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IMPROVING MOISTURE DISTRIBUTION PATTERN OF SUBSURFACE DRIP IRRIGATION IN SANDY SOIL BY USING SYNTHETIC SOIL CONDITIONER

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ABSTRACT

Although, subsurface drip irrigation is controlled system without negative environmental impacts associated with leaching or runoff. However, poor uniformity of moisture content and distribution pattern especially at the upper layer (0-5 cm) in the sandy soil was observed by several studies. Therefore, three stages of the experiments were conducted to improve the uniformity of the moisture content under the subsurface drip irrigation especially in sandy soil.

First stage of the experiments were conducted to investigate the effect of the soil texture, sandy (Bostan area) and sandy loam (El-Hamam area) on the soil water content uniformity and distribution pattern. This experiment was conducted on lateral depths (0 and 15 cm for simulation of surface and subsurface drip irrigation systems, respectively) to indicate the difference in water losses and the uniformity of soil moisture distribution as function of soil texture effect and dripper line position.

The second stage of the investigation was consternated on the selection process of the appropriate buried depth of the subsurface drip laterals (10 and 15 cm) under different operating pressure (0.5, 1.0 and 1.5 bar). After then, the optimal system was used in presence of synthetic soil conditioner thin layer at different locations at (25 and 30 cm) as a third stage of the experimental procedure.

Soils were uniformly packed in a 50 x 50 x 100cm soil box. The dripper line with two emitters was inserted at certain depths. The polyacrylamide polymer was dissolved in the laboratory and diluted to 0.01% as appropriate concentration which was applied in rate 12.3 kg/fed (Aboamera et al., 2000). The polymer was sprayed directly to the soil surface at the desired depths. The results pointed out that the water front was less progressed in sandy loam soil, which caused increasing in the water volume use from each emitter in sandy loam soil by 64 % than that obtained in sandy soil.

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The studies indicated that subsurface irrigation saved the water consumption by 61 and 39 % for both soil textures the sandy (Bostan) and the sandy loam soil (El-Hamam), respectively, than the surface drip irrigation. The moisture content distribution pattern indicated that the dripper line at 15 cm depth was better than the 10 cm depth under any operating pressure. The average moisture content was 10.6% until soil depth 43 cm for 15cm dripper line depth, while the average of moisture content was 9.4% until soil depth 39 cm for 10cm dripper line depth under operating pressure 1.0 bar without polymer.

The synthetic soil conditioner thin layer depth resulted in changing the pattern of the water front spreader and diverted the water cone below and above the dripper line to be moved more horizontally than vertically. Also, it was indicated that the deeper the polymer depth was located, the better the water front distribution was progressed upward and downward. The preferable combination was at dripper line 15 cm depth and polymer layer 30 cm depth working under operating pressure 1.0. However, it should an economical study to indicate the profit due to increasing the yield due to the moisture distribution and the water holding improvement and it would overcome the expenses of baying and manipulation of the synthetic soil conditioner or not.

INTRODUCTION

The type of irrigation systems is becoming more important and scarcely meets the need of agriculture expansion. So, irrigation water is rapidly becoming the primarily limiting factor for crop production. Goldberg et al. (1976) mentioned that determination of consumptive use of crops grown under protected conditions is a good approach towards better water management to achieve optimum water use efficiency. El-Gindy et al. (2001b) abstracted that proper application of water in terms of quantity and timing has major impacted on the crop and its economic feasibility. One of these water management systems is drip irrigation. Since water can be applied with a high degree of control, higher application efficiencies are possible and could be achieved. Camp et al. (1989) reported that micro irrigation offers several advantages, including low water delivery rate, low water pressure and precise placement of water. Unfortunately, the high cost of annual replacement of many system components has limited its application to high-value crop such as vegetables and some tree crops.

Subsurface drip irrigation (SDI) is another type of controlled irrigation system which is defined by Davis and Nelson (1970) as "application of water below the soil surface through emitters, with discharge rates generally in the same range as drip irrigation". SDI allows highly production of crops without negative environmental impacts associated with leaching or runoff. Only the amount of water consumed by the crop needs to be diverted from a stream or reservoir, helping to protect stream water quality in a large number of ways (Shock et al., 2000). The SDI system has been shown by Styles and Bernasconi (1994) to be more profitable than the surface drip irrigation method under some circumstances, while the surface irrigation methods can offer more profit to farmers under circumstances or soil conditions (Caswell et al. 1984; Letey et al. 1990; Fulton et al. 1991). Camp (1998) reported that the importance of the SDI system is referred to its ability for irrigating different agronomic crop patterns (includes turf-grass, forestry products and about 10 different filed crops) and horticultural crops (for over 20 vegetable, fruit, and vine crops). SDI can be achieved by using trickle irrigation (Hanson and Partterson, 1974; Buks et al. 1981; Camp et al, 1989), through porous and perforated plastic pipes, leaky pipe and clay jars (El-Awady et al, 1986 and Bakeer 1997), soil-wick self-regulating (Ismail, 1993) and Typhoon dripper line (Zin El-Abedin et al. 1996 and Sharaf et al. 1996).

El-Berry (1989a) found that the highest values of water use efficiency were observed under subsurface drip system which was approximately twice and seven times that of sprinkler and basin systems respectively in case of alfa-alfa production under desert condition. Although El-Gindy (1988) reported that the moisture content of the top soil (0-20 cm) was higher in the surface drip irrigation field than those of surface and sprinkler ones. On the other hand El-Berry et al. (1989b) pointed out that in subsurface trickle, the upper layer (0-5 cm) had the lowest moisture content (2.4%) both before and after water application, the moisture percentage increased with depth to reach its maximum (16 and 8 % after and before irrigation, respectively) at a depth of 22 cm below the irrigation tube level on sandy soil. Research by the USDA has shown that the wetted pattern around the buried emitter can be managed by irrigation frequency (Phene et al. 1987). For example, if the desired effect is to move more water towards the surface, irrigation frequency should be increased.

Devitt and Miller (1988) investigated several lateral spacing on two soils when using saline irrigation water for Bermuda grass in Nevada, concluding that 0.6 m spacing was acceptable for a sandy loam, but a closer spacing would be required for clay for SDI system. Some high-value crops may require closer spacing on sandy soils (Phene and Sanders, 1976) and/or in arid areas to ensure adequate salt balance and consistent crop quality and yield. Barth (1995) and Welsh et al. (1995) suggested installation of a barrier, either plastic or metal foil, below the lateral to alter water distribution and flow, primarily from vertically downward to more horizontal. Brown et al. (1996) reported a small but consistent benefit of a V-shaped polyethylene strip installed beneath subsurface drip laterals, primarily causing the wetted area to be slightly higher and wider than that from a conventional installation. Others report soil chemical changes caused by various fertilizers, gypsum (Grimes et al. 1990), and organic matter (Mitchell and Sparks 1982).

Synthetic soil conditioner polymers such as polyacrylamide (PAM) can increase the water holding capacity of sandy soil. El-Gindy et al. (2001a) reported that sandy soil has low water holding capacity, so using soil conditioners especially polymers can increase the water holding capacity of the soil. The use of polymer is not restricted to only sandy soils but also to clay soils however it can improve hydraulic conductivity, seed emergence and eliminate crust problems. Ismial (1998) reported that incorporated polymer into the soil will improve soil structure and water retention, thus reducing leaching, reducing water losses due to percolation and evaporation, protecting the plant against water stress and increasing both the nutrient and water supply to the roots. In addition, the structural improvement in soil will lead to better aeration for the root system and reduced soil compaction. Soluble fertilizers can function in combination with polymer to provide slow release characteristics in soil (Aly and Aboamera 2000). Polymer significantly increased the hydraulic conductivity and salt removal in the cracked soils. The increase in hydraulic conductivity did not persist through several wetting and drying cycles (Malik et al. 1991). El-Hady and Lotfy (1987) reported that polyacrylamide (PAM) increased plant growth and dry matter production of plant according to the rate of application due to increase of nutrients uptake and both of water and fertilizer use efficiencies. Frequency of fertilizer application had no effect on both of yield and fruit quality of pepper (Neary et al. 1995; Storlie et al. 1995).

The subsurface drip irrigation system had different features compared to the other ones, as water is applied deep down from the surface. It appeared that capillary rise under such sandy soil is not quick enough to compensate the shortage in moisture content within the 30 - 50 cm surface layer. Thus, changing the location of the dripper line depth or using low operating pressure may improve the moisture content pattern. Moreover, installation of a barrier (Barth 1995 and Welsh et al. 1995) such as a thin layer of synthetic soil conditioner (polymer) may overcome this problem and maintain relatively optimum amounts of water for plant root especially with crops that have shallow root system.

Therefore the objectives of this study were first to investigate: a) the comparison between the surface and subsurface irrigation under different soil textures; b) the effect of the dripper line depth and c) the effect of the changing the operating pressure on the water front and moisture content distributions. These to select the proper dripper line depth and operating pressure to be engaged with the thin layer of synthetic soil conditioner (polymer) spreaded at different locations. This may overcome the problem of the capillary rise weakness under such sandy soil and maintain relatively optimum amounts of water for plant root especially with crops that have shallow root system.

MATERIALS AND METHODS

Soil collection and analysis

Two Egyptian soils (El-Hamam and El- Bostan series) were used in this study to represent the sandy loam and sandy soils, respectively. At each site, the top vegetative cover of the soil was scraped away and the soil from the top 50 cm was removed with a shovel. The soils were placed in heavy-duty (16mm thick) polyethylene bags. Each bag was filled with about 50 kb of soil and sealed. The bags were transported from the collection site to the Irrigation Laboratory of Agricultural Engineering Department, Faculty of Agricultural, Alexandria University.

Soil samples were taken from 3 cores in each soil for bulk density determination. Five samples were taken (every 10 cm soil depth up to 50cm) from each core. Each soil type was analyzed to determine field bulk density and particle size distribution. The pH, saturated hydraulic conductivity (Ks), field capacity (FC), permanent wilting point (PWP) and electrical conductivity (Ec) of each soil were also measured. These tests were carried out according to the procedure described in the in the Methods for Soil ANALYSIS (Black et al., 1982). The results of the soil analysis along with other soil characteristics are presented in Table (1).

Table (1). Some soil characteristics of the soil types.

Soil location	Practical size distribution, %			FC, %	PWP %	BD, g/cm^3	Ks, m/d	EC, ds/m	pH	Soil Text.
	Sand	Silt	Clay							
El-Hamam	66.0	19.2	14.8	19.9	10.8	1.35	0.97	0.9	7.8	Sandy loam
El- Bostan	93.9	4.5	1.6	10.9	5.2	1.62	3.16	1.3	8.2	Sandy

Experimental apparatus

Experiments were conducted on a wooden rectangular soil box (100 x 50 x 50 cm) which was painted with water prove paint to avoid water absorption, as shown in Fig. (1). The front side of this box (100 cm length and 50 cm height) was Plexiglas allowed to observe the water movement behind the wetting front and the water use volume drawn from the buried dripper line in the two dimensions. The other perpendicular wall sides (50 x 50 cm) were holed in the vertical direction (z) at three different levels (0, 10 and 15 cm) from the soil surface. The three holes were drilled in the box wall through which allows the dripper line with two emitters was inserted as surface and subsurface irrigation. These holes were 10 cm apart from the front side (Plexiglas wall). The buried dripper line, one end was connected to the water supply which was glass water tank 0.4 m^3 and the other end was closed tightly. The dripper line was GR 4 ℓph P.E 16 mm in diameter with 50 cm emitter spacing.

Experimental procedure

The soil was air-dried on the dry weight basis for either sandy loam (El-Hamam) or sandy (Bostan) soil. The large clods were removed by passing the soil through 2mm mesh size sieve. The soil was placed into the soil box in 5cm layers to achieve the same bulk densities as measured in the field and leveled until the target depth (25cm and 30cm from the box surface) to add the thin layer of the synthetic soil conditioner (polyacrylamide polymer) which was supposed to sever the 30 to 50 cm of the soil surface ((Malik et al, 1991).

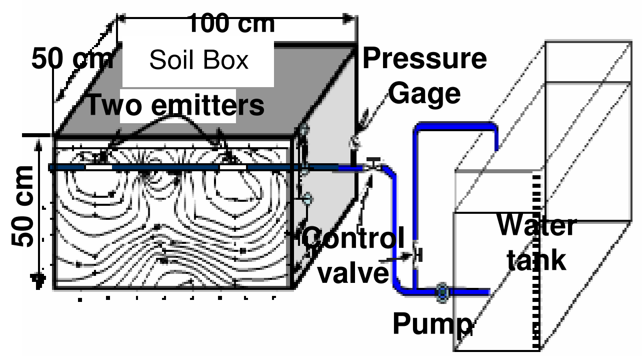


Figure (1): Schematic diagram of the Laboratory experimental apparatus.

The used polyacrylamide polymer (hydrophilic) prename evergreen 500 has a molecular weight 5 million in powder form. The polymer was dissolved in the laboratory in a stock of 1g/l and diluted to 0.01% as appropriate concentration which was applied in rate 12.3 kg/fed (Aboamera et al., 2000). The polymer was sprayed directly to the soil surface at the desired depths, and it was left to air drying. Then the soil box was filled with another soil layer up to the depth of 15cm or 10cm from the soil box surface. The dripper line was inserted through the side holes and laid on the soil surface at these depths. Then the rest of the soil was placed in the same previous procedure up to the 50 cm depth and leveled. The soil box was left for one week to allow the soil to be settled.

The water was supplied from the water tank by using small pump connected to it with 0.008 m^3/hr flow rate through the GR dripper line. The test operating pressure was 0.5, 1.0 and 1.5 bar. The water level in the water tank was recorded as function of time during the experiment to determine the flow into the system as water consumption volume in litters. The position of the wetting front distribution was recorded as function of time in eight directions to identify the water contour line. The wetting front contour was observed through the Plexiglas wall and projected on the transparent paper sheet for all direction. At the end of experiment the soil samples were taken in 5 cm interval for all directions at two vertical planes parallel to the Plexiglas wall (10 and 20 cm) away from that wall to represent the moisture distribution where the dripper line was exactly inserted and 10cm apart from it.

This study was conducted on three different stages of experiments to identify the necessity of using soil conditioner to improve the soil water holding capacity and getting better moisture distribution pattern. The first stage aimed to study the moisture distribution patterns and the advance time of the water front for two soil textures were namely sandy and sandy loam soil, under surface and subsurface drip irrigation system. The experiment was carried out by using two different dripper line locations (surface as 0 cm and subsurface as 15 cm depth) at average operating pressure 1.5 bar, whereas, the common operating pressure at field is varied between 1 – 2 bar. It was to determine the effect of the soil type on the soil moisture distribution uniformity and the advance time waterfront distribution. Also, it was to identify the value of the subsurface drip irrigation system compare with the surface drip irrigation system.

The second stage of experiments was conducted on subsurface drip irrigation for two different dripper line depths (10 and 15 cm) under three operating pressure values (0.5, 1.0 & 1.5 bar) for the sandy soil. These were to study the water front progressed and distribution above and below the dripper line to determine the best combination of the dripper line location and operating pressure to use with the synthetic soil conditioner.

The third stage of experiments was conducted to investigate the effect of both dripper line and synthetic soil conditioner layer depths. This stage was carried out at two dripper line depths (10 and 15cm) with two synthetic soil conditioner depths (25 and 30 cm) starting from the soil box surface for the sandy soil under two operating pressure (1.0 and 1.5 bar). These stages generate three different distances between the dripper line and the polymer layer which were (10, 15 and 20 cm).

RESULTS AND DISCUSSION

Soil texture effect on moisture pattern

The soil texture effect on the waterfront radial progress was recorded under surface and subsurface drip irrigation systems as shown in Figure (2). Table (2) summarized the results of the experimental accumulations of water volume for each emitter (ℓ); the time advance (min), without using the synthetic soil conditioner, for the two soil texture (stage 1) and two subsurface dripper line locations under the three operating pressure (stage 2). Figure (**2**a and b) illustrated the waterfront advance as function of time under surface drip irrigation. This indicated that the advance time was 230 min with water volume use 13.37 ℓ in sandy loam soil, while it was 140 min with water volume 8.14 ℓ in sandy soil. Therefore, the waterfront was less progressed in sandy loam soil may be due to the presence of clay and silt contents which increase the progress the water front in the lateral direction more than the vertical one. This caused increasing in the water volume use. from each emitter in sandy loam soil by 64 % than that obtained in sandy soil as shown in Table (2 stage 1). Moreover the interception of the two water bulbs result from both emitters was fully complete as a strip in sandy loam soil. Also, the water contours distribution was more uniformed

Table (2) the experimental combinations without polymer and their effect on the water volume use in the system (soil box).

Exps. Stage	Soil text.	Dripper line depth, cm	Operating pressure, bar	Maxi. time advance, min	Water use in system for each emitter, liter	Reduction water use percent, %
1	Sandy	0 15	1.5 1.5	140 55	8.14 3.20	61
	Sandy loam	0 15	1.5 1.5	230 140	13.37 8.14	39
2	Sandy	10	0.5	140	5.16	------
			1.0	105	5.10	1
			1.5	85	4.94	4
		15	0.5	120	4.43	------
			1.0	75	3.65	18
			1.5	55	3.20	28

Figure (2 c and d) showed that the water front distribution for the sandy soil was moved faster toward the downward depth than the sandy loam soil under similar conditions of operating pressure 1.5 bars at 15cm dripper line depth. Therefore, during 55 – 60 min the water front was reached the whole depth of the soil box (35 cm under the dripper line or 50 cm from the soil surface). However, the waterfront did not reach more than around 10cm toward the upward depth during this period. The waterfront advance time ratio was calculated between the time progress below and above the dripper line which was 3.5 in the sandy soil. Also, it was clear from Figure (2 c) the contour lines were very close to each other above the dripper line contrary to the contour lines below the dripper line which were away apart from each other. This reflected the weakness of the subsurface drip irrigation to reach the desired moisture content for plant growth and germination progress at the upper layer with suitable amount of water (El-Berry et al. 1989b). On the other hand, it was obvious that the waterfront distribution for sandy loam soil was almost symmetrical below and above the dripper line under similar conditions as shown in Figure (2d).

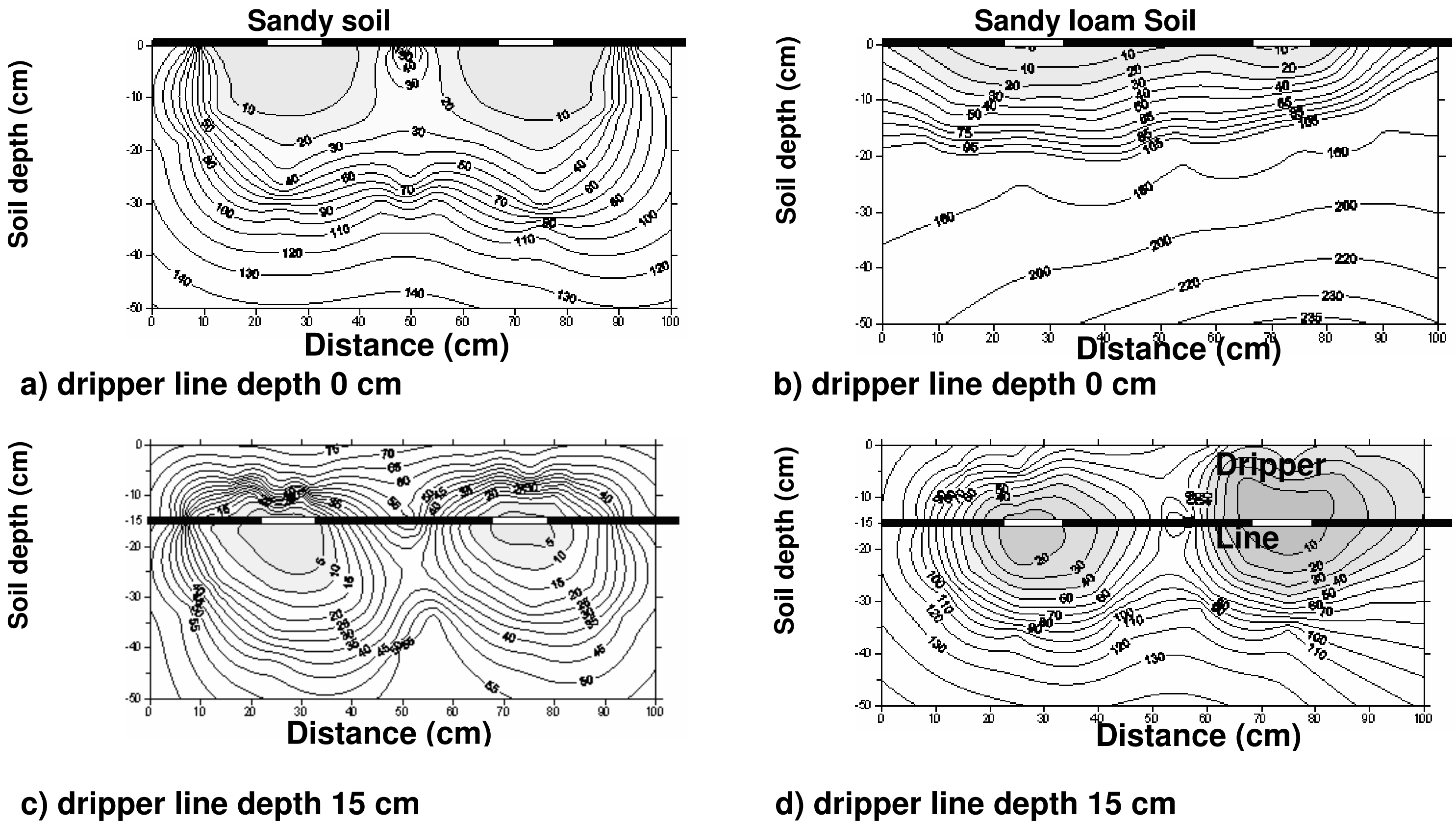


Figure (2) The water front distribution as a function of time (min) for the two emitters into the soil box under operating pressure 1.5 bar for different soil types and dripper line depths.

The water has moved upward and reached the soil surface after 60 – 70 min for both emitters. Simultaneously, the waterfront has reached 17.6 cm depth downward with the advance time ratio 1.17 which resulted in uniform distribution bulb. The waterfront was reached the maximum depth at 140 min. Figure (**2** c & d) indicated that presences clay and silt contents retarded the water movement downward far from the root zone. Moreover, Table (2, stage 1) calculated the percentage of water saved for subsurface drip irrigation than surface drip irrigation based on the value of surface drip water volume in system. This illustrated that the subsurface irrigation system was saved water by 61% and 39% less than surface irrigation under sandy and sandy loam, respectively, (Phene et al. 1989; Howell et al. 1997 and El-Berry et al. 2003). Obviously, it was clear that subsurface irrigation was not compatible with the sandy soil, whereas less water moved upward to the soil surface, so that, poor amounts of soil moisture distribution was obtained.

This was considered as a very critical situation for the plants particularly having shallow root zoon and for all plants during the first stage of growing (germination) (Schwankl et al. 1990).

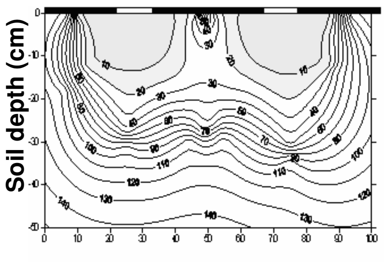
Effect of dripper line depth on moisture pattern

The previous results encourage studying the sandy soil under different dripper line depths (10 and 15 cm) and operating pressure range (0.5, 1.0 and 1.5 bar) to improve the water front progress. The results of the maximum time advance (min) of wetting front, the water volume use per each emitter (ℓ) and the reduction water use percent for the experimental combinations, were summarized in Table (2 stage 2). The results indicated that the lower value of the operating pressure, the higher the water use in system at any dripper line depth. Then the magnitude of the water use decreased in volume toward the higher value of operating pressure. Whereas, the reduction water use percent between the 0.5 and 1.0 bar was 1% while it was 4% between 0.5 and 1.5 bar at dripper line 10 cm. Similar pattern was obtained with dripper line 15 cm depth but more effective reduction value has been occurred which was 18% and 28% at operating pressure 1.0 and 1.5 bar compare with 0.5 bar. Moreover, the changing the dripper line locations affected the waterfront distribution as a function of time for the three operating pressures. The shallower the dripper line depth, the longer the time was taken to reach the maximum soil depth. Figure (**3** a, b & c) pointed out that the time progress increased from 55, 85 to 140 min at 15, 10 and 0 cm dripper line location, respectively. These different locations affected the waterfront upward spread toward the soil surface. The waterfront has reached the soil surface after 50 min with 10 cm depth. However, it has not reached the soil surface at dripper line 15 cm depth.

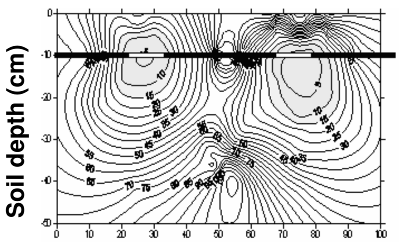
Effect of operating pressure on moisture pattern

Fig (**4** a, b & c) represented the effect of different operating pressure (0.5, 1.0 & 1.5 bar) on the waterfront advance distributions. The lower operating pressure (0.5 bars) resulted in best water distribution especially

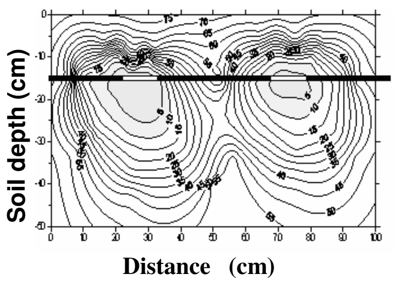
Dripper line depth



a) Dripper line 0 cm



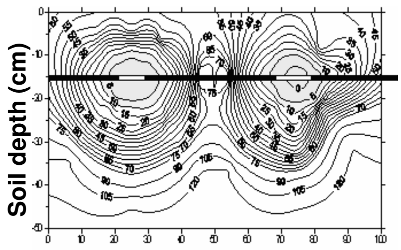
b) Dripper line 10 cm



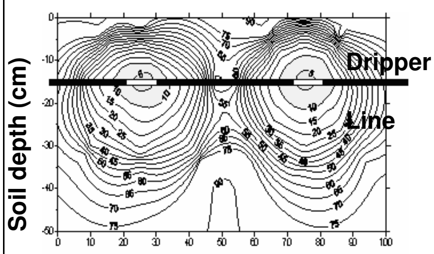
c) Dripper line 15 cm

Figure(3)The water front distribution as function of time (min) at operating pressure 1.5 bar for different dripper line depths (sandy soil).

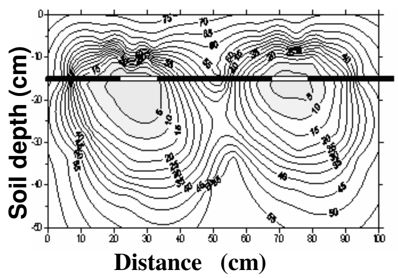
Operating pressure level



a) Operating pressure 0.5 bar



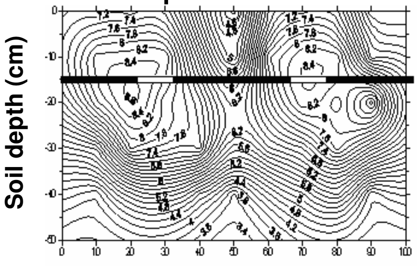
b) Operating pressure 1.0 bar



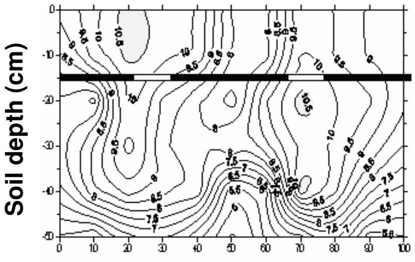
c) Operating pressure 1.5 bar

Figure(4)The water front distribution as function of time (min) at dripper line depth 15 cm for different operating pressure (sandy soil).

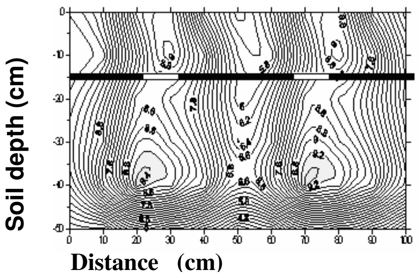
Moisture distribution at 10cm plane



a) Operating pressure 0.5 bar



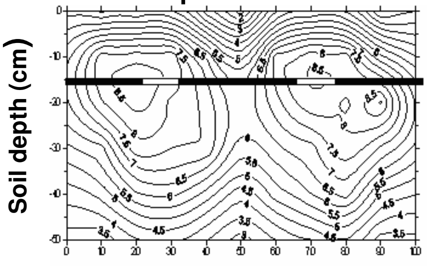
b) Operating pressure 1.0 bar



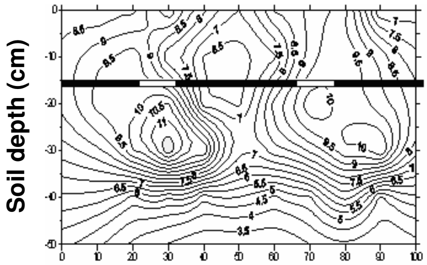
c) Operating pressure 1.5 bar

Figure(5)The moisture distribution through the two emitters into the soil box at 10 cm plane away from the Plexiglas wall for different operating pressure (Bostan soil).

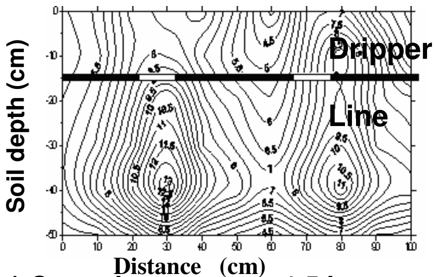
Moisture distribution at 20cm plane



a) Operating pressure 0.5 bar



b) Operating pressure 1.0 bar



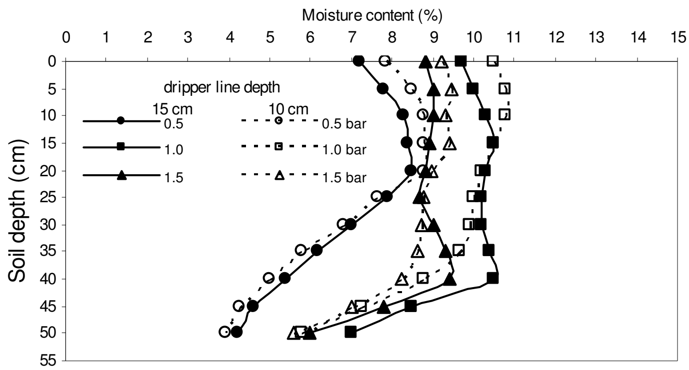
c) Operating pressure 1.5 bar

Figure (6) The moisture distribution through the two emitters into the soil box at 20 cm plane away from the Plexiglas wall for different operating pressure (Bostan soil).

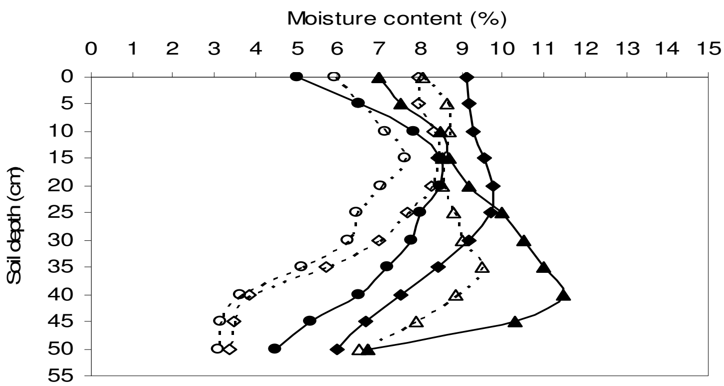
above the dripper line followed by operating pressure 1.0 then finally by 1.5 bars. However the time of the waterfront progress was longer with the lower pressure (0.5 bars) to reach the soil box depth which was 120min to reach 29.2cm under the dripper line (45 cm from the soil box surface) with water use volume 4.43 as shown in Table (2) stage (2). During 55- 60 min water front moved 15cm upward while it moved downward 18.9cm. Therefore, the time advance ratio was 1.26 which resulted in symmetrical bulb around the dripper line; however the operating pressure is very low. On the other hand, at 1.0 bar operating pressure, the advance wetting front was reached the soil surface with satisfactory uniformity at 75 min comparing with the uniformity obtained under 0.5

bar operating pressure. Also, during the last mentioned time 75 min, the wetting front was moved downward to 35cm depth with acceptable intercept between the two water bulbs under the two emitters and water use volume 3.65 litters.

The moisture content distribution pattern for the three operating pressures (0.5, 1.0 & 1.5 bars) was shown in Figure (**5** a, b & c). These moisture content contours represented the first moisture vertical plane 10 cm away from the Plexiglas wall and parallel to it, which was almost at the dripper line position. The moisture content distribution contours indicated that there was saturation cone under the water emissions. Through out the Fig (**5** a, b, and c) illustrated that the saturation cone move downward with increasing the operating pressure. Also, higher moisture content distribution emissions with higher moisture content in the upper 30 cm soil depth, but the.



Figure(7)Effect the operating pressure on moisture distribution at 10cm plane without polymer layer under dripper line depth (10 and 15 cm) for Sandy soil.



Figure(8)Effect the operating pressure on moisture distribution at 20cm plane without polymer layer under dripper line depth (10 and 15 cm) for Sandy soil.

moisture distribution downward decreased with the soil depth increased. Obviously, the moisture bulb immigrated far downward with higher operating pressure. Also, the shape of the cone changed almost from circle to ellipse when the operating pressure was changed from 0.5 to1.0 and 1.5 bar as shown in fig (5 b and c)

Figure (6 a, b, and c) showed that the moisture distribution at the second moisture vertical plane 20 cm away from the Plexiglas wall. This represented the horizontal direction of spreading the moisture bulb distribution. Fig (**6** a) indicated that the bulb was almost similar to what obtained at first moisture vertical plane, however, the moisture distribution contours were not close to each other. Fig (**6** b and c) illustrated that the moisture bulb decreased in its spreader away either vertically or horizontally. Moreover, the moisture cone was still formed and moved more downward as the operating pressure increased. The results proved that, there was a bulb around the dripper line in the both vertical and horizontal water spread way.

Figure (7 and 8) illustrated the value of the moisture content at the point of the water emotion for the two emitters below and above the dripper line. Obviously, the operating pressure 1.0 bar was the applicable operating pressure due to the good uniformity obtained under both dripper line depths (10 and 15 cm) as shown in these Figure. Whereas, the moisture content distribution for both vertical planes indicated that the dripper line at 15 cm depth was better than the 10 cm depth for either the moisture distribution uniformity. The average moisture content was 10.5% until soil depth 43 cm for 15cm dripper line depth, while the average of moisture content was 10 % until soil depth 39 cm for 10cm dripper line depth under operating pressure 1.0 bar for vertical moisture plane at 10 cm apart from the Plexiglas wall. On the other hand, for the second moisture plane, the average moisture content was 8.7% and 7.2% for dripper line 15 and 10 cm depth at same soil depth 43 and 39 cm, respectively. The water use in system was (5.1 and 3.65 L) and reduction water use percent was (1% and 18%) under the dripper line depth 10 and 15 cm, respectively. Therefore, Figure (7 & 8) pointed out clearly that the best combination of the operating pressure was 1.0 bar engaged with the dripper line 15cm as the practical pressure and dripper line depth in the field and gave the best uniformity moisture distribution contour lines through out the soil depth up 43 cm.

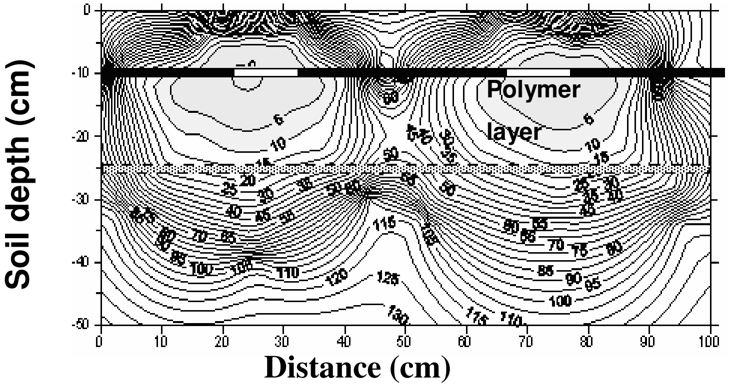
It was concluded that the previous two stages of the experimental combinations were emphasized on increasing the soil water holding capacity and change the sandy soil physical and hydro-physical properties by using the soil conditioner as barrier at certain depth. This may force the water cone to slow down the water moment downward less than the water movement toward the upward direction.

Effect of polymer depth on moisture pattern

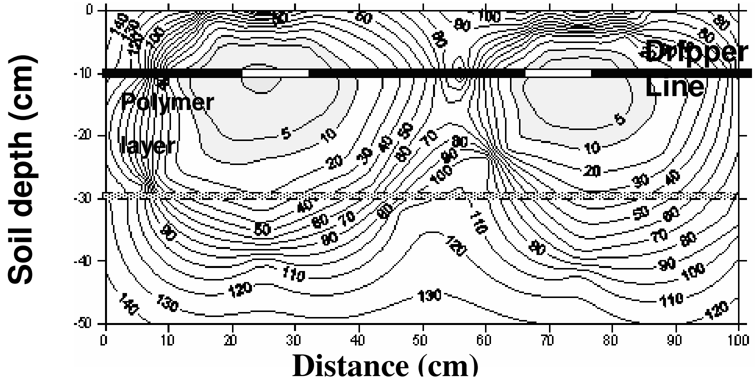
Therefore, the third stage was aimed to investigate the effect of the dripper line depth, the depth of the synthetic soil conditioner layer and the operating pressure on soil water distribution pattern under sandy soil condition. Table (3) indicated that the advance time was increased by increasing the polymer layer depth. Also, water holding in system per emitter increased due to the increasing of the advance time as general pattern for dripper line depths and operating pressure values. The improvement water holding percent was calculated in comparison between the value of without polymer as control treatment and any polymer depth. This percent was higher at operating pressure 1.0 bar more than that obtained at operating pressure 1.5 bar for the two dripper line depths (10 and 15 cm). The improvement percent was 14 and24% at operating pressure 1.0 bar and 1 and 10% at operating pressure 1.5 bar under dripper line 10 cm depth. Similar trend was obtained for the improvement percent at dripper line 15 cm, whereas, it was 40 and 47% at operating pressure 1.0 bar. While it was 14 and 20% at operating pressure 1.5 bar. Therefore, it was obvious that operating pressure 1.0 bar better than 1.5 bar especially with dripper line 15 cm.

Table (3) The experimental combinations with polymer and their effect on the water volume use in the system (soil box).

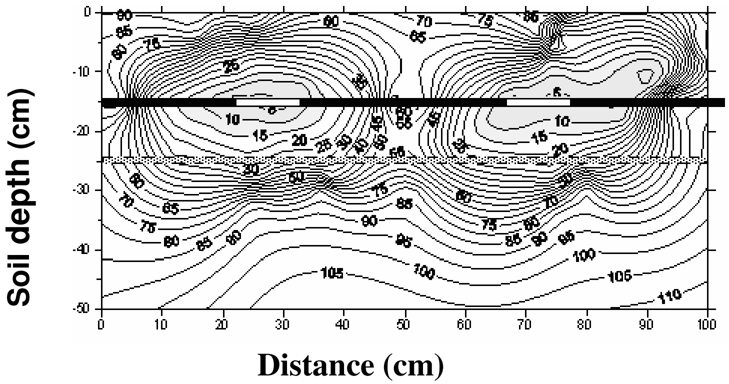
Exps. Stage	Soil text.	Dripper line depth, cm	Operating pressure, bar	Polymer layer depth, cm	Maxi. time advance min	Water holding in system for each emitter, liter	Improv. Water holding percent, %
3	Sandy	10	1.0	--------	105	5.10	------
				25	120	5.83	14
				30	130	6.32	24
			1.5	--------	85	4.94	------
				25	86	5.00	1
				30	94	5.46	10
		15	1.0	-------	75	3.65	------
				25	105	5.10	40
				30	110	5.35	47
			1.5	------	55	3.20	------
				25	63	3.66	14
				30	66	3.84	20



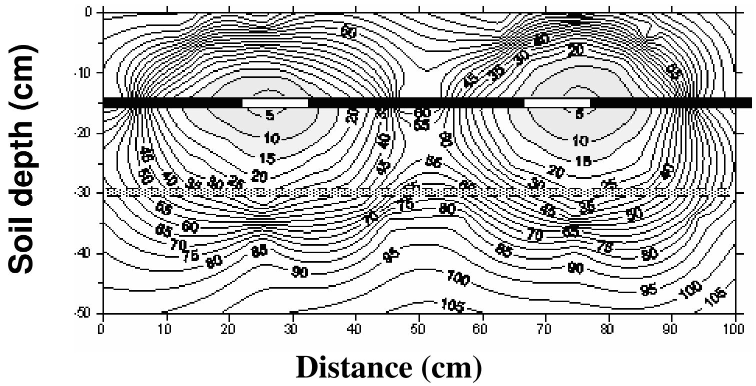
a) Dripper line 10 cm and polymer layer at 25 cm



c) Dripper line 10 cm and polymer layer at 30 cm

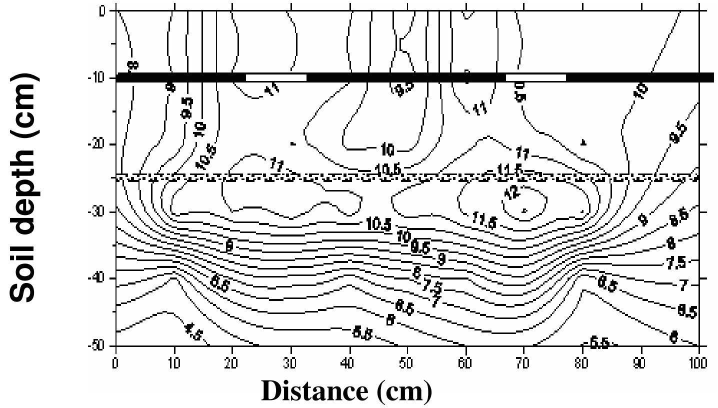


b) Dripper line 15 cm and polymer layer at 25 cm

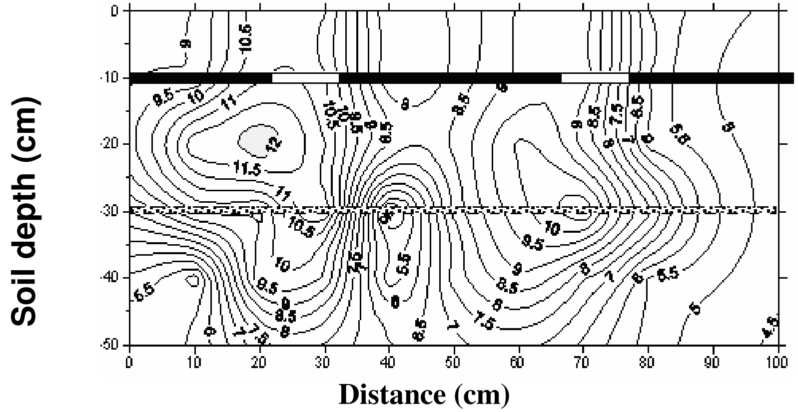


d) Dripper line 15 cm and polymer layer at 30 cm

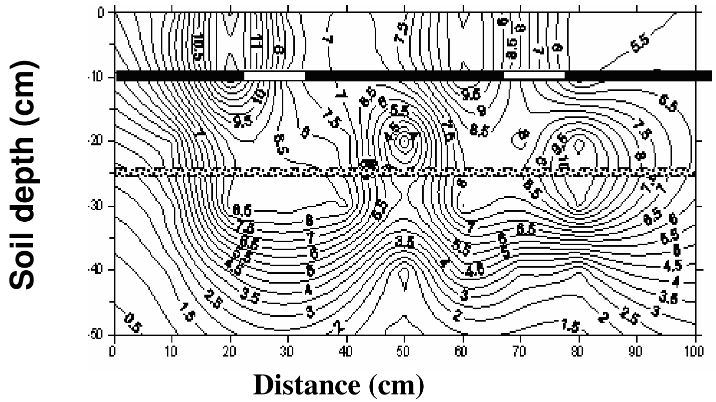
Figure (9) The water front distribution as function of time (min) through the two emitters into the soil box under perating pressure 1.0 bar for dripper line depths and different polymer layer depths (Bostan soil).



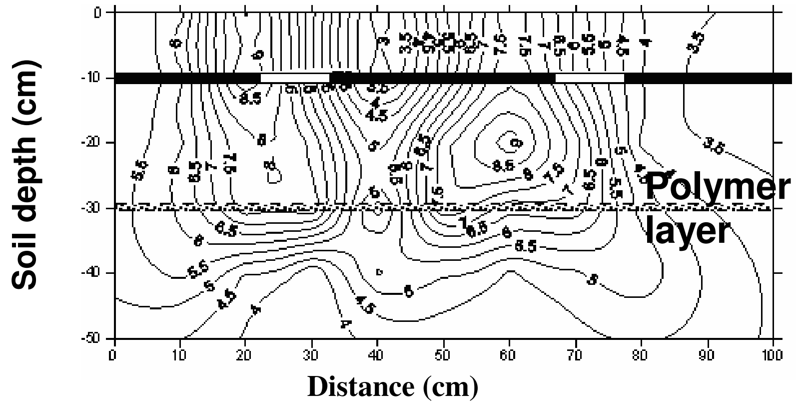
a) Moisture distribution at10cm and polymer layer at 25cm



c) Moisture distribution at 10cm and polymer layer at 30cm

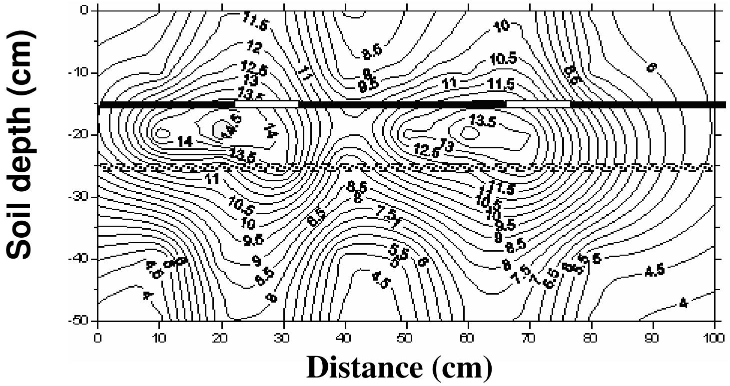


b) Moisture distribution at 20cm and polymer layer at 25cm

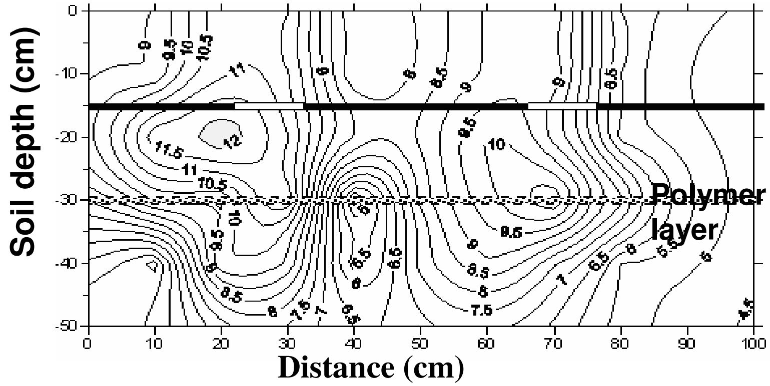


d) Moisture distribution at 20 cm and polymer layer at 30cm

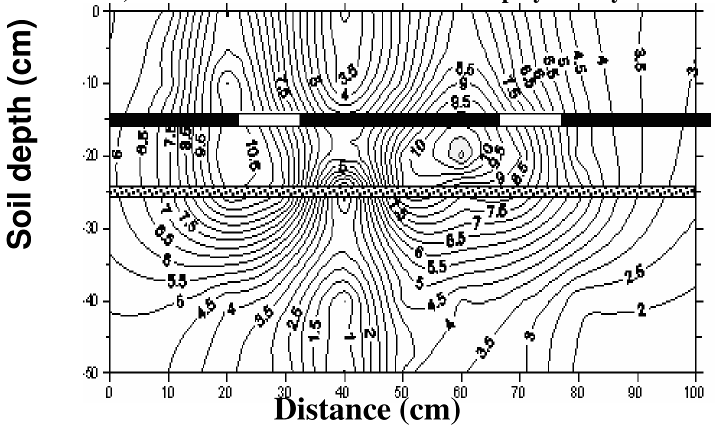
Figure (10) The moisture distribution through the two emitters into the soil box at Dripper line 10 cm depth and under operating pressure 1.0 bar for different moisture level and polymer layer depths (Bostan soil).



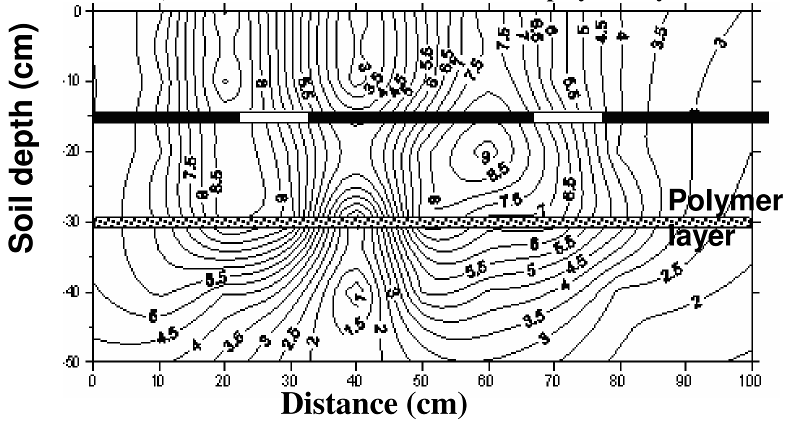
a) Moisture distribution at 10cm and polymer layer at 25cm



c) Moisture distribution at 10cm and polymer layer at 30 cm



b) Moisture distribution at 20cm and polymer layer at 25 cm



d) Moisture distribution at 20cm and polymer layer at 30cm

Figure (11) The moisture distribution through the two emitters into the soil box at Dripper line 15 cm depth and under operating pressure 1.0 bar for different moisture level and polymer layer depths (Bostan soil).

Generally, Figure (9 a, b, c & d) showed the effect of synthetic soil conditioner thin layer depth on the wetting front distribution progress as function of time. This resulted in changing the pattern of the water front spreader and diverted the water cone below and above the dripper line to be moved more horizontally than vertically. Figure (9 a & c) illustrated the effect of the polymer layer depth at 25 and 30cm from the soil surface engaged with dripper line depth 10 cm on the water front distribution. These figures indicated that the deeper the polymer depth was located, the better the water front distribution was spreaded upward and downward. Therefore, the polymer layer at 30cm resulted in slightly delayed in downward water movement than that obtained with the polymer layer depth at 25cm. The time distribution was almost close to each other (120 – 130 min) for both cases as shown in Fig. (9 a and c). The water front distribution became more damped under similar condition of polymer depth with dripper line at 15cm depth as shown in fig (9 b & d). The time advance was increased similarly for both cases (105 -110 min) comparing with cases which did not have polymer (75min) as shown in Table (3).

These figures, shows that contour lines of the moisture content distribution above the dripper line became closer to each other than that in figures 3 and 4. This means that moisture was accumulated in the upper layer and increased with less time advance of the water front for both polymer and dripper line depths. The result, also, indicated that polymer layer work as barrier and accumulated the moisture content reducing the water losses and slowing the water front advance time to reach the maximum soil depth in the box.

Figure (10 a, b, c and d) showed the effect of the two polymer thin layer depth (25 and 30 cm) on the moisture content pattern in two different vertical plane (10 and 20 cm) parallel to the Plexiglas wall under dripper line 10 cm depth and operating pressure 1.0 bar. Figure (10 a and b) indicated that the soil moisture content was apprehended by the polymer layer and helped to move the moisture content toward the soil surface. The moisture content was increased to be around the field capacity for the soil surface up to depth 50 cm downward. Figure (10 c and d) represented similar results for the moisture contour pattern with more water content moved toward the downward. This may due to increase the water holding in system between the polymer layer and the dripper line. However, under any of the previous conditions the polymer layer redistributes the soil moisture content with higher value through out the soil box vertically and horizontally compared with the same situation without the polymer layer.

Figure (11 a, b, c, and d) represented the results under the same conditions for both polymer depth (25 and 30cm) at the evaluated vertical plane of the moisture content with dripper line at 15cm depth. The results showed similar trend were obtained for two polymer layer 25 and 30 cm depth as shown in Figure (10 a, b, c, & d). Unless, more water moved downward through the polymer layer with better distribution and less water losses compare with the same condition without the polymer layer as shown in figures (5b and 6 b).

Figures (10 & 11 a, b, c, & d) illustrated that the polymer layer changed the properties of the sandy soil at the depth of addition. Thus the water holding in system increased to be 66% of the value of the sandy loam soil, where increased from 3.65 to 5.1 or 5.35 litter at dripper line 15 cm under operating pressure 1.0 as shown in Table (3).Figure (12) illustrated that the average moisture content at moisture plane 10 cm increased to be 10.9% and 10.7% due to polymer layer depth at 25 and 30 cm. Similar results have been obtained for vertical moisture plane 20 cm where the moisture content increased to 7.5% and 8.2% at 25 and 30 cm polymer layer, respectively. Figure (13) showed better results due to using dripper line at 15 cm with the two polymer layer. Whereas, the moisture content increased 11.4% and 11.5% for the two polymer layer 25 and 30 cm, respectively, for moisture plane 10 cm .

While for moisture plane 20 cm, the average moisture content was 8.6% and 8.7% for polymer layer 25 and 30 cm, respectively. Moreover, Figures (12 and 13) indicated that the more the depth of the polymer layer, the higher the water holding in system would be obtained.

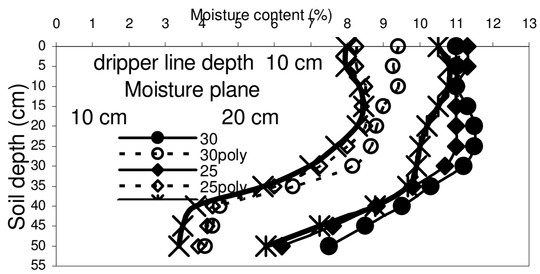


Figure (12) Effect of the polymer layer depth on two moisture distribution planes (10 cm and 20 cm) under dripper line 10cm depth and operating pressure 1.0 bar

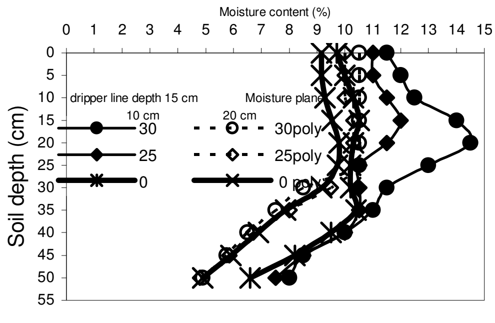


Figure (13) Effect of the polymer layer depth on two moisture distribution planes (10 cm and 20 cm) under dripper line 15 cm depth and operating pressure 1.0 bar.

Clearly, the water front distribution became more restricted to be moved downward and the polymer layer at depth 30 cm increased the water holding in system between that and dripper line comparing with the case of 25cm polymer depth.. This increased the water front movement toward the upward above the dripper line and lead to better distribution with higher values than that case without the polymer layer with time advance (70- 85min). Also, it was clear in Fig. (13)That dripper line 15 cm depth resulted in more uniform distribution in both vertical and horizontal bulb. Whereas, the moisture content distribution in both plane was close to each other and really uniform than that obtained in dripper line 10 cm depth. This was obvious from Table (3) also, the improvement water holding percent was 40 and 47% at dripper line 15cm and operating pressure 1.0 bar, which was higher than improvement water holding at 10 cm dripper line depth and same pressure by 14 and 24% for the two polymer depth 25 and 30 cm, respectively. Therefore the preferable combination was at dripper line 15 cm depth and polymer layer 30 cm depth working under operating pressure 1.0. This gave better moisture content distribution and uniformity for the two evaluated vertical plane with less water use in the system.

CONCLUSION

Subsurface irrigation system is the best irrigation management system with higher efficiency compared with any irrigation system. The subsurface irrigation system was saved water by 61% and 39% less than surface irrigation in soil texture sandy and sandy loam, respectively. The waterfront was less progressed in sandy loam soil may be due to the presence of clay and silt contents which affected by the soil type. This caused increasing in the water volume use from each emitter in sandy loam soil by 64 % than that obtained in Bostan soil.

The waterfront advance time ratio was calculated 3.5 in the sandy soil (Bostan), while it was 1.17 in the sandy loam soil (El- Hamam) which resulted in uniform distribution bulb. It was clear that the lower value of the operating pressure, the higher the water use in system at dripper line depth. Then magnitude of the water use decreased in volume toward the higher value of operating pressure. The shallower the dripper line depth, the longer the time was taken to reach the maximum soil depth. The moisture content distribution for both vertical planes indicated that the dripper line at 15 cm depth was better than the 10 cm depth. The results indicated that there was saturation cone moved downward with increasing the operating pressure. Also, higher moisture content distribution around the dripper line was observed for the three operating pressure.

The best combination of the operating pressure was 1.0 bar engaged with the dripper line 15cm as the practical pressure and dripper line depth and gave the best uniformity moisture distribution contour lines through out the soil depth up 43 cm. The thin layer of synthetic soil conditioner depth resulted in changing the pattern of the water front spread and diverted the water cone below and above the dripper line to be moved more horizontally than vertically.

The deeper the polymer depth was located, the better the water front distribution was spreaded upward and downward. Therefore, the polymer layer at 30cm resulted slightly delayed in downward water movement than that obtained with the polymer layer depth at 25cm. Thus the water holding in system increased to be 66% of the value of the sandy loam soil, where increased from 3.65 to 5.1 or 5.35 litters at dripper line 15 cm under operating pressure 1.0.

The dripper line 15 cm depth resulted in more uniform distribution in both vertical and horizontal bulb. Whereas, the moisture content distribution in both plane was close to each other and really uniform than that obtained in dripper line 10 cm depth. Therefore the preferable combination was at dripper line 15 cm depth and polymer layer 30 cm depth working under operating pressure 1.0. This gave better moisture content distribution and uniformity for the two evaluated vertical plane with less water use in the system. However, it should an economical study to indicate the profit due to increasing the yield due to the moisture distribution and the water holding improvement and it would overcome the expenses of baying and manipulation of the synthetic soil conditioner or not.

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الملخص العربى

تحسين التوزيع الرطوبى للرى بالتنقيط تحت سطحى فى الأراضى الرملية باستخدام محسنات التربة الصناعية

د/ طارق زين العابدين[١]

يعتبرنظام الرى بالتنقيط تحت سطحى أكثر طرق الرى ترشيدا وتحكما فى كمية المياه المضافة بدون آثار ضارة على البيئة نتيجة الجريان السطحى أو التسرب العميق. إلا أن عدم انتظامية توزيع المحتوى الرطوبى خاصة فى الطبقة السطحية (صفر – ٥ سم) فى الأراضى الرملية أدى إلى إجراء هذه الدراسة وقد تمت على مراحل حيث كان الهدف الأساسى هو تغيير نمط التوزيع الرطوبى وجبهة انتشار المياه لتشمل الطبقة الفقيرة باستخدام المحسنات الصناعية للتربة والوصول لأنسب توليفة

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لعمق خط التنقيط وضغط تشغيل مع عمق طبقة بوليمر والتى تعطى أفضل توزيع رطوبى فى الاتجاه الرأسى و الأفقى. تم وضع التربة فى صندوق أبعاده ٥٠×٥٠×١٠٠ سم بطريقة منتظمة وبالكثافة المطلوبة لكل نوع مع وضع خط التنقيط والمكون من منقطين داخل الصندوق وعند العمق المطلوب لكل تجربة (صفر،١٠، ١٥ سم) مع وضع فى الاعتبار رش المحسن الصناعى (البوليمر) على التربة عند العمق المطلوب (٢٥، ٣٠ سم) من سطح التربة وبمعدل ١٢,٣ كيلوجرام/فدان بنسبة ٠,٠١% كتركيز مناسب لما هو فى الحقل.

وقد تمت الدراسة علىقوامين من التربة (البستان وهى رملية) و (الحمام وهى رملية لومية) كمرحلة أولى للوقوف على مدى الفرق فى الفاقد بالنسبة للماء المستخدم واحتياج التربة الرملية لاستخدام سبل أو طرق لتحسين توزيع المحتوى الرطوبى. وتمت الدراسة على عمقين لخط التنقيط (سطحى صفر سم وتحت سطحى ١٥ سم) تعمل تحت ضغط تشغيل ١,٥ بار وهو قيمة متوسطة لما يتم العمل به فى الزراعة والذى يتراوح ما بين ١ – ٢ بار. وكانت تلك الدراسة بمثابة المؤشر الذى أظهر مدى مساهمة توع التربة للاحتفاظ بالماء وخاصة فى نظام الرى تحت سطحى كما ظهر أن الرى تحت سطحى قد وفر فى استهلاك الماء ما بين ٦١%، ٣٩% لتربة الحمام والبستان على الترتيب. هذا أدى إلى استكمال التجارب على تربة البستان لتحسين التوزيع الرطوبى وموجه جبهة الابتلال خاصة فى الرى تحت سطحى كمرحلة ثانية وكان التفكير فى استخدام أعماق مختلفة لخط التنقيط (١٠، ١٥ سم) يتم ذلك تحت ضغط تشغيل (٠,٥ ، ١,٠، ١,٥) بار كخطوة أولى قبل استخدام المحسن الصناعى. و كان هدف تلك التجارب هو الوصول إلى أفضل عمق مع أفضل ضغط تشغيل للاستخدام مع المحسن الصناعى. وأظهرت النتائج أن ضغط ١ بار هو أفضل ضغط من حيث التوزيع الرطوبى مع الاحتفاظ بظهور توزيع متجانس للطبقة السطحية فوق خط التنقيط ولباقى قطاع التربة وذلك لكلا العمقين لخط التنقيط ١٠، ١٥ سم إلا أن عمق ١٥ سم لخط التنقيط أعطى توزيع متجانس بمتوسط يصل إلى ١٠,٦% محتوى رطوبى لعمق ٤٣ سم فى حين أن عمق ١٠ سم لخط التنقيط أعطى توزيع رطوبى متجانس بمتوسط ٩,٤ محتوى رطوبى لعمل ٣٩ سم. وقد أوضحت النتائج السابقة أن أفضل عمق خط التنقيط هو عمق ١٥ سم مع ضغط ١ بار حيث أن تلك التوليفة أعطت أفضل توزيع رطوبى متجانس لقطاع التربة موضع الدراسة ولكن ما زال هناك فاقد فى المياه المضافة وما زال المخروط أسفل النقاط يتحرك بعيدا عن منطقة الجذور. لذا كانت ضرورة استخدام المحسن الصناعى مع الوضع فى الاعتبار أن يتم استخدام هذا العمق مع هذا الضغط ولكن دون التحيز لهما حيث أنهما قد لا يكونا هما الأفضل فى وجود المحسن الصناعى. وعليه تمت التجارب فى المرحلة الثالثة بأنه تم استخدام العمقين السابقين (١٠، ١٥ سم) لخط التنقيط واستخدام الضغط (١، ١,٥ بار) ووضع المحسن الصناعى على عمق (٢٥، ٣٠ سم) من سطح التربة. وقد أوضحت النتائج أن ضغط التشغيل ١,٥ بار مع أى من العمقين ١٠ سم أو ١٥ سم لخط التنقيط قد أدى إلى تحسين ضئيل فى قيمة الاحتفاظ بالماء داخل النظام حيث كانت قيمة نسبة الاحتفاظ بالماء ١، ١٠,٥% وذلك لعمق ١٠ سم خط تنقيط مع عمق محسن صناعى ٢٥، ٣٠ سم على الترتيب فى حين أن تلك النسبة وصلت إلى ١٤,٣، ٢٠ % لعمق ١٥ سم خط تنقيط مع عمق محسن صناعى ٢٥، ٣٠ سم على الترتيب. إلا أن قيمة نسبة المياه المحتفظ بها فى النظام لعمق خط تنقيط ١٠ سم وضغط ١,٠ بار قد تحسنت إلى ١٤، ٢٤% مع عمق محسن صناعى ٢٥، ٣٠ سم على الترتيب فى حين مع عمق خط تنقيط ١٥ سم ونفس الضغط وصلت تلك النسبة إلى٤٠، ٤٧% لعمق بوليمر٢٥، ٣٠ سم على الترتيب. ولذا يعتبر ضغط ١ بار هو الأفضل فى كل الأحوال ولكن لوحظ أن كلما بعد عمق طبقة المحسن الصناعى كانت النتائج أفضل لذا كان من الواضح أن أنسب توليفة للعمل بها هى عمق خط ١٥ سم وضغط ١ بار مع عمق طبقة بوليمر ٣٠ سم والتى أعطت أفضل توزيع رطوبى فى الاتجاه الرأسى والأفقى ولكن يجب أن يكون هناك دراسة اقتصادية للوقوف على مدى تحسن المحصول نتيجة تحسن التوزيع الرطوبى وزيادة الاحتفاظية للتربة. وهل تعطى تكلفة المحسن الصناعى أم لا.