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Surface and Subsurface Drip Irrigation Improving to Cultivate Fennel Plants at Old Land in Nile Valley of Egypt

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ABSTRACT

The object of this study is to improve irrigation system in the old land in Nile Valley in Egypt to diminish the water lost in irrigation process by using the systems of Surface Drip Irrigation (SDI) and Subsurface Drip Irrigation (SSDI). The research also, study the effect of previous systems and drought stress on Fennel growth, yield, essential-oil "percentages and yield" and some chemical constituents in two successes seasons. The results showed that in both seasons, SSDI irrigation system increased all characters of vegetative growth, seed yield and essential-oil percentage and yield, compared with the obtained with SDI system. The results also pointed to drought stress inspired a significant decline in all of the growth parameters and the yield of essential-oil at compared with control in SDI system, while the opposite occurred in the SSDI system where 85 % from ETp treatment gave the highest values in growth and essential-oil compared with other treatments. The water productivity (kg/m3) in SSDI system gave the highest values under the same conditions especially at85% of total water applied, in both seasons. Fifteen essential-oil components were recognized about99.81-99.95 % of total contents of essential-oil. The major essential-oil components were Estragol (71.12-75.80 %), D-Limonene (10.18-15.16 %), and Fenchone (5.46-11.45 %).The percentages of these compounds unclear affected by irrigation system and water applied treatments.

Keywords: Subsurface drip irrigation, surface drip irrigation, evapotranspiration, Foeniculum vulgare, Water Requirement, Irrigation Water Productivity

INTRODUCTION

Environmental sustainability and food security concerns due to climate change and population growth have increased awareness about efficient use of irrigation water (Parmoon *et al*., 2019). The defenition of water deficit is one of the most influencing factors on crop productivity and growth in many regions of the world. (Hassan and Ali, 2014). Under drought stress, water potentials in the root zone become sufficiently negative, lead to reduction of water availability which affects the plant growth and development (Chai *et al*., 2016). In Egypt, the water resources are very limited. And also the River Nile is the main water resource; available rate of River Nile water is 55.5 billion m3 /year. With the fast increase in the population and the consequent increases consuming of water in agriculture, industry and domestic use. On the other hand, it is expected that Egypt will develop the new cultivation projects such as East Eweinat, El-farafra and New Valley to increase the agricultural lands in Egypt (Ashour *et al*., 2009). So, efficient utilization of available water resources is very important for Egypt, however, agriculture remains used more than 85% of the total annual water resources. So, one of the most important axes of sustainable agricultural development is conservation and suitable management of scarce water resources (Abd El-Latif and Abd El-Shafy, 2017).

In Egypt, especially at the Delta and the lands of the Valley requires increasing the efficient use of irrigation water to overcome the problem of water shortage. Where, the most of farmers of its using primitive methods of irrigation, fertilization, and weed and pest control practices. The rudimentary methods in irrigation are short furrows enclosed by small basins. This method is inefficient in many respects: (1)flow rates are not regular so, Water is used overmuch; (2) Loses a lot of space and time in building furrows and channels; (3) 10 - 20% of soil is lost in fringe, small canals and furrow ends; and (4) few similarity and distribution of water in irrigation and drainage, water logging, and rising the soil salinity (Gyanendra *et al*., 2016).The use the of subsurface drip irrigation (SSDI) Works on an improvement of irrigation water use efficiency. These systems set water of irrigation directly inside the ground instead of on the surface (Ayars *et al*., 1999). This method reduces the evaporation from the soil surface, where the water is below the soil surface

Most of previous studies that compared and study the crop yield in both subsurface and other different surface irrigation methods decided that, growth and yields of crops in subsurface drip irrigation systems were same to or best than the other systems in all stuides, including different crops, cropping conditions, and soils and also more efficiently for used water and nutrients, and yields and often a significant improvement in the quantity and quality of the crop (Camp 1998;Phene *et al*., 1987and Martínezand Reca, 2014).

Fennel plant (Foeniculum vulgare L.) from Apiaceous Family had stout, aromatic, annual herb (with potency of regeneration). Also, Fennel is an important for

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medicinal which consider as aromatic plant and containing essential oil that has anti-inflammatory, antispasmodic, diuretic, and it analgesic as antioxidant effects. Whereas, it vigor for dyspeptic complaints, flatulence and bloating (Misharina and Polshkov, 2005, Omer *et al*., 2014 and Said-Al Ahl *et al*., 2014).

The volatile-oil for fennel seeds contain about antioxidant, antimicrobial and hepatoprotective activity (Ozbek *et al*., 2003 and Toma *et al*., 2008). Also, this seed possesses anticancer activity (Anand *et al*., 2008). Essential-oil composition depends upon external and internal factors that affecting on growth of plants such as: climate and environmental conditions, season of harvast, age of plants, the stage of ripening of the fruits and genetic data (Rădulescu *et al*., 2009; Omer *et al*., 2014 and Said-Al Ahl *et al*., 2014)

The main objective of this research where; (1) Improve irrigation system in the old land at Nile Valley in Egypt to reduce the amount of water lost during irrigation process using surface and subsurface drip irrigation. (2 Impact study of drought stress on growth, seed yield, essential-oil and chemical constituents under two irrigation systems.

MATERIALS AND METHODS

Experimental Sit

The present-investigation was done at the Private Farm, El Asalta village, Shebin El Kom region, El-Menoufia Governorate, Egypt during two successive seasons of 2016/2017 and 2017/2018 (longitude 31.01.23 E°, latitude 30.30.38N° and elevation above sea level 13m). The texture of soil measured is loamy. the water field capacity is 26%, wilting point of 13%, soil bulk density is 1.403 g/cm^3 and infiltration rate is 1.05 cm/h. The source of irrigation water was being taken from Shebin El Kom sea.

The samples of soil were get before land preparation and the physical and chemical properties of the soil samples were determined On the calculation method of Jackson (1973) and Cottenie *et al.* (1982) as shown in Table 1. The Meteorological data at El-Menoufia Governorate during the two growing seasons are shown in Fig. 1.

Table1. Most mechanical analysis and some chemical properties of experimental site of soil.

Study site				
Direction[a]		North Cairo		
Distance (km)[a]		60		
Mechanical analysis				
Soil depth cm		0:30	30 : 60	60 : 90
Course sand (%)		01.53	02.18	02.5
Fine Sand %		17.64	10.62	11.82
Silt %		42.27	42.51	34.75
Clay %		38.56	44.69	50.93
Texture		Loamy clay	Loamy clay	Clay
Chemical properties				
pH (1:2:5)		7.45	7.52	7.78
EC (dS/m)		1.13	0.85	0.8
Soluble cations, meq/L	Ca^{++}	2.4	1.53	1.45
	Mg^{++}	1.46	1.42	1.35
	Na^{+}	6.6	4.85	4.55
	K	0.84	0.7	0.65
Soluble anions, meq/L	Cl^{-}	7.65	5.75	5.63
	Co_3^{-2}	-	-	-
	$H Co_3^{-2}$	0.6	0.45	0.4
	So_4^{-2}	3.05	2.3	1.97

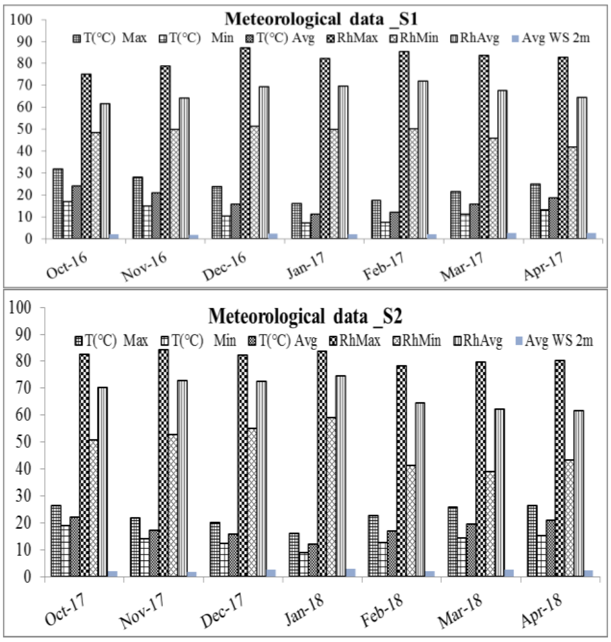


Fig. 1. Meteorological data during the two growing seasons.

The seeds of Fennel (*FoeniculumvulgareL.*) were provided by Medicinal and Aromatic Plants Department, National Research Centre, Dokki, Giza,Egypt.

Experimental Design and Irrigation Treatments

The field experiment was conducted using split plot design with two irrigation system, surface drip irrigation (SDI) and subsurface drip irrigation (SSDI) under three different quantity of irrigation doses: the first dose A (100% of ET_p) and the second dose B (85 % of ET_p) and the third dose C (70% of ET_p) with three replications. The ET_p was estimated by using the Penman Monteith (PM) equation as accepted by the FAO protocol (Allen *et al.*, 1998) for irrigation scheduling according to data we have from a weather station beside our location. The 100% ET_p indicates that the plants were fully irrigated without any water stress throughout the experimental period. The treatment with 85% and 70 % ET_p received only 85% and 70 % related to the irrigation amount applied in the 100% ET_p irrigation. These irrigation levels were performed throughout all the growing seasons for the experimental cycle. Following the most recommendations given by local growers as all water treatments were irrigated on the same day.

Fennel was cultivated in end of October for two seasons 2016/2017 - 2017/2018. The cultivation distances between rows were 0.70 m and 0.25 m between grains in the same row. All rows were irrigated by the method of single lateral line in both of the surface and subsurface drip irrigation plots. The total experimental area was 2100 m^2, (30 m width * 70 m) long for the SDI plots and (30m width * 70 m) long for each plot of the SSDI systems (Fig. 2). Drip lines were the distance between them (1 m) apart. when we look to the case of SSDI we find the lines were placed at a depth of (20 cm) below the soil surface. The Irrigation season of fennel was ended three weeks before harvest. and it's known the Fennel was harvested on the end of May. For all plots and fertilization and weed and pest control applications followed recommendations of the Ministry of Agriculture.

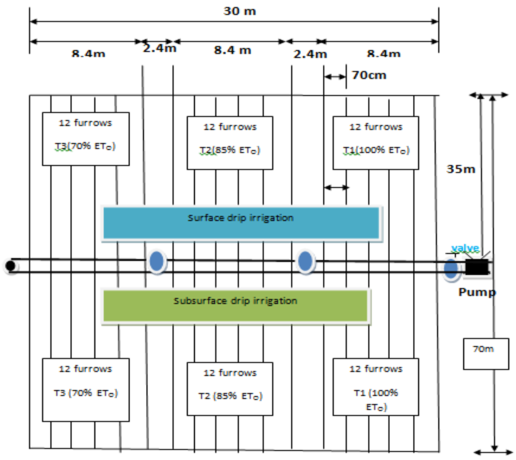


Fig. 2. Lay out of experiment set

Crop evapotranspiration estimation and *Foeniculum vulgare* L. water requirements

We got the meteorological data from Shebin El-kom meteorological station according to the certified data of the Egyptian Ministry of Agriculture in Egypt (Table 2).

Table 2. Average of reference evapotranspiration (mm), and crop coefficients, crop evapotranspiration (mm) under different treatment in two seasons

Month	Days	ETo, mm	Kc	ETc, mm	GWR, m^3/fed./day
		First Season			
Oct-16	10	2.9	0.35	1.02	5.21
Nov-16	30	2.0	0.35	0.69	3.56
Dec-16	31	1.6	0.75	1.17	6.01
Jan-17	31	2.0	1.15	2.32	11.89
Feb-17	28	2.5	1.15	2.92	14.99
Mar-17	31	3.9	1.15	4.48	22.99
Apr-17	30	5.0	0.45	2.25	11.56
		Second Season			
Oct-17	10	3.8	0.35	1.33	6.83
Nov-17	30	2.475	0.35	0.87	4.45
Dec-17	31	2.228	0.75	1.67	8.58
Jan-18	31	2.118	1.15	2.44	12.50
Feb-18	28	3.283	1.15	3.78	19.38
Mar-18	31	4.393	1.15	5.05	25.93
Apr-18	30	5.664	0.45	2.55	13.08

Evapotranspiration reference (ET0, mm/day) was estimate by the Penman_Monteith (PM) equation as appled by the protocol of FAO (Allen *et al*., 1998) for the scheduling irrigation. We find the crop evapotranspiration ET_c can be estimated as:

$$ET_c = K_c \times ET_0 \qquad .... (1)$$

As : (ET_c) refer to the evapotranspiration Crop (mm/day),
(K_c) refer to the Crop coefficient (dimensionless),
(ET_0) refer to the evapotranspiration Reference crop (mm/day).

The Grass water requirement (GWR) measured by following equation (Allen *et al*., 1998) as in Tables 2&3 and Fig. (3)

$$GWR = (ET_o * K_c) * LR * 4.2/Ea \quad ...... (2)$$

As: (GWR) refer to the Grass water irrigate requirement for crop m^3/Fed.day
(K_c) refer to the Crop coefficient [dimensionless]. As well as, the crop coefficient was taken as 0.35, 0.75, 1.15 and 0.45 depend on the day stages, as explained by (Geisenheim Irrigation Scheduling 2017 using the FAO56 PENMAN-Monteith equation).
(ET_o) refer to the Evapotranspiration crop reference [mm/day].
(LR) refer to the Leaching-requirement as a fraction LR (%), assumed as 10% from the total applied water.
(Ea) refer to the Efficiency of irrigation water system, % (Assumed 90% under surface drip irrigation and subsurface drip system).
4.2 is a conversion factor transforming the estimate from millimeters per day to cubic meters per Fadden per day (Feddan = 4200 m^2).

Irrigation Water Productivity, (IWP, kg/m^3).

The productivity of total irrigation water amount (IWP, kg/m3) as it was estimated by (Eid *et al*. 2017)It approved by Pereira *et al*. (2012) to usage as modify of water use efficiency.

$$IWP = \frac{Ya}{TWU} \qquad .... (3)$$

Where: IWP: Irrigation Water Productivity, kg/m^3
Ya: Total yield kg /fed., and
TWU: Total water use, m^3/fed/season.

Essential oil extraction

The extracted of essential-oils were from the seed of all treatments performed by water distillation using Clevenger apparatus for 3 h as ml/100g according to Guenther 1961. Anhydrous sodium sulphate was applied to the extracted-oil and stored at freezer till used for gas chromatography-mass spectrometry (GC-MS) analysis.

GC-MS analysis

The GC-Ms analysis of the essential-oil which extracted from different treatments was performed in the second season by using gas chromatography- spectrometry instrument stands at the medicinal and aromatic plants research, Department National Research Center with the following specifications; TRACE GC Ultra Gas Chromatographs (THERMO Scientific Corp., USA), coupled with a THERMO mass spectrometer detector (ISQ Single Quadruple Mass Spectrometer). The GC-MS system was set with a TR-5 MS column (30 m *0.32 mm i. d., 0.25 µm film thickness).

Analyses were done by using helium as carrier gas at a flow rate of 1.3 ml/min and a split ratio of 1:10 using the following temperature program: 40°C for 1 min; rising at 4°C/min to 260°C and held for 1 min. The injector and detector were held at 210°C. Diluted samples (1:10 hexane, v/v) of 1.0µL of the mixtures were injected. Mass spectra were obtained by electron ionization (EI) at 70 eV, using a spectral range of 40-450 m/z. The identification of compounds was done by matching of their mass spectra with (authentic chemicals, Wiley spectral library collection and NSIT library).

Statistical analysis

Except for the contents of the essential-oil, the data were statistically analyzed as the result of Cochran and Cox (1987), using LSD at level of 5 %.

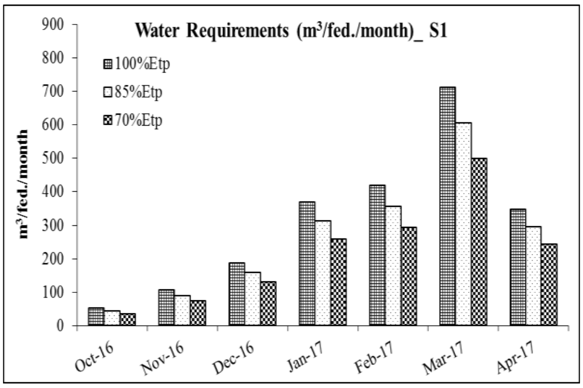
RESULTS AND DISCUSSION

The amounts of irrigation water applied and yield.

The total quantity of water applied during two seasons for different treatments are demonstration in table 3 and Fig. 3. The results showed that the total quantity of applied water was the highest (2594 m^3/fed)at the second season under treatment 100% ET_p, while the lowest values (1535 m^3/fed)were obtained in the first season under treatments 70% ET_p. On the other hand, the quantity of applied water on SSDI were the same quantity to SDI in the same treatment.

Table 3. The total water applied (m^3/fed.), The yield (kg/fed.), The irrigation Water Productivity, (kg/m^3) under different treatment

Type of irrigation methods	The total water applied, m^3/fed			The yield, kg/fed			The irrigation Water Productivity, kg/m^3		
ET_p	**100%**	**85%**	**70%**	**100%**	**85%**	**70%**	**100%**	**85%**	**70%**
				First Season					
SDI	2193	1864	1535	1400	1200	1050	0.64	0.64	0.68
SSDI	2193	1864	1535	1350	1650	1100	0.62	0.89	0.72
				Second Season					
SDI	2594	2205	1816	1208	1100	825	0.47	0.50	0.45
SSDI	2594	2205	1816	1275	1525	950	0.49	0.69	0.52



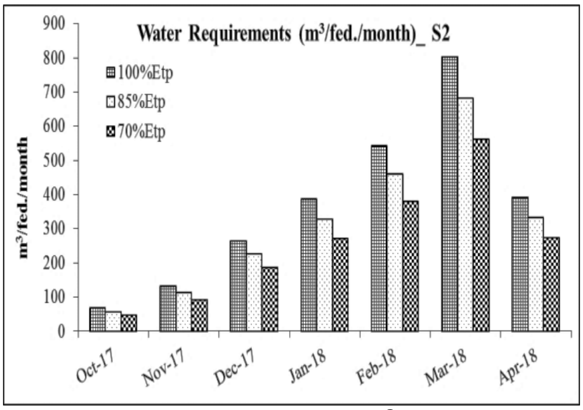


Fig. 3. Water Requirements (m^3/fed./month)under different treatment in two seasons

Irrigation Water Productivity (IWP)

The data presented in table (3) demonstration water productivity data for all treatments. The quantity of applied irrigation water was gaven the higher IWP under SSDI superior values over SDI especially under 85% of total water applied, in the first and second season treatments. Reducing evaporation from the soil surface when using the SSDI and the soil surface is usually drier than SDI. This is due to the fact that the water source is at a certain depth. The quantity of irrigation water productivity ranges between 0.62 to 0.89 kg/m^3 in first seasons and also from 0.45 to 0.69 kg/m^3 in second seasons.

The SSDI methods are the highest values of water productivity were 0.89 and 0.69 kg/m^3 under 85% Total water applied treatment in the first and Second Season treatments respectively.

Also the results can be shown that the irrigation by SSDI method gave the highest values of water productivity where 0.89 and 0.69 kg/m^3 under 85% from total water applied treatment in the first and second season treatments respectively, while the highest values of water productivity in the SDI method were 0.68 and 0.5 kg/m^3 under 70% of total water applied treatment in the first Season and 85% of total water applied treatment in the Second Season treatments respectively.

Irrigation system and irrigation scheduling were impact on Irrigation water productivity (IWP) these results are in accordance with those have got by (Yamac *et al*., 2014).

Variation in growth and yield parameters

The effect of different drip irrigation systems and/or Drought stress on plant height (cm), number of branches/plant, Umbels No./plant, root length, Seed weight g/plant and Seed yield kg/fed during both seasons are shown in Tables 4 & 5 and Fig. 4. Results indicated that, plant height and number of branches/plant, Seed weight g/plant and Seed yield kg/fed were significantly affected by the two irrigation systems (SSDI and SDI) and the irrigation treatments (100 %, 85 % and 70 % ET_p) in both seasons, while Umbels No./plant was insignificantly as affected by drip irrigation systems and water irrigation amounts treatments in both seasons, on the other hand root length (cm) was insignificantly as affected by drip irrigation systems in both seasons and irrigation amounts treatments in the first season, while was significantly influenced by irrigation treatments in the second season.

Regarding to irrigation systems SSDI systems produced the significant highest vegetative characteristics (Plant height (cm), number of branches/plant, Seed weight g/plant and Seed yield kg/acre) during the both tested seasons. Concerning the effect of irrigation amounts treatments, it is clear that irrigation in 85 % ET_p gave the maximum mean values of vegetative characters compared with other irrigation amounts treatments (100% and 70% ET_p) during both seasons, and the irrigation treatments by 100% ET_p came in the second order, while 70% were produced the lowest fennel vegetative characteristics during the both seasons.

The highest average values of Plant height were 152.67 and 147.67 cm, in the first and second season respectively, while number of branches/plant were 13.33 and 13.67 cm in both seasons. On the other hand Seed weight g/plant and Seed yield kg/fed were 66.00 g and 61.00 g and 1650 kg and 1525 kg/fed in the first and second season respectively. The total seeds yield (kg/fed) of fennel plants are presented in table 5. The results indicated that the highest quantity of yield was in SSDI 85% ET_p treatment (1650 and 1525 kg/fed in the first and second seasons respectively), while the lowest values were obtained from SDI 70% ET_p treatment (1050 and 825kg/fed in the first and second seasons respectively).

Table 4. The height of plant and number of branches/plant of *Foeniculum vulgare L.* plant grown under different drip irrigation systems and different treatment of water regime in two seasons

Treatments		The height of plant (cm)						Branches Number					
		First Season			Second season			First Season			Second season		
		Mean		STDV	Mean		STDV	Mean		STDV	Mean		STDV
SDI	A	145.00	±	1.00	141.33	±	4.04	12.33	±	2.52	11.67	±	2.52
	B	143.33	±	3.06	135.33	±	3.06	11.33	±	2.52	10.67	±	2.89
	C	125.33	±	3.06	123.33	±	3.51	10.67	±	2.52	8.33	±	1.53
Mean of SDI		137.89 a	±	2.37	133.33	±	3.54	11.44	±	2.52	10.22	±	2.31
SSDI	A	145.33	±	4.73	137.33	±	5.13	12.33	±	2.31	11.33	±	3.21
	B	152.67	±	3.21	147.67	±	5.03	13.33	±	3.79	13.67	±	3.51
	C	128.67	±	4.16	125.67	±	4.51	11.33	±	3.21	9.33	±	0.58
Mean of SSDI		142.22 b	±	4.03	136.89	±	4.89	12.33	±	3.10	11.44	±	2.43
Mean of Water treatments	A	145.17a	±	2.86	139.33	±	4.59	12.33	±	2.41	11.50	±	2.87
	B	148.00a	±	3.13	141.50	±	4.04	12.33	±	3.15	12.17	±	3.20
	C	127.00b	±	3.61	124.50	±	4.01	11.00	±	2.87	8.83	±	1.05
LSD 5 % Irrigation system		*3.49			3.11*			ns			ns		
LSD 5 % Water treatments		***4.28			3.81***			ns			ns		
LSD 5 % Interaction		ns			**			ns			ns		

A (100% of ET_p) and dose B (85 % of ET_p) and dose C (70% of ET_p), Values are the means ± standard deviation

Table 5. The weight of seed g/plant and the yield of seed kg/Fadden of *Foeniculum vulgare* L. plant grown under different drip irrigation systems and different treatment of water regime in two seasons

Treatments		The weight of seed g/plant						The yield of seed kg/Fadden					
		First Season			Second season			First Season			Second season		
		Mean		STDV	Mean		STDV	Mean		STDV	Mean		STDV
SDI	A	56.00	±	4.00	48.33	±	5.69	1400.00	±	100.00	1208.33	±	142.16
	B	48.00	±	5.00	44.00	±	5.57	1200.00	±	125.00	1100.00	±	139.19
	C	42.00	±	5.29	33.00	±	5.29	1050.00	±	132.29	825.00	±	132.29
Mean of SDI			±	4.76	41.78	±	5.52	1216.67	±	119.10	3133.33	±	137.88
SSDI	A	54.00	±	5.00	51.00	±	6.00	1350.00	±	125.00	1275.00	±	150.00
	B	66.00	±	4.00	61.00	±	4.00	1650.00	±	100.00	1525.00	±	100.00
	C	44.00	±	6.00	38.00	±	5.57	1100.00	±	150.00	950.00	±	139.19
Mean of SSDI			±	5.00	50.00	±	5.19	1366.67	±	125.00	3750.00	±	129.73
Mean of Water treatments	A	55.00	±	4.50	49.67	±	5.84	1375.00	±	112.50	1241.67	±	146.08
	B	57.00	±	4.50	52.50	±	4.78	1425.00	±	112.50	1312.50	±	119.60
	C	43.00	±	5.65	35.50	±	5.43	1075.00	±	141.14	887.50	±	135.74
LSD 5 % Irrigation system		5.06*			* 3.88**			126.66*			97.22***		
LSD 5 % Water treatments		6.20***			* 4.76**			155.13***			119.09***		
LSD 5 % Interaction		*			**			*			**		

A (100% of ET_p) and dose B (85 % of ET_p) and dose C (70% of ET_p), Values are the means ± standard deviation

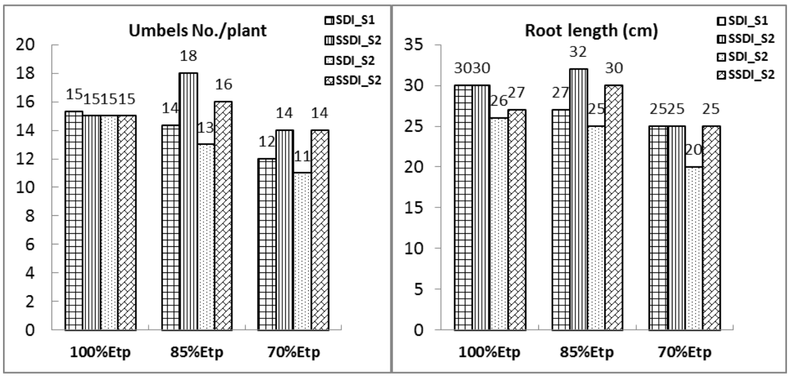


Fig. 4. Umbels No./plant and Root length (cm) of *Foeniculum vulgare* L. plant grown under different drip irrigation systems and different treatment of water regime in two seasons

Under the experimental conditions, the increased vegetative growth parameters under SSDI system might be attributed to the favorable effect of conserving the soil moisture in the effective root zone. These results agreed with those obtained by Abd El-latif and Abd El-shafy (2017) and Sonbol *et al*. (2010) who reported that, highly significant vegetative growth parameters were achieved under drip irrigation treatment, and garlic used most stored water in root zone more than that under surface irrigation treatment.

Essential - oil content (%), yield (ml / plant) and L/fed

The results also showed that essential - oil content (%) and yield (ml / plant and kg/ fed) affected by the drip irrigation systems, irrigation amounts applied and the interaction of both factors Table 6 and Fig. 5. Mean comparison between both drip irrigation systems revealed that the highest essential-oil content (%) and yield (ml/plant or L/fed) were obtained from plants grown under sub surface irrigation system. Concerning the effect of irrigation amounts applied, data presented in the same table indicate that 70 % from ET_p gave the highest mean value of essential-oil content (%) for the 1st and 2nd seasons.The combination treatments between drip irrigation systems and irrigation amounts applied had significant effect on essential-oil percentage during the 1st and 2nd seasons. Generally, plants grown under 70 % ET_p with subsurface irrigation system gave the maximum mean value of essential-oil percentage during both seasons. Concerning the effect of drip irrigation systems, different irrigation amounts applied on essential-oil yield (ml/plant and L / fed) , data tabulated in table 6 indicate that the effect of these treatments gave the same trend almost as shown with essential-oil percentage.

Table 6. Seed essential-oil (ml/plant) and Seed essential-oil (L/fed) of *Foeniculum vulgare* L. plant grown under different drip irrigation systems and different treatment of water regime in two seasons

Treatments		Seed essential-oil (ml/plant)						Seed essential-oil (L/feddan)					
		First Season			Second season			First Season			Second season		
		Mean		stdv	Mean		stdv	Mean		stdv	Mean		stdv
SDI	A	0.77	±	0.05	0.64	±	0.07	19.3	±	1.35	16.07	±	1.83
	B	0.67	±	0.07	0.59	±	0.07	16.8	±	1.75	14.85	±	1.70
	C	0.61	±	0.09	0.46	±	0.07	15.2	±	2.22	11.38	±	1.86
Mean of SDI		2.05	±	0.21	1.69	±	0.22	51.3	±	5.33	42.31	±	5.39
SSDI	A	0.72	±	0.06	0.72	±	0.08	18.1	±	1.40	17.98	±	2.11
	B	1.03	±	0.05	0.88	±	0.07	25.7	±	1.23	22.11	±	1.74
	C	0.70	±	0.09	0.57	±	0.07	17.6	±	2.28	14.250	±	1.86
Mean of SSDI		2.46	±	0.20	2.17	±	0.23	61.4	±	4.92	54.34	±	5.71
Mean of Water treatments	A	0.75	±	0.06	0.68	±	0.08	18.7	±	1.38	17.02	±	1.97
	B	0.85	±	0.06	0.74	±	0.07	21.3	±	1.49	18.48	±	1.72
	C	0.66	±	0.09	0.51	±	0.07	16.4	±	2.25	12.82	±	1.86
LSD 5 % Irrigation system		** 0.071			0.062***			1.80**			1.56***		
LSD 5 % Water treatments		0.087**			0.076***			2.21**			191***		
LSD 5 % Interaction		***			***			**			***		

A (100% of ET_p) and dose B (85 % of ET_p) and dose C (70% of ET_p), Values are the means ± standard deviation

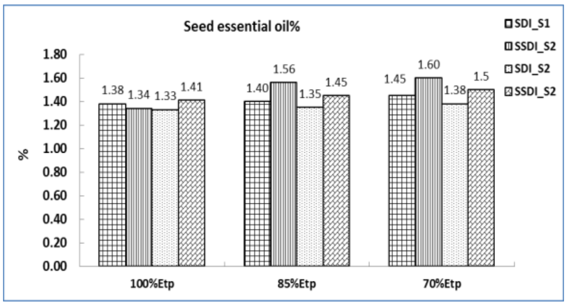


Fig. 5. Seed essential - oil % of *Foeniculum vulgare* L. plant grown under different drip irrigation systems and different treatment of water regime in two seasons

In this case subsurface drip is a high efficiency irrigation system that can use buried drip tubes or drip tape to gave the plants water requirements. Subsurface irrigation reducing loss of water and improves growth and yield by reducing surface water evaporation and reducing the incidence of disease and weeds. A subsurface drip system may be needed to initial high cost, which will vary due to water source, quality, and filtration, soil characteristics and choice of material. Subsurface drip irrigation technologies have been a part of irrigated agriculture since the 1960s, with the technology advancing rapidly in the last two decades. A subsurface drip irrigation system became flexible and can provide frequent light irrigations. This is especially more suitable for arid, semi-arid, hot, and windy areas with limited water supply. Farm operations also become free of impediments that normally exist above ground with any other pressurized irrigation system.

Composition of essential-oils

Fifteen compounds were identified in the essential-oil of all treatments and accounted for more than 99% of the separated compounds by GC-MS. The main constituents of the essential-oil of the different treatments as studied by GC-MSare shown in Table 7 and Fig. 6.

Table 7. Chemical Constitutes of Essential-Oil of *Foeniculum vulgare* L. plant grown under different drip irrigation systems and different treatment of water regime

		Compound name	RT	SDI			SSDI		
				A	B	C	A	B	C
MH	C10H16	α-Pinene	6.95	1.81	1.8	1.82	2.04	2.01	1.78
MH	C10H16	Camphene	7.53	0.08	0.1	0.05	0.08	0.08	0.08
MH	C10H16	Sabinene	8.24	0.48	0.5	0.48	0.51	0.47	0.45
MH	C10H16	β-Pinene	8.45	0.12	0.14	0.13	0.14	0.13	0.13
MH	C10H16	β-Myrcene	8.77	0.24	0.26	0.21	0.26	0.26	0.26
MH	C10H16	α-Phellandrene	9.47	0.11	0.11	0.13	0.12	0.14	0.11
MH	C10H16	D-Limonene	10.32	13.21	10.18	15.16	13.3	12.3	12.4
OM	C10H18O	Eucalyptol	10.48	0.62	1.62	0	1.16	0.36	0.56
MH	C10H16	γ-Terpinene	11.51	0.08	0.15	0.33	0.33	0	0.22
OM	C10H18O	Fenchone	12.94	11.45	11.04	5.46	9.68	10.5	9.02
OM	C10H16O	cis-Verbenol	14.49	0.13	0.05	0.05	0.06	0.12	0.12
OM	C10H16O	Camphor	15.61	0.23	0.27	0.15	0.21	0.25	0.18
OM	C10H18O	Terpinen-4-ol	16.92	0	0.05	0	0	0.05	0
OM	C10H12O	Estragol	17.87	71.12	73.16	75.8	71.81	72.79	74.47
OM	C10H12O	Anethole	19.02	0.25	0.38	0.17	0.25	0.47	0.17
Monoterpene hydrocarbon compound				16.13	13.24	18.31	16.78	15.39	15.43
Oxygenated monoterpenes hydrocarbon				83.8	86.57	81.63	83.17	84.54	84.52
TOTAL				99.93	99.81	99.94	99.95	99.93	99.95

A (100% of ETp) and dose B (85 % of ETp) and dose C (70% of ETp), Values are the means ± standard deviation

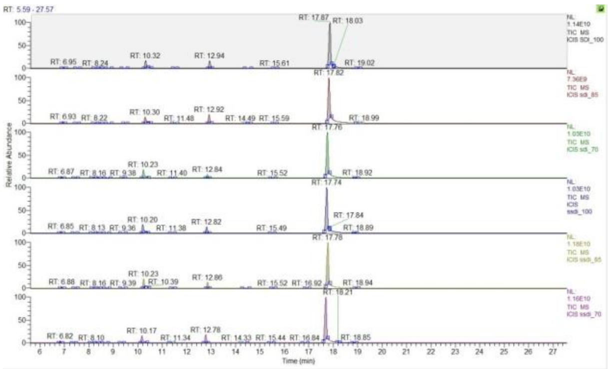


Fig. 6. GC/MS Chromatograms of Fennel plants

The major constituent of essential-oil extracted from all treatments was identified as Estragol (71.12-75.81), followed by D-Limonene(9.02– 15.16%) and then Fenchone (5.46– 11.45%). No considerable differences between the different treatments in the percentage of the major compounds. In other words, no clear trend was observed as a result of different treatments on essential-oil constituents.

CONCLUSION

Based on two years results, it was concluded that subsurface drip irrigation system is more suitable than surface drip irrigation and irrigation amounts applied 85 % from ET_p gave the maximum from growth parameters and essential-oil yield, while irrigation amounts applied 70 % from ET_p gave the maximum from essential-oil percentage.

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تحسين الري بالتنقيط السطحي والتحت سطحي لزراعة نباتات الشمر في الأراضي القديمة بوادي النيل في مصر

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يعد الري بالتنقيط السطحي (SDI) والري بالتنقيط التحت سطحي (SSDI) ذو كفاءة عالية في توفير المياه، ولكن لا يزال غير مستخدم على نطاق واسع خاصة في الأراضي القديمة. لذلك هدفت هذه الدراسة إلى تحسين نظام الري في الأراضي القديمة بوادي النيل في مصر. لتقليل كمية المياه المفقودة في عملية الري وذلك باستخدام النظامي سابقى الذكر. ودراسة تأثير تخفيض كمية مياة الري في كلا النظامين على النمو والمحصول والزيت العطري والمكونات الكيميائية لنباتات الشمر. أوضحت النتائج أنه في كلا الموسمين، زاد نظام الري (SSDI) من جميع صفات النمو الخضري ومحصول البذور ونسبة الزيت العطري ومحصول الزيت العطري مقارنة بنظام الري (SDI). كما أوضحت النتائج أن الإجهاد الناتج عن تقليل مياه الري سبب انخفاضًا ملحوظا في جميع معايير النمو ومحصول الزيت العطري مقارنة مع الكنترول في نظام الري (SDI)، بينما حدث العكس في نظام الري (SSDI) حيث أعطت المعاملة ٨٥ ٪ من البخر نتح (ET_p) أعلى قيم لمعايير النمو ونسبة الزيت العطري والمحصول مقارنة بمعاملات الأخرى. كانت إنتاجية المياه (كجم/م٣) في نظام الري (SSDI) افضل من انتاجية المياه (كجم/م٣) في نظام الري (SDI) تحت نفس الظروف خاصة تحت ٨٥٪ من إجمالي المياه المستخدمة في كلا الموسمين. تم تحديد خمسة عشر مركبا رئيسيا من مكونات الزيت العطري تمثل ٩٩,٨١ - ٩٩,٩٥ ٪ من إجمالي محتوى الزيت العطري. كانت المركبات الرئيسية للزيت العطري هي الاستراجول وتراوحت نسبتة من ٧١,١٢ الي ٧٥,٨٠ % وكان مركب اليمونيين ثاني المركبات الرئيسية وتراوحت نسبة من ١٠,١٨ الي ١٥,١٦ % ثم مركب الفينشون ٥,٤٦ -١١,٤٥ % . ولم تتأثر نسب هذه المركبات بشكل واضح بكلا نظامي الري ومعاملات الري المختلفة.