for the two study location

Location		Baghdad Location			Najaf Location		
		Soil Depth (m)					
Chemical properties		**0.0-0.3**	**0.3-0.6**	**0.6-0.9**	**0.0-0.3**	**0.3-0.6**	**0.6-0.9**
pH		**7.42**	**7.73**	**7.33**	**7.41**	**7.34**	**7.52**
EC dSm^{-1}		**1.12**	**1.33**	**1.25**	**3.27**	**3.66**	**3.78**
Ca^{++}	**Meq L^{-1}**	**9.68**	**10.21**	**10.62**	**12.67**	**15.67**	**14.46**
Mg^{++}		**6.32**	**7.26**	**6.71**	**6.15**	**6.38**	**5.72**
Na^{+}		**10.81**	**12.01**	**9.36**	**17.56**	**20.31**	**19.18**
K^{+1}		**0.08**	**0.09**	**0.06**	**0.13**	**0.22**	**0.23**
SO_4^{2-}		**8.27**	**10.85**	**11.11**	**12.76**	**12.76**	**13.32**
Cl^{1-}		**10.72**	**11.56**	**9.12**	**14.37**	**14.27**	**13.21**
HCO_3^{1-}		**2.82**	**1.96**	**3.52**	**3.97**	**3.67**	**3.16**
NO_3^{1-}		**0.20**	**0.13**	**0.15**	**0.27**	**0.20**	**0.15**
PO_4^{2-}		**0.01**	**0.01**	**0.02**	**0.03**	**0.04**	**0.05**
SAR (mgL^{-1})$^{-1/2}$		**3.82**	**4.06**	**3.18**	**5.72**	**6.12**	**6.04**
CEC (Cmol kg^{-1})		**16.7**	**14.3**	**13.9**	**15.45**	**14.13**	**15.32**
O.M.	**(g kg^{-1})**	**10.21**	**11.35**	**9.46**	**13.22**	**11.09**	**10.18**
Gypsum		**1.24**	**1.20**	**1.13**	**2.32**	**2.56**	**2.62**
$CaCO_3$		**140.21**	**154.11**	**161.16**	**145.05**	**226.00**	**218.12**

Experimental parameters and statistical design:

The study included four parameters for both sites:

1- Plowed soil treatment with the use of subsurface water retention technology (SWRT)

To implement the SWRT system, it was necessary to use a type of plastic membranes with special specifications made of polyethylene. The plastic was installed and planted under the soil surface by placing these strips at a depth of 0.50 m from the middle, with a side depth of 0.10 m, with a side curvature of 3:1, while the height of the plastic from the side edges was 0.15 m and the lower base of the soil was 0.20 m in a geometric style with a trapezoidal shape. Due to the lack of a machine for planting plastic under the soil surface, it was necessary to manually open a trench with dimensions of 0.5 × 0.35 × 14 m^3 (depth × width × length) for each experimental unit and lift the treatment soil.

2- Treating plowed soil with organic matter added to a depth of 35 cm Organic Mater (O.M.)

To apply the organic fertilizer treatment, it was necessary to manually open a trench with dimensions of 50.3 × 0.30 × 14 m^3 (depth × width × length) for each experimental unit and lift the treatment soil, then add the organic matter in the form of a layer with a thickness of 0.05 m, a width of 0.3 m, at a depth of 0.35 m. The organic matter was added at a rate of 31 kg of mtaba-1 i.e. at a rate of 2.2 kg m^{-2} according to the fertilizer recommendation of 75-73 m^3 ha^{-1}.

3- Tillage (T) treatment

4- No Tillage (N.T) treatment

The field was leveled for the open house with dimensions of 9 × 56 m^2 and the area specified for the experiment was divided into terraces, where the length of the terrace was 14 m, width 0.90 m, height 0.10 m and the distance between one terrace and another was 1.0 m. Each replicate was divided into 4 terraces for cultivation with four treatments and a distance of one meter was left longitudinally and transversely to prevent the irrigation treatments from overlapping with each other. The number of treatments in the experiment was sixteen experimental units. The experiment was designed according to the randomized complete block design (RCBD) with four replicates, using a subsurface drip irrigation system for all treatments. corn seeds of Buhuth 5018 variety were planted by the Maize Research Center using the open cultivation system. The data were analyzed using Genstat Discovery Edition 4, and the least significant difference was tested at the 0.05 level to compare the arithmetic means of the coefficients.

Subsurface drip irrigation system:

The subsurface drip irrigation system consisted of a water basin, a water pump, a fertilizer, a water meter, a pressure gauge, and a water purification filter connected to each other on main and secondary pipes to transfer water to the field irrigation tape pipes of the Ro-Drip-Drip Tape type from JOHN DEERE with a diameter of 16 mm as shown in Figure 1. The tape pipes contain drippers that operate according to the principle of water drainage under the influence of low water pressure, they have the ability to self-clean and are resistant to tearing and shocks and do not allow dirt and plant roots to enter the drippers and are resistant to blockage. The discharge of these drippers is low at about 1.37 liters per $hour^{-1}$ for the dripper. The experimental units for the subsurface drip irrigation treatment were equipped with a tape pipe for each experimental unit at the specified design depth of 0.3 m below the soil surface, the length of each pipe is 14 m. The number of drippers in one strip pipe was 140, with the distance between one dripper and another being 0.10 m. The subsurface drip irrigation system was arranged in its experimental units according to the open system to facilitate the cleaning process as well as control the irrigation process with high efficiency (Enciso, 2001). Several tests were also conducted to evaluate the homogeneity coefficient of dripper water distribution at different operating pressures, and a pressure of one bar achieved the highest homogeneity coefficient efficiency of 97.37%.

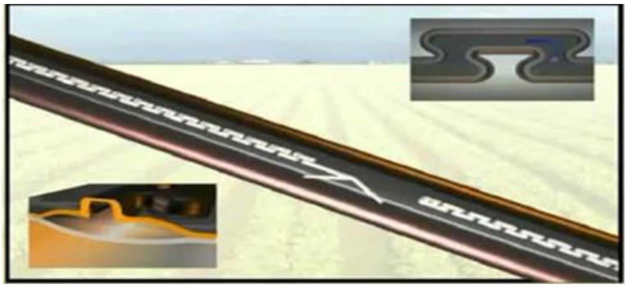

Figure (1) Ro-Drip-Drip Tape subsurface drip irrigation pipes. The figure shows the drippers that discharge irrigation water.

Moisture content monitoring and irrigation method:

The crop was irrigated during the first two weeks using a surface drip irrigation system due to the limited root system at the beginning of cultivation for the two seasons. Then, the subsurface drip irrigation system was relied upon based on the reading of the GS3 sensors (Figure 2), which were placed at depths of 15, 30 and 45 cm and connected to the Data Logger (as in Figure 3) to take continuous volumetric moisture content readings and represent them using computer programs supporting these devices. When the soil moisture content indicates that 50% of the available water has been depleted, irrigation is carried out by adding the depth of water necessary to reach the moisture content at the field capacity of the field soil using the soil moisture description curve for the field capacity values and the sensor readings, i.e. when the volumetric moisture content reading reaches 0.20 cm cm-3 for the effective depth of the root zone according to the growth stage, irrigation is then carried out.

The irrigation process is carried out in two ways: 1) The first mechanism, in which the irrigation process is carried out for each treatment according to its need (after draining 50% of the available water) according to its moisture reading from the sensors in order to estimate and know the effect of the amount of irrigation water for the SWRT treatment compared to the other treatments. This mechanism was applied in the first season: 2) The second mechanism, in which the irrigation process is carried out for all treatments according to the moisture data for the SWRT treatment, and water is added to all treatments in the same amount added to the SWRT treatment in order to simulate rained agriculture and the possibility of using this technology in it. This method is applied in the second season.

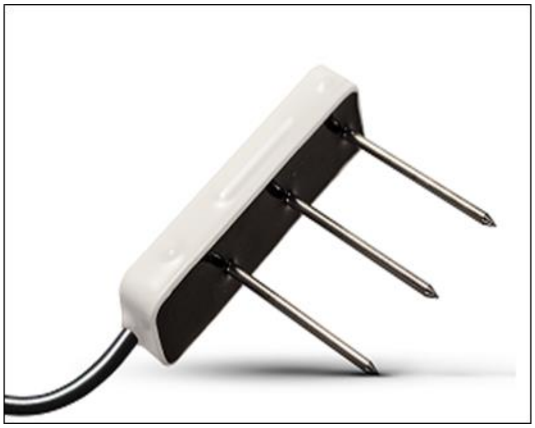

Figure (2) GS3 type sensor

Figure (3) Data Logger type Em50

The irrigation time is calculated based on the drainage and the amount of water the plant needs in each irrigation (m^3 h^{-1}). The equation proposed by (Allen *et al*., 1998) was also used to calculate the depth of water that must be added to compensate for the depleted moisture, as follows:

$$d = (\theta_{f_c} - \theta_w) \times D$$

Where:

d = depth of added water (mm)

θ_{fc} = volumetric moisture at field capacity (cm^3 cm-3)

θ_w = volumetric moisture before irrigation (cm^3 cm-3)

D = soil depth, which is equal to the depth of the effective root system (m)

Estimation of available nitrogen, phosphorus and potassium in the soil

Soil samples were taken for each treatment from the layers 0.0-0.15, 0.15-0.30 and 0.30-0.45 m, at three stages at the beginning, middle and end of the season for both growing seasons, after drying, grinding and passing them through a sieve with a diameter of 2 mm holes. Available nitrogen in the soil was estimated by extracting 2M potassium chloride 2M KCl using the Micro Kjeldahl device and according to the method of (Keeney and Nelson, 1982). Available soil phosphorus was extracted using 0.5 M sodium bicarbonate 0.1 M $NaHCO_3$ according to the Olsen method and the color was developed with ammonium molybdate and ascorbic acid and estimated using the Spectro photometer according to the method of (Olsen and Sommers, 1982). The available soil potassium was extracted using 0.5 M ammonium acetate and was determined using a flame photometer according to the method of (Richards, 1954).

RESULTS AND DISCUSSION

Available content of nutrients in the soil of Baghdad location

1- Available nitrogen content: The results of Table 3 show the effect of different treatments on the available content of nitrogen, phosphorus and potassium in the soil at the beginning, middle and end of the first growing season of Baghdad site and for three depths. The results show that the SWRT treatment is superior in increasing the soil content of available nitrogen in the middle and end of the season compared to other treatments than it is at the beginning of the season. The values in the middle of the season reached 36.45, 34.37 and 35.87 mg N kg^{-1} for depths of 15, 30 and 45 cm, respectively. With a significant increase of 11.98, 27.23 and 20.18% for the depth of 15 cm, and with a significant increase of 10.87, 22.40 and 16.23% for the depth of 30 cm, and with a significant increase of 12.91, 33.00 and 24.16% for the depth of 45 cm compared with the treatments O.M., T. and N.T., respectively. The O.M. treatment outperformed the treatments T. and N.T. in increasing the soil content of available nitrogen with a significant increase of 13.61 and 7.32% for the depth of 15 cm, and with a significant increase of 10.40 and a non-significant increase of 4.84% for the depth of 30 cm, and with a significant increase of 17.80 and 9.97% for the depth of 45 cm in the middle of the season. While the values at the end of the season were 34.34, 33.01 and 33.42 mg N kg^{-1} for depths of 15, 30 and 45 cm, respectively. With a significant increase of 11.60, 30.03 and 25.10% for depth 15 cm, a significant increase of 12.70, 23.40 and 20.30% for depth 30 cm and a significant increase of 10.19, 28.24 and 21.79% for depth 45 cm compared with O.M., T. and N.T. treatments, respectively. The O.M. treatment gave an increase in the soil content of available nitrogen compared with the T. and N.T. treatments. With a significant increase of 16.51% and 12.09% for the depth of 15 cm, with a significant increase of 9.50% and an insignificant increase of 6.74% for the depth of 30 cm, and with a significant increase of 16.39% and 10.53% for the depth of 45 cm at the end of the season.

2-Available phosphorus content: The results in Table 3 show that the SWRT treatment was superior in increasing the available phosphorus content of the soil in the middle and end of the season compared to the other treatments than at the beginning of the season. The values in the middle of the season were 18.77, 17.39 and 17.17 mg P kg^{-1} for the depths of 15, 30 and 45 cm, respectively. With a significant increase of 44.27, 57.33 and 47.80% for the depth of 15 cm, and a significant increase of 43.60, 62.83 and 58.67% for the depth of 30 cm, and a significant increase of 45.63, 49.83 and 52.22% for the depth of 45 cm compared to the O.M., T. and N.T. treatments, respectively. The O.M. treatment was superior to the T. and N.T. treatments in increasing the soil content of available phosphorus and with a non-significant increase of 9.05 and 2.44% for the depth of 15 cm, and with a non-significant increase of 13.39 and 10.49% for the depth of 30 cm, and with a non-significant increase of 2.88 and 4.52% for the depth of 45 cm in the middle of the season. While the values at the end of the season reached 16.89, 16.19 and 5.281 mg P kg^{-1} for the depths of 15, 30 and 45 cm, respectively. With a significant increase of 50.53, 47.13 and 54.39% for the depth of 15 cm and a significant increase of 49.91, 55.67 and 55.08% for the depth of 30 cm and a significant increase of 29.16, 41.74 and 41.22% for the depth of 45 cm compared with the treatments O.M. and T. and N.T. respectively. The O.M. treatment also gave an increase in the soil content of available phosphorus compared with the T. and N.T. treatments, with an insignificant increase of 2.26% and 2.56% for the depth of 15 cm, an insignificant increase of 3.85 and 3.45% for the depth of 30 cm, and an insignificant increase of 9.74 and 9.33% for the depth of 45 cm at the end of the season.

3-Available potassium content: The results in Table 3 show that the SWRT treatment is superior in increasing the soil content of available potassium in the middle and end of the season compared to the other treatments than it is at the beginning of the season. The values in the middle of the season reached 159.20, 163.54, and 160.95 mg K kg^{-1} for the depths of 15, 30, and 45 cm, respectively. With an insignificant increase of 2.91, 7.13 and 6.35% for the depth of 15 cm, with a significant increase of 6.11, 11.88 and 9.16% for the depth of 30 cm, and with a non-significant increase of 1.94, 6.96 and 5.27% for the depth of 45 cm compared with the treatments O.M., T. and N.T. respectively. The O.M. treatment outperformed the treatments T. and N.T. in increasing the soil content of available potassium with an insignificant increase of 4.10 and 3.34% for the depth of 15 cm, with a significant increase of 5.44 and insignificant 2.88% for the depth of 30 cm, and with a significant increase of 4.92 and 3.26% for the depth of 45 cm in the middle of the season. While the values at the end of the season were 155.90, 160.28 and 157.50 mg K kg^{-1} for depths of 15, 30 and 45 cm, respectively. With an insignificant increase of 2.16, significant 7.22 and insignificant 6.42% for depth 15 cm, with a significant increase of 6.08, 11.73 and 8.83% for depth 30 cm, with an insignificant increase of 2.06 and significant increase of 6.90 and 5.39% for depth 45 cm compared with O.M., T. and N.T. treatments, respectively. The O.M. treatment also gave an increase in the soil content of available potassium compared with the T. and N.T. treatments. With an insignificant increase of 4.95 and 4.16% for the depth of 15 cm, a significant increase of 5.33 and 2.59% for the depth of 30 cm, and an increase of 4.74 and 3.26% for the depth of 45 cm at the end of the season.

Table (3) Effect of study treatments on the available content of nitrogen, phosphorus, and potassium in the Baghdad soil location

Appointment	Nutrient	Depth (cm)	Treatments				L.S.D
			SWRT	**O.M**	**T**	**N.T**	
Start of the season	**N**	**15**	32.20	36.03	29.52	31.17	3.93
		30	30.99	36.48	31.85	29.43	3.47
		45	33.10	35.47	32.35	29.56	5.52
	P	**15**	13.85	15.78	13.25	11.71	0.94
		30	13.92	15.48	12.91	11.61	1.02
		45	13.90	15.23	12.78	11.53	0.93
	K	**15**	143.50	167.40	140.80	131.50	11.15
		30	147.90	165.80	139.80	131.40	8.05
		45	145.70	168.01	137.10	133.50	12.67
Mid-season	**N**	**15**	36.45	32.55	28.65	30.33	0.82
		30	34.37	31.00	28.08	29.57	2.12
		45	35.87	31.77	26.97	28.89	1.43
	P	**15**	18.77	13.01	11.93	12.70	1.12
		30	17.39	12.11	10.68	10.96	1.53
		45	17.17	11.79	11.46	11.28	1.84
	K	**15**	159.20	154.70	148.60	149.70	8.98
		30	163.54	154.13	146.18	149.81	4.40
		45	160.95	157.88	150.48	152.89	4.31
End of season	**N**	**15**	34.34	30.77	26.41	27.45	1.56
		30	33.01	29.29	26.75	27.44	2.36
		45	33.42	30.33	26.06	27.44	2.08
	P	**15**	16.89	11.22	11.48	10.94	1.75
		30	16.19	10.80	10.40	10.44	1.71
		45	15.28	11.83	10.78	10.82	1.30
	K	**15**	155.90	152.60	145.40	146.50	9.50
		30	160.28	151.10	143.45	147.28	3.36
		45	157.50	154.32	147.34	149.45	4.42

Available Content of Nutrients in the Soil of Najaf location

1-Available Nitrogen Content: The results of Table 4 show the effect of different treatments on the available content of nitrogen, phosphorus and potassium in the soil at the beginning, middle and end of the growing season and for three depths of Najaf site. The results show that the SWRT treatment is superior in increasing the soil content of available nitrogen in the middle and end of the season compared to the other treatments than it is at the beginning of the season. The values in the middle of the season reached 33.83, 33.73 and 33.65 mg N kg^{-1} for depths of 15, 30 and 45 cm, respectively. With a significant increase of 12.39, 24.51 and 18.08% for the depth of 15 cm, and with an increase of 15.20, 26.24 and 21.07% for the depth of 30 cm, and with a significant increase of 13.57, 22.54 and 16.32% for the depth of 45 cm compared to the treatments O.M., T. and N.T. respectively.

The O.M. treatment also outperformed the treatments T. and N.T. in increasing the soil content of available nitrogen with a non-significant increase of 10.78 and 5.06% for the depth of 15 cm, and a significant increase of 9.58% and a non-significant increase of 5.10% for the depth of 30 cm, and a significant increase of 7.90% and a non-significant increase of 2.42% for the depth of 45 cm in the middle of the season. While the values at the end of the season were 30.20, 30.21 and 31.67 mg N kg^{-1} for depths of 15, 30 and 45 cm, respectively. With a non-significant increase of 5.23%, a significant increase of 11.32% and a non-significant increase of 7.21% for depth 15 cm, a significant increase of 4.06, 11.15 and 9.85% for depth 30 cm and an increase of 8.76, 14.21 and 13.47% for depth 45 cm compared with the O.M., T. and N.T. treatments, respectively. The O.M. treatment also gave a significant increase in the soil content of available nitrogen compared with the T. and N.T. treatments. With an insignificant increase of 5.79 and 1.88% for the depth of 15 cm, with an insignificant increase of 6.81 and 5.56% for the depth of 30 cm, and with an insignificant increase of 5.01 and 4.34% for the depth of 45 cm at the end of the season.

2-Available phosphorus content: The results in Table 4 show that the SWRT treatment is superior in increasing the soil content of available phosphorus in the middle and end of the season compared to the other treatments from what it is at the beginning of the season. The values in the middle of the season reached 14.47, 15.93 and 14.24 mg P kg^{-1} for the depths of 15, 30 and 45 cm, respectively. With a significant increase of 23.04, 54.93 and 40.08% for the depth of 15 cm, with a significant increase of 34.89, 51.57 and 47.77% for the depth of 30 cm, and with a significant increase of 24.80, 42.26 and 34.34% for the depth of 45 cm compared with the treatments O.M., T. and N.T. respectively. The O.M. treatment also outperformed the treatments T. and N.T. in increasing the soil content of available phosphorus with a non-significant increase of 25.91 and 13.84% for the depth of 15 cm, with a non-significant increase of 12.37 and 9.55% for the depth of 30 cm, and with a non-significant increase of 13.99 and 7.64% for the depth of 45 cm in the middle of the season.

While the values at the end of the season were 13.64, 14.92 and 13.84 mg P kg^{-1} for depths of 15, 30 and 45 cm respectively. With a significant increase of 13.29, 40.76 and 52.91% for depth 15 cm and an increase of 23.31, 62.70 and 74.50% for depth 30 cm and a significant increase of 19.93% and an insignificant increase of 54.64 and 53.10% for depth 45 cm compared with O.M., T. and N.T. treatments respectively. The O.M. treatment also gave an increase in the soil content of available phosphorus compared with the T. and N.T. treatments. In increasing the soil content of available phosphorus with a non-significant increase of 24.25 and 34.98% for the depth of 15 cm and a significant increase of 31.95 and 41.52% for the depth of 30 cm and a non-significant increase of 28.94 and 27.65% for the depth of 45 cm at the end of the season.

3-Available potassium content: The results in Table 4 show the superiority of the SWRT treatment in increasing the soil content of available potassium in the middle and end of the season compared to the other treatments from what it was at the beginning of the season. The values in the middle of the season reached 151.40, 148.90 and 153.42 mg K kg^{-1} for the depths of 15, 30 and 45 cm, respectively. With a significant increase of 9.71, 32.92 and 20.73% for the depth of 15 cm, and with an increase of 7.20, 27.70 and 17.34% for the depth of 30 cm, and with a significant increase of 7.80, 35.04 and 22.63% for the depth of 45 cm compared with the treatments O.M., T. and N.T. respectively. The O.M. treatment also outperformed the treatments T. and N.T. in increasing the soil content of available potassium with a non-significant increase of 21.16 and 10.05% for the depth of 15 cm, and with a non-significant increase of 19.13 and 9.46% for the depth of 30 cm, and with a significant increase of 25.27 and 13.76% for the depth of 45 cm in the middle of the season. While the values at the end of the season reached 138.22, 138.57 and 138.44 mg K kg^{-1} for depths of 15, 30 and 45 cm, respectively. With a significant increase of 7.90, 29.31 and 16.44% for depth 15 cm, and an increase of 7.22, 29.43 and 15.84% for depth 30 cm, with an insignificant increase of 7.63% and a significant increase of 27.77 and 17.02% for depth 45 cm compared with the O.M., T. and N.T. treatments, respectively. The O.M. treatment also gave an increase in the soil content of available potassium compared with the T. and N.T. treatments. With an insignificant increase of 19.84 and 7.92% for the depth of 15 cm and an insignificant increase of 20.72 and 8.04% for the depth of 30 cm and a significant increase of 18.72% and an insignificant increase of 8.73% for the depth of 45 cm at the end of the season.

Table (4): Effect of study treatments on the available nitrogen, phosphorus and potassium content in the soil of the Najaf location

Appointment	Nutrient	Depth (cm)	Treatments				L.S.D
			SWRT	O.M	T	N.T	
Start of the season	N	15	28.40	32.59	27.83	29.62	3.14
		30	29.54	32.92	27.88	31.20	2.34
		45	30.28	33.06	29.05	29.45	1.94
	P	15	13.13	14.19	10.79	11.36	2.04
		30	12.73	13.47	11.73	12.53	2.03
		45	11.52	13.61	10.83	11.48	1.32
	K	15	133.70	157.30	126.10	126.20	11.46
		30	131.00	158.60	125.20	127.80	8.09
		45	136.70	158.90	126.00	129.20	8.35
Mid season	N	15	33.83	30.10	27.17	28.65	3.20
		30	33.73	29.28	26.72	27.86	2.29
		45	33.65	29.63	27.46	28.93	1.83
	P	15	14.47	11.76	09.34	10.33	2.41
		30	15.93	11.81	10.51	10.78	1.27
		45	14.24	11.41	10.01	10.60	1.88
	K	15	151.40	138.00	113.90	125.40	9.14
		30	148.90	138.90	116.60	126.90	8.41
		45	153.42	142.32	113.61	125.11	5.64
End of season	N	15	30.20	28.70	27.13	28.17	2.46
		30	30.21	29.03	27.18	27.50	2.16
		45	31.67	29.12	27.73	27.91	1.97
	P	15	13.64	12.04	09.69	08.92	1.30
		30	14.92	12.10	09.17	08.55	1.49
		45	13.84	11.54	08.95	09.04	2.11
	K	15	138.22	128.10	106.89	118.70	4.62
		30	138.57	129.24	107.06	119.62	5.68
		45	138.44	128.63	108.35	118.30	3.92

Reasons for the effects of the study treatments on the available content of nutrients in the soil

The results showed the contribution of SWRT technology in increasing the readiness of each of nitrogen, phosphorus and potassium in the middle of the growing season compared to the beginning of the growing season, while it was observed that the readiness of these elements decreased for the other treatments in the middle and end of the growing season compared to the beginning of the growing season due to the role played by the plastic films of SWRT technology in preserving fertilizers and nutrients within the root zone of plants and reducing their loss. The availability of these elements decreased at the end of the growing season compared to the middle of the growing season due to the large size of the vegetative mass and the root mass and its extension and the increased need of plants for elements and thus their depletion from the soil by plants, which reduces its content at the end of the growing season. In light of the results mentioned above from Tables 3 and 4 it became clear that the SWRT treatment was superior to other treatments in increasing the availability of nitrogen, phosphorus and potassium elements in the soil. This is due to the role of the membranes used for this technology in preserving fertilizers and nutrients and preventing their loss through leaching. Accordingly, the SWRT treatment retained high amounts of nitrogen, phosphorus and potassium in the soil, although the fertilizer additions to it were less by about half compared to the rest of the other treatments. This is consistent with what was reached by (Smucker et al., 2015; Issa, 2016; Al-Rawi, 2016).

In addition, the role of these membranes for the SWRT treatment is highlighted in maintaining a good moisture content. Robertson and Vitousek (2009) also found that the biochemical condition of the plant environment can be improved in coarse sandy soils with low organic matter through membranes installed in an appropriate manner and depths, in addition to increasing soil carbon storage and reducing hydrological losses. The high content of the SWRT treatment with elements is due to the high ability of this treatment to maintain moisture and reduce the temperature in the root zone, which makes the conditions suitable for the plant to absorb water and nutrients. This is consistent with what was reached by (Al-Rawi, 2016). The reason for the increased readiness of these elements for O.M. treatment is due to the role of organic matter in improving the physical and chemical properties of the soil, as it constitutes an important source of nutrients necessary for growth and increases the soil's ability to retain water and improve its structure (Rosen and Bierman, 2007). In addition to what organic fertilizer contains of organic acids and their role in increasing the readiness of nutrients in the soil by reducing the degree of interaction and reducing the retention of nutrients (Miralles et al., 2010).

CONCLUSIONS and RECOMMENDATION

The use of SWRT technology increased the availability of nutrients in the soil as well as increased the concentration of nutrients in the plant despite reducing the fertilizer additions to them by half compared to other treatments. Therefore, the SWRT treatment was superior in increasing the concentration of nitrogen, phosphorus and potassium in the vegetative group, as the concentration of nitrogen increased compared to the tillage treatment in the first season of cultivation for the Baghdad site. It is recommended to use SWRT technology in desert agriculture applications for coarse and medium textured soils in arid and semi-arid areas for the cultivation of strategic field crops, especially in rain-fed agriculture as well as open agriculture with the use of sensors to monitor moisture changes and water and irrigation needs.

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