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SOIL RESPONSE TO IRRIGATION WATER REGIMES AND DRIP IRRIGATION APPLICATIONS

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ABSTRACT

Field experiment was carried out in calcareous loamy sand soil at the Experimental Farm, Faculty of Environmental Agricultural Sciences, Arish University, North Sinai Governorate, Egypt during two successive seasons 2015 and 2016. The objective of this experiment was to evaluate the response of soil water content to water irrigation regimes with and without mulching under surface and subsurface drip irrigation systems. The irrigation system was consisted of 9 irrigation water regime treatments, which were combined with 2 deficit irrigation levels of 25 and 50% from crop evapotranspiration, ETc, were individually subjected throughout the development, flowering and harvesting growth stages and the same deficit irrigation levels were subjected throughout whole growth season as well as the deficit irrigation level of 0% ETc was subjected throughout whole growth season using well water having electric conductivity (ECw) of 7.25 $dSm^{-1}$and 8.68 SAR. Increasing the deficit irrigation levels significantly decreased volumetric soil water content. Volumetric soil water content with mulching were significantly more than that obtained without mulching. Volumetric soil water content under surface drip irrigation systems were insignificant less than that obtained under subsurface drip irrigation system.

Key words: Soil water content, water irrigation regimes, mulching, surface and subsurface drip irrigation.

INTRODOCTION

The amount and quality of applied irrigation water, the irrigation systems and irrigation management affect soil water content distribution in the soil profile were studied by several investigators. **El-Kassas (2008)** reported that soil water content decreased with increasing irrigation deficit before and after irrigation. **Mohawesh (2015)** noted that soil water potential increased with declining of irrigation water amount. **Hashem *et al.* (2018)** explained that the amount of soil water content in the root zone decreased immediately after the deficit irrigation treatments applied, which is less than the full irrigation treatment. At the same time, the rate of the soil water content constantly decreased as the plant growth increased and consumed more water. On the other hand, **Saad *et al.* (2018)** reported that soil water content, (%) in soil layers at the end of different growth stages as affected by deficit irrigation depths of 100, 75 and 50% ETc, using high saline water of 9.15 dSm^{-1} subjected throughout development, flowering and harvesting tomato growth stages, generally decreased comparing to soil water content of full irrigation (100% ETc) under drip and gated pipe irrigation systems.

Machado *et al.* (2003) stated that the use of surface or subsurface drip irrigation; roots grow preferentially around the wetted emitter area and concentrate within the top 40 cm of the soil profile. Drip irrigation is an effective way to supply water and

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nutrients to the root zone and not only saves water but can also increase crop yield. **Ma *et al.* (2005)** observed that power function fits well to the advances of horizontal wet front and ponding water area with time under the condition of sufficient water supply. **Rajak *et al.* (2006)** noted that drip irrigation compared with other irrigation methods, being of higher drip irrigation frequency and requiring less irrigation water, drip irrigation retains higher total soil water potential in the root area and reduce groundwater evaporation and soil salt return. Therefore, drip irrigation is regarded by many as the most suitable technique to use and exploit brackish and salt water resources. **Kang *et al.* (2010)** pointed out that drip irrigation, with its characteristic of low rate and high frequent irrigation applications over a long period of time, can maintain high soil matric potential in the root zone. **Malash *et al.* (2011)** noted that measurements of soil water content distribution after irrigation showed that drip irrigation resulted in higher soil water content and less salt accumulation in the root zone, compared with furrow irrigation.

Lamm and Trooien (2003) using a subsurface drip irrigation system for irrigating corn can reduce water use by 35-55% compared with traditional irrigation systems. In the last decades, subsurface drip irrigation systems were cost competitive for corn production with the traditional irrigation systems in the Great Plains, USA. **Machado *et al.* (2003)** stated that the use of surface or subsurface drip irrigation; roots grow preferentially around the wetted emitter area and concentrate within the top 40 cm of the soil profile. Drip irrigation is an effective way to supply water and nutrients to the root zone and not only saves water but can also increase crop yield. **Abou-Kheira (2009)** pointed out that the distribution of water in the soil profile for subsurface drip irrigation system was uniform for all treatments. Therefore, it can be concluded that under subsurface drip irrigation system, the water available in root zone was enough for plant growth. This is because under subsurface drip, the lateral irrigation line was buried at 25 cm below the soil surface, and the soil profile below this depth became wetter because of the minimum evaporation loss with this system. **Zotarelli *et al.* (2009)** pointed out that the combination of reduced irrigation rate and drip irrigation position in the subsurface drip irrigation treatment directly affected the soil water movement dynamics. **Kandelous and Suimunek (2010)** pointed out that designing subsurface drip irrigation systems for row crops, the dimensions of the wetted volume and the distribution of soil moisture within this volume are two of the main factors in determining installation depth and spacing of drippers to obtain an optimum distribution of water in the crop root zone. On the other hand, **Selim *et al.* (2013)** concluded that the daily irrigation regime kept the top soil layer moist with adequate amount of soil water as compared to the bi-weekly irrigation under drip irrigation system.

El-Mokh *et al.* (2014) pointed out that for all irrigation treatments, significant differences were observed between the soil water content of the subsurface irrigated plots and those irrigated with the surface drip system during the development, mid-season and harvest periods. Subsurface drip irrigation had higher value of soil water content than surface drip irrigation. They added that this was depended on reduce evaporation from soil surface by setting drip line under soil surface. With the subsurface drip method the surface soil layer is not completely wetted as in the case of the surface drip irrigation. On the other hand, **Saad *et al.* (2018)** revealed that the soil water content average of the active root zone (0-50 cm) and deep layers (50-100 cm) at the end of different growth stages of tomato plants as affected by deficit irrigation depths were subjected throughout development, flowering and harvesting growth stages under drip irrigation system, in general, were not significantly lower than that obtained under gated pipe irrigation system.

Chalker-Scott (2007) noted that bare soil exposed to heat, wind, and compaction loses water through evaporation and is less able to absorb irrigation or rainfall. Using mulches, the soil has greater water retention, reduced evaporation, and reduced weeds. One study documented a 35% reduction in evaporation when a straw as mulching was applied. There is a wide variety of permeable mulching materials. Organic mulches conserve water more effectively and do not limit soil water infiltration and retention. Appropriate mulch can reduce the need for irrigation and in some landscapes can eliminate irrigation all together. Coarse organic mulches protect soil water reserves holding water for later release and prevent runoff. Mulch can also protect trees and shrubs from drought stress and cold injury. **Zhang *et al.* (2008)** suggested that mulching was a promising soil management practice that can increase soil water storage especially in arid regions.

MATERIALS AND METHODS

Field experiment was carried out at the Experimental Farm, Faculty of Environmental Agricultural Sciences, Arish University, North Sinai Governorate Egypt, during two successive seasons, 2015 and 2016. The Experimental Farm is located at latitude of 31° 07′ 59″ N and longitude of 33° 49′ 40″ E and 17 m above sea level. The objective of this experiment was to evaluate the response of soil water content to water irrigation regimes with and without mulching under surface and subsurface drip irrigation systems.

Tomato seeds (*Solanum lycopersicon* GS_{12} hybrid) were transplanting on 20^{th} February for 2 successive seasons, 2015 and 2016. After the establishment (in nursery) period, the seedlings were transported to the field calcareous loamy sand on 21^{th} March and irrigated every 2 days by well water. The irrigation water regime treatments were carried out after 25 days from the transporting date, harvesting was on 27^{th} July. The agronomic practices including weed and pest control followed as recommended for tomato production.

The irrigation system was consisted of 9 irrigation water regime treatments combined with 2 deficit irrigation levels of 25 and 50% from crop evapotranspiration, ETc, were individually subjected throughout the development (D), flowering (F) and harvesting (H) growth stages and the same deficit irrigation levels were subjected throughout whole growth season (during the growth season period) as well as the deficit irrigation level of 0 % ETc, control treatment, was subjected throughout whole growth season using well water mulching by black plastic sheet and without mulching was used. Well water is having electric conductivity (ECw) of 7.25 dSm^{-1} and 8.68 SAR (Sodium Adsorption Ratio) and classified as moderately saline irrigation water according to **Rhoades *et al.* (1992).**

Sodium adsorption ratio (SAR) of saline irrigation water sample was calculated according to **Richards (1954)** using the following equation,

$$SAR = Na+/ ((Ca++ + Mg++)/2)0.5 \quad \dots (1)$$

Soil water content of the soil layers was determined by the gravimetric method according to **Klute (1986)**.

Experimental Design

Treatment were randomized distributed in complete randomized design in split-split plot system in three replicates.

Collected Data

Soil water content value was determined at depths of 0-15 and 15-30 cm at the end of tomato plants growth stages.

Table 1. Irrigation water regime treatments under each drip irrigation system

Irrigation water regime (T)	Irrigation water depth level ETc(%) at growth stage			Description
	Development (D)	Flowering (F)	Harvesting (H)	
T1	**100**	**100**	**100**	The tomato plants were irrigated by the applied deficit irrigation level of 0% ETc (irrigation water depth level of 100% ETc, full irrigation) throughout the whole growth season.
T_2	**75**	**75**	**75**	The tomato plants were irrigated by the applied deficit irrigation level of 25% ETc (irrigation water depth level of 75% ETc) throughout the whole growth season.
T_3	**75**	**100**	**100**	The tomato plants were irrigated by the applied deficit irrigation level of 25% ETc (irrigation water depth level of 75% ETc) throughout the development stage and applied the full irrigation (irrigation water depth of 100% ETc) throughout the other growth stages.
T4	**100**	**75**	**100**	The tomato plants were irrigated by the applied deficit irrigation level of 25% ETc (irrigation water depth level of 75% ETc) throughout the flowering stage and applied the full irrigation (irrigation water depth of 100% ETc) throughout the other growth stages.
T5	**100**	**100**	**75**	The tomato plants were irrigated by the applied deficit irrigation level of 25% ETc (irrigation water depth level of 75% ETc) throughout the harvesting stage and applied the full irrigation (irrigation water depth of 100% ETc) throughout the other growth stages.
T6	**50**	**50**	**50**	The plants were irrigated by the applied deficit irrigation level of 50% ETc (irrigation water depth level of 50% ETc) throughout the whole growth season.
T7	**50**	**100**	**100**	The tomato plants were irrigated by the applied deficit irrigation level of 50% ETc (irrigation water depth level of 50% ETc) throughout the development stage and applied the full irrigation (irrigation water depth of 100% ETc) throughout the other growth stages.
T8	**100**	**50**	**100**	The tomato plants were irrigated by the applied deficit irrigation level of 50% ETc (irrigation water depth level of 50% ETc) throughout the flowering stage and applied the full irrigation (irrigation water depth of 100% ETc) throughout the other growth stages.
T9	**100**	**100**	**50**	The tomato plants were irrigated by the applied deficit irrigation level of 50% ETc (irrigation water depth level of 50% ETc) throughout the harvesting stage and applied the full irrigation (irrigation water depth of 100% ETc) throughout the other growth stages.

T= Irrigation water regimes

Statistical Analysis

The obtained data were subjected to statical analysis of variance. Whereas, the seasons (S), the irrigation systems (I), irrigation treatments (T) and mulching treatments (M) were represented the blocks, main plot factor, subplot factor and sub-subplot factor, respectively. Least significant difference (LSD) test was used for the comparison among treatments means, **Steel and Torrie**, **1980**. CoHort computer program was used for the statistical analysis, version 6.400.

RESULTES AND DISCUSSION

The results in Tables 2 and 3 show that the volumetric soil water content, □%, in soil surface and subsurface layers at the end of various tomato growth stages response to deficit irrigation levels of 0, 25 and 50% ETc that were subjected throughout the growth stages (whole season) or individually subjected throughout the development, flowering and harvesting growth stages using moderately saline water of 7.25 dSm^{-1}, significantly decreased with increasing the deficit irrigation levels. This trend was clearly opposite to soil salinity values obtained in soil surface and subsurface layers. This decrease in soil water content attributed to the decreasing of the applied irrigation water amounts. These results are similar to those obtained by **El-Kassas (2008), Mohawesh (2015) and Hashem *et al.* (2018)**. Also, these results indicated that the applied irrigation water amount is effectively a major factor on soil water content values; while, the irrigation water salinity is effectively a minor factor. Consequently, the influences of the same irrigation water salinity with different irrigation water amounts on the soil water content values are closely related to the irrigation water amounts. This conclusion is similar to that obtained by **Selim *et al.* (2013) and Saad *et al.* (2018)**. Furthermore, volumetric soil water content values in soil surface layer at the end of various tomato growth stages responsed to deficit irrigation levels of 0, 25 and 50 % ETc and were more than that obtained in soil subsurface layer, Tables (2, 3, 4 and 5), (2,3,4 and 5), this may be attributed to the soil salinities in surface layer that was more than that obtained in subsurface layer. Thus, the soil osmotic pressure was increased; promotig that the increase of soil water content. The lowest soil water content values in soil surface and subsurface layers at the end of development, flowering and harvesting stages were 4.70, 6.80 and 8.56 as well as 3.62, 6.06 and 7.95%, respectively, were obtained at the deficit irrigation level of 50% ETc that was subjected throughout the whole season (T_6) (Tables 4 and 5). Generally, highest soil water content values in soil surface and subsurface layers at the end of the same growth stages were 8.63, 10.57 and 12.59% as well as 7.74, 9.93 and 11.64%, respectively, were obtained by the deficit irrigation level of 0% ETc (full irrigation water) that were subjected throughout the whole season (Tables 4 and 5). However, the highest value of soil water content at the end of flowering stage was obtained by deficit irrigation level of 50% ETc that was subjected throughout the harvesting stage (T_9). Also, the volumetric soil water content, %, in soil surface and subsurface layers at the 10 cm from emitter for the end of different tomato growth stages response to deficit irrigation levels of 25 and 50% ETc that were individually subjected throughout development, flowering and harvesting growth stages or were subjected throughout the whole season using moderately saline water of 7.25 dSm^{-1}, which were generally significantly decreased compared to the volumetric soil water content at the same soil layers responsed to deficit irrigation level of 0% ETc that was subjected throughout the whole season during the studied seasons (Tables 2, 3, 4 and 5). However, the soil water content in surface layer at the end of flowering stage response to the deficit of 50% ETc was individually subjected throughout the harvesting stage (T_9) and soil water content in subsurface layer response to the deficit of 25% ETc that was individually subjected throughout development stage (T_3) as well as the level of 50% ETc that was individually subjected throughout development and harvesting stages (T_7 and T_9). Whereas, the soil water content values increased. The decrease of average values percentage of soil water content in surface layer at the end of development, flowering and harvesting growth stages of tomato responsed to deficit irrigation levels of 25 and 50% ETc that were subjected throughout the whole season or individually subjected throughout various growth stages relative to the control treatment were ranged between 1.59 – 45.53, 0.24-35.64 and 4.33-32.01%, respectively, Table (4). However, these average values percentage in soil subsurface layer at the end of the same growth stages were ranged between 3.37- 53.28, 4.87-33.28 and 0.70-31.77%, respectively (Table 5).

Table 2. Soil water content in surface layer at the end of various tomato growth stages as affected by irrigation water regimes and drip irrigation applications during first and second growth seasons

Irrigation water regime	Soil water content (%)							
	I_1				I_2			
	S_1		S_2		S_1		S_2	
	M_1	M_2	M_1	M_2	M_1	M_2	M_1	M_2
	Development stage							
T_1	9.46	7.52	9.50	7.96	8.73	7.99	9.22	8.68
T_2	6.16	4.90	6.42	5.31	7.70	6.71	7.79	7.25
T_3	6.96	5.70	6.66	5.60	7.82	7.67	8.49	7.24
T_4	8.99	7.59	8.49	6.41	8.62	7.93	8.64	8.01
T_5	9.26	7.93	9.18	7.19	8.72	7.95	8.76	8.24
T_6	4.47	3.60	5.21	4.25	5.45	4.37	5.76	4.51
T_7	4.87	3.63	5.04	4.35	6.16	5.65	6.26	6.01
T_8	8.87	6.79	9.48	8.48	8.73	7.87	9.04	8.70
T_9	7.98	5.96	8.51	6.53	9.04	8.35	8.76	7.72
	Flowering stage							
T_1	10.66	9.06	10.82	9.22	10.78	10.33	11.60	12.07
T_2	7.81	5.93	7.72	7.41	9.87	8.41	10.13	8.01
T_3	10.70	8.72	11.92	8.15	9.39	9.32	11.01	9.53
T_4	7.52	5.74	8.05	6.78	10.21	9.10	10.36	8.18
T_5	11.03	9.10	10.75	9.39	9.83	9.59	10.10	10.71
T_6	6.88	4.31	7.58	4.88	7.88	6.91	9.00	6.97
T_7	11.09	8.98	10.47	10.03	8.10	10.09	12.18	10.00
T_8	6.91	4.47	7.68	4.98	8.21	7.52	9.15	6.67
T_9	11.03	9.83	11.38	10.83	10.53	9.83	11.18	9.73
	Harvesting stage							
T_1	12.32	11.44	13.14	12.39	13.77	11.35	14.00	12.29
T_2	11.77	10.33	13.11	11.01	11.23	9.32	11.84	9.53
T_3	11.95	10.83	11.95	11.76	13.35	10.69	13.20	12.12
T_4	11.77	10.61	11.95	11.67	12.83	11.04	13.72	12.17
T_5	10.96	9.81	11.70	10.33	11.30	10.40	12.80	10.25
T_6	8.30	6.78	8.56	6.58	10.92	8.39	9.77	9.17
T_7	12.78	11.50	12.70	11.68	12.69	10.27	13.56	11.16
T_8	12.72	11.24	13.31	11.59	12.80	9.84	12.92	10.66
T_9	8.30	7.11	8.76	6.91	10.87	8.62	10.61	9.37
Treatments	I		S		M		T-	
LSD_{05} development	0.109		0.109		0.039		0.511-	
LSD_{05} flowering	0.851		0.851		0.111		0.592	
LSD_{05} harvesting	0.311		0.311		0.069		0.374-	

I_1, I_2= surface and subsurface drip irrigation systems.
S_1, S_2= first and second growth seasons.
M_1, M_2= with and without mulching.
T= irrigation water regime.

Table 3. Soil water content in subsurface layer at the end of various tomato growth stages as affected by irrigation water regimes and drip irrigation applications during first and second growth seasons

Irrigation water regime	Soil water content (%)							
	I_1				I_2			
	S_1		S_2		S_1		S_2	
	M_1	M_2	M_1	M_2	M_1	M_2	M_1	M_2
Development stage								
T_1	7.15	5.88	7.58	7.04	8.65	9.40	7.73	8.52
T_2	5.04	4.35	4.56	3.83	7.70	6.34	7.22	6.23
T_3	5.43	4.49	4.25	3.83	8.18	6.58	7.65	6.76
T_4	6.73	6.49	6.04	5.23	7.10	8.16	7.58	7.09
T_5	6.99	5.89	7.30	6.57	8.50	7.82	8.32	8.47
T_6	3.83	3.32	3.55	2.34	4.81	3.56	4.02	3.51
T_7	4.36	3.28	3.61	2.72	5.06	5.25	5.01	4.60
T_8	6.41	5.44	7.66	6.17	8.07	6.70	8.38	7.14
T_9	6.02	5.25	6.20	3.98	8.39	7.73	7.71	7.19
Flowering stage								
T_1	9.16	7.91	7.74	7.31	10.88	9.79	10.43	9.43
T_2	6.02	5.26	6.73	6.52	11.04	8.81	8.95	8.22
T_3	9.11	7.53	8.06	6.90	10.82	10.22	11.34	9.94
T_4	6.10	4.86	7.44	5.63	10.13	8.89	9.29	7.70
T_5	8.50	8.05	7.01	6.66	10.40	9.76	10.41	8.32
T_6	5.28	3.53	5.68	3.85	8.15	7.44	8.08	6.46
T_7	9.72	7.57	9.05	7.47	11.38	10.22	11.65	10.67
T_8	5.44	3.08	7.00	3.82	8.45	7.53	8.16	6.55
T_9	9.74	9.02	9.08	9.11	11.21	10.27	10.86	10.14
Harvesting stage								
T_1	12.43	11.48	10.92	10.40	12.04	11.79	11.70	12.39
T_2	10.72	9.31	11.61	8.59	11.13	9.34	10.97	8.67
T_3	11.85	10.06	11.35	8.01	11.77	10.84	12.37	10.40
T_4	11.54	10.47	11.42	10.76	11.62	10.42	11.99	10.11
T_5	10.06	8.36	11.03	8.28	11.29	11.19	11.45	10.68
T_6	7.04	5.46	7.68	6.15	11.27	8.86	8.94	8.16
T_7	12.06	10.35	12.10	10.92	11.58	11.27	11.75	10.14
T_8	11.88	10.38	11.75	10.97	13.31	10.74	12.77	10.70
T_9	6.83	6.42	7.81	7.28	11.69	8.98	9.29	8.19
Treatments	**I**		**S**		**M**		**T**	
LSD_{05} development	**0.346**		**0.346**		**0.054**		**0.640**	
LSD_{05} flowering	**2.813**		**2.813**		**0.057**		**0.829**	
LSD_{05} harvesting	**3.102**		**3.102**		**0.077**		**0.765**	

I_1, I_2= surface and subsurface drip irrigation systems.

S_1, S_2= first and second growth seasons.

M_1, M_2= with and without mulching.

T= irrigation water regime.

Table 4. Average and decrease (%) values of soil water content in surface layer at the end of various growth stages as affected by irrigation water regimes and drip irrigation applications during first and second growth seasons

Irrigation water regime	Average soil water content (%)							Decrease (%)
	I_1	I_2	S_1	S_2	M_1	M_2	T	
				Development stage				
T_1	8.61	8.66	8.43	8.84	9.23	8.04	8.63	0.00
T_2	5.70	7.36	6.37	6.69	7.02	6.04	6.53	24.36
T_3	6.23	7.81	7.04	7.00	7.48	6.55	7.02	18.71
T_4	7.87	8.30	8.28	7.89	8.69	7.49	8.09	6.34
T_5	8.39	8.42	8.47	8.34	8.98	7.83	8.40	2.65
T_6	4.38	5.02	4.47	4.93	5.22	4.18	4.70	45.53
T_7	4.47	6.02	5.08	5.42	5.58	4.91	5.25	39.23
T_8	8.41	8.59	8.07	8.93	9.03	7.96	8.50	1.59
T_9	7.25	8.47	7.83	7.88	8.57	7.14	7.86	8.99
Average	6.81	7.63	7.11	7.32	7.76	6.68	7.22	
				Flowering stage				
T_1	9.94	11.20	10.21	10.93	10.97	10.17	10.57	0.00
T_2	7.22	9.11	8.01	8.32	8.88	7.44	8.16	22.77
T_3	9.87	9.81	9.53	10.15	10.76	8.93	9.84	6.86
T_4	7.02	9.46	8.14	8.34	9.04	7.45	8.24	22.00
T_5	10.07	10.06	9.89	10.24	10.43	9.70	10.06	4.78
T_6	5.91	7.69	6.50	7.11	7.84	5.77	6.80	35.64
T_7	10.14	10.09	9.57	10.67	10.46	9.78	10.12	4.26
T_8	6.01	7.89	6.78	7.12	7.99	5.91	6.95	34.24
T_9	10.77	10.32	10.31	10.78	11.03	10.06	10.54	0.24
Average	8.55	9.51	8.77	9.30	9.71	8.36	9.03	
				Harvesting stage				
T_1	12.32	12.85	12.22	12.96	13.31	11.87	12.59	0.00
T_2	11.56	10.48	10.66	11.37	11.99	10.05	11.02	12.47
T_3	11.62	12.34	11.71	12.26	12.61	11.35	11.98	4.82
T_4	11.50	12.44	11.56	12.38	12.57	11.37	11.97	4.91
T_5	10.70	11.19	10.62	11.27	11.69	10.20	10.94	13.06
T_6	7.56	9.56	8.60	8.52	9.39	7.73	8.56	32.01
T_7	12.17	11.92	11.81	12.28	12.93	11.15	12.04	4.33
T_8	12.22	11.56	11.65	12.12	12.94	10.83	11.89	5.58
T_9	7.77	9.87	8.73	8.91	9.64	8.00	8.82	29.94
Average	10.82	11.36	10.84	11.34	11.90	10.28	11.09	

Treatments	**I**	**S**	**M**	**T**
LSD_{05} development	**0.109**	**0.109**	**0.039**	**0.511**
LSD_{05} flowering	**0.851**	**0.851**	**0.111**	**0.592**
LSD_{05} harvesting	**0.311**	**0.311**	**0.069**	**0.374**

I_1, I_2= surface and subsurface drip irrigation systems.
S_1, S_2= first and second growth seasons.
M_1, M_2= with and without mulching.
T= irrigation water regime.

Table 5. Average and decrease (%) values of soil water content in subsurface layer at the end of various growth stages as affected by irrigation water regimes and drip irrigation applications during first and second growth seasons.

Irrigation water regime	Average volumetric soil water content (%)							Decrease
	I_1	I_2	S_1	S_2	M_1	M_2	T	(%)
			Development stage					
T_1	6.91	8.58	7.77	7.72	7.78	7.71	7.74	0.00
T_2	4.45	6.87	5.86	5.46	6.13	5.19	5.66	26.92
T_3	4.50	7.29	6.17	5.62	6.38	5.42	5.90	23.86
T_4	6.12	7.48	7.12	6.49	6.86	6.74	6.80	12.15
T_5	6.69	8.28	7.30	7.67	7.78	7.19	7.48	3.37
T_6	3.26	3.98	3.88	3.36	4.05	3.18	3.62	53.28
T_7	3.49	4.98	4.49	3.99	4.51	3.96	4.24	45.29
T_8	6.42	7.57	6.66	7.34	7.63	6.36	7.00	9.65
T_9	5.36	7.76	6.85	6.27	7.08	6.04	6.56	15.30
Average	5.24	6.98	6.23	5.99	6.47	5.75	6.11	
			Flowering stage					
T_1	8.03	10.13	9.44	8.73	9.55	8.61	9.08	0.00
T_2	6.13	9.26	7.78	7.61	8.19	7.20	7.69	15.28
T_3	7.90	10.58	9.42	9.06	9.83	8.65	9.24	-1.75
T_4	6.01	9.00	7.50	7.52	8.24	6.77	7.51	17.36
T_5	7.56	9.72	9.18	8.10	9.08	8.20	8.64	4.87
T_6	4.59	7.53	6.10	6.02	6.80	5.32	6.06	33.28
T_7	8.45	10.98	9.72	9.71	10.45	8.98	9.72	-6.99
T_8	4.84	7.67	6.13	6.38	7.26	5.25	6.25	31.14
T_9	9.24	10.62	10.06	9.80	10.22	9.64	9.93	-9.33
Average	6.97	9.50	8.37	8.10	8.85	7.62	8.24	
			Harvesting stage					
T_1	11.31	11.98	11.94	11.35	11.77	11.52	11.64	0.00
T_2	10.06	10.03	10.13	9.96	11.11	8.98	10.04	13.75
T_3	10.32	11.35	11.13	10.53	11.84	9.83	10.83	6.98
T_4	11.05	11.04	11.01	11.07	11.64	10.44	11.04	5.17
T_5	9.43	11.15	10.23	10.36	10.96	9.63	10.29	11.60
T_6	6.58	9.31	8.16	7.73	8.73	7.16	7.95	31.77
T_7	11.36	11.19	11.32	11.23	11.87	10.67	11.27	3.20
T_8	11.25	11.88	11.58	11.55	12.43	10.70	11.56	0.70
T_9	7.09	9.54	8.48	8.14	8.91	7.72	8.31	28.62
Average	9.83	10.83	10.44	10.21	11.03	9.63	10.33	

Treatments	I	S	M	T
LSD_{05} development	0.346	0.346	0.054	0.640
LSD_{05} flowering	2.813	2.813	0.057	0.829
LSD_{05} harvesting	3.102	3.102	0.077	0.765

I_1, I_2 = surface and subsurface drip irrigation systems.
S_1, S_2 = first and second growth seasons.
M_1, M_2 = with and without mulching.
T= irrigation water regime.

The obtained results indicated that sensitive tomato stages to the soil water content decrease values responsed to the deficit irrigation water levels of 25 and 50% ETc that were individually subjected throughout the various tomato growth stages were it revealed that the stage was more responded by decrease of soil water content will be depended on the applied deficit irrigation water levels individually subjected throughout the same growth stage under drip irrigation applications, Tables (4 and 5). Generally, the sequences of the sensitive stages at the end of various stages in soil studied layers as responded by soil water content decreased that response to the deficit irrigation level of 25 and 50 % ETc individually subjected throughout development growth stage was as the following: D > H > F, with except that the sequence in soil surface layer response to the deficit irrigation level of 25% ETc; whereas, it was as the following: D > F > H. In general, the sequences of sensitive of growth stages at the end of various stages in soil studied layers as responded by soil water content decreased percentage values responsed to the same deficit irrigation levels individually subjected throughout the flowering stage were as follows: F > D > H. With exception that the sequence in soil surface layer response to the deficit irrigation level of 50% ETc, whereas, it was as the following: F > H > D. The sequences of sensitive of the growth stages in studied soil layers at the end of various stages response to the deficit irrigation levels of 25 and 50% ETc individually subjected throughout the harvesting stage was as the following: H > F > D for response to deficit irrigation level 25% ETc and H > D > F for response to deficit irrigation level 50% ETc, respectively. Consequently, these results evidenced that the tomato plant growth stage was individually subjected by the deficit irrigation levels of 25 and 50% ETc is more sensitive than that other growth stages that irrigated by 0% ETc. Thus, it will be predicted that the tomato growth parameters and fruit yield values response to the deficit irrigation levels of 25 and 50% ETc individually subjected throughout a certain growth stage may be more reduced than that obtained at other growth stages irrigated by deficit irrigation level of 0% ETc.

With respect to the soil water content response to the mulching effect, the soil water content values in soil surface and subsurface layers at the end of various tomato growth stages were significantly more than that obtained without mulching, Tables (2, 3, 4 and 5) this affect due to that mulching suppressed water evaporation from the soil surface. This conclusion was confirmed by **Ji and Unger (2001), Suja and Nayar (2005)**, **Chalker-Scott (2007)** and **Zhang *et al.* (2008).**

For the soil water content response to irrigation systems, the obtained results clear that the soil water content in soil surface and subsurface layers at the end of various tomato growth stages under surface drip irrigation system (I1) were generally significant less than that obtained under subsurface drip irrigation system (I2), except that the values in subsurface layer at the end of flowering and harvesting stages that were no significant. Tables (2, 3, 4 and 5); these results are similar to that obtained by **El-Mokh *et al.* (2014).** This effect is probably due to the downward water movement under the emitters of subsurface drip irrigation system was higher than that upward water movement; thus, the soil water content in soil subsurface layer (15-30 cm) increased. This conclusion is in agreement with **Abou-Kheira (2009)**.

Soil water content values in soil surface and subsurface layers at the end of development, flowering and harvesting growth stages of tomato plants under surface and subsurface drip irrigation systems were 6.81, 8.55 and 10.82 as well as 5.24, 6.97 and 9.83 % for surface drip and 7.63, 9.51 and 11.36 as well as 6.98, 9.50 and 10.83 □% for subsurface drip irrigation systems, respectively (Tables 4 and 5).

With regard to the effect of interaction between water regime treatments, mulching effects and irrigation systems on the soil water content (%) at the end of tomato plants growth stages it was significant. The lowest values in soil surface layer at the end of development (3.60%), flowering (4.31%) stages were obtained at T_6 M_2 I_1 S_1 and harvesting (6.58%) was obtained at T_6 M_2 I_1 S_2, Table 2. The highest value in soil surface layer at the end of development (9.50%) and flowering (12.18%) and harvesting (14.00%) stages were obtained at T1 M1 I1 S2, T7 M1 I2 S2 and T1 M1 I2 S2, respectively, Table 2. The lowest value of soil water content in soil subsurface layer at the end of development (2.34%), flowering (3.08%) and harvesting (5.46 %) stages were obtained at T_6 M_2 I_1 S_2 at the of development and T_8 M_2 I_1 S_1 at the end of flowering T6M2 I1 S1 and at the end of harvesting stages, respectively, Table 3. The highest value in subsurface layer at the end of development (9.40%) and harvesting (13.31%) were found at T_1 M_2 I_2 and T_8 M_1 I_2, respectively, during the first season, while the highest value at flowering stages (11.65%) was obtained at T_7 M_1 I_2 S_2, Table (3). These results indicated that the tomato plants irrigated by deficit irrigation water of 50% ETc without mulching under surface drip irrigation system will decrease the soil water content in active root zone, thus, the tomato plant parameters and fruit yield may be reduced.

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الملخص العربي

استجابة التربة لأنظمة مياه الري وتطبيقات الري بالتنقيط

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أجريت تجربة حقلية في المزرعة التجريبية لكلية العلوم الزراعية البيئية بجامعة العريش بمحافظة شمال سيناء خلال موسمين متعاقبين (٢٠١٥ و٢٠١٦) تهدف هذه التجربة لدراسة استجابة المحتوى الرطوبي لأنظمة مياه الري مع التغطية أو بدون التغطية تحت نظامي الري بالتنقيط السطحي وتحت السطحي، ويتكون كل نظام ري في التجربة من ١٨ قطعة تجريبية تشمل ٩ معاملات لأنظمة مياه الري وعدد معاملتين للتغطية يتكون كل نظام ري من ٩ معاملات لمياه الري وتشمل هذه المعاملات مستويين من الري الناقص هما ٢٥ و٥٠٪ من قيمة البخر- نتح للمحصول، ETc، (مستوى عمق ماء الري محسوبًا كنسبة تكافئ ٧٥ و٥٠% من قيمة البخر- نتح) حيث تم تعريض نباتات الطماطم لهذين المستويين من الري الناقص خلال كل من مرحلة الإنماء (D)، مرحلة التزهير (F) ومرحلة الحصاد (H) كل على حده، أيضاً يتم تعريض نباتات الطماطم لنفس المستويين من الري الناقص خلال موسم النمو الكامل لنباتات الطماطم، بالإضافة إلى مستوى الري الناقص صفر% (مستوى عمق ماء الري محسوبًا كنسبة تكافئ ١٠٠% من قيمة البخر- نتح) خلال موسم النمو الكامل، انخفضت معنويًا قيم المحتوى الرطوبي الحجمي للتربة مع زيادة مستويات الري الناقص. كانت قيم محتوى الرطوبي للتربة في الطبقات السطحية وتحت السطحية عند نهاية مراحل نمو الطماطم المختلفة استجابة لمعاملة التغطية أعلى معنويًا من تلك التي تم الحصول عليها بدون تغطية، كانت قيم المحتوى الرطوبي للتربة في الطبقات السطحية وتحت السطحية عند نهاية مراحل نمو الطماطم المختلفة تحت نظام الري بالتنقيط السطحي، عامة أقل معنويًا من تلك التي تم الحصول عليها تحت نظام الري بالتنقيط تحت السطحي.

الكلمات الإرشادية: المحتوى الرطوبي، أنظمة مياه الري، تغطية سطح التربة، نظام الري بالتنقيط تحت السطحي ونظام الري بالتنقيط السطحي.

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