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Subsurface Water Retention Technology (SWRT) for Water Saving and Growing Tomato in Iraqi Sandy Soils

Mahdi Ibrahim Aoda[1] Alaa Salih Ati[1] Shatha Salim AL-Rawi[2] Alvin J. M. Smucker[3]

[1]*Department of Soil Science and Water Resources-College of Agriculture/ Baghdad University*
[2]*Center studies and Engineering designs-Ministry of Water Resources*
[3]*Michigan State Universities, East Lansing, MI, USA*
E-mail: salih_alaa@yahoo.com

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Abstract

A study was carried out to assess the impact of using SWRT on irrigation water use efficiency IWUE and yields of tomato crop. Experiments were performed by planting tomato in greenhouses during the spring season of 2014 at two locations in Iraq. One location was at north of Baghdad (latitude 33° 38' 58.44" north and longitude 44° 24' 17.74" east) at Jaded at Al-Shat, Diyala Province. The other location was at Najaf Province (latitude 32° 07' 37.80" north and longitude 44° 19' 44.74" east). Soils of the both locations are classified as sandy loam in texture. Four treatments (SWRT, organic matter, tillage and no–tillage farming) were used to represent different tillage practices in studied locations. The experimental design was randomized complete blocked design RCBD with four replications. Irrigation scheduling was performed according to soil moisture content as 50-55% of available water was depleted then irrigation water was added from subsurface drip system to bring soil moisture content back to field capacity. Soil sensors 5TE and GS3 from the Decagon Devices, USA were used to measure volumetric water content hourly. Water balance equation was used to determine the actual water consumption during each stage of plant growth for the whole season.

The results showed that the amount of irrigation water and plant yield varied with treatment. Average tomato yield per plant were 3.53, 3.28, 3.26 and 3.06 kg for Diyala location and 3.03, 2.49, 2.37 and 2.05 kg for Najaf location for treatments SWRT, organic matter, no–tillage and tillage treatments, respectively. Depths of irrigation water for season were 307, 486, 502 and 502 mm for Diyala location and 259, 433, 449 and 449 mm for Najaf location for treatments SWRT, organic matter, no – tillage and tillage treatments, respectively. Values of IWUE for tomato at Diyala location were 7.54, 4.54, 4.36 and 4.09 kg m^{-3} for SWRT, organic matter, tillage and no – tillage treatments, respectively. This shows that SWRT is higher in IWUE by 70, 89 and 77% than organic matter, tillage and no – tillage treatments, respectively. Similar trend of IWUE values for tomato in Najaf was obtained which were 7.78, 3.72, 3.55 and 3.07 kg m^{-3} for SWRT, organic matter, tillage and no–tillage treatments, respectively, as an increase of SWRT by 112, 156 and 122% over organic matter, tillage and no – tillage treatments, respectively.

Introduction

Increasing frequencies of drought coupled with increasing populations require more water for irrigated agriculture. As global populations approach 9 billion by 2050, even more water will be required to produce an estimated 60% to 70% more food ***[1]***. Production of these greater quantities of food requires, at current water use efficiency rates, 50% more water ***[2]***.

A novel subsurface water retention technology (SWRT) dramatically reduced irrigation requirements by retaining at least 50% or more soil water in the plant root zone ***[3,4]*** and ***[5]***. Water-saving membranes reduced drought stress events even during the driest years. The SWRT water saving membranes also is designed to prevent flooding in the root zone of sandy soils ***[5]***. The new SWRT transforms lives and landscapes by retaining both soil water and nutrients in the root zone of food and cash crops in an environmentally sustainable manner that increases productivity, local economies while reducing soil erosion, input costs and environmental contamination of groundwater, and reduce soil salinity, increase irrigation efficiency, decrease irrigation frequency, improve crop yield, and reduce labor ***[6,7,8,9]*** and ***[10]***. Bowl or U-shaped SWRT membranes in the root zone provide continuous supplies of plant available water. These membranes, with aspect ratios of 2:1, are mechanically installed to soil depths of 25 to 60 cm depending upon soil texture (Figure 1) ***[11]***.

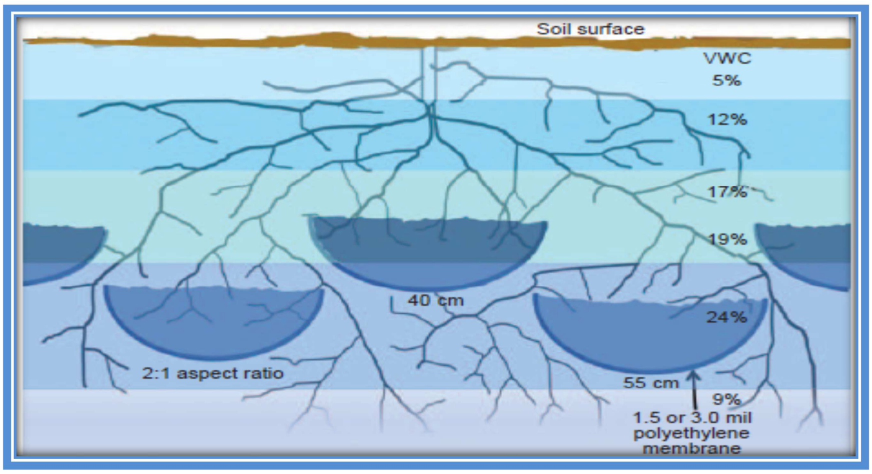


Figure-1: The volumetric moisture content (VWC) according to different depths and geometric forms in the soil system.

Sandy soils are spread in wide area of Iraq in central and south provinces and estimated to be 19% of the cultivable land. These soils are unsuitable for cultivation because of their high hydraulic conductivity and infiltration and these reduced retention of water and nutrients. These poor characteristics reduce soil productivity. Therefore, the aim of the work reported here was to study the effect of using SWRT for the first time in Iraq to produce vegetable crops with increasing water retuned and nutrients in the rizosphere.

Material and Methods

Field experiments (Greenhouses) on Tomato were carried out at two different locations in Iraq, the first was in Najaf province and the second in Diyala province during spring season of 2014 in sandy soil classified as *TypicTorripsamments* and *TypicTorriflovent* (as subgroup classification) at both locations. Soil samples were air dried ground and then sieved through 2 mm sieve. Soil samples then analyzed according to methods described in Black and Page et al., ***[12,13]*** for physical and chemical soil properties, respectively. Results of analyses are shown in (Table 1 and Figure 2).

The experiment included four treatments: SWRT treatment (which include instillation of plastic films with special specifications under the plant's root zone with specific geometrical manner), organic matter, no tillage and tillage (control treatment) treatments (Image 1, 2, 3 and 4). The experiment Design was Randomized Complete Block Design (RCBD) with four replications. Tomatoes planted under subsurface drip irrigation system. Seedlings were planted on trench and plants spaced were 0.50 m × 0.40 m on 22/1/2014 and 21/2/2014 and last harvest was on 26/6/2014 and 14/7/2014 for Najaf and Diyala locations, respectively. Compound fertilizer (N-P_2O_5-K_2O 18-18-18) was applied to all treatments at the rate of 250 kg ha^{-1} through Fertigation according to Kafkafi and Tarchitzky ***[14]***. All required management practices were done as they are required.

Table-1: Some physical & chemical properties of soil used.

location			Depth (m)		
			0-0.3	**0.3-0.6**	**+0.60**
	sand		686.01	746.20	786.32
Al- Najaf	silt	g kg^{-1}	240.32	228.14	189.09
	clay		73.67	25.66	24.59
	Texture		Sandy Loam	Loam Sandy	
	sand		744.45	598.77	585.05
Diyala	silt	g kg^{-1}	131.33	252.26	233.83
	clay		124.22	148.97	181.12
	Texture		Sandy Loam		

Soil Properties	Units	Al- Najaf			Diyala		
	m	+ 0.6	0.3-0.6	0-0.3	+ 0.6	0.3-0.6	0-0.3
pH		7.51	7.35	7.44	7.32	7.17	7.53
EC	dS m^{-1}	2.86	3.36	3.20	1.14	1.47	0.84
Ca		4.18	15.10	11.46	4.68	5.27	4.18
Mg		1.23	7.27	8.23	4.01	4.25	1.23
Na	Meq L^{-1}	5.14	20.31	17.22	6.22	6.65	5.14
K		0.03	0.21	0.13	0.07	0.04	0.03
Cl		5.10	13.79	12.53	6.80	5.98	5.10
Organic matter		8.21	9.4	11.1	6.0	7.1	8.21
gypsum	g Kg^{-1}	0.85	2.34	2.27	0.62	0.71	0.85
Carbonate mineral		120	210	191	118	134	120

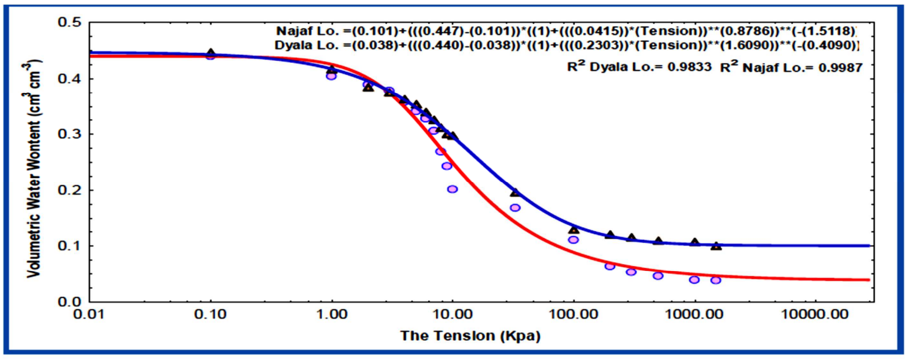


Figure-2: Soil moisture characteristic curves for soils of both locations.

Image-1, 2, 3 and 4: Descriptive photos of SWRT instillation and organic matter application.

Subsurface drip irrigation was used in this experiment. Irrigation scheduling was used according to volumetric water contents which were measured by soil moisture sensors 5TE (Decagon Devices, USA). These sensors were manufactured to take instantaneous reading of VWC, EC and soil temperature. Reading is stored in an EM50 data logger (Figure 3).

At maturity stage 10 plants from middle line in each treatment were selected for calculations of total yield and Water use efficiency. Data were analyzed using Genstat Discovery Edition 4 and differences among treatments tested according to LSD $_{0.05}$.

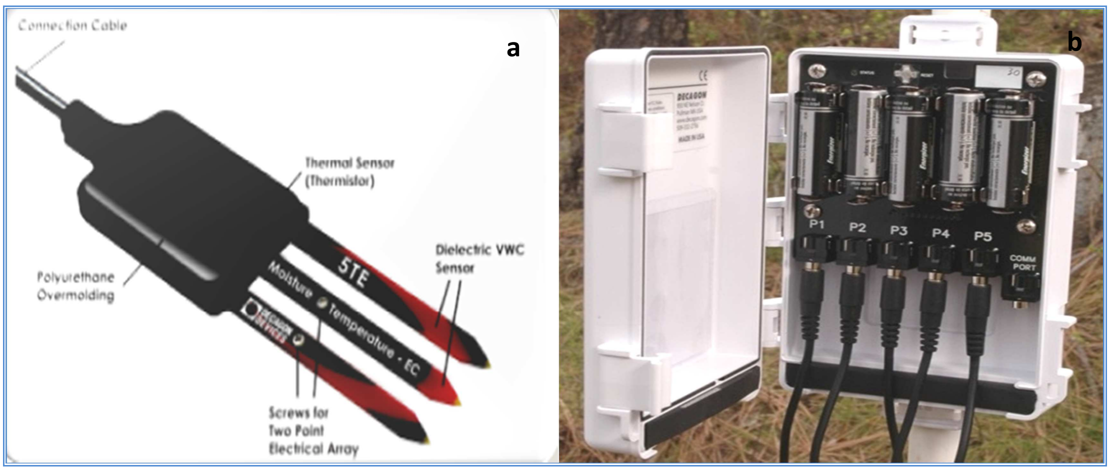


Figure-3: The sensors 5TE (a) and data logger (b).

Results and Discussion

The results of tomato yields per plant and per hectar are plotted in Figure 4 and 5 for both Diyala and Najaf locations. Average yield per tomato plant was 3.53, 3.28, 3.26 and 3.06 kg for Diyala location and 3.03, 2.49, 2.37 and 2.05 kg for Najaf location for treatments SWRT, organic matter (O.M.), No-tillage (NT) and tillage (T), respectively. From them value and value of LSD $_{0.05}$ it is obvious that SWRT produced a significantly higher than all other treatments. Same trends were found for tomato yields as kg per hectar (Figure 5). High performance of SWRT application was mentioned by many researchers in different parts of the world.

The organic matter treatment has produced higher but not significant tomato yields than no –tillage and tillage treatments. The reason could be related to the high ability of organic matter to absorb water and hence nutrients. The no–tillage treatment has produced higher but not significant yield than the tillage treatments. This is probably due to the fact that tillage resulted in large pores therefore water holding capacity and nutrient are lower the no-tillage treatment.

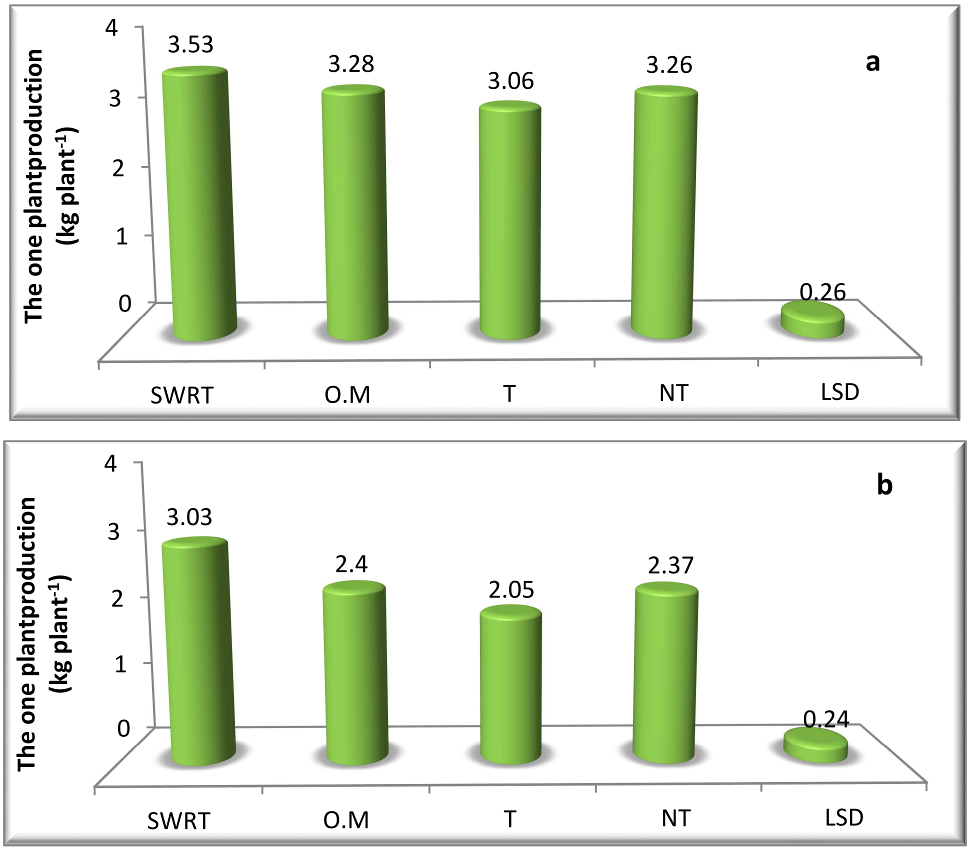
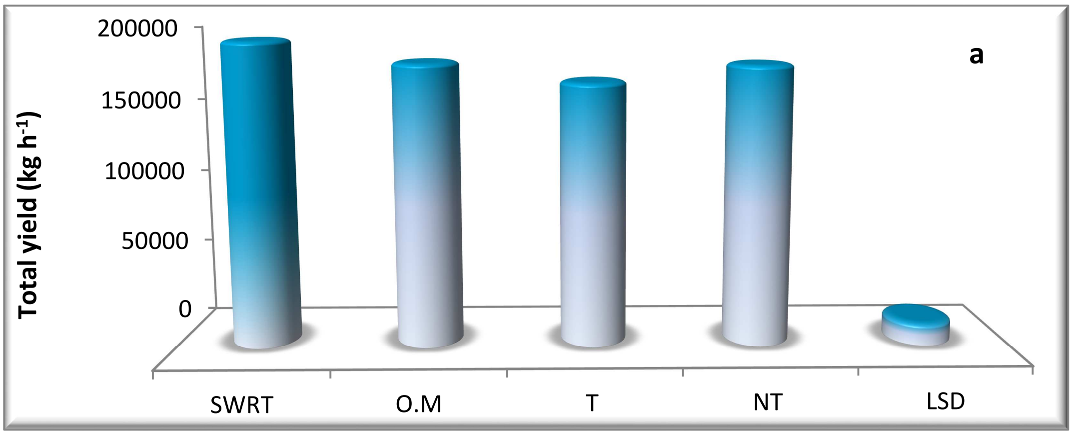


Figure-4: Production of one plant (a- Diyala location and Al-Najaf location –b).



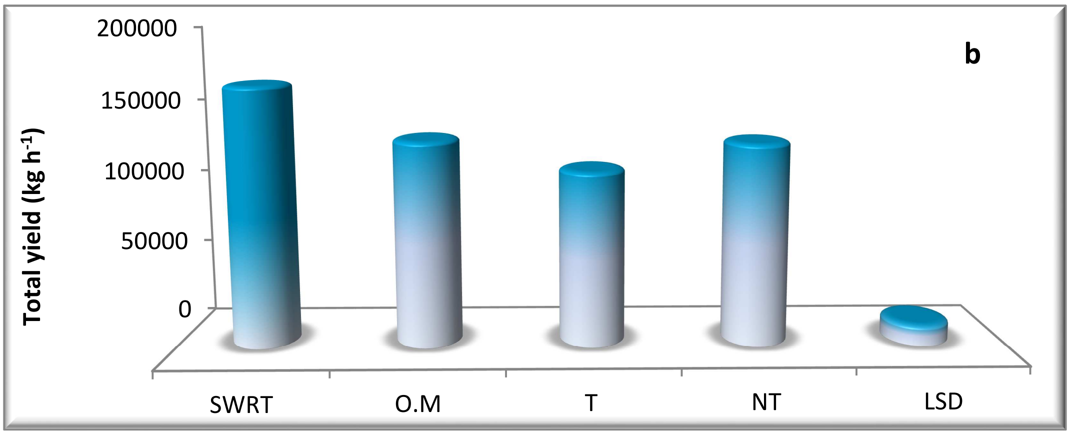


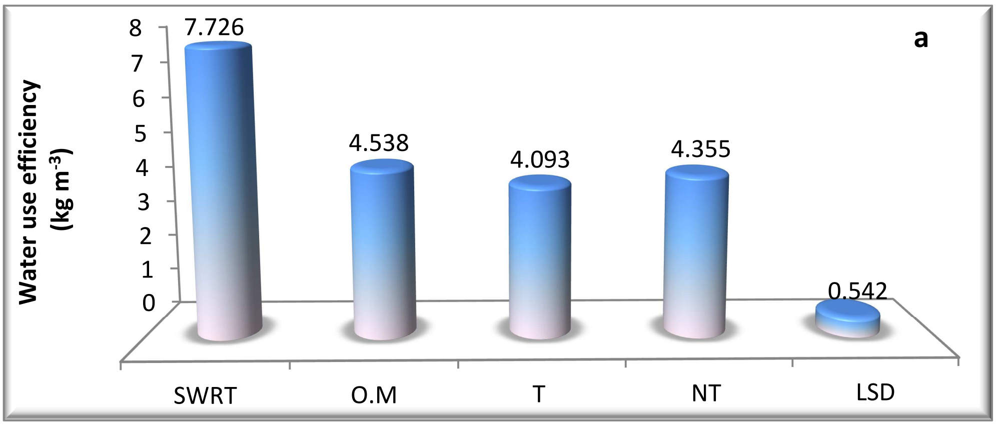
Figure-5: Total yield (a- Diyala location and Al-Najaf location –b).

The quantity of irrigation water was measured throughout the growing season for all treatments and for both locations and the results are listed in Table (2). Results are expressed in terms of depth since all water applied was used as evapotranspiration (ET). The depth of water applied for SWRT is highly significant lower than all treatments. This is due that fact the irrigation water applied is retained by the root zone. The quantity of irrigation water for each treatment is lower than the surface drip irrigation under tomato planted by almost one half in both locations. In addition SWRT performance was much better than other treatments as a result of polyethylene membrane.

Table-2: Seasonal irrigation water depth (mm) added to tomato plants for the different treatments and two locations.

Treatments	Diyala	Najaf
SWRT	307	259
Organic matter	486	433
No-tillage	502	449
Tillage	502	449

One other impact aspect to be studied is the irrigation water use efficiency (IWUE). Values of IWUE are shown figure 6 indicating the superiority of SWRT treatment over all other treatments. Average values were 7.726, 4.538, 4.355 and 4.093 for Diyala and 7.865, 3.723, 3.545 and 3.065 kg m^{-3} for Najaf for treatments SWRT, O.M., No-tillage and tillage, respectively. Values of IWUE for SWRT are almost doubled by using plastic membrane below the root zone. The reason of having higher IWUE for SWRT treatment is related to the reduced quantity of irrigation water applied to SWRT in comparison with other treatments.



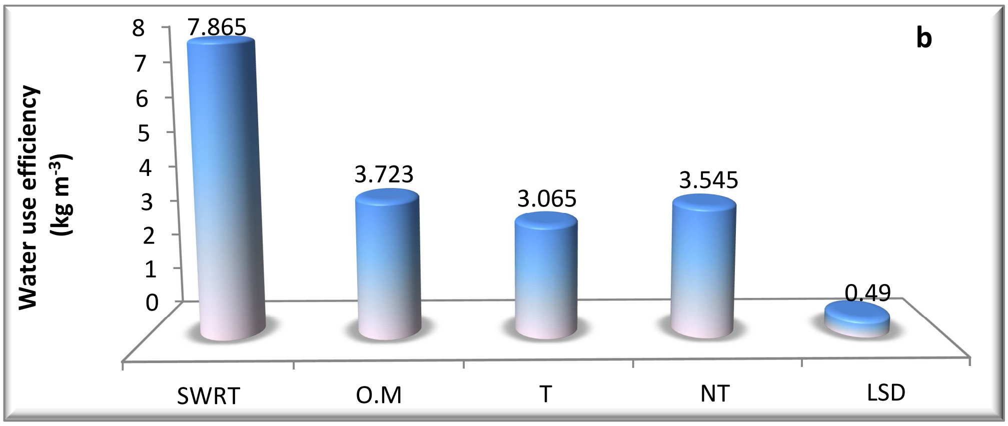


Figure-6: Water use efficiency for the different treatments at Diyala location (a) and Al-Najaf location(b).

Conclusions

It can be concluded from this study the SWRT has enhanced tomato growth and yields, reduced irrigation water requirements, reduced fertilizers applications, increased IWUE and reduced energy and cost for better environmental and ecological circumstances.

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