Effects of Drip Irrigation Water Amount on Crop Yield, Productivity and Efficiency of Water Use in Desert Regions in Egypt

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Abstract

A surbsurface drip irrigation (SDI) system was used to investigate the appropriate irrigation water schedules in open fields and greenhouse for different vegetables. The study investigated and analyzed different pipeline material, spacing between emitters, and soil profile. Also, it investigates the effects of soil type and climate on water consumption. Two (2) Enviroscan sensors were installed to measure the soil moisture. Also, two (2) weather stations were installed to measure the climate parameters. The crop evapo-transpiration and the amount of irrigation water were determined using software based on Penman–Monteith approach. The FAO guidelines were used as a reference. The obtained climate and crop growth parameters were analyzed and the crop water use (which was simultaneously adjusted by the moisture graphs of the Enviroscan) was determined. These determined values were used to develop an appropriate schedule for water use and for crop production in order to ensure sustainable water management. The results revealed that there was a significant increase in crop productivity by 18% when the proposed SDI system is used over the normal drip irrigation system.

***Key words**:* Subsurface Drip Irrigation, agriculture, Water Efficiency, crop productivity

1. INTRODUCTION

Irrigation represents 85% of the water consumption in developing countries and 62% in developed countries [1]. Use of SDI decreases the amount of irrigation water more than conventional drip irrigation.

In Egypt, surface irrigation is used. This results in wasting 40% of the total irrigation water. The Egyptian government had thus set rules to forbid surface water irrigation in the new reclaimed lands. Most of these lands use sprinkler and drip irrigation. SDI is relatively a new technique in Egypt. Egyptian farmers should know this technique and its advantages. They should also be aware that its high revenue (i.e. increase of crop yield, decrease of diseases and increase of water efficiency) can compensate its disadvantages (i.e. high initial costs and difficult installation).

This study was thus initiated in order to determine the effects of different SDI systems and irrigated water quantity on the yield, quality and evapo-transpiration of plants; as well as to choose the optimum subsurface drip irrigation scheduling for vegetables in order to minimize the water consumption, salt distribution and increase the crop yield. This is done by regulating these parameters using moisture soil sensors and weather stations placed in the fields of the experiment at El-Adlia farm, Belbeis, Sharkia governorate, Egypt. The research is conducted in Sekem farm, *Belbeis,* Sharkia Governorate, Egypt, as a part of the Subsurface Project funded by the Industrial Modernization Centre (IMC). Sekem farm follows the organic agriculture rules in crop production.

2. PRESVIOUS STUDIES

Several researches investigated the SDI system and other irrigation systems. B. Hanson, D. May (2004) showed that the production of tomatoes increased when SDI was used. It also stated that the crop yield of lettuce increased when furrow and subsurface drip methods were used, while it decreased when surface drip method was used.

B.R. Hanson, L.J. Schwakl, K.F. Schulbach, G.S. Pettygrove, (1997) indicated that the consumed water in the drip method is 40% less than the consumed water in the furrow method. While .M. Selim, A.A. Mosa, A.M. El-Ghamry (2009) indicated that the SDI is more efficient than surface drip irrigation in terms of enhancing nutrients concentration in tubers, soil fertility after harvesting.

Camp C R; Lamm F R; Evans R G; Phene C J (2000) argued that SDI has many advantages such as: minimizing soil water evaporation and nutrient leaching; maintaining a uniform water distribution resulting in greater control of the irrigation water and nutrients; increasing the adaptability of livestock wastewater disposal; reducing deep percolation losses that can decrease ground water pollution; and increasing flexibility to match various soil type and plant rooting depth. It also declared that the factors affecting SDI uniformity are: emitter clogging, root intrusion, root pinching, mechanical and pest damage, soil overburden and compaction, soil hydraulic parameters, and, possibly, system age.

Freddie R. Lamm and Carl R. Camp (2007) stated that a typical SDI system often requires additional components, compared to surface drip irrigation. SDI provides more consistent soil water and nutrient environment for optimum crop growth. On the other hand, SDI has some disadvantages in some regions, such as salinity management, soil water redistribution, and application of some agrochemicals. Jose´ O. Payero, David D. Tarkalso, Suat Irmak, Don Davison, James L. Petersen (2008) mentioned that the good relationship between crop performance indicators and seasonal ET_c demonstrates that accurate estimates of Et_c on a daily and seasonal basis can be valuable for making tactical in-season irrigation management for strategic irrigation planning and management. Zhi Wang, Dawit Zerihun, Jan Feyen (1995) stated that a general efficiency performance index is defined as the ratio of crop transpiration to the sum of the volume of applied water and the volume of deficit. This index combines the characteristics of traditionally used irrigation efficiencies: application efficiency, storage efficiency and the Christiansen's coefficient of uniformity. The relationships between these indices were also presented using a transpiration fraction which is defined as the ratio of transpiration to evapo-transpiration. J.M. Blonquist Jr., S.B. Jones, D.A. Robinson (2006) mentioned that the electromagnetic measurements of apparent permittivity with transmission line sensors provide a mean to estimate volumetric soil water content, and therefore storage within the plant root zone, and directly infer evapo-transpiration for use in irrigation scheduling. This is a useful irrigation research tool for estimating dynamics and predicting future conditions based on known inputs. Inferring the amount of water draining below the plant root depth is demonstrated as well as how soil moisture content may vary with the sensor burial depth.

Researches on SDI systems were also conducted by scientists at the Water Management Research Laboratory over a period of 15 years. The data are presented for irrigation and fertilization management on tomato, cotton, sweet corn, alfalfa, and cantaloupe for different field applications. The research indicated that the yield and water use efficiency increase. Other studies demonstrated that after 9 years of SDI system operation, it was as good as the time of installation if the management procedure was followed to prevent root intrusion, J.E. Ayars et al. (1999). An experiment in a solar greenhouse was conducted to determine the optimum irrigation frequency and quantity for cucumber under subsurface drip irrigation based on evaporation from a 20 cm diameter pan placed above the crop canopy. Two irrigation intervals and three plant pan coefficients were compared. The experiment showed that the crop evapo-transpiration (ET) and fruits yield increased by increasing irrigation water, Campbell Sentek EnviroSMART EasyAG SDI-12 Manual v 3.4, (2006).

3. DESCRIPTION OF THE STUDY SITE

A study site was chosen to carry on the present investigations. This was at El-Adlia Farm in Belbis (30°25'3"N and 31°33'50"E), Sharkia Governorate. The study site is nearly five feddans in the Nile Delta in Egypt,Figure (1).

Figure 1: Study site location in the Nile Delta in Egypt

4. METHODOLOGY

Field investigations were designed and executed. The field work covered a field of nearly five feddans. This is attributed to the fact that this area would be sufficient to install and test various system components and various soil composition. The experimental work proceeded as follows:

The subsurface drip irrigation system was installed, incorporating a fertigation and filtration system, pressure regulators, air relief valves, pressure gauges, main lines, sub-mains, laterals, connectors, and line end-caps.

A moisture monitoring system was installed. It composed of two soil moisture sensors with transmitter and receiver to send continuous soil water monitoring graphs. Two weather stations were placed. One was placed in the open field and the other was a mini station in the greenhouse. Three different pipelines materials were tested (GR drippers, Leaky and flexible pipes) to choose the most suitable material. Drip tape (subsurface laterals) was installed with a tractor in the open field and manually in the greenhouse. The SDI system is subjected to monitoring and testing schemes with the purpose of tuning and assessing the uniformity of soil water and crop productions. A GR surface drip irrigation plot was set-up, as a control for the different SDI plots, in the open field and greenhouse. Subsurface drip irrigation systems were installed at two fields (2.4 feddans) and one in the greenhouse (1.5 feddans) with the control plot GR surface drip irrigation system. The effect of water use efficiency for both surface and subsurface drip system was investigated with its impacts on moisture and salt distribution in the soil profile. The subsurface irrigation system in the greenhouse was transplanted for pepper crop, while tomato and eggplants are transplanted in the open field area. The two moisture soil sensors Enviroscan were installed at the DI and SDI systems in the open field to control the irrigation water quantity with time and investigate the output graphs at different depths of the sensors (10, 20, 30, 40, and 50cm). Soil samples were collected at different depths of the different plots to analyze the soil profile to a depth of 75 cm. Each 15cm, the physical characteristics and chemical properties were determined. Two agro-metrological stations where installed in El Adlia farm that give real time reading. The main weather station located in the open field with 5 sensors to measure; solar energy, rainfall, relative humidity, temperature, and wind speed. The second is a mini-weather station installed in the greenhouse to monitor the weather inside. Water samples were collected from the two irrigation sources to Aldlia to determine their chemical properties. The irrigation system in El Adlia farm is initially designed to apply groundwater for irrigation, but due to the expansion in the cultivated areas within the last years, the Sharkia Governorate accepted to supply the farm partially with Nile water sub-branch on shift basis depending on water availability. So, now two sources for irrigation exist in the farm: Groundwater, from two wells (no.7 and 8), and surface Nile water supply which is used whenever available.

At the end of May 2009, the different crops (tomato, eggplants and pepper) were harvested. Random samples of plants from each vegetable crop were collected monthly to measure the growth of root distribution in the soil and its length, the number of leaves, flowers, and fruits. The fertilizers applied were all organic and the schedule of quantities and application times were set based on the monthly analysis of the soil and plants needs.

Fresh fruits of each studied vegetable crop were harvested at proper maturity stage and weighted in each harvest to calculate the total yield per feddan. The soil samples were analyzed and the physical properties were determined. The percentage of particle size, field capacity, permanent wilting point, available water and bulk density were determined according to Peterson and Calvin [14], standard methods. The results are given in (table (1).

Table 1: Physical properties of the soil samples

	Depth (cm)	Field capacity (% by weight)	Permanent wilting point (% by weight)	Available water (% by weight)	Bulk density (gm/cm^3)
Open Field	15	13.2	6.8	6.4	1.29
	30	12.9	6.5	6.4	1.39
	45	12.9	6.6	6.3	1.32

	60	13	6.7	6.3	1.28
	75	13.3	6.8	6.5	1.28
Greenhouse	15	13.2	6.7	6.5	1.24
	30	13.3	6.2	7.1	1.35
	45	12.8	6	6.8	1.38
	60	13.8	6.2	7.6	1.31
	75	13.6	6.7	6.9	1.33

Also the chemical properties of the soil samples were determined at the American University laboratory at Cairo. The results are given in Table 2. It is to be noted that the soil salinity or accumulation of salts in the surface zone has different sources, which vary with different geological and climatic conditions. Natural sources are due to clearing of native vegetation (dry land salinity), or due to irrigation system applied.

Table 2: Chemical properties of soil samples at different depths (0-75cm)

PROPERTIES	OPEN FIELD					GREENHOUSE				
	0-15	15-30	30-45	45-60	60-75	0-15	15-30	30-45	45-60	60-75
EC (dS/m)	3.5	2.3	2.3	2.1	5.0	3.8	2.6	2.8	2.0	5.7
Ca++	6.9	4.1	4.7	4.0	12.8	7.9	5.35	5.5	4.5	17.0
Mg++	6.1	3.7	4.1	3.5	6.9	7.1	4.65	4.5	4.0	7.1
Na+	22.0	14.6	14.0	13.3	30.0	23.0	15.5	18.0	12.0	33.3
K+	0.74	0.76	0.75	0.7	0.79	0.74	0.72	0.74	0.75	0.77
HCO-3	4.9	4.7	4.9	4.6	5.0	4.9	4.6	4.7	4.9	5.3
Cl-	21.1	12.9	12.5	12.3	29.5	21.1	13.1	16.5	12.5	30.1
SO-4	9.74	5.56	6.15	4.6	15.99	12.7	8.52	7.54	4.25	22.7

The climate of Egypt is arid with an average annual rainfall of 40 mm, falling during the winter months (November-January). The average monthly minimum and maximum temperatures are 8°C and 40°C, respectively. The mean monthly minimum and maximum relative humidity are 40% and 70%, respectively. Table (3) shows the average monthly climate parameters of El Adlia farm in Belbis within the cultivation seasons as measured from the main weather station.

Table 3: Metrological data for El Adlia farm

	TEM	RH%	SOLAR ENERGY	WIND SPEED	WIND SPEED
Aug.	27.1	63.9	310.2	1.70	0.47
Sep.	25.9	61.7	250.6	1.90	0.52
Oct.	24.0	63.1	184.9	1.40	0.39
Nov.	21.8	56.8	172.0	1.80	0.50
Dec.	15.3	66.2	134.8	1.80	0.50
Jan, 9	13.5	59.4	147.8	2.35	0.65
Feb.	14.8	51.4	198.4	3.13	0.86
Mar.	15.9	52.3	251.2	2.70	0.75
April	19.9	55.6	290.9	2.30	0.63
May	22.8	50.9	319.6	2.50	0.64
June	27.3	51.7	357.8	2.10	0.58

The water samples were analyzed. The results are given in table (4).

Table 4: chemical properties of water irrigation & pumps characteristics

IRRIGATION WATER SOURCE	CHEMICAL PROPERTIES		*PUMPS CHARACTERISTICS*		
	EC (dS/m)	pH	Power (Horse)	Q (m^3/h)	*Pressure (bar)*
Canal	0.378	8.0	50	120	*2.7*
Well 7	1.388	7.6	20	27.5	*2.2*
Well 8	*1.04*	*8.3*	*15*	*15.6*	*2.2*

Tomato Nemastar variety and Eggplant Patra variety are planted during 7-10 November 2008 and are harvested by the end of May 2009. The two crops are transplanted in two opposite fields, each with an area of (30x40 = 1200m^2). They were divided into four plots: one control plot surface drip irrigation using GR pipelines, and three subsurface plots each with different laterals types (Tuporex, Eolose, and T-tape). The plot is planed in 20 ridges with one lateral in the center of each ridge, 40m length, and 1.5 m apart, Fig. (2). Plant capacity of tomato is 6930 unit/feddan, while that of eggplants is 7700 plants/feddan.

Figure 2: Irrigation setup in the field

For the greenhouse, pepper variety Kapino is cultivated during 5-7 August 2008 and are harvested at the end of May. The greenhouse experimental area is divided into 10 main plots, 2 opposite with control surface drip GR lines, and the remaining plots are subsurface drip irrigation system divided into 4 plots Eolose and 4 plots with Tuporex laterals. The surface area of each plot is (15.4x38 = 585.2 m^2) divided into 20 ridges, 38 m length and 75cm apart. The capacity of plants is 17500plants/feddan.

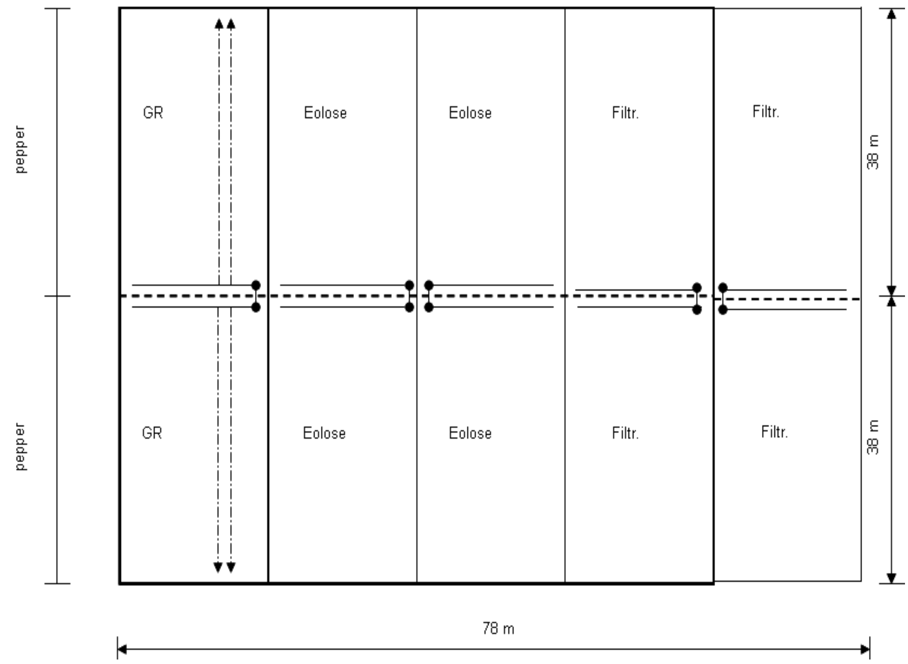

Figure 3: Irrigation setup in the greenhouse

The organic fertilizer system for the farm consists of a mixing basin for composting followed by two filters systems: sand system (5 units each 45 m^3/h) and screen system (6 units each 35m^3/h). The main pipelines are PVC of 155mm diameter connected to 125mm sub-main pipes conveying into 75mm till it reaches the plots with the 50 mm supply lines to the laterals. The laterals used in surface drip system are GR 16 mm diameter with 30 cm apart emitters discharging 4 l/hr at 1.0 bar operating pressure. The pipelines used for subsurface system are 18 mm diameter, discharging 4 l/hr at 1.0 bar with different emitters spacing: 30cm in Eolose and T-tape, while for porous tuporex pipes no emitters are found as water is discharging along all the length of the pipelines with 6 l/hr/m at 1.5 bar operating pressure. Distribution losses occur mainly due to connections and operational losses that flow directly from the filtration, and distribution system into the field network.

In the office, the following was executed: Substituting in the FAO formula with the climate measured parameters and crop coefficients, the evapo-transpiration for crop (ET_c) are calculated using Cropwat software [13]. It is to be noted that the FAO developed practical procedures to estimate crop water requirements and yield response to water stress as widely accepted standards in the planning and management of irrigated agriculture, S. Metin Sezen, Attila Yazar, Salim Eker (2006) . They show the output graphs of the Enviroscan were used to monitor the soil moisture contents in the root zone of the crops. They provide data to the soil water at different depths. By coupling the two methods of calculating and measuring soil moisture needs and contents, an accurate irrigation schedule was obtained. Daily water irrigation needs are estimated using climate data measured and the different crop characteristics observed and estimated in the FAO tables (crop coefficient, Kc and plant cover, p) in order to calculate the Crop evapotranspiration (ET_c), which is approximately equal to these needs. This calculation is done using Cropwat program which is a decision support system developed by the Land and Water Development Division of FAO. Its main function is to calculate reference evapotranspiration, crop water requirements, and crop irrigation requirements and to develop irrigation schedules under various management conditions. The computer program calculated daily ET_c and the water balance in the crop root zone using the procedure described in FAO-56. The ET_o calculated using the weather data as input to the Penman–Monteith equation and the K_c used to adjust the estimated ET_o for the reference crop to that of other crops at different stages and growing environments Jose´ O. Payero et al. (2008).Weather data were obtained from the two weather stations installed in the study area, the main one is located at the open field, Figure (4), while the mini-weather station in the greenhouse. These weather stations have five sensors (i.e., solar energy, wind, rainfall, relative humidity, and temperature).

Figure 4: Photos of the Mini and Main weather stations & soil water tubes

The data obtained by the Enviroscan sensors is collected by a central logger and is downloaded through a cable to the laptop. The Enviroscan Plus installed in the field combines the proven sensor technology of the soil water monitoring solution, with the latest in web compatible and wireless communication solutions, Campbell Sentek EnviroSMART EasyAG SDI-12 Manual v 3.4, (2006). It is to be noted that the Enviroscan is a complete, continuous soil moisture monitoring solution. Figure (5) shows the used Enviroscan probe in a schematic view. It has 5 main sensors at 10, 20, 30, 40 and 50 cm depth respectively to measure the water soil content precisely at these different depths in order to determine the active root zone effectively. Enviroscan utilizes GPRS communication to send soil water data from the probe to the users PC via the Internet.

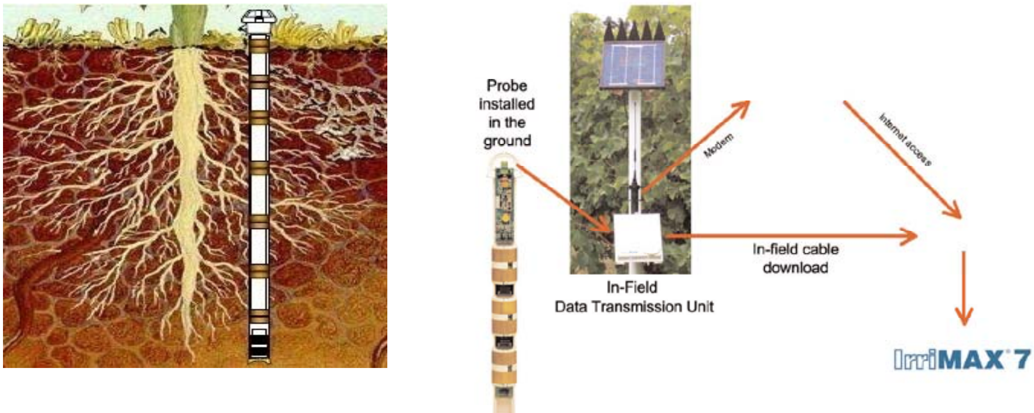

Figure 5: Enviroscan installation and operation (source: IrriMAX7 manual)

5. RESULTS AND DISCUSSION

Figures (6 and 7) show samples of data output of the two Enviroscan installed in the open field cultivated with tomato at GR surface system and Eolose subsurface system, respectively. In the upper part of the graph, the soil moisture curves for each sensor is drawn, any changes in these curves identify the water movement at the relative depth of the sensor. From that it can be concluded that there is no water movement deeper than 20 cm in GR system (figure 6), while in the Eolose system there is a water movement at 30 cm and 40 cm. This is normally interpreted due to the embedded irrigation system at 15 cm below surface in the SDI system, so the wetted depths recorded are 40cm in SDI while only 20cm in GR respectively. This moisture is at the different sensors' depth. The lower part of the graph indicates the average soil water movement for the five total depths. The upper and lower edges represent the field capacity and welting point respectively, so the water irrigation amounts should always be kept in the intermediate green part, as this is the water that can be used by the plants easily as shown in the figures.

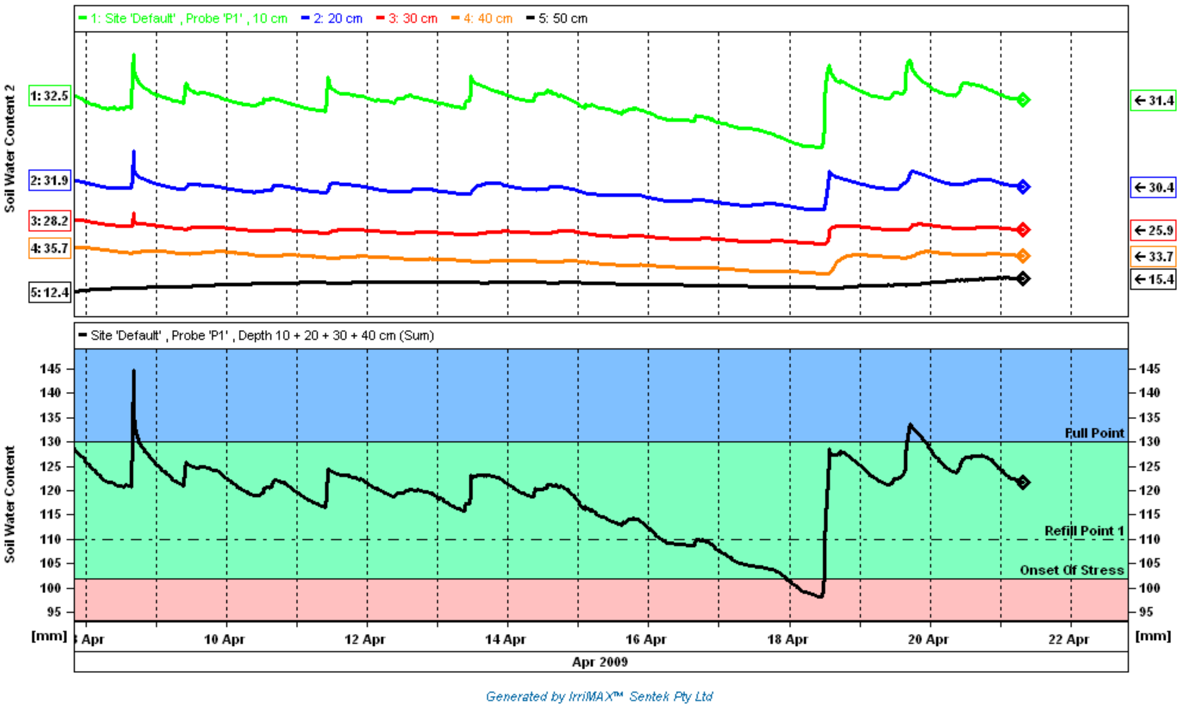

Figure 6: Enviroscan output graph from sensor installed in GR tomato field

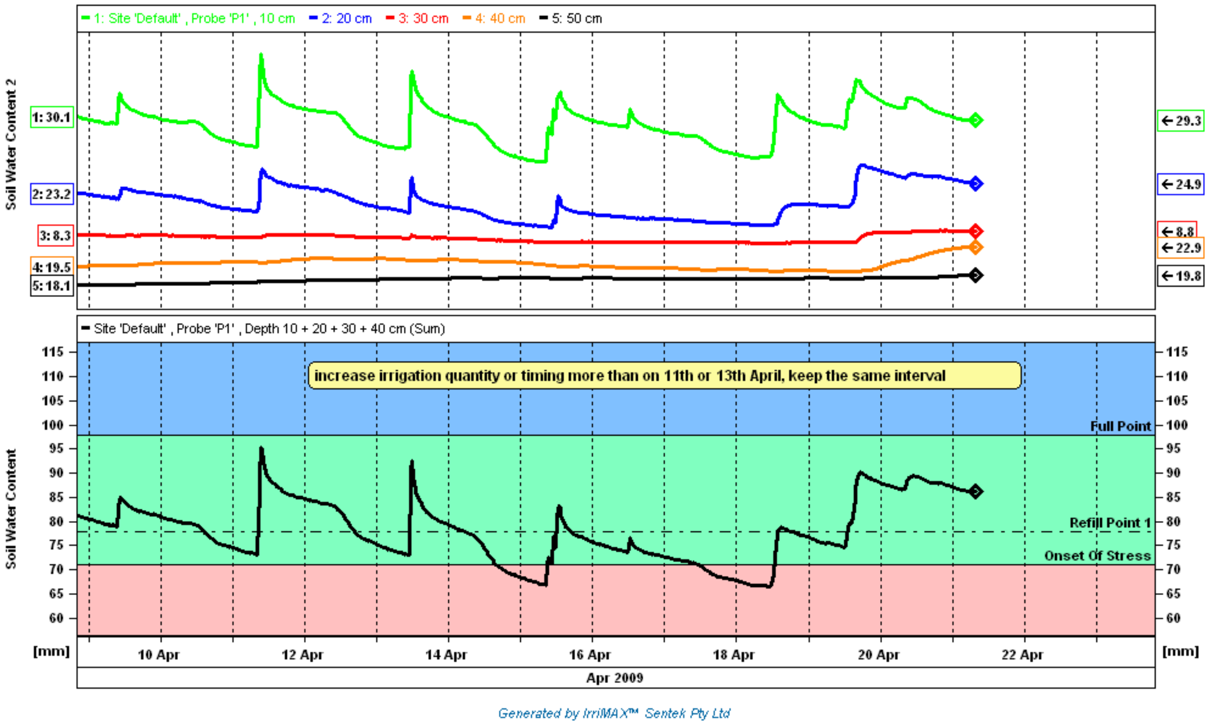

Figure 7: Enviroscan output graph from sensor installed in Eolose tomato field

Based on the harvested fresh fruits Yield of each vegetable crop at proper maturity stage the total yield per feddan was calculated. Unfortunately, the eggplants crop didn't give accepted results (very low production). This was related to installation faults and lack of maintenance of the system. So the results of this crop were excluded from the comparison as it was of insignificance.

As for the tomato, the results indicated that the plants' characteristics are significantly increasing using different subsurface drip systems compared to surface drip one, Figuress (8) and(9). The Eolose pipelines have the best results over T-tape and Tuporex types, respectively, at the same agriculture practices and environmental conditions.

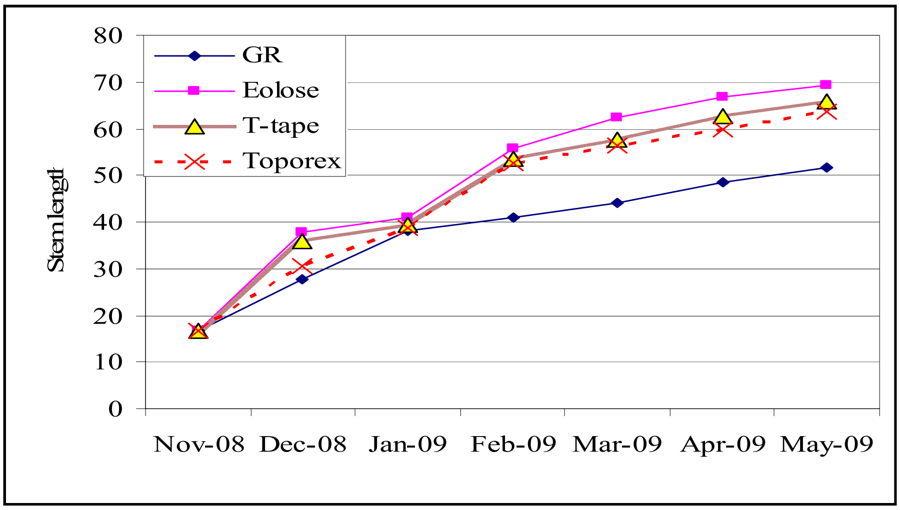

Figure 8: Stem length in cm for Tomato

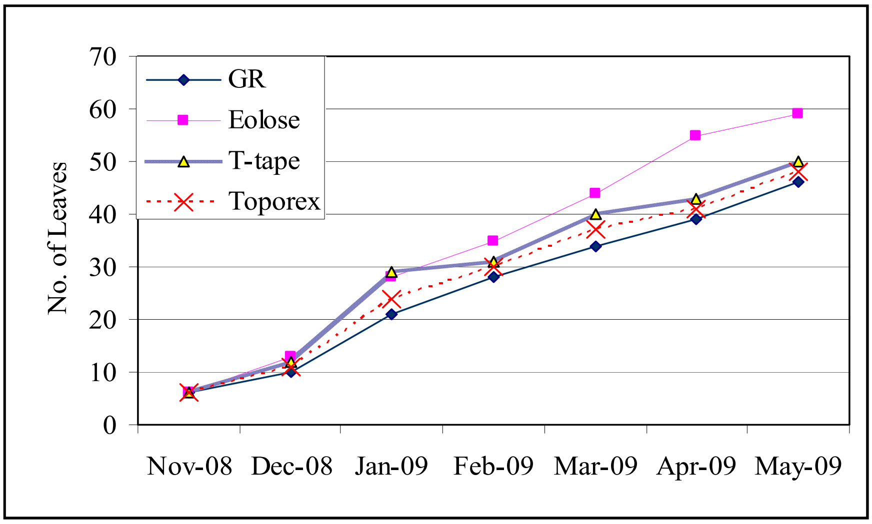

Figure 9: Number of leaves in Tomato

This is attributed to the fact that the movement and the distribution of water applied at the root zone, as the subsurface drip system goes directly to the root zone while the surface drip system is partially lost in evaporation and weed germination. As it has been also noted the decrease of weed germination around the plants in the subsurface field compared to the surface one.

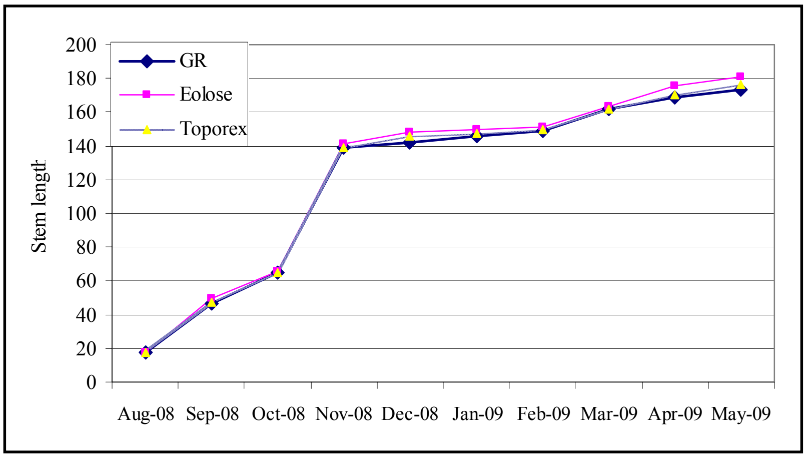

Figure 10: Stem length (cm) for Pepper

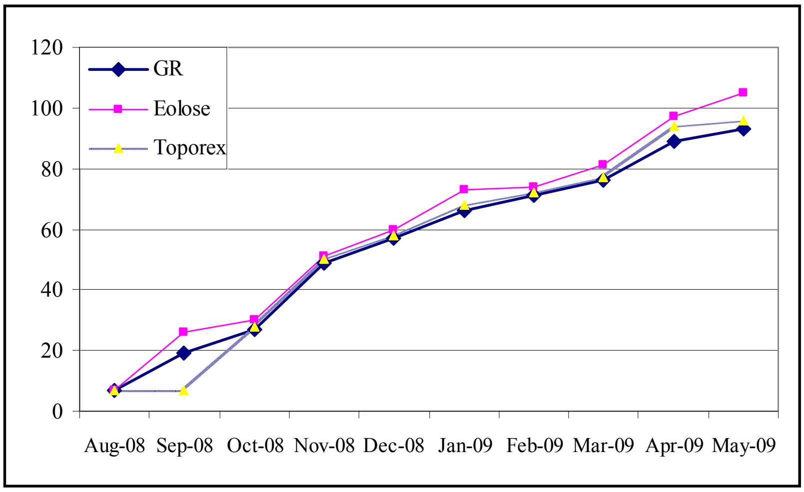

Figure 11: Number of leaves in Pepper

Figures (10) and (11) show the morphological parameters of the pepper crop in the greenhouse. It is clear that the difference between surface and subsurface is much less significant in greenhouse than open field this may be due to the local climate inside the greenhouse. Moreover, all plants morphological characters increased significantly using Eolose pipelines than T-tape and Tuporex, respectively. The reduction in plant growth is interpreted by the irregularity of water distribution in the soil profile and the water stress causing losses in tissue water which reduce pressure in the cell. The decreases in enlargement and division of cells decrease leaf area and hence the effectiveness of photosynthetic surface. The fresh yields average for tomato are 16243, 17717, 16866 and 16809 kg/fed under surface drip system with GR emitter and SDI system using Eolose, T tape and Tuporex emitters, respectively in open field. While they are equal to 12832, 13762 and 12971 kg/fed for pepper under surface drip with GR emitter and SDI system for Eolose and Tuporex emitters, respectively. Table (5) shows the different characteristics of root under wet and dry conditions for the different crops. The data revealed that fresh yields of tomato and pepper were significantly affected by the different studied surface and subsurface drip irrigation systems.

Table 5: Roots characteristics for different irrigation systems

Irrigation system	Parameter	Tomato	Pepper
GR	Root length (cm)	16.9	30.4
	Dry root weight (gm)	15.5	22.2
Eolose	Root length (cm)	27.8	40.9
	Dry root weight (gm)	19.6	28.5
T-tape	Root length (cm)	25.1	-

	Dry root weight (gm)	18.2	-
Tuporex	Root length (cm)	22.7	32.3
	Dry root weight (gm)	16.9	24.4

For each vegetable type the higher productivity is obtained for SDI with Eolose, T-tape then Tuporex pipelines, whereas it shows the lower yield using surface dripping GR. Fig (12 & 13) demonstrate the different productivity elements (i.e., weight of ten fruits, and weight of largest ones) that are directly related to the total fresh yield per feddan.

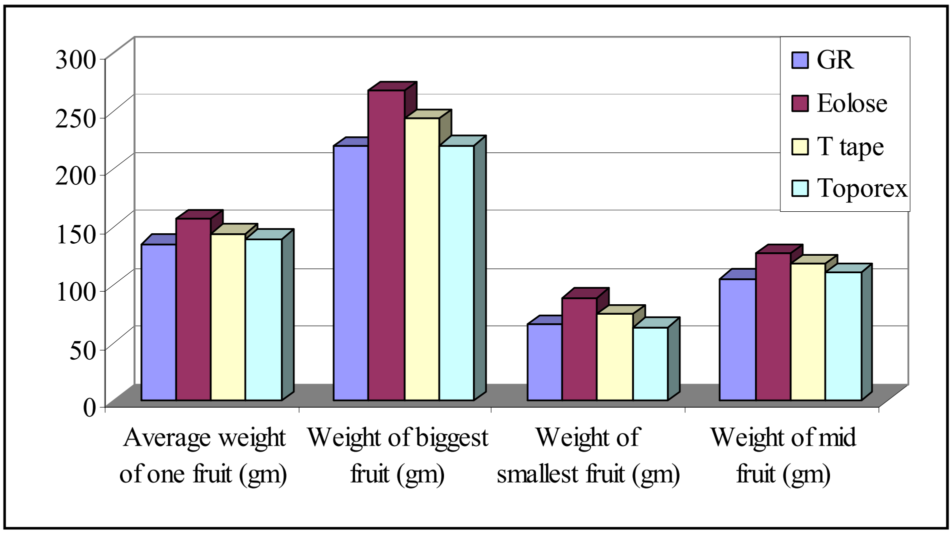

Figure 12: Productivity elements of Tomato

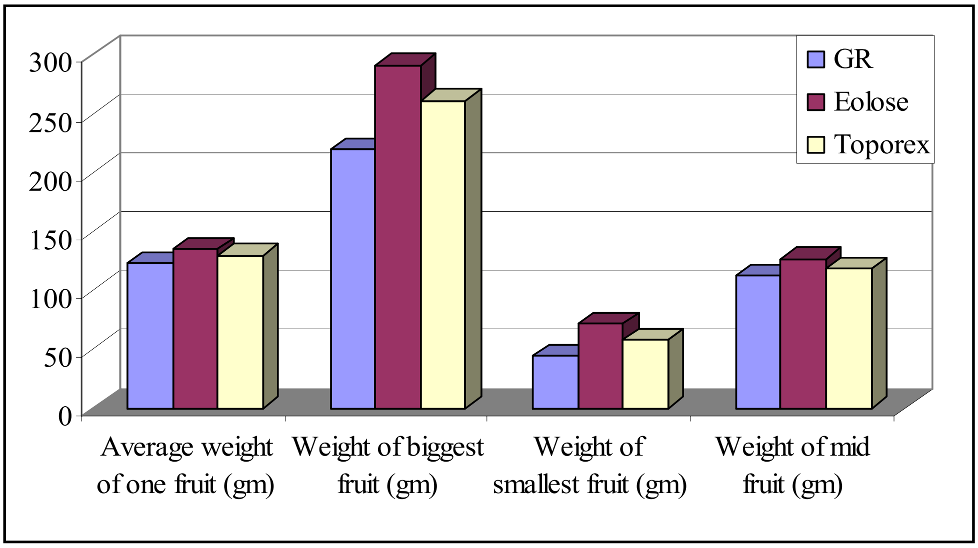

Figure 13: Productivity elements of Pepper

The monthly values of water applied for all surface and subsurface drip systems increased with the plant growth. The maximum values are recorded at May, as the plants are at the maximum vegetative growth and the climate condition is relatively high. Figures (14 & 15) show the water use efficiency of the two crops under the different irrigation systems. The results indicated water saving by 8.92% and 10.56%, respectively in average using SDI in tomato and pepper over surface drip system.

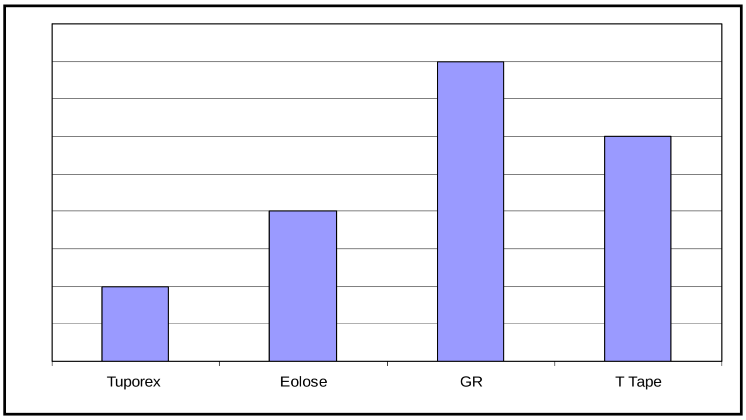

Figure 14: Irrigated water (m3/feddan) for tomato

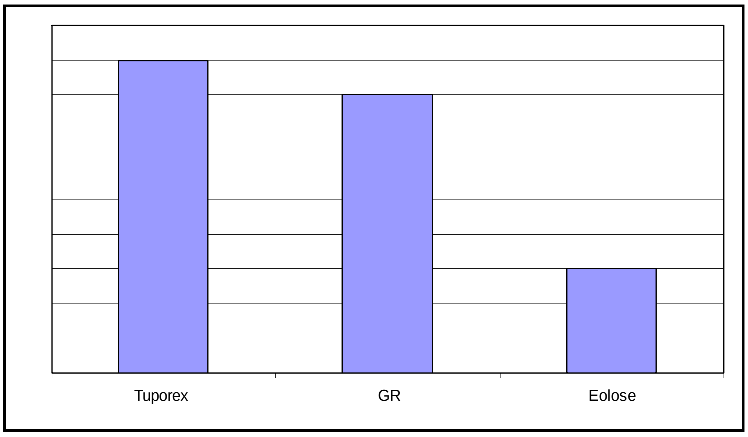

Figure 15: Irrigated water (m3/feddan) for pepper

The total water consumptive use values of tomato and pepper using GR drip irrigation systems are 1325.02 and 2826.73 m3/fed, respectively. While the SDI water consumptive uses are (1662.07 and 1633.72), (1367.27 and 1352.82), and (2923.54 and 2870.87 m3/fed) using Eolose, T-tape and Tuporex, respectively. These latter results demonstrate that the highest values of water consumptive use were obtained with Eolose followed by T-tape and Tuporex, respectively. SDI water consumptive use values are relatively higher than that of DI using GR pipelines, which may be interpreted by the increase of evaporation from soil for DI over SDI systems.

Water use efficiency in open field increased considerably by 11.73%, 7.11% and 4.52% for tomato referred to the DI GR system. For greenhouse, the increment percentage for pepper were 16.42% and 10.80% for Eolose and Tuporex compared to GR drip system, respectively.

The measured soil salinity showed an increase in horizontal and vertical distances from the line source or the emitter and reached maximum values at the soil surface just above the line in the subsurface drip, at (30-45) cm layer while it directly beneath the emitter in the surface drip system as well as at the bottom of the wetted zone in both systems.

Within this experimental study, the soil salinity in the main root zone was relatively low, so the plant growth and consequently yield of production were not affected by the salinity but mainly by soil moisture distribution and its amount. Therefore, the accumulated salts can be easily leached out with additional irrigation water in case of increase.

6. CONCLUSIONS

From the above investigations, the following were concluded:

1. Comparing different subsurface irrigation system pipelines materials: Eolose pipelines had given the best results when installed at 15 cm depth for vegetables followed by T-tape, while Tuporex pipelines and GR surface drip irrigation showed the least advantages.

2. Based on the results of this field work, it can be concluded that subsurface drip irrigation might be used as a good alternative for improving irrigation in such sandy soil of arid zone as El Adlia farm over sprinkler and surface drip irrigation.
3. The SDI has a significant effect on improving vegetables fresh yield and productivity. Also it decreases considerably weed germination (one of the biggest problem in the farm) due to the reduction of soil moisture at the surface.
4. SDI system shows higher water use efficiencies in open field and greenhouse, as well as its noticeable reduction of soil moisture at the surface, and consequently reducing diseases infection due to humidity around the stem of plants. The only difficulty for SDI will be the raise of costs for maintenance of the system, and the qualified staff needed for management of the whole monitoring system using weather station, soil moisture sensors.

7. ACKNOWLEDGEMENT

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9. LIST OF SYMBOLS

SDI: Subsurface Drip Irrigation
AUC laboratory: the American University laboratory for soil and water analysis (new campus)
GR, Eolose: Types of pipelines materials using in drip irrigation system
IMC: Industrial Modernization Center

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