MOISTURE DISTRIBUTION FROM SUBSURFACE DRIPPING USING SALINE WATER IN SANDY SOIL

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ABSTRACT

The aim of this investigation is to evaluate the behavior of the soil moisture distribution under surface and subsurface drip irrigations in hyper-arid conditions using low quality water. Experiments were carried out in Siwa Oasis – Matruh Governorate. Experimental results showed that irrigation should be scheduled every twelve hours. The 10 cm dripline depth was the best in soil moisture-distribution and the best spacing ranged from 60 to 90 cm. The saving of soil moisture over an underneath PE foil increased with foil width and decreased with the foil width intersecting flow. In addition, less soil depth above foil increased the wetting width and reduced the efficiency of saving soil moisture at the root zone. The two Vertically-Spaced Lines (VSL) gave more uniformity of soil moisture than two Adjacent Lines (AL). The highest tomato yield (4.8 t/fed) was obtained with underneath PE foil, at 10 cm depth, 0.6 – 0.9 m width, and VSL arrangement.

***Keywords*:** Drip irrigation, Subsurface drip, Underneath PE foil, Saline water, Siwa Oasis.

INTRODUCTION

Shortage of water resources and increasing demand for water have created a whole new set of issues and problems confronting irrigated agriculture. For many years, the emphasis of sustainable irrigated agriculture has been improving the effectiveness of water management, water conservation and salinity control. Micro-irrigation is one of the technologies, which offers many unique agronomic, water conservation and economic advantages needed to address the challenges for irrigated agriculture in the future.

In regions such as Siwa oasis (واحـة سيوة), which has saline water in shallow aquifers and a lot of drainage water, which can be utilized for

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agriculture, where the quest for water has stimulated an extensive use of saline water as potential solutions for the water shortage.

The use of surface and subsurface drip irrigations on field-grown crops have become quite a common practice in agricultural production using saline water, as means to achieve sustainable irrigation. Efficient water use and economic yields are the main advantages associated with drip irrigation (Keller and Bliesner, 1990). Trickle irrigation is the daily or frequent slow application of water at the soil surface to replenish water and/or nutrients, which are utilized by plants. This type of irrigation is normally accomplished using emitters at selected spacing (Howell and Hiller, 1974). On the national level, the first trickle-irrigation system in Egypt was developed and tested by Awady *et al.* (1975). That technique depended on low water-pressure on flat land in Moshtohor area near Cairo, thus using wide emitters under low pressure, with less plugging troubles. Water saving ranged from about 20 to 70 % compared with other methods of irrigation when the system was used on pea crop.

The economical advantages of the subsurface irrigation are savings in water and energy as well as significant improvements in yield. The subsurface irrigation has productivity rates between 30 to 70 % above surface irrigation methods. Further economic factors influence the social situation and minimize maintenance. Due to the subsurface layout, the laterals are not as exposed to damage and a fully mechanized labor saving operation is possible. Management problems are reduced to a minimum due to the simplicity of the system (Barth, 1995). In high permeable coarse-textured soils, water and nutrients move quickly down wards from the emitter, making it difficult to wet the surface zone if emitters are buried too deep, Cote *et al.* (2003).

The present investigation aims to compare the effects of surface and subsurface drip irrigation methods on the soil moisture distribution and yield of tomato under Siwa oasis conditions or hyper arid zone.

MATERIALS AND METHODS

Location and soil properties of experimental site:

Two field experiments were conducted during winter season (2006 – 2007) in Experimental Station of the Desert Research Center, Siwa oasis – Mersa Matruh Governorate. Siwa oasis is located on the western desert at three hundred kilometers west south Mersa Matruh. The soil profile of experiments site is homogenous sandy texture, fine well-drained. It is leveled at 4 m depth sand dune, and the water table-surface was not detected.

Before preparing and applying treatments, infiltration rate and soil moisture characteristics were tested. Infiltration rate test was carried out in the field to determine infiltration characteristics of soil under field conditions. Volume balance technique by using a double cylinder (double rings) infiltrometer was applied, based on the rate of advance of the waterfront. The volume of the water surface storage was measured primarily by vertical rate of water movement into (one dimension) from the pond it encloses, as described by Bouwer (1986).

The method used of determining the soil moisture retention characteristics involves establishing a series of equilibrium states between water in the soil sample and a body of water at known potential. The soil-water system is in hydraulic contact with the body of water via a water-wetted porous plate or membrane. At each equilibrium, the volumetric water content, θ, of the soil is determined and paired with a value of the matric pressure head, hm, determined from the pressure in the body of water and the gas phase pressure in the soil. The data pair (θ, hm) is one point on a retention function. A drainage curve is mapped by establishing a series of equilibrium by drainage from zero pressure head. Soil moisture retention was determined at 0.12 bar (corresponding to soil field capacity), 0.33, 0.66, 1, 2, 5, and 15 bar (corresponding to soil wilting point) in the undisturbed soil cores using the methods were fully described by Klute (1986).

In order to monitor soil moisture content during the experiments period, Neutron Scattering moisture meter, (Hydro Probe) with its access tubes were used for measuring soil moisture content of soil profile. Neutron probe meter can measure the moisture directly after the calibration procedure in the different depths but its accuracy decreases in the top surface soil-moisture measurement. Thus profile probe with HH2 device plus its tubes were used also to measure the top zone (0 – 40) in order to compensate the decreasing in the neutron accuracy in the surface zone. All were calibrated to the experimental site conditions. Collected soil moisture data were taken before and 2, 12 h after irrigation.

Access tubes of neutron probe were 50-mm dia. PVC pipes, and 150 cm long with closed bottom ends. The tubes were pushed into the soil till 140 cm depth, at distances of 0, 10 and 40 cm from lateral line of treatment. Access tubes of profile probe with special tubes its long about 50 cm coming with the profile probe and HH2 device. Two neutron-access tubes and one profile probe-access tube were used for selected treatment. Measurements were conducted at 10, 20, 30, and 40 cm for **profile probe** and for **neutron probe** 20, 45, 70, 95, and 120cm depths from soil surface.

Calibrating the measured data from neutron scattering at a point with three readings, and 5 soil samples for every zone depth were taken from every depth around the access tubes against neutron reading, where soil moisture was measured for each soil sample by drying in electrical oven at 105 ^{o}C and weighing. These procedures were taken, with 25 cm steps until reaching 1.35 m depth. Data obtained from profile probe plus HH2 device, were calibrated similar to neutron probe.

Irrigation system installation and experimental treatments:

The experiments were varied in the absence or presence of underneath Poly Ethylene (PE) foil.

The **first experiment** (E_1) was without PE foil and with the following treatments:

a. Two Adjacent Lines (AL) or two Vertically-Spaced Lines (VSL) at 15 cm in between.
b. Variation in driplines depth ((upper dripline in VSL or AL depth was 0 or 10 cm).
c. Variation in width between driplines (0.4 to 1.0 m).

The main treatment was the state of driplines and named AL and VSL. Sub-main treatments varied in depth of surface or subsurface dripline as 0, and 10 cm from the soil surface, respectively. In the same time, the width range between driplines varied from 0.4 to 1.0 m, as shown in Table (1) and Figs. (1 and 2).

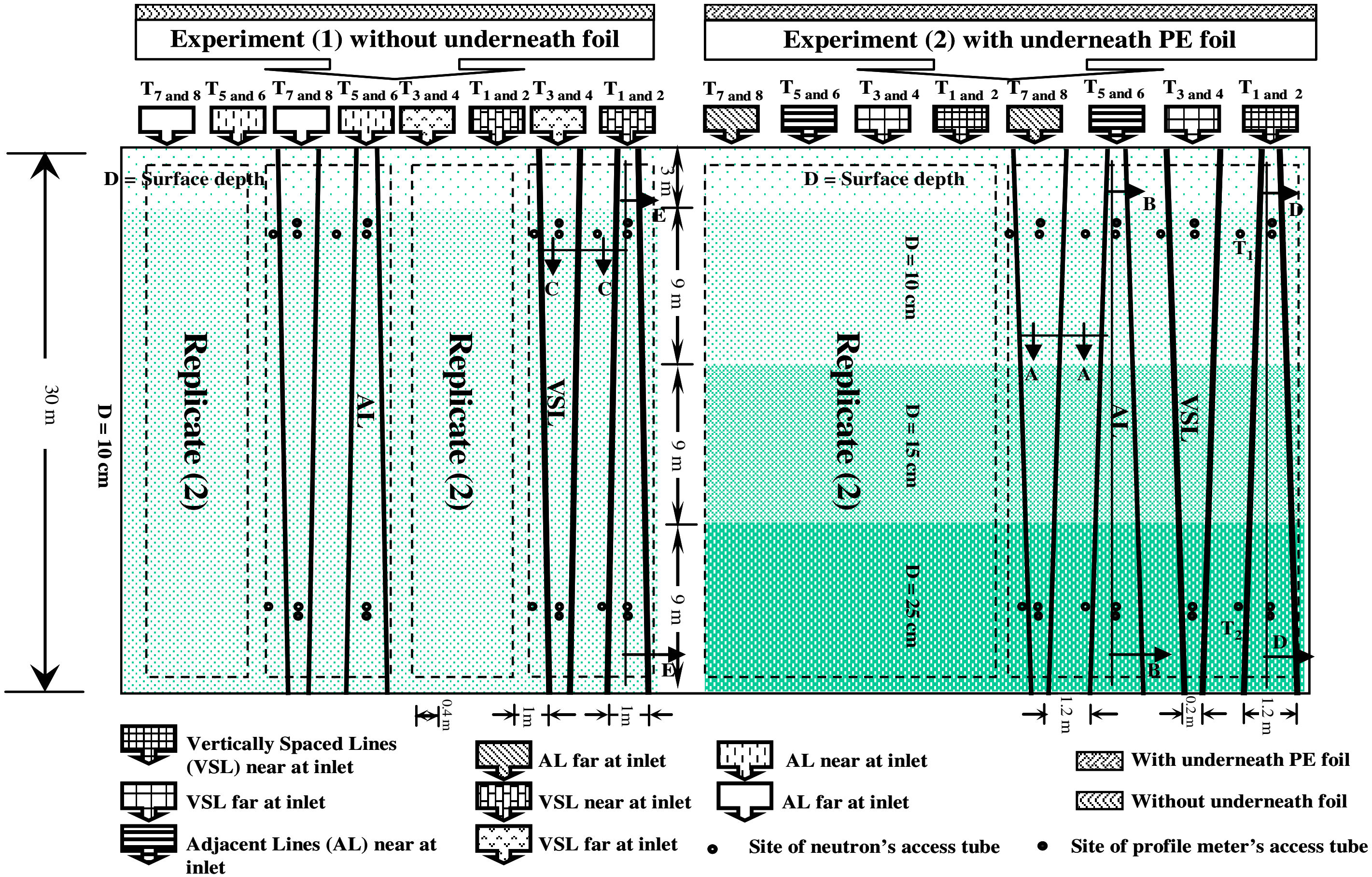

Fig. (1): Sketch design of field experiment.

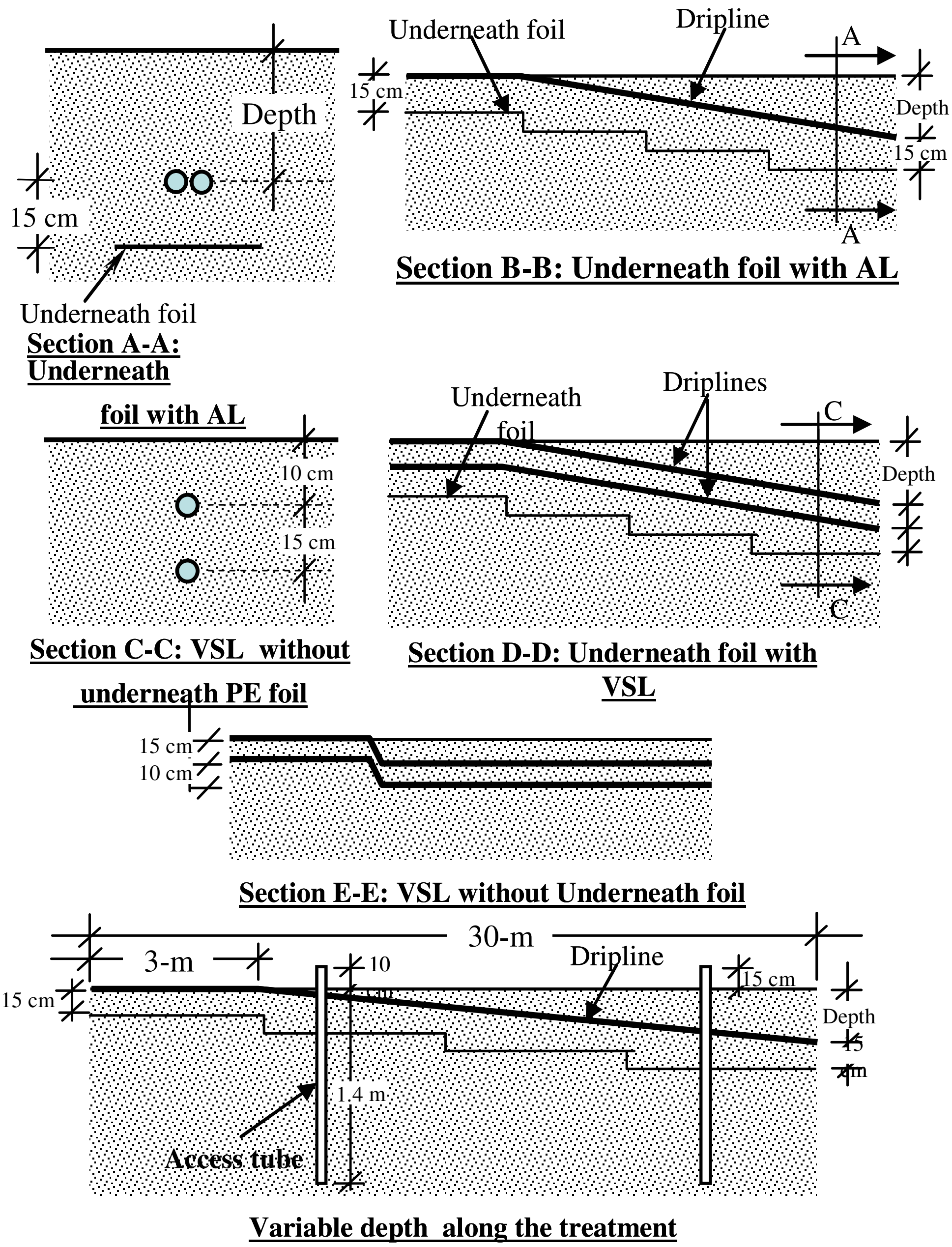

Fig. (2): Sections showing access tube, driplines and underneath foil.

It is worth to mention that certain treatments were selected for recording soil moisture content at different periods after irrigation due to the limitation of access tubes of HH2 device or Neutron probe, which were used for the treatments as illustrated in Tables (1 and 2). But in case of crop yield, the effect of all treatments was recorded. Reading and recording soil moisture data were after 2, 12 h, and before next irrigation, and every datum was calculated from three replicates.

Table (1): Soil moisture selected treatment of Exp. (1) without underneath PE foil.

Arrangement	Depth (cm)	Range of width between driplines (m)	Treatment	Symbol
VSL	0	0.4 - 0.5	T_1	E_1 T_1
		0.8 - 1.0	T_3	E_1 T_3
	10	0.4 - 0.5	T_4	E_1 T_4
		0.8 - 1.0	T_2	E_1 T_2
AL	0	0.4 - 0.5	T_5	E_1 T_5
		0.8 - 1.0	T_7	E_1 T_7
	10	0.4 - 0.5	T_8	E_1 T_8
		0.8 - 1.0	T_6	E_1 T_6

E = Experiment No. T = Treatment No.

The **second experiment** (E_2) had underneath PE foil, with following treatments:

a- Driplines case (AL and VSL).

b- Variation in driplines depth (upper dripline in VSL or AL depth was from 0 to 25 cm).

c- Variation in the width between driplines (0.2 to 1.2 m).

The main treatment was the state of driplines AL or VSL. Sub-main treatment was depth of driplines, as 0 (surface drip irrigation), 10, 15 and 25 cm from the soil surface this for AL or upper dripline in VSL case, in the same time width range varied between 0.2 to 1.2 m, as shown in Table (2) and Figs. (1 and 2).

Table (2): Soil moisture selected treatment of Exp. (2) with underneath PE foil.

Arrangement	Depth (cm)	Range of wide between driplines (m)	Treatment	Symbol
VSL	10 – 15	0.3 - 0.6	T_1	E_2 T_1
		0.9 - 1.2	T_3	E_2 T_3
	25	0.3 - 0.6	T_4	E_2 T_4
		0.9 - 1.2	T_2	E_2 T_2
AL	0	0.3 - 0.6	T_5	E_2 T_5
	10 – 15	0.9 - 1.2	T_7	E_2 T_7
	25	0.3 - 0.6	T_8	E_2 T_8
		0.9 - 1.2	T_6	E_2 T_6

E = Experiment No. T = Treatment No.

Tomato seedling (Super strain B, Lycopersicon esculentum L.) was sown on 3/1/2007. The yield tomato was obtained and recorded for each experiment.

Water use efficiency, "yield / cu. m. of water" followed, Burman *et al.* (1983).

The statistical analysis of the obtained each treatment results was conducted using computer program (Statistix version 7 under window) with using the linear model and LSD.

Results and Discussions

Some soil hydrology properties:

Soil hydrology properties, infiltration rate and moisture tension curve of the soil in experimental site were determined as shown in Fig. (3).

The data of infiltration rate test were fitted with two parameters of Costiacov equation as described by Bouwer (1986). The equation is:

$$I_t = a\,t^{\,b} \qquad\qquad v_i = a\,b\,t^{\,b-1}$$

Where: I_t = Accumulated infiltration depth in mm

v_i = infiltration rate in mm/min

t = intake opportunity time in min

a and b = constants.

- In the conditions of experiment, it was found that:

Where: **a = 2.52** **b = 1.239**

$$I_t = 2.52\ t^{1.239}$$
$$v_i = 3.125\ t^{0.239}$$

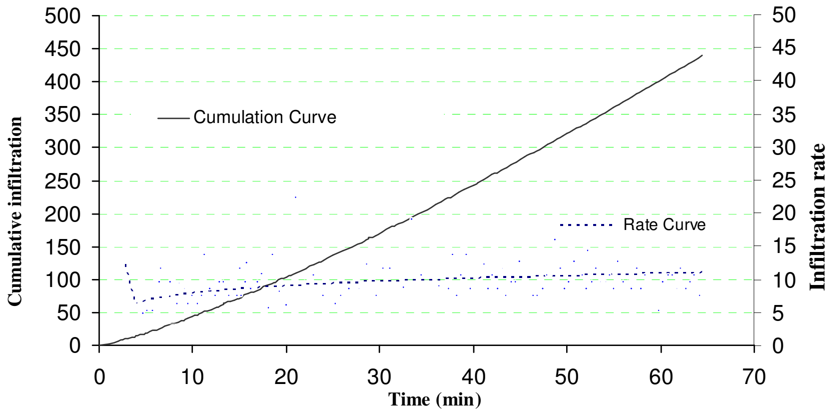

Fig. (3): Cumulative infiltration (mm) and infiltration rate (mm/min).

The curve of infiltration rate decreased then reached to the steady state with time. This is characteristic of the texture of soil profile of the experimental site, as shown in Fig. (3).

Soil moisture content (V %) for the soil samples at 0.12, 0.33, 0.66, 1, 2, 5, and 15 bar were determined. The mean value of moisture content was plotted against tension (bar) and this relation is illustrated in Fig. (4).

It is clear that the moisture content at field capacity and wilting point are 16.24 and 7.56 %, respectively. Consequently, the available water is (8.68 %).

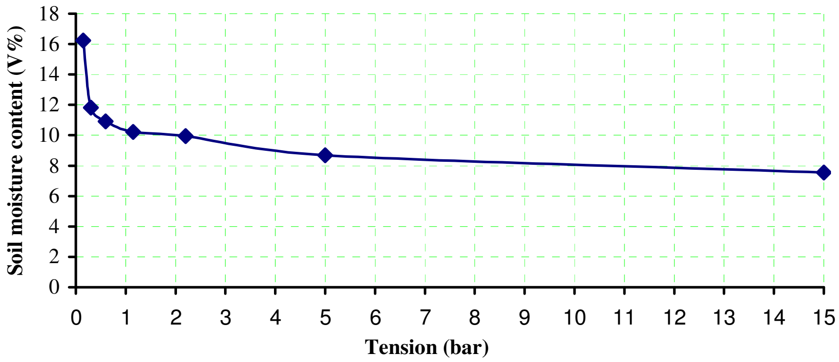

Fig. (4): Retention characteristic curves for the soil.

Soil moisture distribution without underneath PE foil:

As mentioned before, the experiment (E_1) was carried out without underneath PE foil. In this case two depths were tested with VSL and AL states of driplines. In the same time, each depth for each state had two ranges of width between driplines. Soil moisture contents after 12 h from irrigation were 9 – 8, 8 – 7, 8 – 7, 8 – 7, 9 – 8, 8 – 7, 7 – 6, and 8 – 7 % for T_1, T_2, T_3, T_4, T_5, T_6, T_7 and T_8, respectively, as shown in Figs. (5 and 6).

These data show that the values reached to the wilting point in case of E_1 (T_2, T_3, T_4, T_6, T_7, and T_8) however, the other treatments E1 (T_1, and T_5) did not reach to wilting point after 12 h from irrigation. From the soil moisture content point of view, the plants grown under E_1 (T_1, and T_5) treatments did not subjected to soil moisture stress, if they irrigated every 12 h.

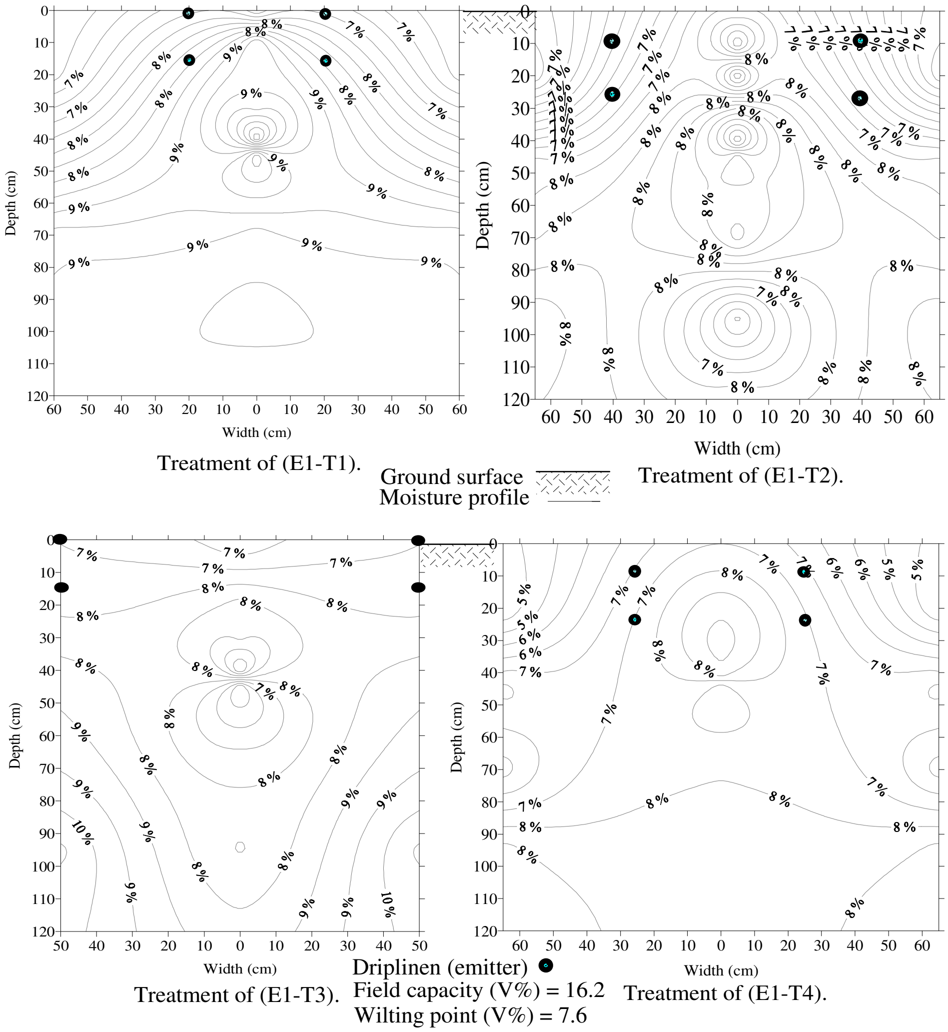

Fig. (5): Soil moisture distribution after twelve hour without underneath PE foil.

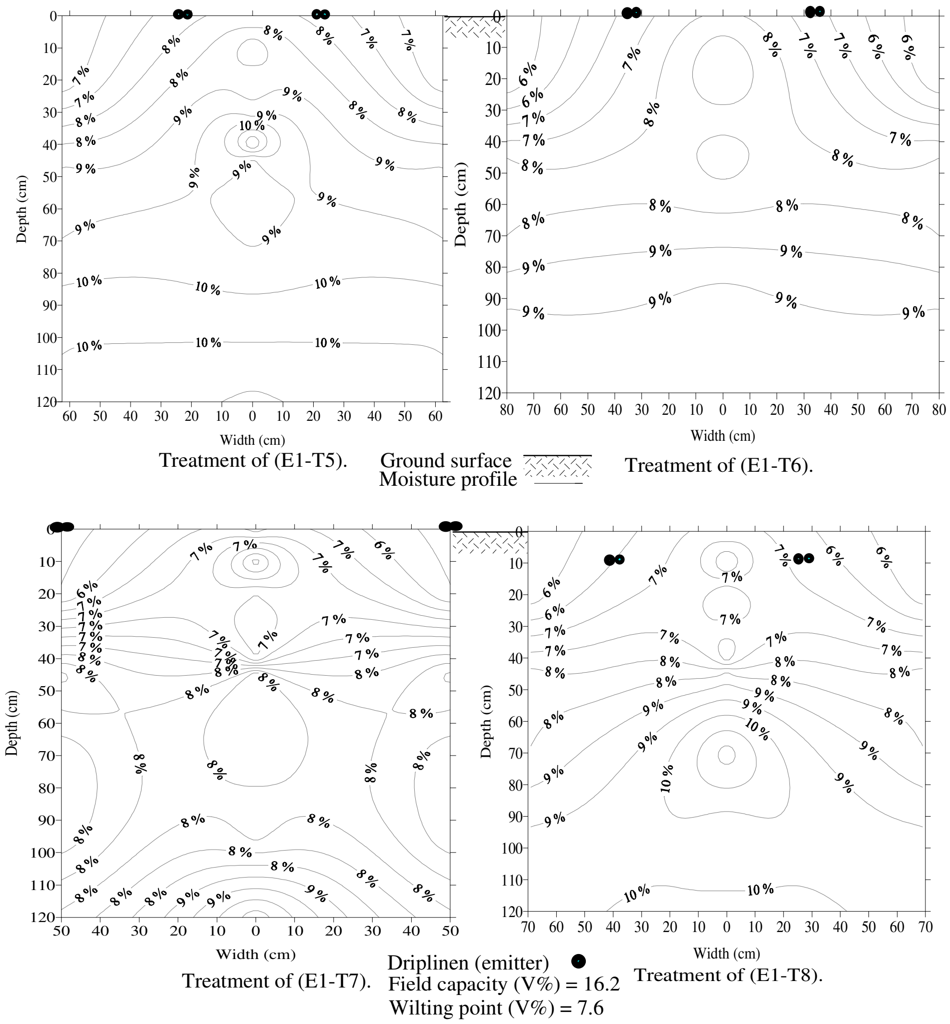

Fig. (6): Soil moisture distribution after twelve hour for treatments without underneath PE foil.

Soil moisture distribution with underneath PE foil (E1):

Fig. (7) shows the soil moisture distribution after 2, 12, and 24 h from irrigation as affected by a treatment under consideration and Figs. (8 and 9) show the other treatment at 12 h after irrigation. It is clear that soil moisture content of (T_1) did not reach to wilting point till after 24 h from irrigation. However, the values of some treatments (T_5, T_7, and T_8) did not reach to wilting point after 12 h from irrigation but reached to wilting point after 24 h from irrigation. However, in the other treatments, the values reached to wilting point after 12 h from irrigation. In all treatments the soil moisture content occurred in the available water range after 2 h from irrigation.

These data of with underneath PE foil indicated that soil moisture distribution of T_1 is the best because the values of soil moisture content did not reach to the wilting point after 24 h from irrigation. This means that the plants grown under T_1 treatment will not be subjected to soil moisture stress.

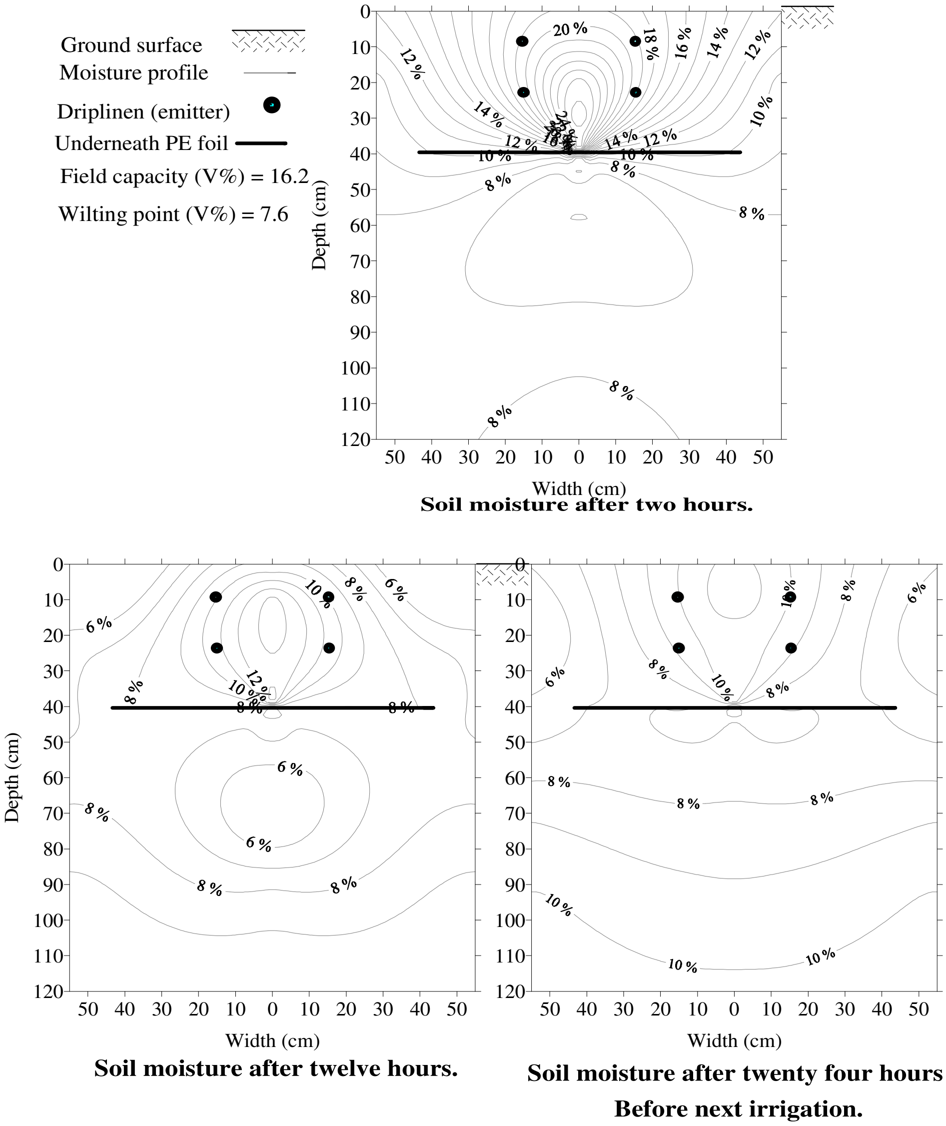

Fig. (7): Soil moisture distribution after different times from subsurface driplines irrigation (E_2, T_1).

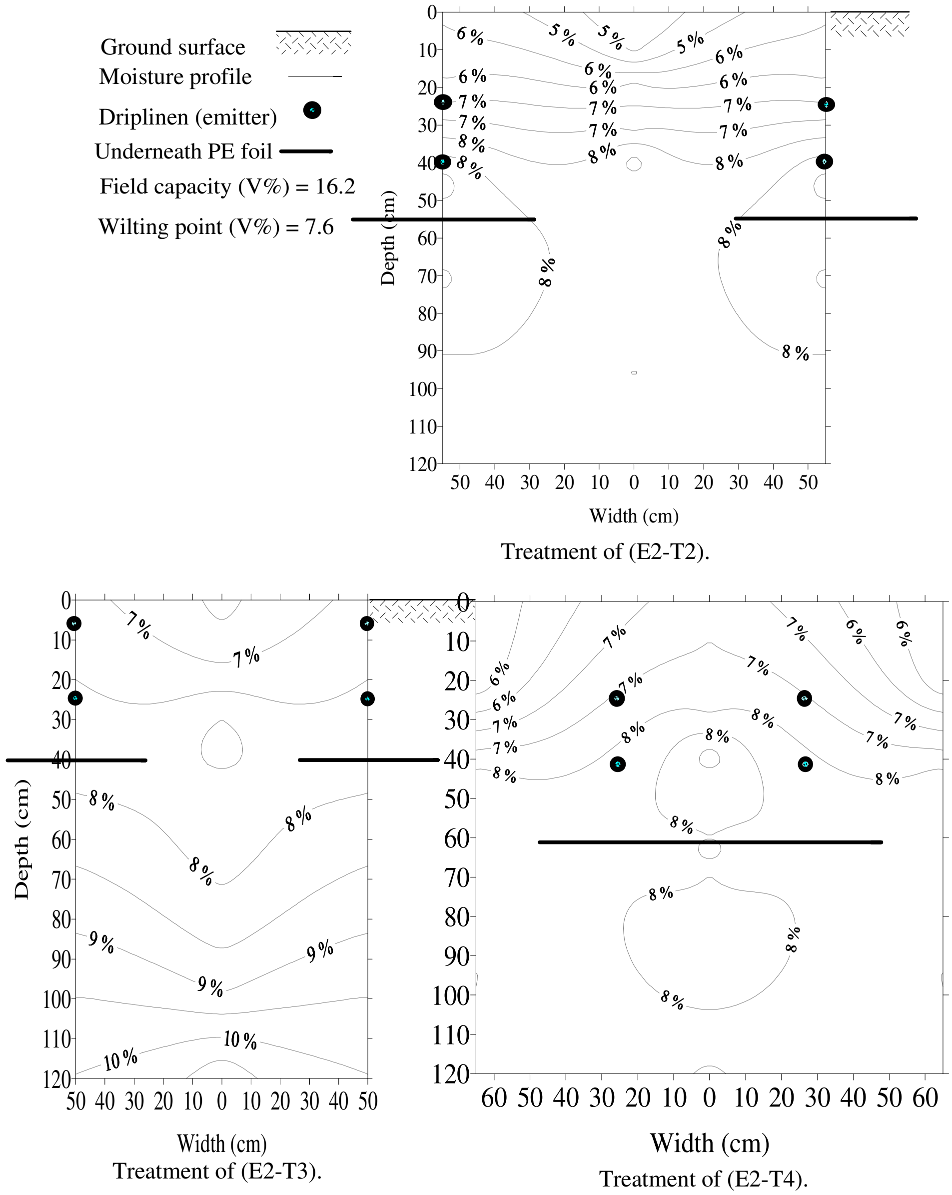

Fig (8): Soil moisture distribution after twelve hour with underneath PE foil.

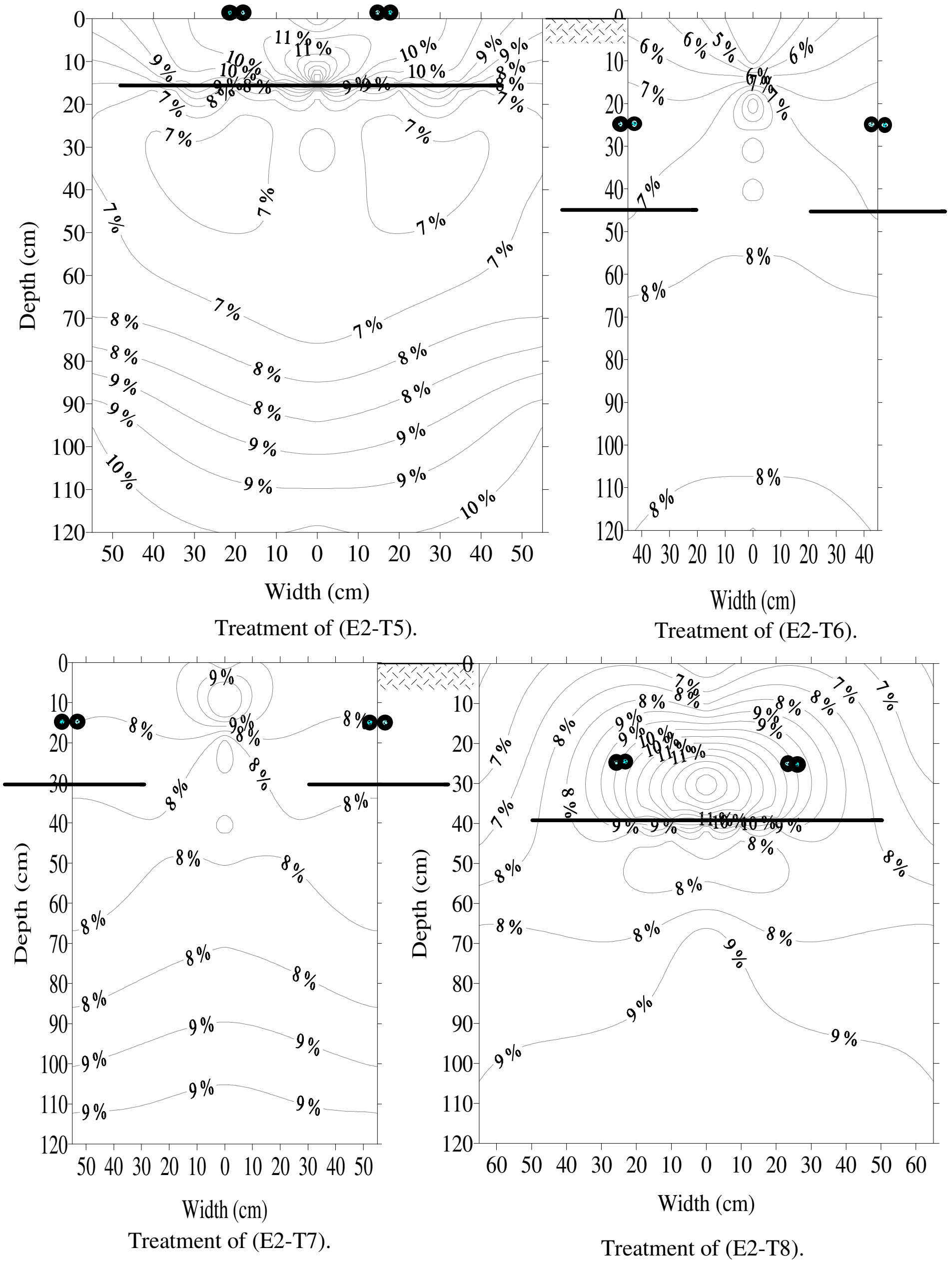

Fig (9): Soil moisture distribution after twelve hour with underneath PE foil.

Tomato yield under treatments without underneath PE foil:

Tomato yield mean values were 1.0 and 1.7 t/fed in surface and 10 cm dripline depth respectively, in VSL arrangement, followed by 1.2 t/fed for both surface and 10 cm dripline depth in AL arrangement, as shown in

Table (3). Also, WUE was affected by dripline depth and its mean values were 0.4 and 0.2 kg/m^3 for surface and 10 cm dripline depth respectively, in VSL, followed by 0.2 kg/m^3 for both surface and 10 cm dripline depth in AL.

The main effect of driplines depth regardless of driplines wide on tomato yield under VSL and AL arrangements of driplines without underneath PE foil.

Table (3): Tomato means yield and WUE with different treatments.

Arrangement	Depth (cm)	Width range between driplines (m)	Yield (ton/fed)	WUE (kg/m^3)
VSL	0	0.4 - 0.5	1.3	0.2
		0.8 - 1.0	0.7	0.2
	10	0.5 - 0.65	2.4	0.5
		0.65 - 0.8	1.7	0.4
		0.8 - 1.0	1.0	0.3
AL	0	0.4 - 0.5	0.8	0.13
		0.8 - 1.0	0.6	0.20
	10	0.5 - 0.65	1.1	0.22
		0.65 - 0.8	1.0	0.24
		0.8 - 1.0	0.7	0.21

The high mean values of tomato yield affected by width range between driplines were 2.4 and 1.7 t/fed in ranges of 0.5 – 0.65 and 0.65 – 0.8 m for VSL arrangement and 1. 1 and 1.0 t/fed for ranges 0. 5 – 0.65 and 0.65 – 0.8 m at AL. WUE was also affected by width range between driplines and its high mean values were 0.5 and 0.4 kg/m^3 in ranges of 0.5 – 0.65 and 0.65 – 0.8 m, respectively, for VSL arrangement and 0.24 and 0.22 kg/m^3 for ranges 0.65 – 0.8 and 0.5 – 0.65 m, respectively at AL.

Arrangement of driplines affected also in yield mean values, which were 1.4 and 0.84 t/fed for VSL and AL arrangement, respectively. WUE gave response to the arrangement of driplines and its high mean values were 0.3 and 0.2 kg/m^3 for VSL and AL, respectively.

Tomato yield under treatments with underneath PE foil:

Tomato yield gave a highly significant difference with the interaction of arrangement and depth of driplines, but there was no significance in either arrangement or depth alone. The high yield mean values were 4.1 and 3.5

t/fed with dripline depths 10 and 15 cm respectively, in VSL, followed by 2.7 t/fed in 10 cm dripline depth in AL arrangement, as shown in Table (4). Also, Water use efficiency (WUE) was affected by driplines depth and took the same trends of yield, and its high mean values were 0.9 and 0.7 kg/m^3 in dripline depth 10 and 15 cm respectively, in VSL, followed by 0.5 kg/m^3 in 10 cm dripline depth in AL.

The main effect of driplines depth regardless of driplines wide on tomato yield under separated and closed state of driplines with underneath PE foil.

Table (4): Tomato yield and WUE with different treatments.

Arrangement	Depth (cm)	Width range between driplines (m)	Yield (ton/fed)	WUE (kg/m^3)
VSL	0	0.2 - 0.3	4.0	0.5
		0.9 - 1.2	0.0	0.0
	10	0.3 - 0.6	3.4	0.5
		0.6 - 0.9	4.8	1.2
	15	0.3 - 0.6	3.9	0.6
		0.6 - 0.9	3.1	0.8
	25	0.2 - 0.3	0.0	0.0
		0.9 - 1.2	0.0	0.0
AL	0	0.2 - 0.3	1.3	0.2
		0.9 - 1.2	1.02	0.4
	10	0.3 - 0.6	4.2	0.6
		0.6 - 0.9	1.3	0.3
	15	0.3 - 0.6	3.4	0.5
		0.6 - 0.9	0.0	0.0
	25	0.2 - 0.3	1.2	0.2
		0.9 - 1.2	0.0	0.0

Width range between driplines also gave a significant difference in its single effect and a high significance with the interaction with the arrangement or depth of driplines, the obtained high mean values were 4 and 3.7 t/fed in ranges of 0.6 – 0.9 and 0.3 – 0.6 m for VSL and 3.8 t/fed for range 0.3 – 0.6 m at AL. WUE was also affected by width range between driplines and its high mean values were 1.0 and 0.6 kg/m^3 in ranges of 0.6 – 0.9 and 0.3 – 0.6 m for VSL and 0.6 kg/m^3 for range 0.3 – 0.6 m at AL.

Arrangement of driplines did not give a significant difference alone but gave a high significance with the interaction with other factors. Yield mean values were 2.4 and 1.56 t/fed for VSL and AL, respectively. And this was agree with Ismail *et al.* (2006) and considered the VSL case as using a hydraulic barrier. WUE gave response to arrangement of driplines and its high mean values were 0.5 and 0.27 kg/m^3 for VSL and AL arrangement, respectively.

Underneath PE foil did not give a significant difference alone but gave a high significance with the interaction with other factors. Tomato yield mean values were 3 and 1.7 t/fed for with and without underneath PE foil, respectively. Also, WUE was affected by underneath PE foil, which means were 0.8 and 0.3 kg/m^3 for with and without underneath PE foil, respectively.

CONCLUSION

- In these experiments, a system of subsurface drip irrigation was developed and used with saline water in coarse sandy soil in Siwa Oasis. PE (Poly ethylene) foils were also tested underneath driplines to conserve water. Results of Water Use Efficiency (WUE) of subsurface drip irrigation (combined with the effect of using underneath foil) showed improvement to 0.9 kg/m^3 compared with 0.3 kg/m^3 for surface drip irrigation.
- Driplines were placed at depths ranging from 0 (surface) to 25 cm. The underneath foil was 50 cm wide, at 15 cm below dripline. The shallow line depth of 10 cm gave best results linked with foil effect, due to porosity of soil and water tendency to seep downwards.
- Two dripline arrangements were tested:
  (1) Two Adjacent Lines (AL) to produce double the rate of a single line,
  (2) two Vertically-Spaced Lines (VSL) at 15 cm in-between of the same rate of discharge as the AL. The two systems were compared to show that the wetting pattern of the second arrangement is more favorable to downward plant-root penetration.
- In general, sandy soil lost gained moisture after twelve hours from irrigation, thus requiring twice-a-day irrigations.
- Underneath PE foil efficiency increased with its width.
- In the experiment with underneath PE foil, wilting point was reached after 24 h from irrigation, compared with 12 h for other treatments without foil.

* For the experiment without foil:
  - Tomato yields were 1.7 and 1.0 t/fed for 10 cm depth and surface driplines respectively, in the VSL arrangement followed by 0.93 and 0.7 t/fed for 10 cm depth and surface dripline respectively, in the AL arrangement (Fed. = 4200 sq.m.)
  - Line spacings of 0.5 to 0.65 m gave best tomato yield of 2.4 t/fed with VSL compared with 1.7 t/fed for 0.65 to 0.8 m spacing.
  - AL gave 1.1 t/fed tomato compared with 2.4 t/fed for the VSL.
  - Best WUE for tomato reached 0.5 kg/m^3 in the case of VSL with 0.5 – 0.65 m spacing and 10 cm depth.

* For the experiment with foil:
  - Tomato yields were 4.1 and 3.5 t/fed in dripline depths 10 and 15 cm respectively, with VSL arrangement, followed by 2.7 t/fed in 10 cm AL depth.
  - Line spacing of 0.6 to 0.9 m gave best tomato yield of 4 t/fed with VSL compared with 3.7 t/fed for 0.3 to 0.6 m spacing.
  - AL gave tomato yield of 4.2 t/fed compared with about 4.8 t/fed for VSL.
  - Best WUE for tomato reached 1.2 kg/m^3 in the case of VSL with 0.6 – 0.9 m spacing and 10 cm depth when using PE foil.

- Tomato yield values were 4.8 and 2.4 t/fed for with and without underneath PE foil, respectively.
- WUE were 1.2 and 0.5 kg/m^3 with and without underneath PE foil, respectively.

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الملخص العربي

التوزيع الرطوبي للتنقيط تحت سطحي باستخدام المياه المالحة في أرض رملية

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أجري هذا البحث بمحطة مركز بحوث الصحراء بواحة سيوة – محافظة مطروح، بهدف دراسة تأثير الأبعاد الهندسية المختلفة لنظام الري في ظروف الواحة ومع إستخدام مياه ذات ملوحة عالية (حوالي 6000 ديسيسيمنز/م)، وقد استخدامت شريحة غير منفذة تحت خط التنقيط في بعض المعاملات وذلك بعرض 50 سم أسفل الخطوط بحوالي 15سم، وتم إختبار أعماق مختلفة لخط التنقيط (من صفر إلى 25 سم)، ومسافات بين خطوط التنقيط للتجربة الأولى (من 0.20إلى 1.2 م) وللتجربة الثانية (0.40إلى 1.0 م).

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وأخذ توزيع الرطوبة في قطاع التربة على عمق واحد أوعمقين وذلك بوضع خطي تنقيط متلازمين (خ م) أو مزاحين رأسيا بمسافة 15 سم (خ ر)، وقيس الناتج المحصولي، وكفاءة إستخدام مياه الري لمحصول الطماطم المنزرع بأرض رملية، وذلك باستخدام خطوط ري تنقيط نقاطين (GR)/ المتر، بتصرف 4 لتر/س عند ضغط واحد جوى.

وقد توصلت الدراسة إلى النتائج الآتية:

- يفقد القطاع الرملي الرطوبة المضافة من ماء الري في حوالى 12 ساعة بعد الري بوجه عام، ولذا يلزم الري في مثل تلك الظروف مرتين في اليوم.
- تزداد كفاءة العازل (PE) التحتى مع زيادة عرضة.
- أدى استخدام العازل تحت السطحي إلى تحسين متوسط كفاءة الإستهلاك المائي من 0.9 إلى 0.3 كج/م^3 للري تحت السطحي والسطحي على الترتيب.
- تصل معاملات التجربة المحتوية على عازل تحت التربة إلى نقطة الذبول بعد 24 ساعة مقارنة مع 12 ساعة لغير المحتوية على عازل.
- في التجربة غير المحتوية على عازل تحت التربة:

- وصل محصول الطماطم 1.7، 1 طن/فدان للعمق 10 سم، والسطحي على الترتيب وذلك لخطى التنقيط "خ ر"، تلاه 0.93، 0.7 طن/فدان للعمق 10 سم والسطحي لحالة "خ م".
- أعطى مدى الإتساع من 0.5 إلى 0.65 م بين خطوط التنقيط محصولا قدره 2.4 طن/فدان، مقارنة بمحصول قدره 1.7 طن/فدان للإتساع من 0.65 إلى 0.8 م.
- أعطى ترتيب خ ر محصولا قدره 2.4 طن/فدان في حين أعطت الحالة خ م 1. 1 طن/فدان.
- أفضل كفاءة للإستهلاك المائي وصلت 0.5 كج/ م^3 مع خ ر والإتساع بين الخطوط من 0.5 إلى 0.65 م وعمق خط التنقيط 10 سم.

- في التجربة المحتوية على عازل تحت التربة:

- أعطى محصول الطماطم أعلى إنتاجية مع الحالة خ ر حيث أعطت 4.1، 3.5 طن/فدان للأعماق 10، 15 سم بالترتيب، تلاه 2.7 طن/ فدان للحالة خ م للعمق 10 سم للخطوط.
- أعطى محصول الطماطم 4، 3.7 طن/ فدان لكل من المدى 0.6 – 0.9 م والمدى 0.3 – 0.6 م بالترتيب وذلك لحالة خ ر، و أعطى 3.8 طن/ فدان للمدى 0.3 – 0.6 م بالنسبة للحالة ح م.
- أعطى محصول الطماطم 4.8، 4.2 طن/ فدان للحالتين "ح ر" و "ح م" على الترتيب.
- بلغت كفاءة إستخدام المياه 1.2 كج/م^3 للإتساع بين خطوط التنقيط من 0.6 إلى 0.9 م وعمق 10 سم وذلك للحالة ح ر، في وجود غازل تحت سطحي.
- أعطى محصول الطماطم 4.8، 2.4 طن/ فدان في وجود أوعدم وجود عازل بالترتيب.
- بلغت كفاءة إستخدام المياه 1.2، 0.5 كج/ م^3 في وجود أوعدم وجود عازل على الترتيب.