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MANAGEMENT OF SOME TRICKLE IRRIGATION SYSTEMS IN SANDY SOILS

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Abstract

Field experiments were carried out at El-Bustan Research Station, Nobaria District, Abdel-Monem Reyad Village in order to evaluate the potential of using surface and subsurface drip irrigation (GR. lateral). Lines were installed at two depths of 15 and 30 cm to irrigate squash under the conditions of sandy soil. There were two treatments (daily and three days intervals fertigation). The obtained results showed the superiority of sub-surface drip at depth of 15 cm in case of daily fertigation over surface and sub-surface drip systems installed at 30 cm depth in case of three days intervals fertigation as follows:

1- The soil moisture distribution as percentage ratio from field capacity was after irrigation with two hours 95.8 %. 93.8%, 90.8% and before irrigation with two hours 85.4%. 83.3%,76.5% in case of daily fertigation .

2- Under sandy soil conditions, the good water and nutrients management for plant growth could be achieved by using subsurface drip irrigation systems (daily fertigation at depth 15 cm) over other treatments.

3- Crop yield increased in daily fertigation of subsurface drip irrigation over the other treatments with ratio 7.55 % to 14.88%.

4- Water use efficiency increased in daily fertigation of subsurface drip irrigation over the other treatments with ratio 8.26 % to 15.1%.

Keywords: pressurized surface and sub-surface irrigation Fertigation - Water distribution uniformity – Management - Salt distribution uniformity - Crop yield – Water use efficiency.

INTRODUCTION

As water resources are limited in Egypt it is extremely important to introduce modern irrigation systems and management techniques to save water for expanded agriculture. Considerable research and field trials have been demonstrated, to the producer, showing the advantages of irrigation management which includes increased crop yields, more profit, water conservation and reduced pumping costs. Many factors such as crop evapotranspiration (ET_c), deep percolation, runoff, leakage losses, changes in soil water and efficiency of the irrigation system which affect water requirements, must be considered when planning and operating the irrigation systems. The present work aims to:

1. Study the potential of using sub surface drip irrigation system to irrigate squash in sandy soil compared to surface drip irrigation system.

2. Calculate squash irrigation water requirements.

3. Determine irrigation schedule for squash under the studied specific condition.

Irrigation management consists of determining when to irrigate, and how much water to apply at each irrigation, during each growth stage of plant and operation of irrigation system. Irrigation management should maintain optimum soil water content for the given production system and should avoid applying too little or too much water. (Xin *et al.*, 1995). Lamm *et al.* (1995) reported that careful management of subsurface drip irrigation systems reduced net irrigation needs by nearly 25% while still maintaining top yields of 12-15 t/ha. Prajamwon *et al.* (1997) reported that improved water management practices in agriculture can lead to substantial benefits in terms of water availability for expanded agricultural activities and for other uses and can directly address many environmental concerns. Heerman *et al.* (1990) reported that irrigation scheduling is a key element to proper management of irrigation systems. The goal is to apply the correct amount of water at the right time to meet management tasks, to maximize water efficiency, crop production and/or economic return to minimize irrigation costs. Joshi *et al.* (1995) defined irrigation scheduling as a strategy for the distribution of water from reservoir to the plants in such a way to get maximum irrigation efficiency. Thomas *et al.* (1995) reported that an irrigation scheduling method must provide accurate daily estimates of soil water in the root zone of the irrigated crops. This requires an accounting method that records the amount of rain received on the field, the amount of irrigation water applied, and an accurate estimate of daily crop water use. Doorenbos and Pruitt (1984) reported that plant water consumptive use increased with plant growth depending on crop variety, plant growth stage and climatic condition. Rashid and Ahmad (1988) found that actual water consumptive use decreased with decreasing the available soil moisture. Essam and Fekry (1995) defined potential evapotranspiration as the rate at which water, if available, would be removed from wet soil and plant surfaces expressed as the rate of latent heat transfer per unit area, or as a depth of water per unit time. Day (1996) reported that the most significant crop factor affecting Et_c is the amount of ground area covered by the crop. He added that irrigation scheduling for drip irrigation involves two major things: the first is the estimation of Et_c. The second is the monitoring of soil moisture. Yousef (1989) studied scheduling irrigation of soybean using the evaporation Pan method and calculated the potential evapotranspiration by five methods (i.e. Turce, Blaney-Cradle, modified Penman, Jesen and Haise and class (A) Pan evaporation). He found that the class (A) evaporation offers a good method and reliable estimates of the potential evapotranspiration. He also added that the class (A) Pan can be used successfully in scheduling crop irrigation. El-Sabbagh (1993) calculated the potential evapotranspiration of maize by modified Penman, Radiation, modified Blaney-Criddle and Class (A) Pan method. Potential evapotranspiration values obtained by Blaney-Criddle and class (A) pan were lower than those obtained from Penman and Radiation. Phene *et al.* (1982) demonstrated that in a sandy loam soil, multiple small quantity of irrigation per day with a trickle system resulted in both higher yields and less plant water stress than with irrigation each six days. El-Berry (1989) found that the water use efficiency was highest in case of subsurface drip system (5.93 kg/m^3) which was approximately twice and seven times that of sprinkler and basin irrigation systems, respectively. In case of Alfa-Alfa production under desert conditions, Kim and Lee (1989) reported that on using subsurface irrigation, the value of wetted distance in vertical direction in sandy loam soil decreases with irrigation rate while the wetted distance in the horizontal optimum direction changes in opposite direction. Awady *et al.* (1975) reported that a trickle irrigation system was designed, constructed, and tested, for the first time in Egypt. The system used "micro-tube emitter" under low head, thus reducing amenability to clogging among other advantages. Awady *et al.* (1976) reported that pea and squash were grown on the system to estimate optimum WUE. Water application factor of 0.7 was recommended, based on the evaporation from open pan. For the pea trail, the total water consumption was about 1000m^3/fed. season giving a yield of 2.5 t/fed and water utilization efficiency of 0.0025 t/m^3. Water saving of 17-70% was reported compared with other surface flood methods reported in literature. In addition, an increase of 100% in pod production was estimated in comparison with control plots irrigated manually in the same experiment.

MATERIALS AND METHODS

Two field experiments were conducted in sandy soil in 15th Aug. 2001 at El-Bustan Research Station, Nobaria District, Abdel-Monem Reyad Village. The site belongs to the ministry of Agriculture and Land Reclamation. Tables (1) and (2) show the results of soil mechanical and chemical analysis before starting the experiment. Some values of chemical analysis of the irrigation water are presented in table (3).

Table (1): Some mechanical analysis of the soil at El-Bustan research station.

Depth (cm)	Particle size %				F.C. %	P.W.P. %	Texture Class
	C.sand	F.sand	Silt	Org. matter			
0 – 15	52.8	41.4	4.1	1.7	9.4	4.3	Sandy
15 – 30	50.0	43.5	5.0	1.5	9.3	4.4	Sandy
30 – 45	52.0	42.0	4.3	1.7	9.2	4.4	Sandy
45 - 90	50.0	43.5	4.5	2.0	9.1	4.5	Sandy

Table (2): Some chemical analysis of the soil at El-Bustan research station.

depth (cm)	pH	EC mmhos/cm	Soluble Cations, meq/l				Soluble Anions, meq/l			
			Ca^{++}	Mg^{++}	Na^{+}	K^{+}	$CO3^{--}$	HCO_3^{-}	SO_4^{--}	Cl^{-}
0 - 15	8.2	1.27	2.9	3.0	6.1	0.6	-	3.5	2.0	7.1
15 - 30	8.3	1.22	2.7	2.7	5.9	0.7	-	3.4	1.7	6.9
30 – 45	8.3	1.3	3.3	2.2	6.5	0.9	-	3.9	2.1	6.9

Table (3): Some chemical analysis of irrigation water (Nile Water from Bustan Canal) at Bustan Site.

pH	EC mmhos/cm	Soluble Cations, meq/l				Soluble Anions, meq/l			SAR
		Ca^{++}	Mg^{++}	Na^{+}	K^{+}	HCO_3^{-}	SO_4^{--}	Cl^{-}	
7.74	1.02	1.03	0.74	8.01	0.42	1.95	4.52	3.73	8.51

Three irrigation depths treatments were used in this study " 0,15 and 30 cm of GR drip irrigation. Chemical nutrition was injected through the irrrigation system to obtain the advantage of proper management. Therefore, the experiment included six treatments and six replicates as shown in fig. (1).

Components of the irrigation system (0, 15 and 30 cm deep).

The control head is located at the source of water supply. It consists of a centrifugal pump, back flow prevention device, pressure regulator, pressure gauges, flow meter, sand media filter, venturimeter of one inch diameter, flow rate of 400 l/h and screen filter. Main and sub-main lines: 110 mm diameter (OD) P.V.C. pipe was used for the main and 63 mm P.V.C. for sub-main. Manifold: 32 mm PVC pipes were used to supply water to the constructed laterals on one side: 16 mm P.E. tube, built in drip line with flow rate of 4 lph/ 0.5 m. The line spacing in drip irrigation system is 0.75 m for squash growing and spacing of plants on the same line are 0.5 m (traditional spacing in Egypt). The experimental area was divided into two sections. Each section was divided into three experimental plots. The experimental plot was 20 m in length and 4.5 m width (90 m^2) and contained 6 rows as replicates in both the two treatments daily and every three days fertigation as shown in figure (1). Fertilization program per cubic meter of water for squash according the recommendation by The Ministry of Agriculture is shown in Table (4).

Table (4): Fertilization program per cubic meter of water for squash

Plant Stages	Ammonium Sulfate(kg) (33.5%)	Potassium Sulfate(kg) K_2O (48%)	Phosphoric Acid (cm^3) (85%)
Initial stage.	0.25	0.50	50
Development stage.	0.50	1.00	250
Mid stage.	0.50	0.50	100
Late Stage	0.25	0.50	50

Table (5): Total fertilization quantities for different stages for squash.

Plant Stages	Ammonium Sulfate (kg) (33.5%)	Potassium Sulfate (kg) K_2O (48%)	Phosphoric acid (cm^3) (85%)
Initial stage.	0.322	0.644	64.35
Development stage.	3.297	6.953	1648.25
Mid stage.	6.518	6.518	1303.6
Late Stage	1.83	3.66	366.05
Total fertilization quantities	11.967	17.775	3382.25

Table (6): Calculated crop evapotranspiration (mm/day) of squash using pan evaporation method.

Plant Stages		Av. Et_o mm/day	K_c	Crop evapotranspiration Et_c mm/day	Crop evapotranspiration Et_c m.3/ Fed/ season	Total crop evapotranspiration Et_c $m.^3/90m.^2$/ season
Initial	4-5 to 14-5-03	6.5 in May	0.2	1.3	60.06	1.287
Development	15-5 to 31-5-03	6.5 in May.	0.35	2.275	162.434	3.481
	1-6 to 13-6-03	7.6 in June	0.35	2.66	145.236	3.112
Mid	14-6 to 30-6 -03	7.6 in June	0.94	7.144	510.082	10.93
	1-7 to 3 –7- 03	8.3 in Juli	0.94	7.802	98.305	2.106
Late	4-7 to 17-7-03	8.3 in Juli	0.7	5.81	341.628	7.321
At harvest	18-7 to 27-7-03	8.3 in Juli	0.5	4.15	174.3	3.735

The total crop evapotransipiration for each plot/season is 31.972 m^3, and for each section is 82.74 m^3 (1492.045 m^3/ feddan. season). As the calculated water irrigation efficiency was 90% and the calculated leaching requirements was 9.5 %. The total irrigation requirements 1719.7 m^3/ feddan Season. Irrigation water quantities were determined using the following equations

$$Et_{crop} = ET_0 \ (Kc) \qquad (1)$$

where :

Et_{crop} = Crop evapotranspiration (mm/day).

K_C : Crop coefficient, (dimensionless).

ET_o and Kc according to Central Laboratory of Agricultural Climate 1996- 2001.

The soil samples were taken every 15 cm up to depth 45 cm. The samples were taken using auger in the vegetative stage within two hours before and after two successive irrigations. The irrigating water was applied between two limits that are the wilting point and field capacity. The water application was designed to reach depth of 45 cm to meet the maximum water consumption of squash. Therefore, there was no chance to expect deep percolation loss. The moisture distribution percentage was calculated on weight base. The salinity distribution was measured by the electrical conductivity meter (EC) mmhos/cm using soil extract solution, 1:5 on weight base.

RESULTS AND DISCUSSION

The objective of any effective irrigation is to obtain the highest possible sustained agriculture return per unit of water applied. This could be achieved through providing a suitable water supply, time and quantity to the cultivated plants. The distribution of water through soil profile of sandy soil under surface and subsurface drip irrigation system is considered one of the most important factors for good soil water management.

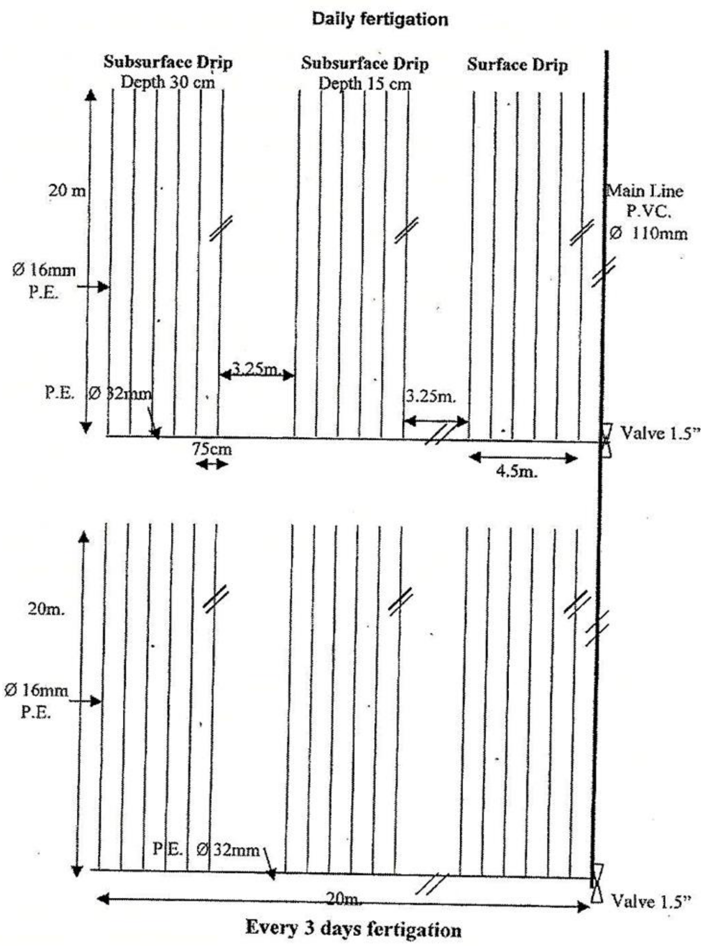


Fig. 1. Layout of the experiment.

1-Moisture distribution

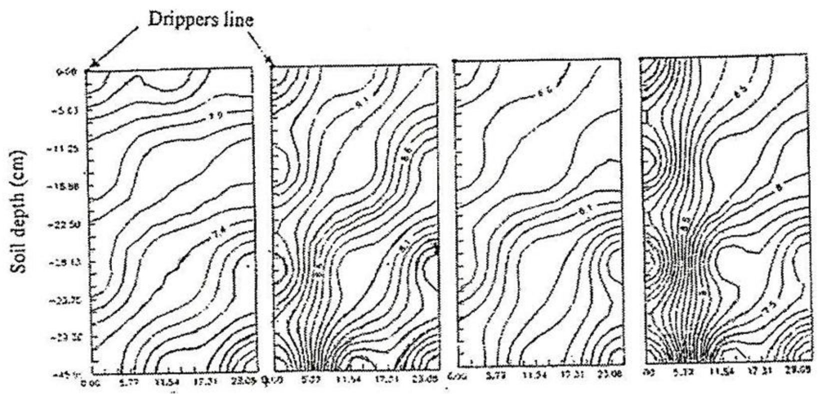
The soil moisture distribution data were illustrated in figures (2, 3 and 4) which show the mean soil moisture pattern for 0, 15 and 30 cm depths all the way until 45 cm for different treatments surface and subsurface trickle systems (15, 30 depth respectively). The emitter wetted diameter was 0.5m at discharge rate of 4 l/h. The moisture contour lines intervals were represented each (0.1%). The soil moisture under surface drip irrigation systems (0 cm depth) as shown in figure (2) moved downward until the depth 45 cm for both daily and three days irrigation intervals. The mean soil moisture content was determined two hours after irrigation which reached 90.8% and 89.1 % of the field capacity calculated for vegetative stage In case of surface drip irrigation daily and three days irrigation intervals, respectively. Meanwhile these values were 76.5% and 67.6 % of field capacity calculated for two hours before irrigation. In this concern to achieve the critical water balance in the plant life which means that daily irrigation was the most efficient when compared to the other treatment. The data are shown in figures (3 and 4) for depths 15 and 30 cm of subsurface drip irrigation. The soil moisture content values before irrigation were 85.4 % and 83.3 % of field capacity for depths 15 and 30 cm of subsurface drip irrigation, while the moisture content values after irrigation were 95.7 % and 93.8% of field capacity for daily fertigation of vegetative stage for depths 15 and 30 cm of subsurface drip irrigation, respectively. On the other hand, for the three days interval fertigation as shown in figures (3 and 4) the soil moisture content values before irrigation were 68 % and 61.8% of field capacity, while the moisture content values after irrigation were 90% and 88.1% of field capacity respectively. The results indicated that using subsurface drip irrigation systems at depth of 15 cm with daily fertigation was more efficient than subsurface drip fertigation at depth 30 cm. That was due to the water losses through evapotranspiration in case of surface drip irrigation systems. Finally, from the above discussion under sandy soil fertigation, good water management could be achieved by using both subsurface 15 cm and surface drip systems. Theses results agree with those obtained by Kim and Lee (1989).

2-Salt distribution

The idea of supplying mineral nutrients to the crop through irrigation (fertigation) is one of the latest steps in the revolution of the fundamentals of traditional agronomy. Usually, fertilization application through irrigation water leads to a better uniformity distribution compared with the traditional fertilization practice. Under surface and subsurface drip irrigation, the results in figures (5, 6 and 7) show the salinity distribution (mmhos /cm) in the vegatative stage. The salt distribution through the soil in case of surface and subsurface (at depths 15 and 30cm) for both daily and every three days intervals fertigation (with contour interval 0.2 mmhos/cm) were represented in figures (5, 6 and 7). A clear increase in the EC (mmhos/cm) values of the soil extract were observed toward the soil surface due to high evaporation of water. The same attitude were noticed in the horizontal direction from the drippers placement then decreased in the vertical direction gradually. The salt distribution increased in both vertical and horizontal directions from the emitter, above the subsurface line treatments, at the interface between laterals lines in the surface and at the bottom of the wetted zone in both systems. In the mean time, the soil salinity in the main root zone was relatively low. This shows that the plant growth and consequently squash production may not be greatly affected by the salinity but mainly by the soil moisture distribution and water availability. Finally, from the above discussion, it is noticed that under sandy soil conditions, the good water and nutrients management for plant growth could be achieved by using subsurface drip irrigation system (daily fertigation at depth 15 cm) than other treatments.

3-Crop yield

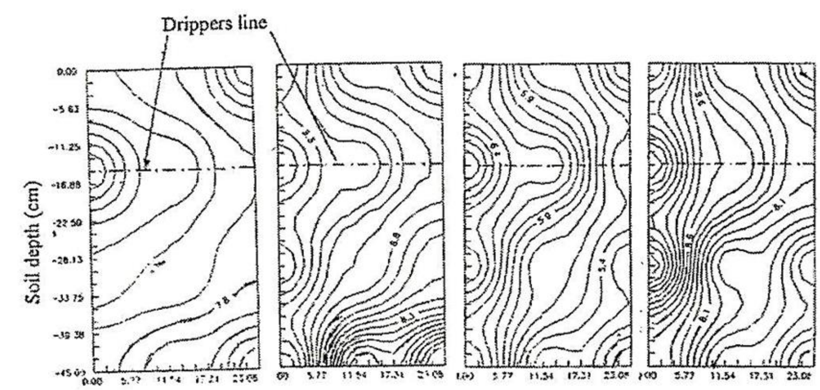
The crop yield was harvested for ten days. The mean squash yields collected from surface and subsurface treatments throughout the harvesting season are illustrated in table (7). The obtained data showed that the lateral line depth significantly affected the squash yield. The total yield averages under surface and subsurface (15 and 30 cm depth) were 6050, 6950 and 6550 kg/feddan for daily fertigation, respectively. Meantime it was 5300, 6000, and 5700 kg/feddan under surface and subsurface treatments (15 and 30 cm depth) for three days intervals fertigation, respectively. It was clear that higher yields are obtained in daily treatment for subsurface at depths 15 cm and 30 cm compared to surface drip irrigation. The same trend was observed in every three days intervals fertigation as shown in table (7). In the same time, the crop yield in case of daily irrigation was significantly higher than that obtained from all treatments. The highest yield was for subsurface laterals at depths of 15cm and 30 cm, compared with surface one with percentage 14.88% and 8.26% in daily treatment. While in the case of three days interval fertigation the excess was 13.20 % and 7.55% respectively. That means uniform distribution of sufficient available water and fertilizers directly in the root zone. Meanwhile, the lower crop yields in case of every three-day compared with daily treatment may be attributed to the insufficient upward movement of water to reach the root zone. It was particularly at the early growth stage, where a small root system could not extend to reach the subsurface water source.



2 h. before fertigation. 2 h. after fertigation. 2 h. before fertigation. 2 h. after fertigation.
Daily fertigation. Three days interval fertigation.

Contour interval 0.1

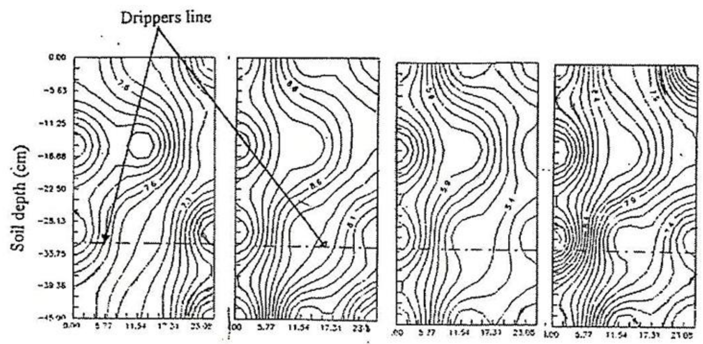
Fig. 2. Soil moisture distribtion percentage by weight under surface drip irrigation system.



2 h. before fertigation. 2 h. after fertigation. 2 h. before fertigation. 2 h. after fertigation.
Daily fertigation. Three days interval fertigation.

Contour interval 0.1

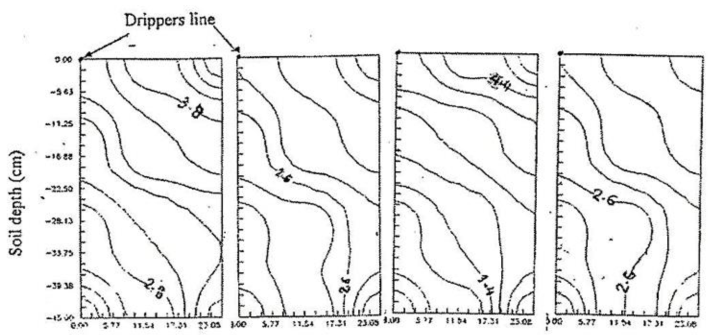
Fig. 3. Soil moisture distribtion percentage by weight under sub-surface (15 cm) drip irrigation system.



2 h. before fertigation. 2 h. after fertigation. 2 h. before fertigation. 2 h. after fertigation.
Daily fertigation. Three days interval fertigation.

Contour interval 0.1

Fig. 4. Soil moisture distribtion percentage by weight under sub-surface (30 cm) drip irrigation system.



2 h. before fertigation. 2 h. after fertigation. 2 h. before fertigation. 2 h. after fertigation.
Daily fertigation. Three days interval fertigation.

Contour interval 0.2

Fig. 5. Salinity distribution (mmhos/cm) under surface drip irrigation systems.

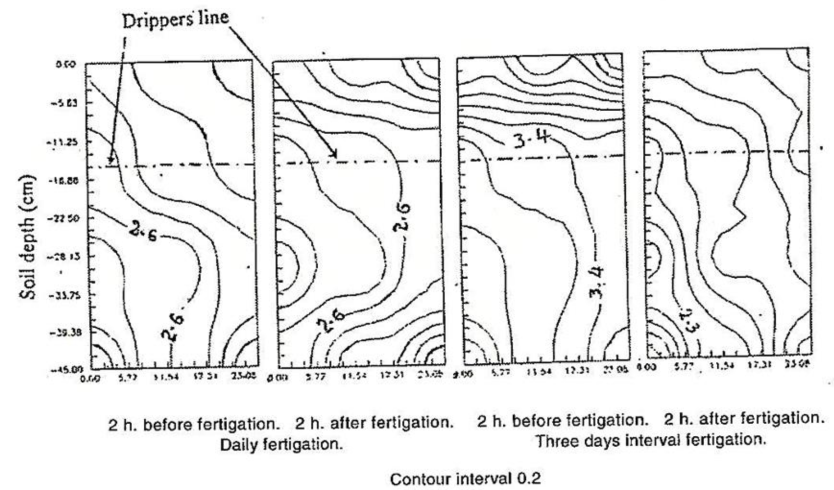


Fig. 6. Salinity distribution (mmhos/cm) under sub-surface (15 cm) drip irrigation systems.

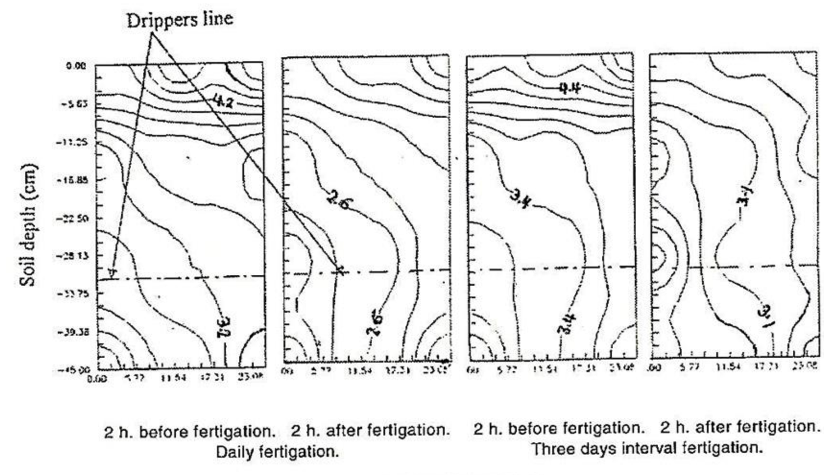


Fig. 7. Salinity distribution (mmhos/cm) under sub-surface (30 cm) drip irrigation systems.

Table (7): Squash yield for different treatments.

Treatments	Crop yield (kg/feddan)		
	Surface	Subsurface 15cm	Subsurface 30cm
Daily fertigation	6050	6950	6550
Three days intervals fertigation	5300	6000	5700

4-Water use efficiency (WUE).

Since all treatments received the same amount and frequency of irrigating water and the same fertilizer doses, the yield variation should be attributed to the lateral line placement, i.e. surface and subsurface (15and 30 cm depth). The WUE is defined as the total yield production kg/ the total irrigation requirements 1719.7 m3/feddan Season. The results are shown in table (8). The data revealed that the WUE increased in case of daily fertigation by 0.53 kg/m.^{3} and 0.29 kg/m.^{3} with ratios of 15.1% and 8.26 % that were obtained when used with both 15 and 30 cm depths compared with the surface treatment. Meanwhile, in case of three days intervals fertigation the data revealed 0.41 kg/m.^{3} and 0.23 kg/m.^{3} with ratios of 13.31% and 7.47% increased than that obtained when using both 15 and 30 cm depths compared with the surface treatment. This increase is mainly due to the corresponding increase in crop yields. The lower WUE in case of three days interval fertigation treatments compared with daily fertigation treatments was due to the losses in water and fertilizers by deep percolation.

Table (8): Squash water use efficiency (WUE) for different treatments.

Treatments	Water use efficiency WUE (kg/m.3)		
	Surface	Sub-surface 15cm	Subsurface 30cm
Daily fertigation.	3.51	4.04	3.8
Three days intervals fertigation.	3.08	3.49	3.31

CONCLUSION

When using two treatments in irrigation and fertilization (daily and every three days), the subsurface drip irrigation in squash plant applied daily irrigation and fertilizers at 15-30 cm soil depth could be considered as optimum methods to maintain uniform distribution and sufficient available moisture and acceptable salinity level in the plant root zone throughout the growing season resulting in higher yield and WUE compared with surface treatment.

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إداره بعض نظم الري بالتنقيط في الأراضي الرملية

مجدي توفيق الطنطاوي ، السعيد محمد كمال ، عصام واصف

معهد بحوث الهندسة الزراعية - مركز البحوث الزراعية - وزارة الزراعة.

أجريت التجربة في الخامس عشر من أغسطس ٢٠٠١ في محطة بحوث تطوير الري بالبستان - قرية عبد المنعم رياض - منطقة البستان. ويهدف البحث ألي دراسة تأثير إضافة السماد الكيمائي مع مياه الري يوميا وكل ثلاث أيام علي أعماق صفر، ١٥سم ، ٣٠ سم علي التربة وإنتاجية محصول الكوسة في نسب متساوية خلال نظامي الري بالتنقيط بالأراضي الرملية المستصلحة ولمعرفة تأثير ذلك علي التوزيع الرطوبي وتوزيع الأملاح قبل وبعد الري بساعتين في مرحلة النمو الخضري ، وكمية المحصول الناتج ، وكفاءة الاستخدام لمياه الري . وتم استخدام مياه ري سطحية لمصدر ري ذات درجة توصيل كهربائي ١,٠٢ ملليموز/ سم. وتم أخذ عينات التربة حتى عمق ٤٥ سم علي أمتداد خطوط النقاطات، وكان قطر خط النقاطات ١٦ مم ومزود بنقاطات داخلية بتصرف ٤ لتر/ساعة والمسافة بين النقاطات ٥٠ سم وبين الخطوط ٧٥ سم وقد أوضحت النتائج مايلي:

١- التوزيع الرطوبي في التربة : قبل وبعد الري بساعتين كانت النسبة المئوية للمحتوي الرطوبي للتربة في معاملة الري والتسميد اليومي أعلي بصفة عامه عن معاملة الري والتسميد كل ثلاث أيام في المعاملات المشابهة و بصفة خاصة الري بالتنقيط تحت السطحي علي أعماق ١٥سم ، ٣٠ سم مقارنة بالري التنقيط السطحي حيث تمثل من السعة الحقلية بعد الري ٩٥,٨٪، ٩٣,٨٪، ٩٠,٨٪ وبعد الري ٨٥,٤٪ ، ٨٣,٣٪، ٧٦,٥٪ في معاملة الرى والتسميد اليومى على الترتيب.

٢- توزيع الأملاح فى التربة: يفضل نظام الرى بالتنقيط تحت السطحى على عمق ١٥ سم لمحصول الكوسة فى الأراضى الرملية فى معاملة التسميد والرى اليومى وذلك لحركة الأملاح بصورة أكبر نسبياً فى منطقة الجذور والتقليل من الأثر الضار للأملاح والفقد بالبخر من سطح التربة مقارنة بالري السطحي وكذلك الفقد بالرشح العميق لمياه الري والسماد في معاملة الري والتسميد كل ثلاث أيام.

٣- إنتاجية المحصول : زادت إنتاجية المحصول في الري تحت السطحي عند عمق ١٥ سم في معاملة التسميد والري اليومي عن كل المعاملات الأخرى بنسب تتراوح من ٧,٥٥٪ إلى ١٤,٨٨٪ .

٤- كفاءة استخدام المياه : زادت كفاءة استخدام المياه في الري تحت السطحي عند عمق ١٥ سم في معاملة التسميد والري اليومي عن كل المعاملات الأخرى بنسب تتراوح من ٨,٢٦٪ إلى ١٥,١٪.