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Effect of the Smart Drip Irrigation System and Water Deficit on Contour Maps of Soil Moisture Distribution

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Abstract
Among the modern technologies of irrigation systems use of smart and automatic irrigation systems, which depends on the use of sensors in the soil connected to electric locks automatically shut and open According to signals from humidity sensors, this fieldwork was carried out in the village of Abu-Ghalib in the north of Giza governorate in Egypt in clay soil. Concerning the contour maps of soil moisture contents and the mean soil moisture content, the applied irrigation systems could be arranged in the following ascending order: Smart drip irrigation system before and after irrigation at differences in moisture percent between any two irrigation treatments were significant at the 5 % level except that between land leveling 0 % and land leveling 2% before irrigation. According to soil moisture content the irrigation, smart drip irrigation system before irrigation and after irrigation, the differences in soil moisture content between land leveling 0 % one side and land leveling 2% from the other side was significant at 5 % level. It could be concluded that the effect of the smart drip irrigation system was positive on soil moisture content and that the contour maps produced are of immense importance in clarifying this effect and thus can be recommended for use to indicate the extent to which the soil is affected by the modern and the high techniques of smart irrigation systems.

Keywords: Smart, Drip, Irrigation, Soil Moisture, Contour Maps, Land leveling

Introduction

Drip or high frequency irrigation will often maintain low soil moisture suction (high moisture content) in a portion of the effective root zone. Root growth can possibly augment the influence of low soil moisture suction and maintain more favorable soil, water intake characteristics around the emitters Gerard (1974) mentioned that the wetting pattern can be affected by the soil hydrological properties. The author has indicated that, the reduction in the ability of the soil to conduct water could be large enough to create saturated soil conditions and cause a significant loss of effective roots area. However, as was found by the reduction in the ability of soil to conduct water can be serious enough to create saturated soil conductions and significant loss of effective roots. Earl and Jury (1977) reported that moisture profiles for the daily irrigation treatment under cropped conditions showed that downward water movement is restricted to depth 60 cm in which lateral movement occurs no further than 60 cm from the emitter and commented that water movement is observed to almost 100 cm from the emitter, while downward movement is restricted to about 75 cm. The rate of water application in drip irrigation will affect the distribution of the applied chemicals. By varying the parameters of the irrigation regime different distribution may be obtained. Levin *et al*, (1979) and Sabreen *et al.*, (2016) studied the soil moisture distribution pattern when a certain amount of water was applied from a point source, but with different discharge rates. The continuous irrigation treatment showed a loss, by deep percolation, about 26% of the total amount of irrigation water below 60-cm depth after 12 hours. The lateral distribution, in the same treatment, showed that 80% of the water in the wetted volume was distributed up to 45 and 43cm horizontally from the point source after 12 and 24 hours, respectively. Only 12% loss under the depth of 60 cm was found with the pulsed irrigation group and 29 and 40 cm lateral distribution after 12 and 24 hours, respectively. Bacon and Davy (1982) observed that irrigation resulted in an outward movement of water from the application point to from a wetted zone in the shape of a shallow dish.

The size and duration of the wetted zone depended on the season and length of irrigation while the shallow depth was caused by the low hydraulic conductivity of the subsoil. Norris and Tennessee (1985) indicated that lateral movement is enhanced if the soil is stratified, the initial soil moisture is low, and the application rate is low. They also observed that, at high moisture tension (low moisture content) lateral movement is more pronounced in finer soil layers than in coarser layers. El-Gindy (1988) reported that, the moisture content of the topsoil (0-20 cm) was higher in the drip irrigated field than those of the surface, and sprinkler ones. Meanwhile the lowest moisture content in the same layer was in the surface irrigated field. Hanafy (1993) said that the major fluctuations in soil, water tension occurred in the top 30 cm of the soil profile. This is mainly due to that most crops moisture withdrawal from the soil is near the surface where more roots are growing normally.

Control of subsurface drip irrigation systems helped to increase the productivity of water to decrease the proportion of water evaporation from the soil and plant surfaces. This is well illustrated in the case of the comparison between drip irrigation where the root growth area is partially wet Unlike spray irrigation moistening the kidneys of all field space happens (Mansour *et al.*, 2015 a and b). The use of saline water in agriculture successfully (Mansour *et al.*, 2014). When using salt water and take advantage of them, the wheat crop is the important consideration biggest (Malash et al., 2005).

Under drip irrigation, the pending zone that develops around the emitter is strongly related to both the water application rate and the soil properties (Assouline, 2002). Consequently, the water application rate is one key factor determining the soil water content around the emitter Bresler, 1978 and Sabreen and Mansour (2015) and the water uptake pattern Phene et al., 1991; Coelho and Or, 1999. However, excessive or inadequate water application has a significant impact on either drip irrigation efficiency or final grain yield. For instance, very high rates of water application can eliminate crop water stress, but it will also lessen drip irrigation efficiency by increasing the amount of water and nutrients that leach below the root zone Morton et al., 1988; Jordan et al., 2003, Mansour 2006, and Mansour 2012.

The objectives of this research work are studying the effect of automatic drip irrigation with different land levels and different treatments of water rates/or amounts from field capacity on soil moisture distribution in clay loam soil.

Material and Methods

This study was conducted at the private farm carried out in the village of Abu-Ghalib in the north of Giza governorate in Egypt in clay loam soil, Egypt. Field experiments were carried out through two successive growing under tow land leveling and three water amount treatments from field capacity irrigation systems drip, low-head bubbler and the modified surface by using gated pipes that considered as control. Soil of experimental field represents the (Nile alluvial) clay loam.

Soil particle size distribution was carried out using pipette method after Gee and Bauder(1986) as shown in Table (1). Soil bulk density (B.D.) was measured after Black and Hartage (1986). Soil moisture content at field capacity (F.C) and permanent wilting point (P.W.P) were measured according to Walter and Gardener (1986) as shown Table (1). The available water (AW) was calculated from the following equation:

AW=F.C - P.W.P………………..……………(1)

Where:

AW= available water ($\ominus_w$ %),

F.C = field capacity ($\ominus_w$ %) and

P.W.P = permanent wilting point ($\ominus_w$ %).

Soil hydraulic conductivity (HC)was determined under a constant head technique according Klute and Dirksen, (1986).HCwascalculating using the following formula :

HC = (QL)/(At. H)……………………………(2)

Where:

Q = volume of water flowing through the sample per unite time (L^3/T),

A = cross sectional flow area (L^2),

L = length of the sample (L), and

H = differences in hydraulic head across the sample (L).

Soil pH and EC were measured in 1:2.5 soil, water suspensions and in soil past extract, respectively, according to Jackson (1967), $CaCO_3$ content, soluble Cations and anions are measured by Scheiblercalcimeter (Soil Survey Staff, 1993) as shown in Table (2).

Ground water is the source of irrigation water. Irrigation water analysis is given in Table (3).

Table 1: Soil physical properties of the experimental site

Soil sample Depth(cm)	Particle size distribution (%)				Texture class	* FC	* PWP	* AW	BD (g/cm^3)	** HC (cm/h)
	Coarse sand	Fine sand	Silt	Clay		$\ominus_{\%}$				
0-15	0.8	27.8	41.6	29.8	***	35.46	19.1	16.36	1.25	3.12
15-30	0.7	27.5	41.2	30.6	***	35.21	19.24	15.97	1.28	2.36
30-45	0.6	27.9	38.5	33	****	34.72	19.76	14.96	1.28	1.74
45-60	0.6	28.7	37	33.7	****	34.78	20.1	14.68	1.29	1.56

(*)Determined as percentage in weight basis; (**) HC: Hydraulic conductivity; (***): Silty clay loam and (****): Clay loam

Table 2: Chemical analysis of the soil

Soil sample depths(cm)	Cations (Meq/l)				Anions(Meq/l)				pH	E.C (dS/m)
	Ca^{++}	Mg^{++}	Na^+	K^+	CO_3^{--}	HCO_3^-	Cl^-	SO_4^{--}		
0-15	0.40	0.48	0.41	0.19	0	0.63	0.49	0.30	7.7	0.26
15-30	0.46	0.35	0.51	0.18	0	0.76	0.51	0.24	7.6	0.23
30-45	0.57	0.55	0.62	0.20	0	0.79	0.75	0.40	7.4	0.25
45-60	0.48	0.66	0.67	0.16	0	0.86	0.66	0.46	7.2	0.27

Table 3: Chemical analysis of irrigation water

Cations(Meq/l)				Anions(Meq/l)				pH	E.C (dS/m)	S.A.R
Ca^{++}	Mg^{++}	Na^{+}	K^{+}	$Co_3^{=}$	Hco_3^{-}	Cl^{-}	$So_4^{=}$			
2.73	1.4	2.19	0.21	0.0	2.4	2.5	1.0	7.3	0.37	1.52

Fig. (1) shows the automation controller circuits of drip irrigation for wheat field experiments under study. The automation controller system consists of moisture sensors, temperature sensors, signal conditioning circuit, digital to analog converter, LCD Module, Relay driver, solenoid control valves, etc. The unit is expressed in Figure (1). The important parameters to be measured for the smart drip irrigation systems are soil moisture and temperature. The entire field is first divided into small sections such that each section should contain one moisture sensor and one temperature sensor. Fig (2) showing the layout of experiments for soil moisture distribution under automation controller drip irrigation system and different water treatments.

For the determination of soil's Mechanical constitution, it was used the Bougioukou method, pH was measured with a pH electronic meter and the organic matter with the method of humid combustion of sample with divine acid. Measurements were taken of the dripper discharge flow and pressure and were seen to be within the limits set down by the manufacturer Fig. (3). Also, because of the distance between drippers and the drip lateral length, it was achieved high uniformity of irrigation that approaches 95-97%. Measurements were taken of the volumetric soil moisture (θ_s) in the experimental plots daily and were taken from soil at the depths (0, 10, 20, 30, and 40 cm) depths and (5, 10, 15, 20, and 25cm) distances from dripper in that time. Throughout the entire irrigation season. The TDR (Time Domain Reflectometry) method was used, a non-radioactive method which has been proved to be quick and reliable, irrespective of soil type (except extreme cases of soils), Enviromental Sensors INC., 1997; Filintas, 2003; Dioudis *et al.*, 2003a; Filintas *et al.*, 2006a; Filintas *et al.*, 2007.

The working principle of TDR is based on the direct measurement of the dielectric constant of soil and its conversion to water volume content. A TDR device from the E.S.I. Company was used along with TDR probes (Figure 3), which were tested and calibrated using laboratory measurements at the beginning.

ATDR device from the E.S.I. Company was used, which was tested and calibrated using laboratory measurements at the beginning of each cultivation season. Testing the soil moisture content is a very complex process and the placing of a sensor at the root level of the crop is, in most of cases, not sufficient for a satisfactory performance of the test. As a solution to this problem, quite many researchers, Filintas (2005), Mansour *et al.*, 2016, and Mansour 2012 recommend using two or more sensors at various depths, so that a greater area of the root level is covered. To do this and to ensure greater accuracy, soil moisture probes with five sensors each were used and lay permanently installed in the 12 experimental plots, where they were in continuous contact with the soil. Each probe had sensors which measured the soil moisture content at five different depths: 0–15, 15–30, 30–45, and 45–60 cm. From the measurements taken at each position, the average value was calculated from the five depths for each treatment. Surfer software program had been used for contour maps of soil moisture distribution.

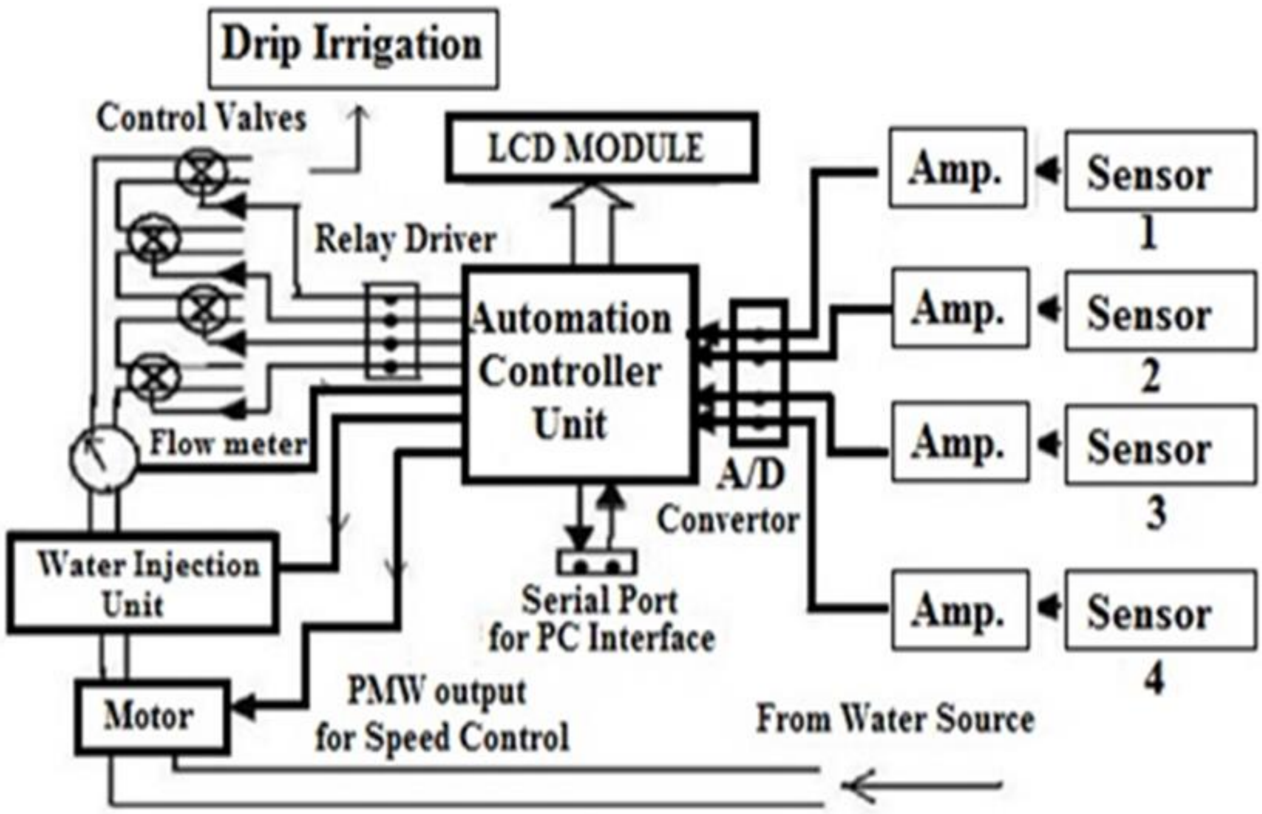

Fig. 1: Automation controller of drip irrigation system

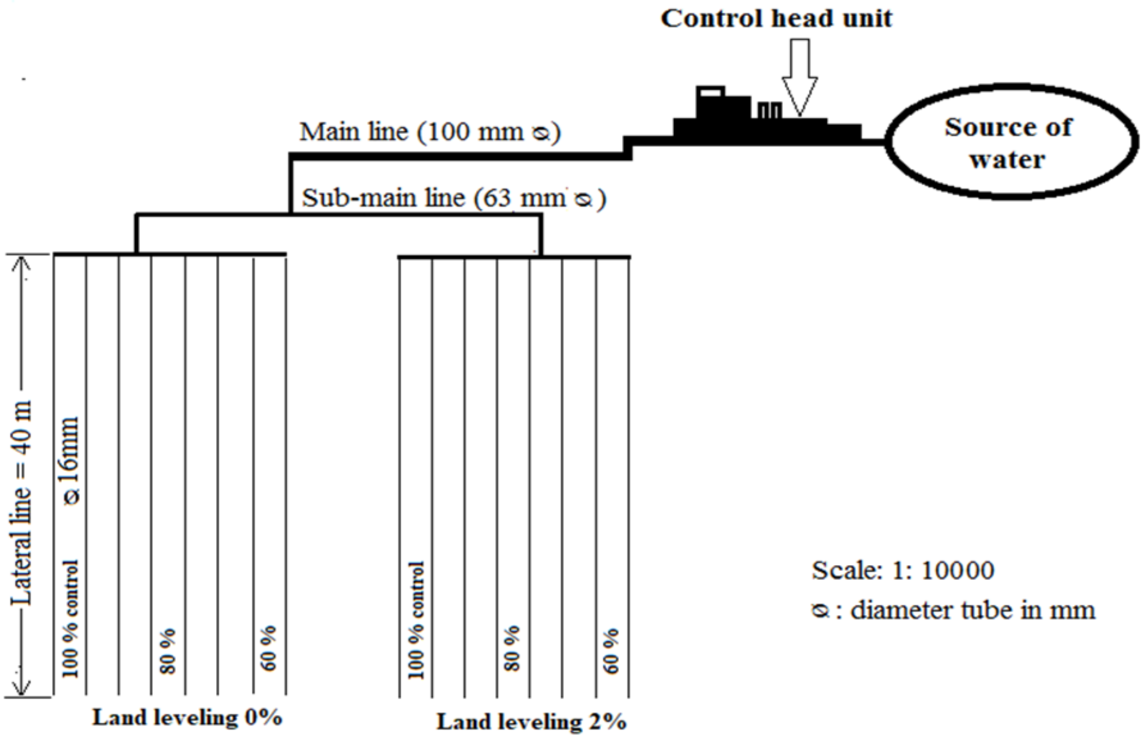

Fig. 2: Layout of experiments for soil moisture distribution under automation controller drip irrigation system and different water treatments

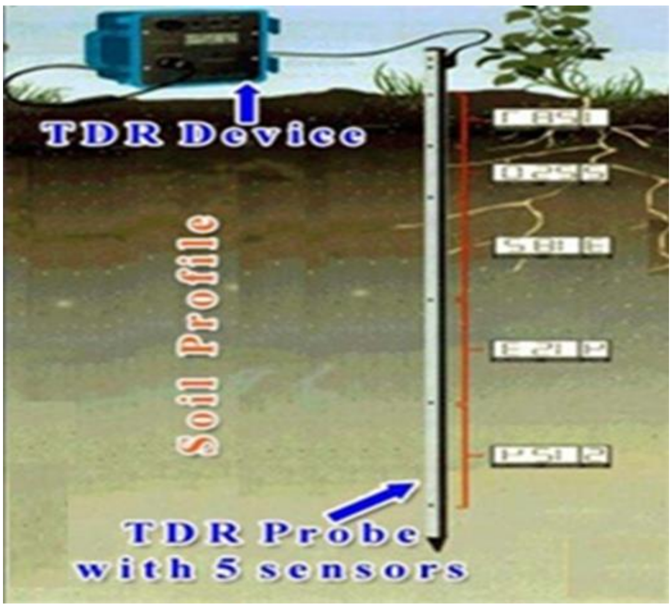

Fig. 3: TDR device and probe with five sensors.

MSTATC program (Michigan State University) was used to carry out statistical analysis. Treatments mean were compared using the technique of analysis of variance (ANOVA) and the least significant difference (L.S.D) between systems at 5 % had been done. The randomized complete block design according to Steel and Torrie (1980).

Results and Discussion

Data of Table (4) and Figs. (4, 5 and 6) show the effect of automation control drip irrigation system at different land leveling conditions and different FC treatments on moisture distribution pattern. The effect of lateral length 40 m of smart drip irrigation connection methods on soil moisture distribution pattern on volumetric basis (⊖s %). It is important to mention that, when land leveling 0% conditions the mean soil moisture content ⊖s % were 12.03, 12.21 and 10.63 % under 100% FC, 80% FC, and 60% FC, respectively, before irrigation, whereas, they were 30.31, 27.89 and 27.54 % after irrigation in the same sequence. On the other hand, the mean ⊖s % were 12.54, 11.97 and 10.40 % before irrigation while they were 30.41, 27.72 and 27.52 % after irrigation under 100% FC, 80% FC, and 60% FC, respectively when land leveling conditions 2 %. There is a slight increase in ⊖s % with depth, whether soil moisture was measured before or after irrigation. This may be attributed to decreased clay fraction with depth. According to the mean soil moisture content (⊖s %), smart drip irrigation systems used could be arranged in the following ascending orders: 60% FC<100%; FC<80% FC before irrigation, and 60% FC<80% FC<100% FC after irrigation when land leveling

0 %conditions. Differences in ⊖s % between any two smart drip irrigation systems were significant at the 5 % level.

Table 4: Effect of smart drip irrigation on moisture distribution patterns when lateral length 40 m.

Land leveling	Soil Depth(cm)	100% FC		80% FC		60% FC	
		Before	After	Before	After	Before	After
0%	0	11.25	28.97	11.87	28.87	10.48	27.64
	10	11.87	29.24	11.96	28.43	10.51	27.63
	20	12.22	30.22	12.22	27.52	10.56	27.51
	30	12.48	31.75	12.56	27.34	10.88	27.48
	40	12.33	31.35	12.45	27.27	10.72	27.44
Mean		**12.03**	**30.31**	**12.21**	**27.89**	**10.63**	**27.54**
2%	0	11.88	31.54	11.46	28.34	10.32	27.73
	10	12.00	31.48	11.45	28.31	10.36	27.58
	20	12.54	30.49	12.21	27.46	10.33	27.54
	30	13.76	29.55	12.37	27.42	10.62	27.45
	40	12.50	28.97	12.34	27.08	10.35	27.32
Mean		**12.54**	**30.41**	**11.97**	**27.72**	**10.4**	**27.52**
LSD 5%:							
Land leveling		**0%**			**2%**		
Water treatments	**Before**	0.11			0.13		
	After	0.09			0.14		
Depths		0.17			0.23		
Interaction		0.06			0.08		

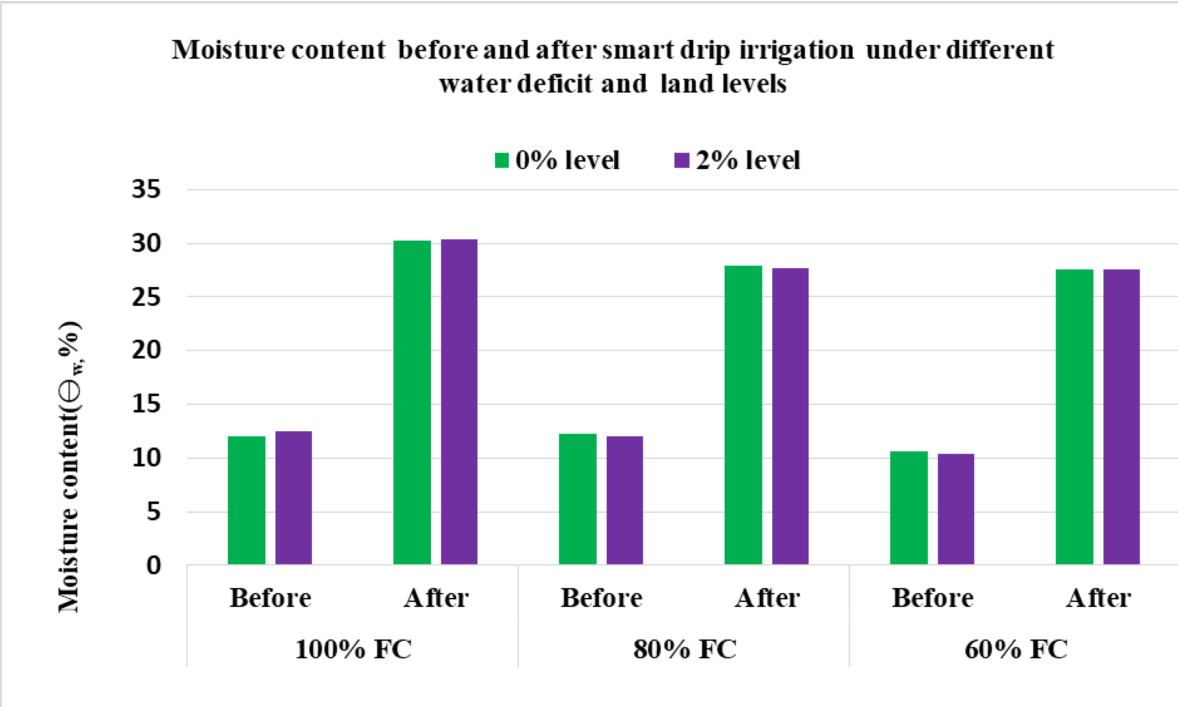

Fig. 4: Effect of water deficit, land leveling on moisture content before and after smart drip irrigation system.

The obtained contour maps of soil moisture distribution under different water treatments by smart drip irrigation connection methods after and before irrigation when land leveling (0 % and 2 %) conditions are shown in Figs. (4, 5 and 6), respectively. Concerning to ⊖s %, the smart drip irrigation systems could put in the following ascending orders 60% FC<80% FC<100% FC before and after irrigation both at when land leveling 2% conditions. Difference in ⊖s % between any two smart drip irrigation systems were significant at the 5 % level this may be due decreasing salt accumulation under 100% FC before irrigation in comparison with 80% FC and 60% FC. Maximum and minimum values of moisture content ⊖s % were 12.56 % (30 cm) and 10.48 % (0 cm) under 80% FC and 60% FC, respectively before irrigation and 31.75 % (30 cm) and 27.27 % (40 cm) under 100% FC and 80% FC, respectively after irrigation when land leveling 0 % condition. But when land leveling 2 % conditions, the values of⊖s % were 13.76 (30 cm) and 10.32 %(0 cm) for 100% FC and 60% FC before irrigation and 31.54% (0 cm) and 27.08 % (40 cm) under 100% FC and 80% FC, respectively after irrigation. The effect of automatic irrigation was positive on wet soil content and that the contour maps produced are very important in clarifying this effect and thus can be easy used to indicate the extent to which the soil is affected by the modern irrigation systems. These data agreed well with both of Filintas *et al*. (2007), Dioudis *et al*.(2008), Dioudis*et al*.(2003a), Dioudis*et al*.(2003b) Mansour 2006, Mansour 2012, Mansour *et al*., (2014); Sabreen and Mansour (2016).

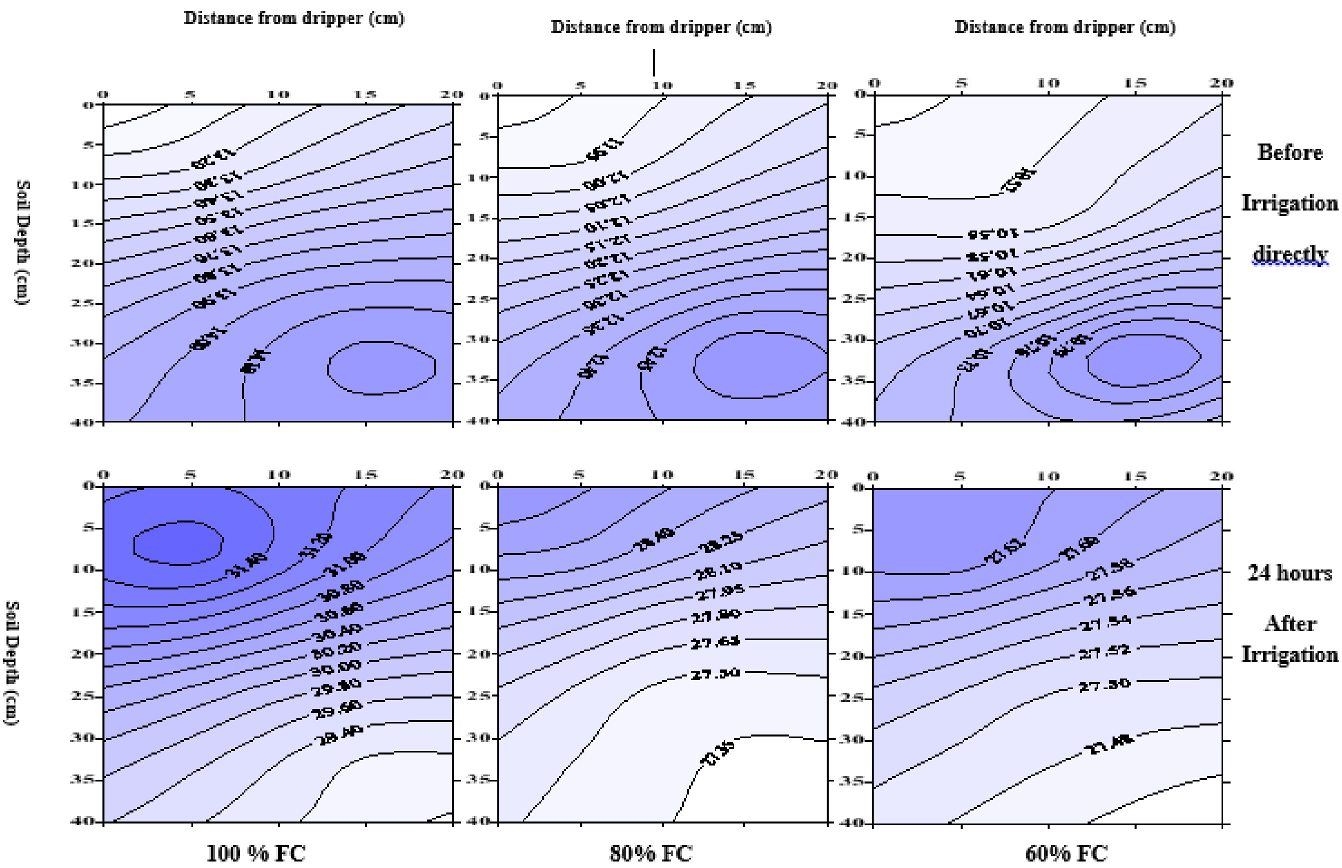

Fig. 5: Contour maps for soil moisture distribution patterns by using smart drip irrigation system before and after irrigation when land leveling 0 % conditions under different FC.

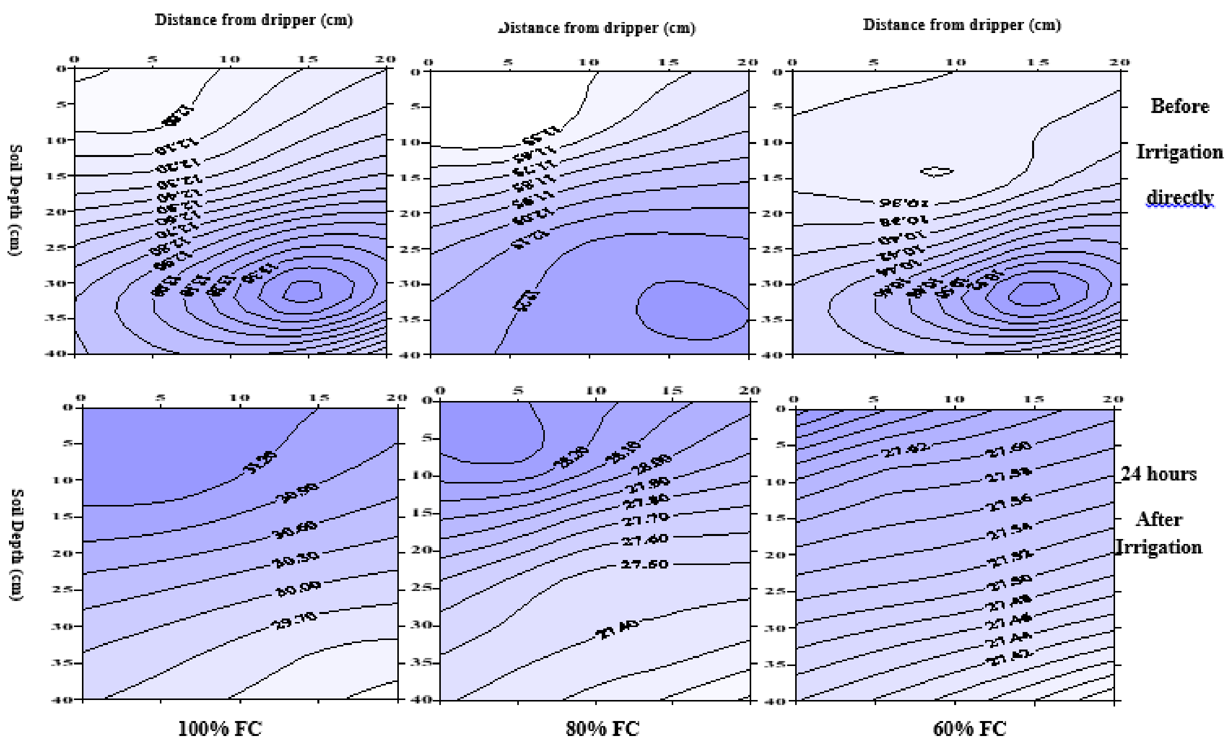

Fig. 6: Contour maps for soil moisture distribution patterns by using smart drip irrigation system before and after irrigation when land leveling2 % conditions under different FC.

Conclusion

Concerning the contour maps of soil moisture contents and the mean soil moisture content (Θ_w,%), the applied irrigation systems could be concluded that: Smart drip irrigation system before irrigation, and after irrigation at the beginning of growing season the differences in moisture percent between any two irrigation treatments were significant at the 5 % level except that between Land leveling 0 % and Land leveling 2% before irrigation. According to soil moisture content the irrigation, smart drip irrigation system before irrigation and after irrigation, the differences in soil moisture content between Land leveling 0 % one side and Land leveling 2% from the other side was significant at 5 % level. It could be concluded that the effect of the smart drip irrigation system was positive on soil moisture content and that the contour maps produced are significant in clarifying this effect and thus can be recommended for use to indicate the extent to which the soil is affected by the modern and the high techniques of smart irrigation systems.

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