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The Role of Subsurface Water Retention Technology (SWRT) for Growing Chili Pepper in Iraqi Sandy Soils

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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 chili pepper crop. Experiments were performed by planting chili pepper in greenhouses during the spring season of 2015 at two locations in Iraq. One location was at north of Baghdad (latitude 33 north and longitude 44 east) at Jadedat Al-Shat, Diyala Province. The other location was at Najaf Province (latitude 32 north and longitude 44 east). Soils of these 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 the Iraq. 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 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 result showed that the amount of irrigation water and plant yield varied with treatment. Average chili pepper yield per plant were was 0.61, 0.51, 0.47 and 0.53 kg for Diyala location and 0.2, 0.18, 0.17 and 0.16 kg for Najaf location for treatments SWRT, organic matter, tillage and no–tillage treatments, respectively. Depths of irrigation water for season were 338, 582, 693 and 693 mm for Diyala location and 346, 446, 544 and 544 mm for Najaf location for treatments SWRT, organic matter, tillage and no–tillage treatments, respectively.

Values of IWUE for chili pepper at Diyala location were 16.652, 8.087, 6.236 and 7.076 kg m^{-3} for SWRT, organic matter, tillage and no – tillage treatments, respectively. This shows that SWRT is higher in IWUE by 106, 167 and 135% than organic matter, tillage and no – tillage treatments, respectively. Similar trend of IWUE values for chili pepper in Najaf was obtained which were 3.724, 2.692, 2.094 and 1.972 kg m^{-3} for SWRT, organic matter, tillage and no – tillage treatments, respectively, as an increase of SWRT by 38, 79 and 89% over organic matter, tillage and no – tillage treatments, respectively.
Keyword: Subsurface Water Retention Technology, Chili Pepper, Iraqi Sandy Soils

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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 (McKenna, 2012). Production of these greater quantities of food requires, at current water use efficiency rates, 50% more water (Clay 2004).

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 (Kavdir et al., 2014; Guber et al., 2015 and Smucker, 2014b). 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. The new subsurface water retention technology (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 (Smucker et al., 2012; Smucker et al., 2014a; Smucker, 2014a; Smucker et al., 2014b and Guber er al., 2014). 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) (Smucker and Basso, 2014).

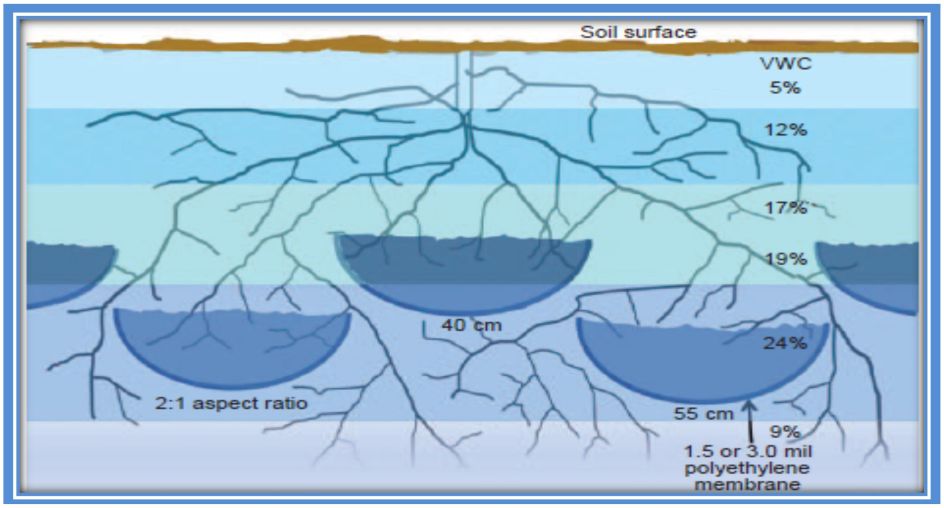


Figure 1: The volumetric moisture content (VWC) according to different depths and geometric forms in the soil system

The chili pepper (also chile pepper or chilli pepper) is the fruit of plants from the genus Capsicum, members of the nightshade family, Solanaceae In Australia, Britain, India, Ireland, New Zealand, Pakistan, South Africa and in other Asian countries, it is usually known simply as chili (Heiser, 1976). Capsaicin is considered a safe and effective topical analgesic agent in the management of arthritis pain, herpes zoster-related pain, diabetic neuropathy, mastectomy pain, and headaches. However, a study published in 2010 has linked capsaicin to skin cancer. A 2015 cohort study in China found that eating foods containing chili peppers at least twice a week led to a 10 percent reduced mortality rate all else being equal and eating foods containing chili peppers 6 to 7 days a week had a 14 percent relative risk reduction in total mortality (Hwang et al., 2010).

Sandy soils are spread in wide area of Iraq in most provinces and estimated to be 19% of the cultivable land. These soils unsuitable for cultivation because of their high hydraulic conductivity and infiltration and 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 by increasing water retened and nutrients in the rizosphere.

Material and Methods

Field experiments (Greenhouses) on Chili pepper 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 *Typic Torripsamments* and *Typic Torriflovent* (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 (1965) and Page et al. (1982) for physical and chemical soil properties respectively. Results of analyses are shown in (Table 1 and Figure 2).

Table 1: Some physical & chemical properties of soil used

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

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

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. Chili pepper planted under subsurface drip irrigation system. Seedlings were planted on trench and plants spaced were 0.50 m × 0.35 m on 3/11/2014 and 8/11/2014 and last harvest was on 27/5/2015 and 1/6/2015 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 (2011). All required management practices were done as they are required.

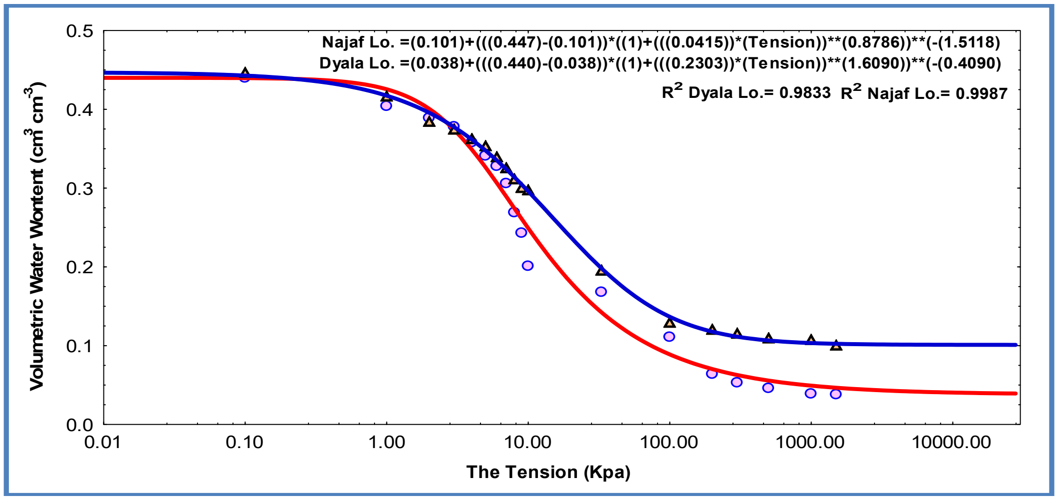


Figure 2: Soil moisture characteristic curves for soils of both locations.

Images 1, 2, 3 and 4: Descriptive photo 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 GS3 (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).

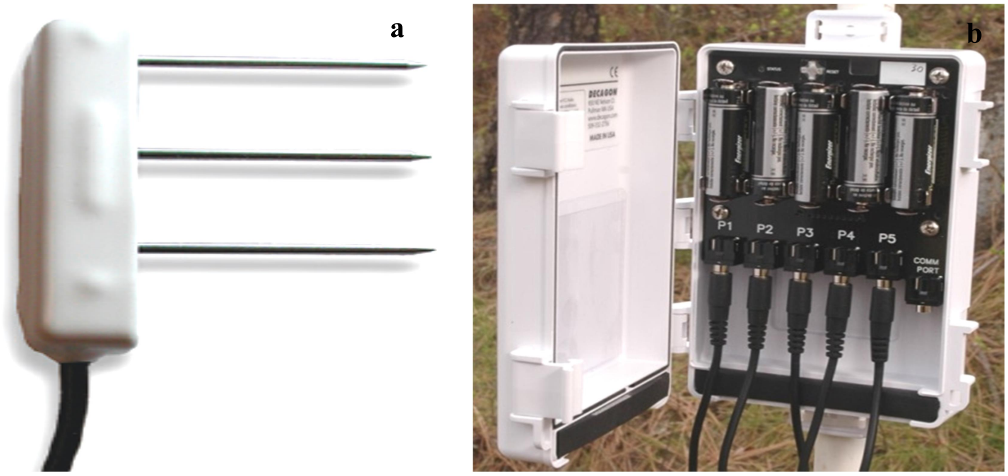


Figure 3: The sensors GS3 (a) and data logger (b)

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 Gestate Discovery Edition 4 and differences among treatments tested according to LSD $_{0.05}$.

Result and Discussion

The results of chili pepper yields per plant and per hectare are plotted in Figure (4) and (5) for both Diyala and Najaf locations. Average yield per chili pepper plant was 0.61, 0.51, 0.53 and 0.47 kg for Diyala location and 0.2, 0.18, 0.16 and 0.17 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 chili pepper yields as kg per hectare (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 chili pepper 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.

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 chili pepper planted by almost one half. In addition SWRT performance was much better than other treatments as a result of polyethylene membrane. The range of water saving under SWRT treatment ranged between 22-51% in comparison with the control treatment (tillage). If furrow irrigation is used for planting chili pepper, the quantity of irrigation is very much higher than the SWRT quantity and yet yields are much lower than SWRT. One other aspect of SWRT is saving fertilizers since fertilization performed as Fertigation. Therefore the percentage of fertilizer saving is about 50%.

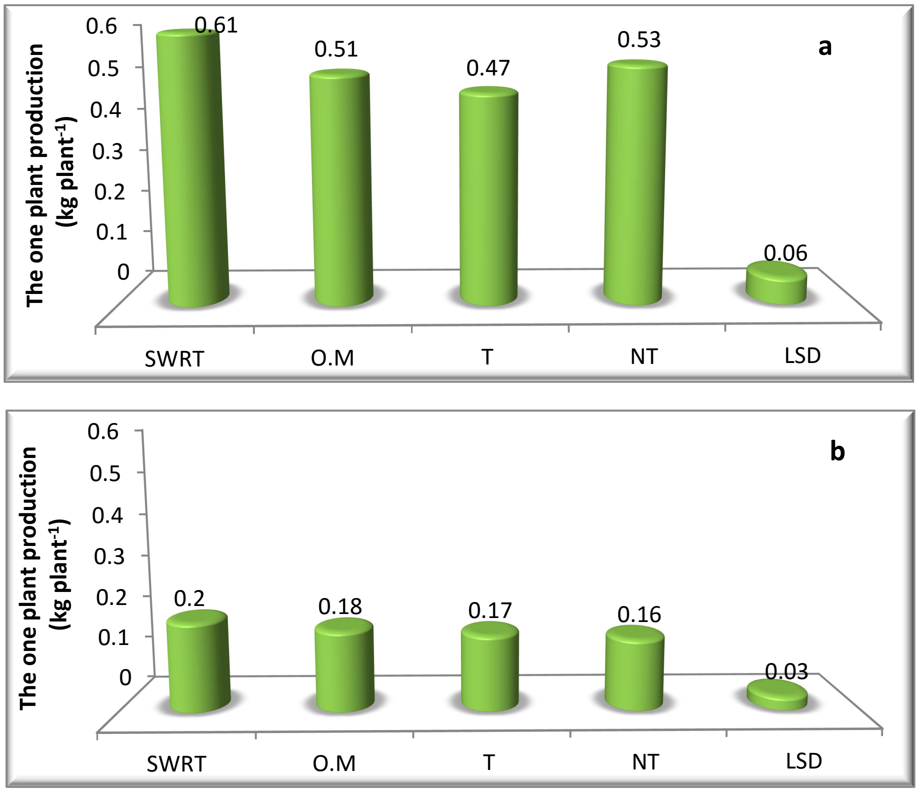


Figure 4: Production of one plant (a - Diyala location and Al- Najaf location - b).

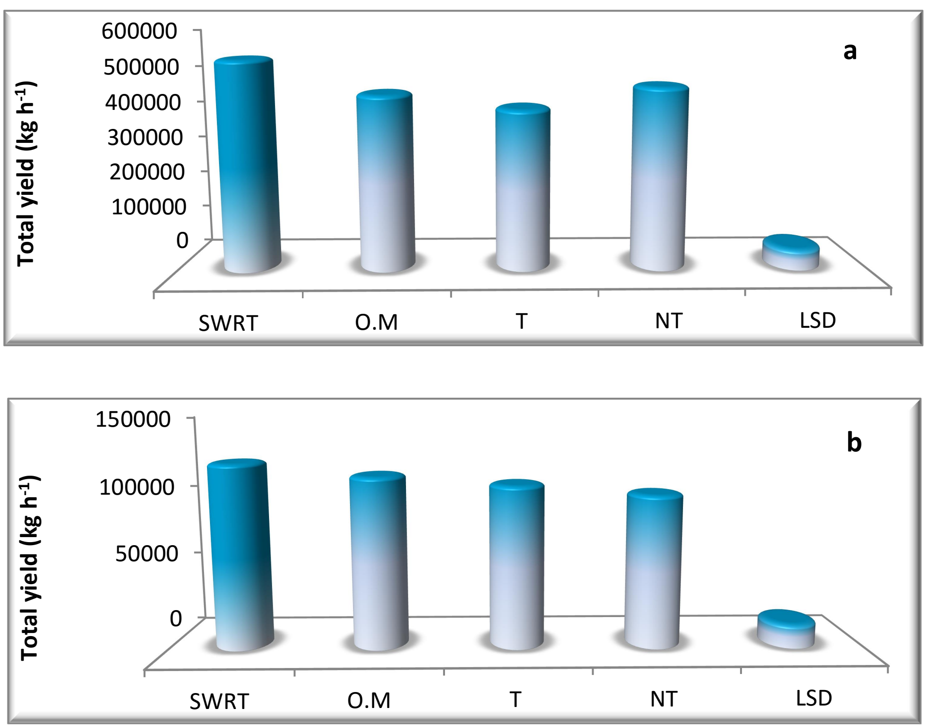


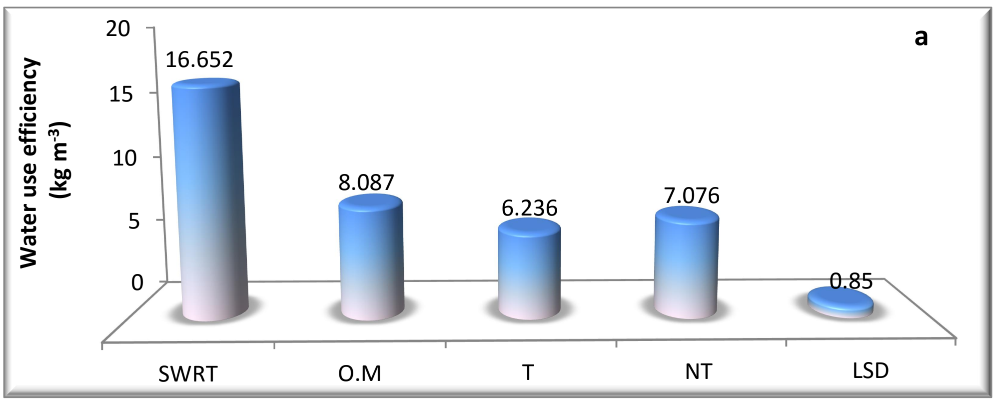
Figure 5: Total yield (a - Diyala location and Al- Najaf location - b).

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

Treatments	Diyala	Najaf
SWRT	338	346
Organic matter	582	446
No-tillage	693	544
Tillage	693	544

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 16.652, 8.087, 7.076 and 6.236 for Diyala and 3.724, 2.692, 1.972 and 2.094 kg m^{-3} for Najaf 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.

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



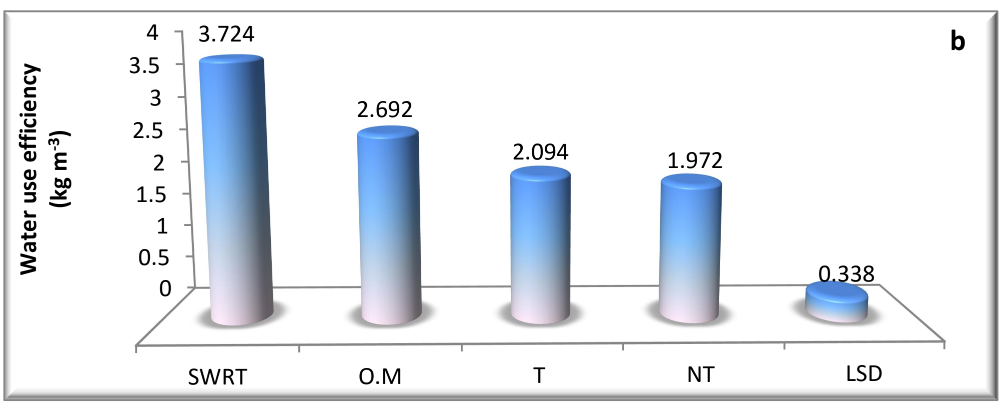


Figure 6: Water use efficiency for the different treatments at Diyala location (a) and Al- Najaf location (b).

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