J. Soil Sci. and Agric. Eng., Mansoura Univ., Vol. 2 (9): 939 - 962, 2011

EFFECT OF SPATIAL DISTRIBUTION OF SOIL MOISTURE AND HEAT CONTENT ON IRRIGATION SCHEDULING OF SOME CROPS GROWN IN EL-SHEIKH ZUWAID AREA, NORTH SINAI - EGYPT

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ABSTRACT

The current research aims to study the effect of spatial variability of soil moisture and soil heat content on irrigation scheduling of olive trees and tomato plants under drip irrigation system in desert sandy soil of North Sinai Governorate.

Field experiment has been conducted in El-Sheikh Zuwaid experimental station in North Sinai during 2011 growing season. The studied area includes two sites: one cultivated with olive trees and the other with tomato crop. Three profiles were examined in each site to verify the spatial variability of soil moisture and three infiltration tests had been carried out. Physical and chemical analyses were carried out for the soil profiles. Meteorological data were collected for the 15 last years of the site as the irrigation schedules were designed for the tested two crops. The measurements of soil moisture and soil temperature were carried out over the studied growth season which lasted to 6 months. The data show the following:

1- Infiltration rate (IR) values express the horizontal spatial variability among profiles, while the soil moisture characteristics express the vertical one.
2- The intake rate of water into soil is affected by soil texture, plant cover and soil bulk density. The latter influences the water infiltration to soil as the differences reach to double in olive and 20% in tomato. Olive farm gives the lowest IR values while tomato gives the highest ones.
3- Soil moisture shows great differences due to the differences in particle size distribution (soil texture), its content increased gradually from March to August coordinated with soil temperature as well. On daily base, the moisture content shows declination through daytime while get maximum levels at night. Meanwhile, soil moisture fluctuations were more detected under olive than under tomato due to the difference in coverage rates for both. So, intercropping of tomato is recommended through olive lines as the assumption has been verified statistically.
4- There were positive significant correlations between moisture content and each of available soil moisture, soil temperature and soil heat content under tomato farm. But for olive no significant correlation was found between moisture content and available soil water, but the rest variable were significant.
5- Soil temperature increased from March to August, being higher than air temperature from March to May but lower from June to August. Minimum soil temperature was recorded at daytime hours while the maximum were at night time. Soil temperature values were coordinated with soil moisture ones. The soil heat content values show the same trends of soil temperature.
6- Some modification on irrigation schedule has been undertaken adjust the soil moisture at desired level of depletion, where two calculations had been carried out:
    a- Modifying the depletion level to compensate the loss of water curve, so, creating new irrigation intervals.
    b- Back calculation using the new intervals reaching to new crop coefficient (Kc). Modifications for olive from 14 – 25 to 11 – 22 days with the same irrigation amount, for tomato from 3 – 7 to 2 – 5 days with the same irrigation

amount, but with modifying Kc for the modified intervals the gross irrigation amount change from 1029 to 1177 and 2404 to 2678 m^3/fed/season for olive and tomato, respectively.

7- Significant positive correlations were found between available soil water and irrigation scheduling for both olive and tomato crops.

8- Intercropping hypothesis was checked statistically and the resulted relations were all significant.

The work concludes the importance of spatial variability of soil characters and their effect on irrigation scheduling. Furthermore, the back calculation for adjusting the soil moisture regime could be resulted in new irrigation intervals and Kc values. Also, the concept of intercropping under such similar conditions is quite acceptable.

Keywords: spatial variability, irrigation scheduling, soil moisture and heat content.

INTRODUCTION

As water for irrigation becomes increasingly scarce, accurate scheduling using soundly based management methods and tools is necessary, particularly in arid areas. Spatial variability considerations in interpreting soil moisture measurements are essential for accurate irrigation scheduling (Bradley and Jeffrey, 2004). The soil profile should be placed in a location that will most represent the irrigated area. Soil moisture can has highly variable spatially in the some field (Warrick, 2003). The factors that affect soil moisture variability are slope, vegetation type, bulk density, soil type, microclimate, and other variables. An irrigation regime which represents an area should be homogenous enough that the soil moisture variability will be low and the soil moisture data will represent the entire irrigation regime. There should be at least one soil profile for every irrigation regime. Irrigation regimes are selected according to crop type, crop age, soil type, slope, and irrigation method.

Irrigation scheduling is one of the important managerial activities that aim at effective and efficient utilization of water (Khalifa, 2009). An appropriated irrigation scheduling plays an important role in achieving water savings, higher irrigation performances, and controlling the percolation resulting from excess water applied to irrigation (Smith et al., 1996 and Pereira et al., 2002). Irrigation scheduling and irrigation uniformity are two water management issues that need attention to maximize production efficiency. Irrigation scheduling involves determining the proper timing and amount of water applications throughout the growing season. Theoretically, irrigation scheduling can be performed using a calculated daily water balance in conjunction with estimated daily crop water use values or repeated soil moisture monitoring. In practice, a combination of crop water use information and soil moisture monitoring is necessary to achieve acceptable results. Thus, adjusting irrigation schedules to account for general changes in crop water use combined with soil moisture monitoring to correct for local conditions is necessary for effective irrigation scheduling.

Haws *et al.* (2004) and Wuest (2005) reported that water intake rate (IR) to soil is affected by soil factors which embrace soil texture, structure, bulk density, pore-size distribution, water content, and chemical composition of soil solution as well as topography. The water-holding capacity of a soil and the numeric value of measures used to quantify soil moisture are highly dependent on soil texture. Unfortunately, soil texture commonly varies with depth and location.

This spatial variability in soil texture is an important consideration in both irrigation system design and irrigation scheduling and can confound field soil moisture measurements taken for irrigation scheduling purposes. Therefore, the present investigation is to study the effect of spatial variability of soil moisture and soil heat content on irrigation scheduling of olive trees and tomato plants.

MATERIALS AND METHODS

Trials were carried out in the Agricultural Experimental Station of the Desert Research Center at El–Sheikh Zuwaid City, about 35 Km East of El-Arish, North Sinai Governorate, Egypt during 2011. Climatic conditions of the experimental site were obtained from a meteorological station installed in the station (Table, 1) which indicates high relative humidity all over the year. It lies between Latitude 31^{o}.08\` N, Longitude $34^{o}$.01\` E, with an altitude of 15 m above M.S.L. Daily reference evapotranspiration (ETo) was computed by Penman–Monteith equation (Allen et al., 1998).

Table (1): Measured climatic data of studied area during the period of 15 years from 1996-2010.

Avg. 15 Yr (1996-2010)	Jan.	Feb.	Mar.	Apr.	Ma.	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	Avg.
Max. temp. (^{o}C)	18.71	19.73	25.42	27.80	29.81	32.05	33.65	34.56	34.12	31.05	26.43	21.56	27.91
Min. temp. (^{o}C)	7.80	8.08	10.67	12.37	14.69	18.54	21.66	22.28	20.39	17.32	13.75	10.21	14.81
Avg. temp. (^{o}C)	13.26	13.91	18.05	20.09	22.25	25.30	27.66	28.42	27.26	24.19	20.09	15.89	21.36
Relative Humidity (%)	85.86	89.90	84.72	85.38	87.21	91.87	93.39	92.57	87.97	86.95	87.39	88.06	88.44
Wind speed (m/sec)	2.91	3.16	2.10	2.17	1.88	1.43	1.47	1.27	1.47	1.31	2.00	2.68	1.99
Sunshine (hour)	7.01	7.80	8.41	9.53	10.48	11.93	12.02	11.65	10.55	9.48	7.88	6.78	9.46
Rainfall (mm)	29.18	48.35	8.57	2.06	0.12	0.11	0.03	0.02	0.05	22.37	13.10	22.09	146.04*
Solar radiation (Wat/m^{2})	2.61	3.08	5.01	7.08	7.00	7.43	7.38	6.40	4.54	3.06	2.67	2.46	4.89
ETo (mm/day)	1.95	2.27	3.41	4.40	4.99	5.44	5.71	5.54	4.81	3.55	2.60	1.94	3.88

Source: El-Sheikh Zuwaid station (Desert Research Center), * Total, temp.: temperature, ETo: Potential evapotranspiration , Avg.: Average

The area under study includes one feddan distinguished into an old olive farm (0.5 feddan) and non cultivated land which was cropped with tomato plants (0.5 feddan) for one season. Six IR tests were conducted on both areas, 3 tests each. Besides, six soil profiles were dug adjacent to IR tests. IR tests were determined under constant head of water using double ring infiltrometer, as described by Klute (1986). The cumulative depth of infiltrated water D in cm as a function of time t, according to the Philips two terms equation (1957 a, b).

$$D = At^{0.5} + Bt$$

$$i = 0.5t^{-0.5} + B$$

Where; i is the IR at large time, i.e., the steady state IR, and A, B are constants.

The study also included the determination of irrigation intervals for olive trees and tomato plants that might be considered to be potentially-grown in this area. These determinations were based on the IR tests and available soil water by using meteorological data. Tables (2 to 5) present the soil physical and chemical properties of the two studied areas.

Table (2): Soil physical properties of olive farm area in El-Sheikh Zuwaid region.

Profile No.	Depth (cm)	Particle size distribution in mm (%)						T.C.	$CaCO_3$	*bd* (Mg m^{-3})	Moisture content %		Available soil water (Sa) %
		2.0-1.0	1.0 – 0.5	0.5 – 0.2	0.2 – 0.1	0.1 – 0.063	> 0.063				F.C.	W.P.	
1	0 – 15	0.16	2.20	77.83	19.33	0.24	0.06	S.	2.55	1.61	9.95	3.45	6.50
	15 – 30	0.20	3.18	76.38	19.64	0.41	0.19	S.	2.60	1.59	9.88	3.42	6.46
	30 – 45	0.19	2.29	76.55	20.17	0.55	0.25	S.	2.70	1.61	10.03	3.87	6.16
	45 – 60	0.18	3.33	74.28	21.32	0.66	0.23	S.	2.80	1.60	9.98	3.56	6.42
	> 60	0.21	3.41	73.89	21.34	0.65	0.50	S.	2.05	1.62	10.11	3.77	6.34
2	0 – 15	0.20	3.36	76.14	19.78	0.45	0.07	S.	2.59	1.61	10.11	3.56	6.55
	15 – 30	0.21	2.29	76.73	20.11	0.47	0.19	S.	2.44	1.63	9.99	3.77	6.22
	30 – 45	0.23	3.36	73.30	22.34	0.51	0.27	S.	2.53	1.61	10.01	3.56	6.45
	45 – 60	0.17	3.18	75.62	20.09	0.65	0.29	S.	2.04	1.62	10.05	3.25	6.80
	> 60	0.18	3.31	74.17	21.33	0.49	0.52	S.	2.60	1.60	9.95	3.25	6.70
3	0 – 15	0.19	3.22	77.93	18.11	0.50	0.05	S.	2.89	1.62	10.31	3.09	7.22
	15 – 30	0.22	2.22	77.63	19.40	0.37	0.16	S.	2.62	1.63	10.15	4.01	6.14
	30 – 45	0.13	2.55	77.16	19.34	0.45	0.37	S.	2.53	1.62	10.11	3.70	6.41
	45 – 60	0.19	2.66	74.32	22.31	0.47	0.41	S.	2.40	1.63	10.08	3.56	6.52
	> 60	0.18	3.71	72.00	23.22	0.49	0.40	S.	2.34	1.60	10.22	3.26	6.96

T.C.: texture class S.: sand *bd*: bulk density Mgm^{-3} : Mega gram/m^3
F.C.: field capacity W.P.: wilting point

Table (3): Soil physical properties of tomato plants area in El-Sheikh Zuwaid region.

Profile No.	Depth (cm)	Particle size distribution in mm (%)						T.C.	$CaCO_3$	*bd* (Mg m^{-3})	Moisture content %		Available soil water (Sa) %
		2.0-1.0	1.0 – 0.5	0.5 – 0.2	0.2 – 0.1	0.1 – 0.063	> 0.063				F.C.	W.P.	
4	0 – 15	0	4..00	75.84	19.52	0.52	0.12	S.	2.88	1.57	11.22	3.99	7.23
	15 – 30	0	3.66	75.93	19.43	0.53	0.45	S.	3.45	1.60	10.99	3.67	7.32
	30 – 45	0	4.22	74.52	20.38	0.46	0.42	S.	2.55	1.61	10.33	4.13	6.20
	45 – 60	0	3.68	74.00	21.44	0.49	0.39	S.	2.49	1.58	11.15	4.02	7.13
	> 60	0	2.66	73.81	22.52	0.59	0.42	S.	2.82	1.59	10.19	3.87	6.32
5	0 – 15	0	4.29	74.61	20.29	0.62	0.18	S.	3.52	1.56	10.65	4.21	6.44
	15 – 30	0	4.83	73.16	21.00	0.55	0.46	S.	3.60	1.58	10.25	3.98	6.27
	30 – 45	0	4.18	74.51	20.34	0.55	0.42	S.	3.20	1.57	10.23	3.99	6.24
	45 – 60	0	4.26	74.80	19.99	0.48	0.40	S.	2.71	1.60	11.35	4.12	7.23
	> 60	0	3.49	73.58	21.82	0.68	0.43	S.	2.80	1.60	9.87	3.53	6.34
6	0 – 15	0	4.52	69.82	24.32	0.59	0.75	S.	3.45	1.55	11.01	3.99	7.02
	15 – 30	0	4.12	73.41	21.34	0.57	0.56	S.	3.52	1.60	11.98	4.23	7.75
	30 – 45	0	3.99	75.11	19.89	0.55	0.46	S.	3.71	1.61	10.96	4.03	6.93
	45 – 60	0	4.39	74.62	20.04	0.50	0.45	S.	2.84	1.59	10.56	3.78	6.78
	> 60	0	4.80	73.39	21.62	0.48	0.43	S.	2.50	1.59	10.12	4.01	6.11

T.C.: texture class S.: sand *bd*: bulk density Mgm^{-3} : Mega gram/m^3
F.C.: field capacity W.P.: wilting point

Table (4): Soil chemical properties of olive farm area in El-Sheikh Zuwaid region.

Profile No.	Depth (cm)	EC	pH	Cations (me/l)				Anions (me/l)			
		dSm^{-1}		Na^+	K^+	Ca^{++}	Mg^{++}	$CO_3^=$	HCO_3^-	Cl^-	SO_4^{--}
1	0 – 15	0.79	8.00	4.70	0.39	2.40	0.41	0.00	2.50	4.10	1.30
	15 – 30	0.77	8.10	4.60	0.38	2.20	0.52	0.00	2.50	4.20	1.00
	30 – 45	0.75	8.20	4.50	0.35	2.00	0.65	0.00	2.00	4.11	1.39
	45 – 60	0.70	8.10	4.40	0.37	1.98	0.55	0.00	1.89	3.81	1.30
	> 60	0.68	8.20	3.95	0.36	1.89	0.60	0.00	1.89	3.20	1.71
2	0 – 15	0.80	8.00	4.50	0.40	2.80	0.30	0.00	2.80	4.22	0.98
	15 – 30	0.80	8.10	4.40	0.42	2.60	0.58	0.00	2.60	3.88	1.52
	30 – 45	0.78	8.20	4.60	0.38	2.40	0.42	0.00	2.50	4.11	1.19
	45 – 60	0.75	8.20	4.70	0.38	2.10	0.48	0.00	1.88	4.00	1.65
	> 60	0.70	8.10	4.20	0.42	2.20	0.18	0.00	1.89	4.13	0.98
3	0 – 15	0.81	8.20	4.30	0.42	2.40	0.98	0.00	2.60	3.88	1.62
	15 – 30	0.80	8.10	4.50	0.41	2.60	0.49	0.00	2.60	3.99	1.41
	30 – 45	0.79	8.00	4.40	0.39	2.70	0.41	0.00	2.80	4.12	0.98
	45 – 60	0.78	8.00	4.40	0.44	2.80	0.46	0.00	2.80	4.20	0.80
	> 60	0.71	8.00	4.50	0.42	1.98	0.20	0.00	2.00	3.88	1.22

Table (5): Soil chemical properties of tomato plants area in El-Sheikh Zuwaid region.

Profile No.	Depth (cm)	EC	pH	Cations (me/l)				Anions (me/l)			
		dSm^{-1}		Na^+	K^+	Ca^{++}	Mg^{++}	$CO_3^=$	HCO_3^-	Cl^-	SO_4^{--}
4	0 – 15	0.82	8.20	4.90	0.42	2.60	0.28	0.00	2.80	4.22	1.18
	15 – 30	0.80	8.20	4.80	0.40	2.50	0.30	0.00	2.60	4.40	1.00
	30 – 45	0.79	8.10	4.75	0.44	2.60	0.11	0.00	2.50	4.60	0.80
	45 – 60	0.76	8.20	5.00	0.38	2.02	0.20	0.00	2.80	4.30	0.50
	> 60	0.75	8.10	4.80	0.40	1.88	0.42	0.00	2.60	4.00	0.90
5	0 – 15	0.84	8.20	5.05	0.40	2.80	0.40	0.00	2.80	4.40	1.20
	15 – 30	0.82	8.20	4.80	0.42	2.45	0.53	0.00	2.60	4.10	1.50
	30 – 45	0.78	8.00	4.75	0.41	2.17	0.47	0.00	2.80	4.30	0.70
	45 – 60	0.76	8.10	4.05	0.38	1.88	0.29	0.00	2.60	3.82	1.18
	> 60	0.75	8.00	4.42	0.38	2.24	0.46	0.00	1.85	3.85	1.80
6	0 – 15	0.82	8.20	5.19	0.45	2.05	0.50	0.00	2.65	4.28	1.27
	15 – 30	0.79	8.00	4.80	0.42	2.15	0.50	0.00	2.75	4.40	0.75
	30 – 45	0.78	8.20	4.02	0.40	2.42	0.94	0.00	1.88	4.10	1.82
	45 – 60	0.76	7.90	4.05	0.35	2.62	0.53	0.00	2.82	4.35	0.40
	> 60	0.75	7.90	4.15	0.38	2.63	0.34	0.00	2.00	3.75	1.75

The physical and chemical analyses were carried out according to Klute (1986) and Page et al. (1982), the data show almost similar properties for the studied profiles either in old cultivated or cultivated with tomato plants.

The conventional agricultural practices were used for cultivating tomatoes. Crop management practices carried out on olive, i.e. pruning, fertilizing and pest management practices were similar to those applied in the intensive orchards (Masmoudi-Charfi *et al.,* 2006). Irrigation was applied using ground water with drip irrigation system the analyses of well water is illustrated in Table (6).

Table (6): Chemical analysis of the well irrigation water of North Sinai research station.

P^H	E.C (dSm^{-1})	S.A.R	Soluble cations (me/l)				Soluble anions (me/l)				Class
			Ca^{++}	Mg^{++}	Na^+	K^+	$CO_3^=$	HCO_3^-	$SO_4^=$	Cl^-	
7.5	4.81	4.49	12.93	12.85	16.11	6.23	0	13.98	14.93	19.21	C_4 S_2

Soil heat capacity was measured using copper calorimeter method by Partington (1963). Volumetric water content was determined gravimetrically at various depths: 0 -15, 15 - 30, 30 - 45, 45 - 60 and > 60 cm (Young and Nobel, 1986). Hourly soil temperature (ºC) was recorded with model 063 temperature sensor at the same depths. All sensors were connected to a data logger (Model C R 10 X, Campbell Scientific Inc., Logan U T) (Bilskie *et al.,* 1998). El-Nawawy (1986) gives the following simple equation to calculate the total heat content (Ht): Ht = Hs + Hm + Hv

Where; H: heat content (calories), t: total, s: solid phase, m: liquid phase and v: vapor phase.

For each component it can be calculated as follows; Hn = n component, g x CVn x T

Where; CVn is the heat capacity in cal/g, and T is soil temperature in centigrade.

The amounts of applied irrigation water for tomato were calculated by the equation:

D iw = (ETo X Kc) / E_a (Dorrenbos and Pruitt, 1984)

Where:

D_{iw} = Depth of applied irrigation water, (mm)

ETo = References or Potential (ETp) evapotranspiration, (mm/day).

Kc = Crop coefficient.

Ea = Irrigation system efficiency, (0.85%).

The water use of olive tree (ETc) was calculated as: ETc = ETo x Kc x Kr (Vermeiren and Jobling, 1980), To estimate ETc, the reference evapotranspiration was corrected by a crop coefficient Kc of 0.6 (Vermeiren and Jobling, 1980) and a reduction coefficient Kr of 0.9 (Masmoudi et al., 2004).

Irrigation scheduling was based on the set depletion percentage of total available water (TAW) in the crop root depth position. The TAW was considered as the difference between the existing root zone water storage at field capacity and the permanent wilting point. The readily available water (RAW) was computed by multiplying selected maximum allowable depletion (MAD) at a given time with TAW on daily basis.

I = ((p. Sa). D) / (ETc – Pe) (Dorrenbos and Pruitt, 1984)

Where:

I = interval of irrigation (days).

p = fraction of available soil water permitting unrestricted evapotranspiration.

Sa = total available soil water, mm/m soil depth.

D = rooting depth, (m)

ETc = maximum crop evapotranspiration (mm) = ETo X Kc.

Pe = effective rainfall (mm)

Sa = (F.C.% - W.P.%) x b_d x 1000.
F.C. = Field capacity of soil water, %.
W.P. = Wilting point of soil water, %.
b_d = Bulk density of soil, Mgm^{-3}.

The pressure plate extraction apparatus was used to determine soil water content at field capacity (θ_{FC}) and at wilting point (θ_{WP}).

RESULTS AND DISCUSSION

Infiltration rate:

The study of infiltration rate (IR) in selected sites of the two studied farms expresses the spatial variability on horizontal scale among these sites, while the soil moisture measures of different layers express the vertical scale. The infiltration of water into soil is mainly affected by soil texture and structure, but it also depends on soil moisture, vegetation and soil bulk density. Nevertheless, the accurate evaluation and consequently, modeling and application of infiltration rate may be influenced significantly by the extent and nature of spatial variability of soil. Therefore, the intake rate (IR) is the first step that expresses the movement of water into and thorough the soil.

Data in Table (7) show that the values of intake rate (IR), either initial or basic IR, varied from one zone to another and even within the same zone according to variations in soil physical properties. The small differences in soil bulk density (b_d) and fine fractions are seemingly effective in changing both IR values either initial and basic.

Table (7): Infiltration parameters and classis of different soil profiles.

Profile No.	Equations	Initial I.R	Basic I.R $cmhr^{-1}$	Class of I.R
1	$D=0.866t^{0.5} + 0.887t$ & $I= 25.98t^{-0.5} + 53.22$	79.19	55.16	VR
2	$D= 1.11t^{0.5} + 0.983t$ & $I= 33.3t^{-0.5} + 58.98$	92.28	61.46	VR
3	$D=0.879t^{0.5} + 1.931t$ & $I= 20.37t^{-0.5} + 115.86$	136.28	117.38	VR
4	$D=0.793t^{0.5} + 2.013t$ & $I= 23.79t^{-0.5} + 120.78$	144.57	122.55	VR
5	$D=0.931t^{0.5} + 2.387t$ & $I= 27.93t^{-0.5} + 143.22$	171.15	145.30	VR
6	$D=1.001t^{0.5} + 2.119t$ & $I= 30.03t^{-0.5} + 127.14$	157.17	127..21	VR

VR = very rapid

From Tables (2, 3 and 7) it seems that the infinite variations in (b_d) affect the basic IR despite the IR class. The variations reach to ≈ twice in olive farm while being about 20% in tomato farm. The values of IR in the first cultivated area (olive farm) ranged from 55.16 to 117.38 $cmhr^{-1}$ rising in the second area (tomato plants) from 122.55 to 145.30 $cmhr^{-1}$, to reach the maximum in soil profile No. (5).

The data spot light on two remarks; 1) The importance of spatial variability in irrigation practices and, 2) The urgent need to apply drip irrigation in the experimental site due to high IR values. This finding is in harmony with (Hawas et al., 2004 and Wuest, 2005).

Soil water content distribution:

Data presented in Tables (8a & b) show the soil water distributions determined at five different soil depths (15, 30, 45, 60 and > 60 cm) during the growing season. These data, under olive trees and tomato, Tables (8a &b) indicate that, soil moisture content increased progressively from March to August.

To detect the effect of the variation of available moisture (Tables 2 & 3) on measured soil moisture in the two studied farms (Tables 8a & b), the differences among these values for each month and the average over the whole season, were analyzed for correlation and percent.

Table (8a): Soil moisture (%) under olive trees grown in El-Sheikh Zuwaid region.

Profile No.	Depth (cm)	Mar.	Apr.	May	Jun.	Jul.	Aug.	Moisture %	Available water (mm)
1	0 – 15	7.61	7.69	7.93	8.05	8.33	8.27	7.98	15.70
	15 – 30	7.31	7.40	7.64	7.76	8.05	7.98	7.69	15.41
	30 – 45	7.25	7.34	7.57	7.69	7.97	7.91	7.62	14.88
	45 – 60	7.61	7.69	7.92	8.03	8.32	8.25	7.97	15.41
	> 60	7.42	7.50	7.74	7.86	8.15	8.08	7.79	15.41
2	0 – 15	6.99	7.07	7.30	7.41	7.70	7.63	7.35	15.82
	15 – 30	6.80	6.87	7.09	7.20	7.47	7.41	7.14	15.21
	30 – 45	6.83	6.91	7.11	7.21	7.45	7.40	7.15	15.58
	45 – 60	7.17	7.25	7.45	7.56	7.81	7.76	7.50	16.52
	> 60	7.12	7.19	7.41	7.52	7.79	7.73	7.46	16.08
3	0 – 15	7.59	7.67	7.89	8.00	8.27	8.21	7.94	17.54
	15 – 30	6.44	6.51	6.71	6.82	7.07	7.01	6.76	15.01
	30 – 45	6.91	6.99	7.21	7.32	7.60	7.54	7.26	15.58
	45 – 60	7.09	7.17	7.38	7.49	7.76	7.70	7.43	15.94
	> 60	7.26	7.33	7.55	7.66	7.93	7.87	7.60	16.70
Average		7.16	7.24	7.46	7.57	7.84	7.78	7.51	15.79
r0.05 = 0.497 & r0.01 = 0.623		0.388	0.382	0.366	0.358	0.340	0.344	0.363 ns	

Table (8b): Soil moisture (%) under tomato grown in El-Sheikh Zuwaid region.

Profile No.	Depth (cm)	Mar.	Apr.	May	Jun.	Jul.	Aug.	Moisture %	Available water (mm)
4	0 – 15	7.37	7.50	7.71	8.64	8.54	8.22	8.00	17.03
	15 – 30	7.56	7.70	7.91	8.87	8.76	8.44	8.21	17.57
	30 – 45	6.45	6.57	6.75	7.57	7.49	7.21	7.01	14.97
	45 – 60	7.15	7.28	7.49	8.44	8.34	8.02	7.79	16.90
	> 60	6.64	6.76	6.94	7.74	7.66	7.38	7.19	15.07
5	0 – 15	6.82	6.94	7.12	7.94	7.85	7.57	7.38	15.07
	15 – 30	6.71	6.83	7.01	7.84	7.75	7.47	7.27	14.86
	30 – 45	6.53	6.64	6.82	7.64	7.55	7.27	7.08	14.70
	45 – 60	7.59	7.72	7.93	8.88	8.78	8.46	8.23	17.35
	> 60	6.72	6.84	7.03	7.87	7.77	7.49	7.29	15.22
6	0 – 15	7.33	7.46	7.66	8.58	8.48	8.17	7.95	16.32
	15 – 30	8.05	8.20	8.42	9.43	9.33	8.98	8.74	18.60
	30 – 45	7.28	7.41	7.61	8.51	8.41	8.11	7.89	16.74
	45 – 60	7.27	7.40	7.59	8.48	8.38	8.08	7.87	16.17
	> 60	6.70	6.81	6.99	7.79	7.70	7.43	7.24	14.57
Average		7.08	7.20	7.40	8.28	8.18	7.89	7.67	16.08
r0.05 = 0.497 & r0.01 = 0.623		0.963	0.964	0.966	0.974	0.973	0.971	0.969 **	

From the data, one can work out the following:

a- The olive farm which is an open cultivated area as the covered area by olive trees represents about 34% while the rest is exposed to direct climatic conditions. The correlation coefficient between soil moisture and available moisture variations is insignificant which means that the climatic conditions overcome the soil properties effect on soil moisture readings.

b- Regarding tomato farm which represent 70% covered area, the relation between soil moisture and available moisture variations is highly significant. This means that under similar condition of dense cropping and high plant coverage percent, the spatial variations in soil are more effective than climatic conditions.

Figs. (1 & 2), illustrate, show the variations in average daily soil moisture % measured at all months from March to August for the two studied areas. Those figures show that the lowest soil moisture was obtained diurnally, while the highest average soil moisture was recorded nocturnally.

In addition, for olive farm the fluctuations of soil moisture being higher than those of tomato, which could be attributed to the effect of mid-day (both high wind and air temperature) which overcome the effect of the planned moisture regime. This will undoubtedly raise the water consumption to compensate the water loss under olive trees more than tomato.

Meanwhile, tomato curves (Fig., 2) show slight fluctuations of soil moisture which indicate the dependence of values on the available moisture property rather than the climatic conditions due to the high coverage of plant on soil under these conditions. From these data one can propose the intercropping of tomato within olive farm to avoid the possible loss in soil moisture which will be discussed afterwards.

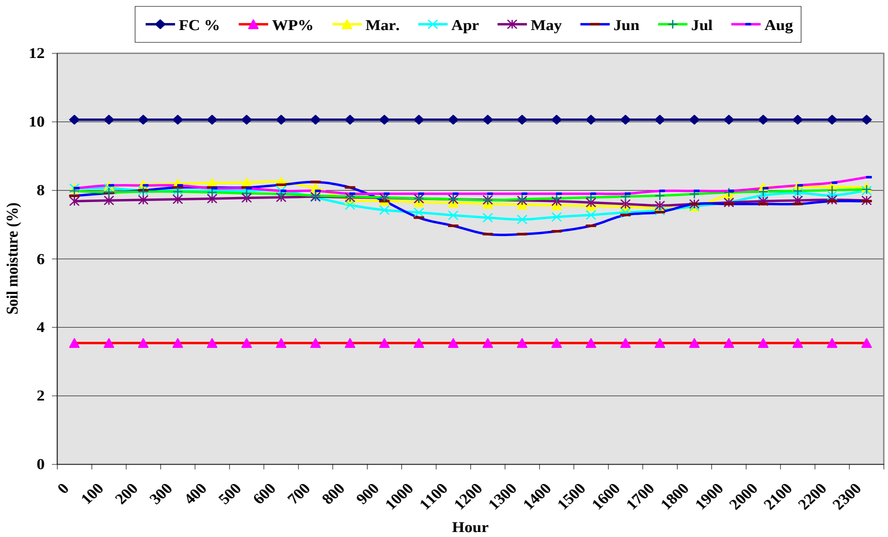

Fig. (1) Daily variations in soil moisture (%) under olive trees grown in El-Sheikh Zuwaid region.

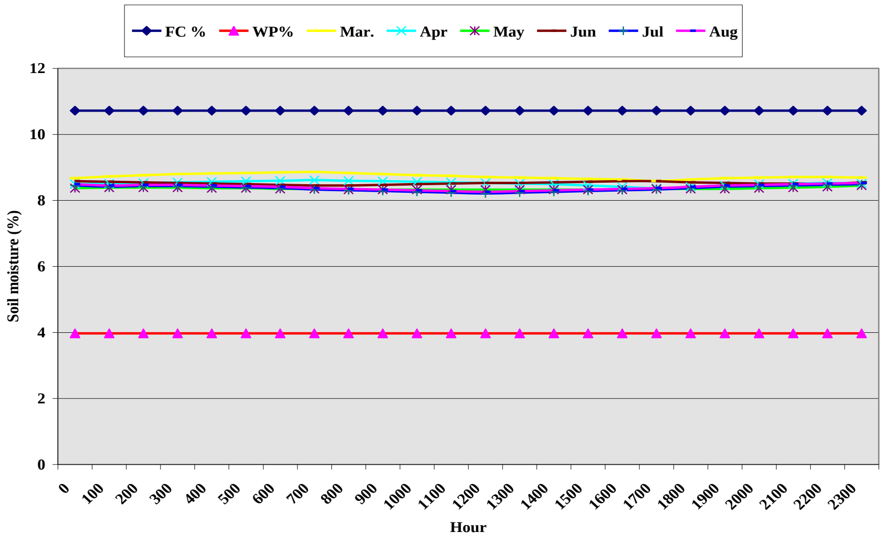

Fig. (2) Daily variations in soil moisture (%) under tomato plants grown in El-Sheikh Zuwaid region.

The data in Table (8c) show the measured soil moisture as depletion percent in randomized selected day over 6 months of the studied growth season.

Table (8c): Actual soil moisture depletion levels (%) of olive and tomato grown in El-Sheikh Zuwaid region.

Month	Mar.		Apr.		May		Jun.		Jul.		Aug.	
Hour	Olive	Tomato	Olive	Tomato	Olive	Tomato	Olive	Tomato	Olive	Tomato	Olive	Tomato
0	30.64	30.36	30.67	33.04	36.47	34.82	34.05	31.71	31.88	33.58	30.67	33.04
100	29.74	29.53	30.67	32.77	36.17	34.51	32.82	31.97	32.56	34.18	29.45	33.61
200	29.18	29.00	31.75	32.50	35.88	34.51	31.60	32.23	32.22	33.88	29.45	33.33
300	28.63	28.49	31.75	32.23	35.59	34.51	30.37	32.50	32.22	33.88	29.45	33.33
400	28.36	28.24	31.75	31.97	35.31	34.82	30.37	32.77	32.56	34.18	30.67	33.61
500	28.10	28.00	31.75	31.71	35.04	34.82	30.37	33.04	32.92	34.48	30.67	33.91
600	27.84	27.76	31.75	31.46	34.76	35.14	29.14	33.33	33.28	34.79	31.90	34.21
700	30.66	27.52	34.82	31.21	34.50	35.14	27.91	33.61	34.02	35.44	31.90	34.82
800	35.77	28.00	38.19	31.46	34.76	35.47	30.37	33.61	34.41	35.77	33.13	35.14
900	36.30	28.49	40.49	31.71	35.04	35.47	36.50	33.33	34.81	36.11	33.13	35.47
1000	36.85	29.00	41.56	31.97	35.31	35.47	43.87	33.04	35.22	36.45	33.13	35.80
1100	37.13	29.27	42.79	32.23	35.59	35.47	47.55	32.77	35.63	36.81	33.13	36.14
1200	37.71	29.80	43.87	32.50	35.88	35.47	51.23	32.50	36.07	37.18	33.13	36.49
1300	38.00	30.08	44.63	32.77	36.17	35.47	51.23	32.50	35.63	36.81	33.13	36.14
1400	38.31	30.36	43.56	33.04	36.47	35.47	50.00	32.23	35.22	36.45	33.13	35.80
1500	38.62	30.65	42.64	33.61	37.08	35.47	47.55	31.97	34.81	36.11	33.13	35.47
1600	38.93	30.94	41.56	34.21	37.72	35.47	42.64	31.71	34.41	35.77	33.13	35.14
1700	39.59	31.55	40.64	34.82	38.39	35.14	41.41	31.71	34.02	35.44	31.90	34.82
1800	38.93	30.94	38.80	34.21	37.72	35.14	37.73	32.23	33.28	34.79	31.90	34.21
1900	33.71	30.36	36.96	33.61	37.08	35.14	37.73	32.50	32.56	34.18	31.90	33.61
2000	30.33	30.08	33.90	33.04	36.47	34.82	37.73	32.77	32.22	33.88	30.67	33.33
2100	30.04	29.80	32.82	32.77	36.17	34.51	37.73	32.77	31.88	33.58	29.45	33.04
2200	30.04	29.80	33.90	32.50	35.88	34.21	36.50	33.04	31.55	33.30	28.22	32.77
2300	30.33	30.08	31.75	32.77	36.17	33.61	36.50	32.23	31.23	33.02	25.77	32.50
Average	**33**	**30**	**37**	**33**	**36**	**35**	**38**	**33**	**34**	**35**	**31**	**34**

Hypothetically, to avoid this behavior of olive farm it is suggested to correct either the depletion level (P) or the crop coefficient (Kc). However, these assumptions will be discussed thereafter in irrigation scheduling part.

Statistically, highly significant positive correlations were found between soil moisture content and both soil temperature and soil heat content for both olive trees and tomato crops. In this regard, Persson and Berndtsson (1998) concluded that water content increased with increasing soil temperature and the temperature dependence of the bulk electrical conductivity, mainly due to continuous cooling of soil by increasing soil water content, thus increasing soil thermal conductivity, which causes some heat trap in soil. Similar results were reported by Seidhom (2001) and (Seidhom *et al.*, 2002).

Soil temperature and heat content:

Soil temperature is considered as one of the important factors controlling plant growth. Instantly, it is important to note that the difference in soil temperature by ± 1 ºC is equal to ± 244 Mega cal/fed down to 15 cm depth of soil having 1.6 Mgm^{-3} bulk density and 0.24 cal/g heat capacity.

Tables (9a & b) give the soil temperature (ºC) over 20 cm depth, under olive trees and tomato, respectively. Data show that soil temperature increased progressively from March to August and has higher values in March to May (+3.1 & +3.53 ºC) and lower values from June to August (-1.28 & – 0.54 ºC) than the average air temperature in olive and tomato trails, respectively.

Table (9a): Soil temperature (ºC) under olive trees grown in El-Sheikh Zuwaid region.

Profile No.	Depth (cm)	Mar.	Apr.	May	Jun.	Jul.	Aug.	Season	Available Water mm
Avg. air temperature (ºC)		**18.05**	**20.09**	**22.25**	**25.30**	**27.66**	**28.42**	**23.63**	
1	**0 – 15**	24.36	24.91	26.40	27.15	28.98	28.57	26.73	15.70
	15 – 30	23.79	24.32	25.78	26.51	28.30	27.90	26.10	15.41
	30 – 45	23.39	23.92	25.35	26.07	27.82	27.43	25.66	14.88
	45 – 60	24.14	24.67	26.15	26.89	28.71	28.30	26.48	15.41
	> 60	24.02	24.56	26.03	26.76	28.57	28.17	26.35	15.41
2	**0 – 15**	22.20	22.69	24.05	24.73	26.40	26.03	24.35	15.82
	15 – 30	20.48	20.94	22.20	22.82	24.36	24.02	22.47	15.21
	30 – 45	21.28	21.76	23.06	23.71	25.31	24.96	23.35	15.58
	45 – 60	23.39	23.92	25.35	26.07	27.82	27.43	25.66	16.52
	> 60	22.25	22.75	24.11	24.79	26.47	26.10	24.41	16.08
3	**0 – 15**	22.82	23.33	24.73	25.43	27.15	26.76	25.04	17.54
	15 – 30	20.94	21.41	22.69	23.33	24.91	24.56	22.97	15.01
	30 – 45	22.08	22.57	23.93	24.60	26.26	25.89	24.22	15.58
	45 – 60	22.25	22.75	24.11	24.79	26.47	26.10	24.41	15.94
	> 60	22.42	22.92	24.30	24.98	26.67	26.30	24.60	16.70
Average		22.66	23.16	24.55	25.24	26.95	26.57	24.85	15.79
r0.05=0.497&r0.01= 0.623		0.393	0.393	0.393	0.393	0.393	0.393	0.393 ns	

Meanwhile, soil temperature values increased significantly with increasing soil moisture during the growing season of both olive and tomato as r = 0.876** and 0.756**, respectively. In some regions many investigators reported that soil temperature give higher values than the average air temperature by about (0.08 - 5.0 ºC) and increased by increasing soil moisture depletion (irrigation interval) and by decreasing irrigation water quantities, Seidhom (2001), (Seidhom *et al.*, 2002), Evon Rizk (2007) and Seidhom (2007). In addition, Nobel and Geller (1987) found that decreasing and increasing the air temperature at 2 m by 10 ºC changed the maximum surface temperature of dry soil by – 5.5 ºC and + 5.4 ºC, respectively.

Table (9b): Soil temperature (ºC) under tomato grown in El-Sheikh Zuwaid region.

Profile No.	Depth (cm)	Mar.	Apr.	May	Jun.	Jul.	Aug.	Season	Available Water mm
Avg. air temperature (ºC)		**18.05**	**20.09**	**22.25**	**25.30**	**27.66**	**28.42**	**23.63**	
4	**0 – 15**	22.87	23.17	23.61	23.91	26.89	25.33	24.30	17.03
	15 – 30	23.01	23.31	23.76	24.06	27.06	25.48	24.45	17.57
	30 – 45	21.81	22.09	22.52	22.80	25.64	24.15	23.17	14.97
	45 – 60	22.73	23.02	23.47	23.76	26.73	25.17	24.15	16.90
	> 60	22.44	22.74	23.18	23.47	26.39	24.86	23.85	15.07
5	**0 – 15**	23.72	24.03	24.49	24.80	27.89	26.27	25.20	15.07
	15 – 30	22.83	23.13	23.58	23.87	26.85	25.29	24.26	14.86
	30 – 45	22.02	22.31	22.74	23.02	25.89	24.39	23.39	14.70
	45 – 60	24.07	24.39	24.86	25.17	28.31	26.66	25.58	17.35
	> 60	23.19	23.49	23.94	24.25	27.27	25.68	24.64	15.22
6	**0 – 15**	24.64	24.96	25.44	25.76	28.97	27.29	26.18	16.32
	15 – 30	25.56	25.89	26.39	26.73	30.06	28.31	27.16	18.60
	30 – 45	23.08	23.38	23.83	24.13	27.14	25.56	24.52	16.74
	45 – 60	22.69	22.99	23.43	23.73	26.68	25.13	24.11	16.17
	> 60	21.74	22.02	22.44	22.73	25.56	24.07	23.09	14.57
Average		23.09	23.39	23.85	24.15	27.16	25.58	24.54	16.08
r0.05 = 0.497 & r0.01 = 0.623		0.675	0.675	0.675	0.675	0.675	0.675	0.675 **	

Concerning the relation between soil temperature and available soil moisture, non significant correlation is obtained under olive, while being highly significant under tomato.

With respect to daily soil temperature, Figs. (3 & 4) present the variations in average daily soil temperature measured for the two areas during all months from March to August. Those figures dictate that the lowest soil temperature was obtained diurnally, while the highest average soil temperature recorded nocturnally. Higher soil water content may be the reason for higher soil temperature.

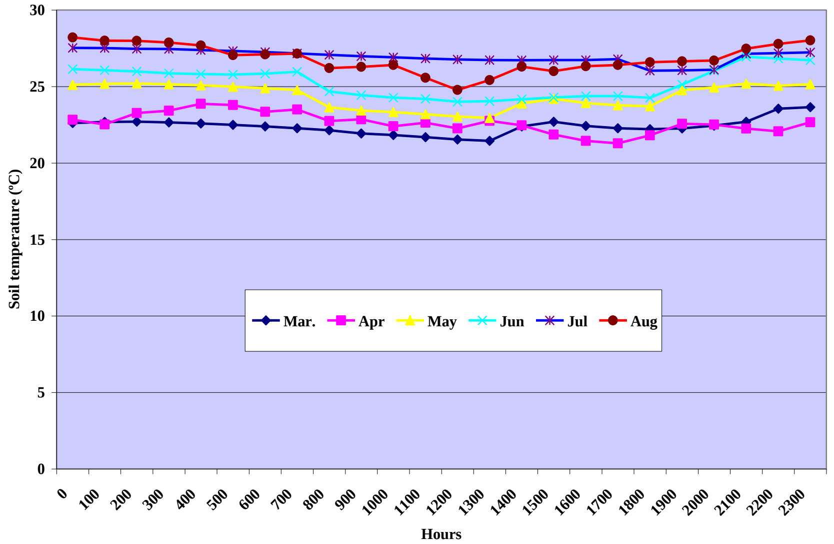

Fig. (3) Daily variations in soil temperature (°C) under olive trees grown in El-Sheikh Zuwaid region.

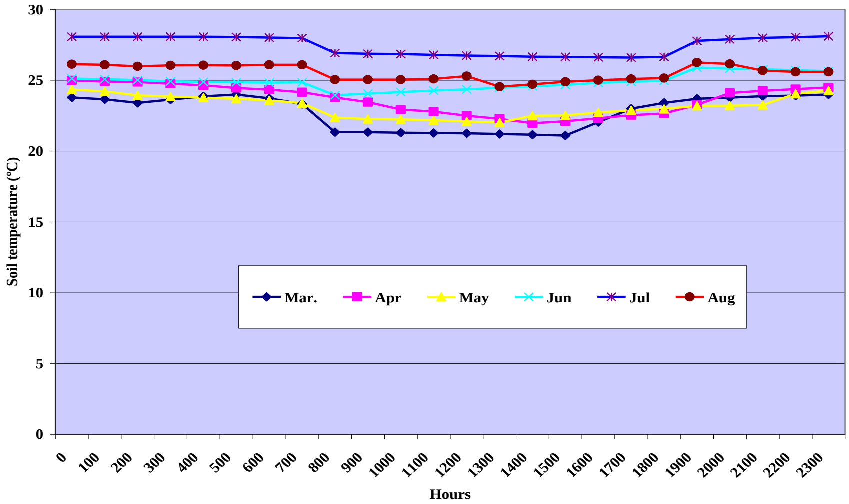

Fig. (4) Daily variations in soil temperature (°C) under tomato plants grown in El-Sheikh Zuwaid region.

Statistically, highly significant positive correlations were found between soil temperature and both soil moisture content and soil heat content for both olive trees and tomato crops.

For the soil heat content, the same trend of soil temperature was observed. Tables (10a & b) give the soil heat content (Mega cal/fed) over five depths, under olive trees and tomato, respectively. The soil heat capacities were almost the same (0.24 and 0.23) cal/g for olive and tomato areas, respectively.

Table (10a): Soil heat content (Mega cal/fed) under olive trees grown in El-Sheikh Zuwaid region.

Profile No.	Depth (cm)	Mar.	Apr.	May	Jun.	Jul.	Aug.	SHC season	ASW (mm)
1	0 – 15	7314	7493	7990	8240	8861	8722	8103	15.70
	15 – 30	7089	7263	7746	7989	8591	8457	7856	15.41
	30 – 45	6959	7130	7602	7840	8431	8299	7710	14.88
	45 – 60	7245	7423	7913	8161	8774	8637	8025	15.41
	> 60	7176	7352	7840	8086	8695	8559	7951	15.41
2	0 – 15	6558	6718	7163	7387	7943	7819	7265	15.82
	15 – 30	6022	6169	6575	6780	7288	7175	6668	15.21
	30 – 45	6263	6414	6834	7046	7569	7452	6930	15.58
	45 – 60	6944	7113	7580	7815	8397	8267	7686	16.52
	> 60	6596	6757	7202	7427	7982	7858	7304	16.08
3	0 – 15	6849	7016	7478	7711	8287	8159	7583	17.54
	15 – 30	6098	6246	6656	6863	7374	7260	6750	15.01
	30 – 45	6510	6669	7110	7332	7882	7759	7211	15.58
	45 – 60	6592	6752	7197	7421	7976	7852	7298	15.94
	> 60	6671	6834	7284	7511	8072	7947	7386	16.70
Average		6726	6890	7345	7574	8141	8015	7448	15.79
r0.05=0.497 & r0.01 = 0.623		0.133	0.133	0.131	0.130	0.128	0.128	0.130 ns	

Table (10b): Soil heat content (Mega cal/fed) under tomato grown in El-Sheikh Zuwaid region.

Profile No.	Depth (cm)	Mar.	Apr.	May	Jun.	Jul.	Aug.	SHC season	ASW (mm)
4	0 – 15	6610	6720	6887	7147	8017	7488	7145	17.03
	15 – 30	6685	6797	6967	7234	8113	7577	7229	17.57
	30 – 45	6148	6248	6400	6627	7435	6950	6635	14.97
	45 – 60	6530	6640	6806	7066	7925	7402	7061	16.90
	> 60	6360	6464	6621	6851	7687	7187	6862	15.07
5	0 – 15	6755	6865	7032	7278	8166	7634	7289	15.07
	15 – 30	6483	6588	6749	6987	7839	7328	6996	14.86
	30 – 45	6221	6322	6476	6703	7520	7031	6712	14.70
	45 – 60	6999	7116	7294	7570	8491	7931	7567	17.35
	> 60	6585	6693	6857	7101	7967	7447	7108	15.22
6	0 – 15	7114	7232	7412	7688	8624	8057	7688	16.32
	15 – 30	7523	7651	7844	8153	9143	8536	8142	18.60
	30 – 45	6655	6765	6933	7189	8065	7535	7190	16.74
	45 – 60	6541	6649	6813	7062	7922	7403	7065	16.17
	> 60	6170	6269	6421	6643	7453	6969	6654	14.57
Average		6625	6735	6901	7153	8024	7498	7156	16.08
r0.05=0.497 & r0.01 = 0.623		0.769	0.771	0.773	0.784	0.783	0.779	0.777 **	

Soil heat content: SHC, Available soil water: ASW

However, despite the highly significant relations among soil heat content and both soil moisture and soil temperature, it seems that the values between both soil heat content and soil temperature going to be perfect (near 1.0) more than with soil moisture.

The relationship between soil moisture as (x) and soil heat content as a (y) under olive trees and tomato: y = 1178.7 x – 1402.8 $R^2 = 0.823$,

y = 676.64 x + 1964.8 $R^2 = 0.722$

The relationship between soil temperature as (x) and soil heat content as a (y) under olive trees and tomato: y = 343.22 x – 1081.9 $R^2 = 0.995$,

y = 360.12 x – 1679.5 $R^2 = 0.975$

Regarding the correlations between soil heat content and available soil moisture under the two studied crops (Tables, 10a &b), non significant relation is apparent under olive area, while being highly significant under tomato area. This in turn, insists on the trend of soil moisture under olive which is somewhat different from tomato area.

From the aforementioned presentation of soil moisture content, soil temperature and soil heat content it seems that the open and exposed cultivation system of olive farm tend to overcome the climatic conditions over soil characters. On the contrary, with tomato the high coverage for soil seems to make soil characters controlling these measures than the climatic conditions.

These findings may be due to the increase in soil water content that caused a small increase in soil temperature and thus soil heat content. For convinces, increasing soil water content from 6.76% to 7.98% (18%) increased the soil temperature from 22.97 to 26.73 ºC (17%) and soil heat content from 6750 to 8103 Mega cal/fed (21%) in olive trail. Also, the increase of soil moisture from 7.01% to 8.74% (25%) increased the soil temperature from 23.17 to 27.16 ºC (18%) and soil heat content from 6635 to 8142 Mega cal/fed (23%) in tomato trail (Tables, 8a,b & 9a,b and 10a,b). The increase in soil temperature due to the increase in soil water content could be related to the thermal diffusivity of sand content which constitute > 90% of this soil. The thermal diffusivity of wet sand is higher than that of dry sand. Another specific reason for this soil is that, the thermal conductivity of wet soil is higher than that of dry soil. These results are in harmony with Seidhom (2001) and (Seidhom *et al.*, 2002).

Spatial Variability

The natural forces of wind and water over geologic time are responsible for the soil deposits overlying bedrock flows that constitute much of fertile irrigated farmlands. The action of wind and water also segregates many of the soil deposits according to particle size. The ability of both wind and water to move soil particles is velocity dependent. Thus, often the heavier sand-sized particles are left behind while the smaller particles are removed and deposited where velocities are decreased because of localized geographical obstructions. The result over geologic time is spatial variability in soil texture. The larger the area of concern, the greater the potential for spatial variability in soil texture. Spatial variability in soil texture results in spatial variability in water retention characteristics because of the close dependency on soil particle size distribution. Thus, soil texture spatial variability can create problems when interpreting soil moisture measurements from a large area for irrigation scheduling decisions (Hawas et al., 2004).

In the experimental area, the water holding capacity varies by about (18 and 25%) across the field of olive and tomato, respectively, due entirely to spatial variability in soil texture. The area of the field with the lowest water holding capacity is the most critical in terms of irrigation system design requirements and irrigation scheduling to avoid crop water stress and leaching of nitrogen below the crop root zone.

Spatial variability in soil texture usually becomes apparent during normal field tillage operations. Significant variations in soil texture show up as differences in draft as tillage operations traverse the field. Spatial differences in surface soil structure and soil color also are good indicators of soil texture spatial variability. The areal extent of soil textural classes often can be determined from soil survey maps and/or aerial photography of bare soil conditions. Dividing the field into water management zones based on soil textural classification provides a basis for locating soil water monitoring equipment. Each water management zone can then receive separate irrigation scheduling if the irrigation system provides such capability, which often is not the case. Theoretically, scheduling irrigations for the area of the field with the lowest water holding capacity should satisfy the irrigation needs of the remaining field area (Bradley and Jeffrey, 2004).

However, in practice this may lead to areas of the field becoming wetter than optimum. In general, scheduling irrigations for the predominate soil texture may become the best solution. Some areas of the field may develop soil water contents through the seasons that are above and below the optimum range for the crop.

Accommodating Spatial Variability:

The influence of soil texture spatial variability on soil water content can be effectively removed by using a site-specific calibration of the soil water monitoring equipment. For irrigation scheduling purposes, the absolute value of soil water content is not important; the relative value with respect to that corresponding to field capacity is of consequence; however, this applies to both stationary and portable soil water-monitoring systems. The important feature of a soil water monitoring system for irrigation scheduling is repeatability and reliability. The key to using any soil water monitoring system is to remove measurement bias that could result from sensor error or soil texture spatial variability by developing a site-specific calibration (s) for the monitoring location (s). This is accomplished by interpreting a specified reading for soil water content relative to the reading for soil water content at field capacity. It is imperative that the sensor reading corresponding to field capacity be determined from actual field measurements and not taken from a textbook or laboratory analysis. The reading for field capacity at a given location can be estimated as that obtained in the spring 12 to 24 hours after a full irrigation. This procedure assumes that drainage is not restricted and that the irrigation is sufficient to replace the soil water deficit at the sensor location in the soil profile. For a soil water monitoring system that uses a sensor that is reasonably accurate (i.e. ±3%) and insensitive to soil texture (i.e. one calibration curve) to determine volumetric soil water content, the difference between the field capacity reading and any other reading can be used directly to determine soil water deficit or available soil water (Warrick, 2003, Bradley and Jeffrey, 2004, Hawas et al., 2004 and Bellingham, 2009).

In this work, the spatial variability in the experimental site had been detected in light of the previous discussion for infiltration and soil moisture measurements.

Irrigation scheduling:

With respect to irrigation scheduling, Giriappa (1983) clarified that the irrigation scheduling is the process of determining when to irrigate and how much water to apply per irrigation, scheduling is essential for the efficient use of water, energy and other production inputs, such as fertilizers and its benefit with other farming activities including cultivation and chemical application. Also, modifying the soil moisture depletion, crop coefficient (Kc) and using mulch techniques improve the water relations (Seidhom, 2001).

Table (11a) shows the irrigation water amounts and irrigation scheduling of olive trees. The data reveal that the variations in irrigation intervals of olive irrigation scheduling at proposed moisture deficit 30% were pronounced during the different stages due to small spatial variability of soil moisture, root depth, potential evapotranspiration and crop coefficient. Also, the table shows the irrigation water amounts during the different growing stages of olive grown in sandy soil in North Sinai. The irrigation intervals varied between 14 to 23 days with average 17 days for total water requirements of 1029 m^3/fed/season by drip irrigation system.

Table (11a): Irrigation water amounts and irrigation scheduling of olive trees grown in El-Sheikh Zuwaid region at proposed depletion 30%.

Sa = 105 mm	Establish	flowering		Yield formation				Ripening	
Stages	**Initial**	**Crop development**			**Mid-season**		**Late-season**	**at harvest**	**Season**
Month	**Mar.**	**Apr.**	**May**	**Jun.**	**Jul.**	**Aug.**	**Sep.**	**Oct.**	
ETo (mm/day)	3.41	4.40	4.99	5.44	5.71	5.54	4.81	3.55	4.73
Growing period (days)	16	30	31	30	31	31	30	31	230
Crop coefficient (Kc)	0.60	0.60	0.60	0.60	0.60	0.60	0.60	0.60	0.60
Moisture depletion (P)	0.30	0.30	0.30	0.30	0.30	0.30	0.30	0.30	0.30
Root Depth (m)	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5
Intervals (days)	23	18	16	14	14	14	16	22	17
Diw (mm/day)	2.17	2.80	3.17	3.46	3.63	3.52	3.06	2.26	3.01
Diw (mm/interval)	49.91	50.40	50.72	48.44	50.82	49.28	48.96	49.72	49.78
Diw (liter/tree/day)	27.34	35.28	39.94	43.60	45.74	44.35	38.56	28.48	37.91
Diw (liter/tree/interval)	628.87	635.04	639.07	610.34	640.33	620.93	616.90	626.47	627.24
Diw (m^3/fed/day)	3.17	4.09	4.63	5.06	5.31	5.14	4.47	3.30	4.40
Diw (m^3/fed)	50.75	122.77	143.63	151.71	164.47	159.49	134.17	102.40	1029.40

Modification of irrigation scheduling:

Referring to the proposed correction to irrigation scheduling depending on the measured soil moisture with olive farm, Tables (11b and c) recalculate the irrigation schedule for two assumptions; i.e., one for modifying depletion level, (Table, 11b), and the other for modifying crop coefficient, (Table, 11c), Doorenbos and Pruitt (1984). From Table (11b) it can be noted that with modifying the depletion level to compensate the deviation in soil moisture (Table, 8c) the irrigation intervals changed than the planned in the experiment.

Table (11b): Modified soil moisture depletion for olive trail to correct the deviations in soil moisture curve.

Month	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Season
ETo (mm/day)	3.41	4.40	4.99	5.44	5.71	5.54	4.81	3.55	4.73
Growing period (days)	16	30	31	30	31	31	30	31	230
Crop coefficient (Kc)	0.60	0.60	0.60	0.60	0.60	0.60	0.60	0.60	0.60
Moisture depletion (P)	0.27	0.23	0.24	0.22	0.26	0.29	0.30	0.30	0.26
Root Depth (m)	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5
Intervals (days)	21	14	13	11	12	14	16	22	15
Diw (mm/day)	2.17	2.80	3.17	3.46	3.63	3.52	3.06	2.26	3.01
Diw (mm/interval)	45.57	39.20	41.21	38.06	43.56	49.28	48.96	49.72	44.45
Diw (liter/tree/day)	27.34	35.28	39.94	43.60	45.74	44.35	38.56	28.48	37.91
Diw (liter/tree/interval)	574.18	493.92	519.25	479.56	548.86	620.93	616.90	626.47	560.01
Diw (m^3/fed/day)	3.17	4.09	4.63	5.06	5.31	5.14	4.47	3.30	4.40
Diw (m^3/fed)	50.75	122.77	143.63	151.71	164.47	159.49	134.17	102.40	1029.40

Table (11c): Modified crop coefficient (Kc) for olive trail to correct the deviations in soil moisture curve.

Month	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Season
ETo (mm/day)	3.41	4.40	4.99	5.44	5.71	5.54	4.81	3.55	4.73
Growing period (days)	16	30	31	30	31	31	30	31	230
Crop coefficient (Kc)	0.65	0.75	0.75	0.80	0.70	0.60	0.60	0.60	0.71
Moisture depletion (P)	0.30	0.30	0.30	0.30	0.30	0.30	0.30	0.30	0.30
Root Depth (m)	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5
Intervals (days)	21	14	13	11	12	14	16	22	15
Diw (mm/day)	2.35	3.49	3.96	4.61	4.23	3.52	3.06	2.26	3.44
Diw (mm/interval)	49.35	48.86	51.48	50.71	50.76	49.28	48.96	49.72	49.89
Diw (liter/tree/day)	29.61	43.97	49.90	58.09	53.30	44.35	38.56	28.48	43.28
Diw (liter/tree/interval)	621.81	615.64	648.65	638.95	639.58	620.93	616.90	626.47	628.61
Diw (m^3/fed/day)	3.43	5.10	5.79	6.74	6.18	5.14	4.47	3.30	5.02
Diw (m^3/fed)	54.96	153.03	179.43	202.14	191.66	159.49	134.17	102.40	1177.27

Regarding Table (11c) the resulted irrigation intervals from Table (11b) were inserted in back calculations to adjust the new crop coefficients with assumption of getting the recommended depletion of 30% from available soil water. Therefore, the resulted Kc values ranged between 0.60 and 0.80 which stood in agreement with Doorenbos and Kassam (1986). Meanwhile, the amount of irrigation water increased from 1029 to 1177 m^3/fed/season.

Data presented in Table (12a) reveal that the variations in irrigation intervals of tomato irrigation scheduling at proposed moisture deficit 30% were pronounced during the different stages due to small spatial variability of soil moisture, root depth, potential evapotranspiration and crop coefficient.
Also, the table shows the irrigation water amounts during the different growing stages of tomato grown in sandy soil in North Sinai. The irrigation intervals varied between 3 to 7 days with average 4 days for total water requirements of 2404 m^3/fed/season by drip irrigation system.

The same scenarios of modifications which applied with olive have been adopted with tomato in Tables (12b & c). However, minor modifications have been achieved either with irrigation intervals or Kc values. Meanwhile, the gross irrigation amount increased from 2404 to 2678 m^3/fed/season.

Table (12a): Irrigation water amounts and irrigation scheduling of tomato grown in El-Sheikh Zuwaid region at proposed depletion 30%.

Sa = 107 mm	Establish	Vegetative	Flowering	Y formation	Ripening	
Stages	Initial	C development	Mid-season	Late-season	at harvest	Season
Month	Mar.	Apr.	May	Jun.	Jul.	
ETo (mm/day)	3.41	4.40	4.99	5.44	5.71	4.79
Growing period (days)	15	30	31	30	14	120
Crop coefficient (Kc)	0.45	0.75	1.15	0.85	0.60	0.76
Moisture depletion (P)	0.30	0.30	0.30	0.30	0.30	0.30
Root Depth (m)	0.15	0.3	0.5	0.7	0.7	0.47
Intervals (days)	3	3	3	5	7	4
D_{iw} (mm/day)	1.81	3.88	6.75	5.44	4.03	4.38
Diw (mm/interval)	5.43	11.64	20.25	27.20	28.21	18.40
D_{iw} (m^3/day)	7.60	16.30	28.35	22.85	16.93	18.40
D_{iw} (m^3/interval)	22.81	48.89	85.05	114.24	118.48	77.89
D_{iw} (m^3/fed)	114.03	488.88	878.85	685.44	236.96	2404.16

Sa: available water,ETo: potential evapotranspiration, D_{iw}: irrigation water amounts

Table (12b): Modified soil moisture depletion for tomato trail to correct the deviations in soil moisture curve.

Month	Mar.	Apr.	May	Jun.	Jul.	Season
ETo (mm/day)	3.41	4.40	4.99	5.44	5.71	4.79
Growing period (days)	15	30	31	30	14	120
Crop coefficient (Kc)	0.45	0.75	1.15	0.85	0.60	0.76
Moisture depletion (P)	0.30	0.27	0.25	0.27	0.25	0.27
Root Depth (m)	0.15	0.3	0.5	0.7	0.7	0.47
Intervals (days)	3	3	2	4	5	3
D_{iw} (mm/day)	1.81	3.88	6.75	5.44	4.03	4.38
Diw (mm/interval)	5.43	11.64	13.50	21.76	20.15	14.50
D_{iw} (m^3/day)	7.60	16.30	28.35	22.85	16.93	18.40
D_{iw} (m^3/interval)	22.81	48.89	56.70	91.39	84.63	60.88
D_{iw} (m^3/fed)	114.03	488.88	878.85	685.44	236.96	2404.16

Table (12c): Modified crop coefficient (Kc) for tomato trail to correct the deviations in soil moisture curve.

Month	Mar.	Apr.	May	Jun.	Jul.	Season
ETo (mm/day)	3.41	4.40	4.99	5.44	5.71	4.79
Growing period (days)	15	30	31	30	14	120
Crop coefficient (Kc)	0.45	0.75	1.30	0.95	0.80	0.85
Moisture depletion (P)	0.30	0.30	0.30	0.30	0.30	0.30
Root Depth (m)	0.15	0.3	0.5	0.7	0.7	0.47
Intervals (days)	3	3	2	4	5	3
D_{iw} (mm/day)	1.81	3.88	7.63	6.08	5.37	4.95
Diw (mm/interval)	5.43	11.64	15.26	24.32	26.85	14.85
D_{iw} (m^3/day)	7.60	16.30	32.05	25.54	22.55	20.81
D_{iw} (m^3/interval)	22.81	48.89	64.09	102.14	112.77	70.14
D_{iw} (m^3/fed)	114.03	488.88	993.43	766.08	315.76	2678.17

Statistically, a highly significant positive correlation was found between available soil water and irrigation scheduling of olive grown in the studied area. Highly significant positive correlation was found between soil moisture, soil temperature and soil heat content as (x) and irrigation scheduling (interval) as a (y) under tomato:

y = 0.228 x – 0.21 R^2 = 0.939**, y = 0.073 x – 0.25 R^2 = 0.455** and y = 0.001 x – 0.10 R^2 = 0.604**, respectively.

These results are in harmony with Chiraz et al. (2010).

Intercropping as a solution for the soil moisture curves problem:

On of the studied solution for the discrepancy between soil moisture curves of olive and tomato is to hypothesize the intercropping of both crops in one site. The re-calculated data for all values of both olive and tomato give significant correlations with available soil moisture values which give impression of success with intercropping of tomato through the lines of olive. The data of both crops sites for soil moisture, soil temperature and soil heat content in relation to irrigation intervals displayed significant correlation as; r = 0.591**, 0.422* and 0.569**, respectively. This result has been confirmed by earlier work of Evon Rizk (2009) who found the superiority of intercropping of been and corn than the single cultivation. At least, intercropping will enlarge the surface roughness values which improve the calculation of consumptive use by any empirical equation like Penman-Monteith (Allen et al., 1998). Also, modifying the soil moisture depletion, crop coefficient (Kc) and using mulch techniques will improve the water relations (Seidhom, 2001). These findings give a vision to the important consideration of this assumption through its application in new experiments to assess the soil moisture results under intercropping system for olive and tomato. The obtained results confirmed the previous findings of Smith et al. (1996), Allen et al. (1998), Pereira et al. (2002), Bellingham (2009) and Khalifa (2009).

Conclusions:

From the previous findings, one can conclude that: soil moisture monitoring is necessary for effective irrigation scheduling. It provides the information needed to ensure that the irrigation schedule is supplying the water needs of the crop while maintaining optimum soil moisture for maximum crop yield and quality. Soil texture has a large impact on actual soil water content values and water holding capacity. The existence of spatial variability in soil texture can create problems when interpreting soil water measurements for irrigation scheduling decisions.

The experiment indicates that the following is needed:

1- Modifying the irrigation schedules depending on the measured moisture curves to avoid stresses on cultivated crops which, in turn, could modify the crop coefficients, so the gross amount of irrigation water.

2- Modifications being great with open fruit orchards like olive, while being minor with tomato or field crops which have great coverage of field.

3- Intercropping has been checked from the available data which give good impression for the expected relations among the studied measurements of soil moisture, available soil water level, soil temperature and soil heat content. From previous works it can recommended with soil mulching which could adjust the moisture profiles especially under olive trees.

REFERENCES

Allen, R. G., L. S. Pereira, D. Raes and M. Smith (1998). In "*Crop evapotranspiration. Guidelines for computing crop water requirements*". Irrig. & Drain. Paper No. 56, FAO, Rome, Italy.

Bellingham, B. K. (2009). Method for irrigation scheduling based on soil moisture data acquisition. Paper originally submitted to and published by the *United States Committee on Irrigation and Drainage*, Irrigation District Conference. Stevens Water Monitoring Systems, Inc.

Bilskie, J. R., R. Horton and K. L. Bristow (1998). Test of a dual-Probe heat-pulse method for determining thermal properties of porous materials. Soil Sci., 163 (5): 346-355, U.S.A.

Bradley, A. K. and C. S. Jeffrey (2004). Spatial variability considerations in interpreting soil moisture measurements for irrigation scheduling. University of Idaho Cooperative Extension System Bulletin 837.

Chiraz, C. M., M. A. Mouna, G. Mohamed, L. Foued, Ben R. Saloua, O. A. Abderrazzek and B. Mohamed (2010). Water relations of olive trees cultivated under deficit irrigation regimes. Scientia Hort., 125: 573–578.

Doorenbos, J. and A.H. Kassam (1986). In: *"Yield response to water*". Irrig. & Drain. Paper No. 33, FAO, Rome, Italy.

Doorenbos, J. and W.O. Pruitt (1984). Crop water requirements. Irrig. & Drain. Paper No. 24, FAO, Rome, Italy.

El-Nawawy, M. M. M. (1986). A study on water & salt movement in some calcareous soils. PhD. Thesis Agric. (Soils), Al-Azhar Univ., Cairo, Egypt.

Evon, K. Rizk (2007). Effect of sowing dates on water requirements of corn grown in Maryut area. Egypt. J. Appl. Sci., 22 (11) 308 – 321, Egypt.

Evon, K. Rizk (2009) Intercropping of kidney bean on corn and its effect on increasing soil productivity per water unit. Environmental Science: an Indian J., 4 (6): 10-19.

Giriappa, S. (1983). Water use efficiency in agriculture. Agricultural development and rural transformation unit. Inst. for Social and Economic Change Bangalore. Oxford & IBH Publ. Co., U.K.

Hawas, N. W., B. Liu, C.W. Boast, P.S.C. Rao, E. J. Kladivko and D.P. Fronzme (2004) Spatial variability and measurement scale of infiltration on an agricultural landscape. Soil Sci. Soc. Am. J., 68 (6): 1818 – 1826.

Khalifa, Q. L. (2009). Perceptive research on irrigation scheduling and water management. PhD. Theses in Irrigation Engineering. Faculty of Engineering. Mehran University of Engineering & Technology, Jamshoro. Pakistan.

Klute, A. J. (1986). Methods of soil analysis. No. (9), *Part 1 - Physical and Mineralogical Methods*. Am. Soc., Agron., Inc. Soil. Sci., Mad., Wisc., U.S.A.

Masmoudi, Ch., M. M. Masmoudi and N. Ben Mechlia (2004). Irrigation de l'olivier: cas des jeunes plantations. Rev. Ezz 10 (1&2), 57–65

Masmoudi-Charfi, C., M. Msallem and M. B. Say (2006). Plantations irriguées d'olivier -Document Technique no. 2. Institut de l'Olivier, p. 7.

Nobel, P. S. and G. N. Geller (1987). Temperature modelling of wet and dry desert soils. J. Ecology, 75: 247-258.

Page, A. L., R. H. Miller and D. R. Keeney (1982). Methods of soil analysis. No. (9), *Part 2. Chemical and Microbiological Properties.* Am. Soc., Agron., Inc. Soil. Sci., Mad., Wisc., U.S.A.

Partington, J. R. (1963). An Advanced Treatise on Physical Chemistry; Vol. III. The Properties of Solids. John Wiley and Sons Inc., New York., U.S.A.

Pereira, L. S., T. Oweis and A. Zairi (2002). Irrigation management under water scarcity. Agric. Water Manag., 57: 175–206.

Persson, M. and R. Berndtsson (1998). Texture and electrical conductivity effects on temperature dependency in time domain reflectometry. Soil Sci. Soc. Am. J., 62: 887-893.

Philip, J.R. (1957a) The infiltration equation and its solution. Soil Sci., 83: 345 – 357.

Philip, J.R. (1957b) The theory of infiltration. 4: Sorptivity and algebraic infiltration equation. Soil Sci., 84: 257 – 268.

Seidhom, S. H. (2001). “Water use efficiency and water economy of some crops as affected by soil heat”. Ph.D. Thesis Fac. Agric., (Soil Science), Zagazig Univ., Egypt.

Seidhom, S. H. (2007). "Effect of moisture deficit and fertilization on sunflower crop grown under calcareous soil conditions". Egyptian J. Desert Res., 57 (1): 55-73, Egypt.

Seidhom, S. H., A. M. Talaat and G. Abdel-Rahman (2002). Environmental factors affecting soil heat and water use efficiency of faba bean in the newly reclaimed area of El-Salheia. Egypt. J. Appl. Sci., 17 (10): 884-907, Egypt.

Smith, M., L.S. Pereira, J. Berengena, B. Itier, J. Goussard, R. Ragab, L. Tollefson and P. Van Hoffwegen (1996). Irrigation Scheduling: From Theory to Practice. FAO Water Report 8, FAO, Rome, 384 pp.

Vermeiren, I. and J. A. Jobling (1980). Localized irrigation: design, installation, operation, evaluation. FAO Irrig. & Drain., Paper 36. Rome, Italy.

Warrick, A. W. (2003). Soil Water Dynamics. Oxford University Press.

Wuest, S.B. (2005) Bias in ponded infiltration estimates due to sample volume and shape. Vadose Zone J., 4(4): 1183 – 1190.

Young, D. R. and P. S. Nobel (1986). Predictions of soil water potentials in the northwestern Sonoran Desert. J. Ecology, (74): 143-154.

J. Soil Sci. and Agric. Eng., Mansoura Univ., Vol. 2 (9), September, 2011

تأثير التوزيع المكاني للرطوبة الأرضية والمحتوي الحراري للتربة علي جدولة ري بعض المحاصيل المنزرعة في منطقة الشيخ زويد - شمال سيناء ، مصر.

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يهدف هذا البحث إلى دراسة تأثير التوزيع المكاني للرطوبة الأرضية والمحتوي الحراري للتربة علي جدولة ري أشجار الزيتون ونباتات الطماطم تحت ظروف الري بالتنقيط في الأراضي الرملية الصحراوية بمحافظة شمال سيناء. أقيمت تجربة حقلية بمزرعة محطة بحوث الشيخ زويد بشمال سيناء بمصر خلال موسم ٢٠١١ حيث قسمت منطقة الدراسة الي نطاقين: (منطقة منزرعة بأشجار الزيتون & ومنطقة مستوية بها نباتات طماطم) ، وكل منطقة مثلت ثلاثة قطاعات ، وكل قطاع يمثل خمسة أعماق ، وتم تحليل التربة بكل الأعماق طبيعيا وكيميائيا ، وأجري ثلاثة أختبارت لنفاذية التربة بكل منطقة ، ورويت التجربة بكمية مياه ري محسوبة طبقا لمعادلة بنمان- مونتيث ، وتم رصد بيانات الأرصاد المناخية ، ومحتوي رطوبة التربة ، ودرجة حرارة التربة وتقدير السعة الحرارية للتربة وحساب المحتوي الحراري بالتربة ، وتم عمل جدولة لري المحصولين ، وتم تعديل الجدولة نتيجة للأختلافات المكانية لرطوبة التربة والمحتوي الحراري للتربة عن طريق إعادة الحسابات بتغيير مستوي الإستنفاذ الرطوبي من الماء الميسر أو تغيير معامل المحصول ، وأقتراح أستخدام نظم تحميل الطماطم علي أشجار الزيتون أو إستخدام تقنيات التغطية تحت أشجار الزيتون لتجنب فقد المياه ، وقد تم تحليل النتائج إحصائيا وكانت النتائج التالية:

١- أظهرت الدراسة أن التغيرات المكانية لمعدل الرشح ظهرت علي النطاق الأفقي لقطاعات الدراسة ، في حين أن خصائص رطوبة التربة تعبر عن التغيرات المكانية علي النطاق العمودي.
٢- يتأثر معدل دخول المياه لسطح التربة بقوام التربة والغطاء النباتي والكثافة الظاهرية للتربة ، وكثافة التربة تؤثر علي نفاذية المياه والأختلافات وصلت للضعف في مزرعة الزيتون ، و٢٠% في مزرعة الطماطم ، وقد أعطي معدل دخول المياه في المنطقة المنزرعة بأشجار الزيتون أقل قيم بينما كان أعلي معدل للمنطقة المنزرع بها نباتات الطماطم.
٣- هناك أختلافات مكانية لمحتوي رطوبة التربة بين الموقعين نتيجة لأختلافات التوزيع الحجمي لحبيبات التربة الممثلة لقوام كل منطقة ، وزاد محتوي رطوبة التربة تدريجيا من شهر مارس الي أغسطس وبزيادة درجة حرارة التربة خلال موسم النمو ، وكان متوسط أقل محتوي لرطوبة التربة خلال ساعات النهار ، ولكن أعلاها سجلت خلال ساعات الليل. وقد زادت تقلبات رطوبة التربة في تجربة الزيتون عن تجربة الطماطم ، لذلك ينصح بتحميل الطماطم علي الزيتون لتجنب فقد رطوبة التربة ، حيث أن التكثيف المحصولي وإرتفاع نسبة كثافة الغطاء النباتي والإختلافات المكانية في التربة أكثر فاعلية عن الظروف المناخية للموقع. أحصائيا هناك إرتباط معنوي قوي موجب بين محتوي رطوبة التربة وكل من حرارة التربة ، والمحتوي الحراري بالتربة لكل من تجربتي الزيتون والطماطم ، بينما كان هناك إرتباط معنوي قوي موجب بين محتوي رطوبة التربة ورطوبة التربة الميسرة في الطماطم فقط.
٤- زادت تدريجيا درجة حرارة التربة من مارس الي أغسطس ، وكانت أعلي من درجة حرارة الهواء من مارس الي مايو ، وأقل من يونية الي أغسطس ، وزادت درجة حرارة التربة بزيادة رطوبة التربة ، ومتوسط أقل درجة حرارة تربة سجلت خلال ساعات النهار ، ولكن أعلاها سجلت خلال ساعات الليل. وقد سلك المحتوي الحراري بالتربة نفس سلوك حرارة التربة. حيث كانت السعة الحرارية ٠.٢٤ & ٠.٢٣ سعر/جرام لكل من تجربتي الزيتون والطماطم علي الترتيب.

٥- كان جدول الري لأشجار الزيتون يتراوح بين فترات ري من ١٤ الي ٢٥ يوم بمتوسط ١٧ يوم والري بكمية مياه ١٠٢٩ م٣/فدان/موسم بالري بالتنقيط ، وقد عدل مستوي الأستنفاذ لتتراوح فترات الري بين ١١ الي ٢٢ يوم بمتوسط ١٥ يوم لنفس كمية مياه الري ، وأيضا عدل معامل المحصول لفترات الري المعدلة ولكن زادت كمية مياه الري الي ١١٧٧ م٣/فدان/موسم ، بينما كان من ٣ الي ٧ أيام بمتوسط ٤ أيام لري الطماطم بكمية مياه ٢٤٠٤ م٣/فدان/موسم بالري بالتنقيط ، وقد عدل مستوي الأستنفاذ لتتراوح فترات الري بين ٢ الي ٥ أيام بمتوسط ٣ أيام لنفس كمية مياه الري ، وأيضا عدل معامل المحصول لفترات الري المعدلة ولكن زادت كمية مياه الري الي ٢٦٧٨ م٣/فدان/موسم.

٦- وجدت علاقة إرتباط موجبة معنوية قوية جدا بين ماء التربة الميسر وجدولة الري في تجربة الزيتون ، وبين كلا من محتوي رطوبة التربة ودرجة حرارة التربة والمحتوي الحراري بالتربة والماء الميسر ، وجدولة الري في تجربة الطماطم. ونظريا وحسابيا بأفتراض أستخدام نظام تحميل الطماطم علي الزيتون وضم النتائج وتحليلها أحصائيا أعطت النتائج إرتباط معنوي موجب لكل القياسات السابقة مع جدولة الري مما يدعم فكرة التحميل.

وتوصى الدراسة بأهمية رصد الأختلافات في محتوي رطوبة التربة نتيجة الأختلافات المكانية للتوزيع الحجمي لحبيبات التربة لأختلافات القوام ، لعمل جدولة للري سليمة للمشاريع الكبري تعطي أمثل إنتاجية للمحاصيل وتوفر في الاحتياجات المائية والسمادية والعمالة وتدر أعلي عائد أقتصادي.

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