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RESEARCH ARTICLE

ASSESSMENT OF SUBSURFACE DESIGN CRITERIA USING SAND TANK

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ABSTRACT

Subsurface drip irrigation (SDI) is the application of drip irrigation technology below the ground surface. The use of subsurface drip irrigation (SDI) technology in Saudi Arabia may well be the future of irrigation in the coming years. The materials being used today in subsurface drip irrigation come in three basic configurations: hard hose, drip tape, and porous tubing. Design criteria of SDI system investigated using analogue model i.e. a simulation sand tank. These criteria include effects of pipes, laterals spacing, impermeable layer depths, and operation pressure on water movement in the soil. The iron tank fabricated with dimension of 4 meters length, one meter wide, and height of 1.2 meters. The tank aspects and floors are of iron sheets with 5 mm thickness, the front longitudinal been manufactured board transparent plastic with 10 mm thickness while the other side opposite to the board plastic equipped with 45 small slot with 5 mm diameter, along the reservoir interface in a single row. The height of the tank floor is 50 mm. In the laboratory, experiment two types of pipes used built in pipes and perforated pipes. These pipes operated using freshwater and treated wastewater at different depths and lateral spaces between irrigation pipes. The experiment shows that the time required to raise the water level to 0.3 m decreased when you increase the distance between endocrine and irrigation pipes. For example, when the pressure 1.0 and 1.5 bar (Figure 10 b, c) changed savings time ratios to 50, 65, 147%, and 28, 67.113%, when we increased the endocrine layer depth of 0.2-0.3, 0.3-0.4, 0.2-0.4, respectively. It also shows that the time it takes the water to rise in the soil tank at least with the increase on depth of the layer endocrine, for example, the proportion of savings in time, up to 35, 15, 54% when changing endocrine layer depth of 0.2-0.3, 0.3-0.4, 0.2-0.4, respectively. Timesaving ratios between the different cases of endocrine layer depths. it is clear that the rate of savings in time is equal to 18, 60, 88% in the case of the irrigation system by pressing 1 bar. While equal to 17, 29, 50% in the case of the operating pressure of 1.5 bar. Studies with sand tanks revealed that the outcome results could be a good guidance to adopt a suitable lateral spacing in designing a subsurface irrigation system for crop production since it has a tremendous effect on soil-water movement. This sand tank model have led to useful results such that; the depth of the impermeable layer has an effective influence on water dispersion in the soil profile. In same time results showed there are vast effects on water distribution due to operation pressure and the type of tubing used in subsurface irrigation. Coloration relationships developed between measured time required to water rises in mid spacing between pipes and that predicted values.

INTRODUCTION

In arid areas like the kingdom of Saudi Arabia the wise use of water, become very important due to the shortage in water resources. Moreover; Saudi Arabia has a vast agriculture areas, and the agriculture sector consumes more than 70 % of water resources. Therefore; modern irrigation systems been applied in the Kingdom are implemented to save water and reduce water losses. Subsurface Drip Irrigation considered as one of various types of micro-irrigation systems (Conservation Practice Standard 441). This system applied directly to the root zone of plants and operated under low pressure, which is currently considered as one of the more advanced irrigation methods. It is potentially more efficient than sprinkler irrigation, due, in large part to reduced evaporation. Advances in plastics technology and automation equipment have made SDI is more affordable and long-lasting. SDI systems are currently being used in many countries including Saudi Arabia. Such technology, in this country is still not used intensively except on few hectares owned by some agricultural companies in different regions. There are many other techniques used to reduce water requirement, increase the availability of water and raise the yields that can assist to save water and increase the efficiency and productivity of water (Castilla, 2000). Phene *et al*. (1992) reported that, to maximize tomato yield and water-use efficiency, the laterals in

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subsurface drip irrigation are buried permanently at 20-60 cm below the soil surface to provide the necessary control and uniformity of water and fertilizer distribution. The location of emitters had major effects on incidence of diseased pepper plants, severity of root symptoms, yield, shoot dry weight, level of soil moisture and plant leaf water potential (Cafe and Duniway., 1996). EI Awady *et al*. (2003) reported that, increasing the drip line depth will decrease the evaporation, and that could reduce evapotranspiration, ET from sub-surface drip irrigation to 40 % when the drip irrigation line is buried at a depth of 15 cm compared with irrigation from surface drip line, with sorghum crop. Experiment on spinach showed a similar trend of enhanced growth with optimum drip line depth of 20 cm. El-Gindy *et al*. (1996) showed that, two field experiments were conducted at Maryout, Egypt, to evaluate the use of surface and sub-surface drip irrigation for vegetable crops production. The soil was a Typic Calciorthid, which was only marginally suitable due to salinity and high carbonate content. Irrigation water quality was moderate. Soil moisture, salinity, root density, yield, and water use efficiency were considered for cucumber (Cucumis sativus) under plastic and open field tomatoes (Lycopersicon esculentum) for both irrigation systems. Less salt accumulation and more dense roots were observed under sub-surface drip irrigation in both cucumber and tomatoes. Crop yield and water use efficiency were slightly higher when applying 4 liters/h daily through sub-surface drip irrigation.

Therefore, sub-surface drip irrigation may be more suitable for vegetable production in the highly calcareous soil of Maryout. I irrigation scheduling in such soil was of major importance. The main constrains of limiting expansion in using this technology is the lack of experiences and availability of related design information. Drip line spacing, emitter spacing, and installation depth are the mean design features must be considered when planning to lay out such system. The drip line spacing is an important factor in system cost, and economics suggest wider spacing. However, wide spacing will not uniformly supply crop water needs and will likely result in excess deep percolation on many soil types. The drip line spacing is dictated by the lateral extent of the crop root zone, lateral soil water redistribution, and in-season precipitation. The installation depth is also related to the crop and soil type. Deep installations may also limit the effectiveness of the SDI system for seed germination. Acceptable results have been obtained with installation depth of approximately 18 inches in KSU studies in western Kansas on deep silt loam soils. Drip line should probably be installed above any restrictive clay layers that might exist in the soil. This would help increase lateral soil water redistribution. The main objective of this study was to evaluate the performance of sub-surface drip irrigation system using simulation tank, particularly to assess the subsurface design criteria such as depth of the layer, lateral and emitters spacing.

MATERIALS AND METHODS

Studying area

The experiment conducted in the irrigation and hydraulics Laboratory of the Department of Agricultural Engineering, College of Food and Agriculture Sciences, King Saud University, Riyadh

Fabricating the simulation tank

A galvanized iron tank fabricated with dimension of 4 meters length, one meter wide, and height of 1.2 meters (Figure 1). The tank aspects and floors are of iron sheets with 5 mm thickness, the front longitudinal been manufactured board transparent plastic with 10 mm thickness. It has the ability to withstand pressure of soil and water, and allowed to watch and control the movement of water in the soil, while the other side opposite to the board plastic equipped with 45 small slot with 5 mm diameter, along the reservoir interface in a single row. The height of the tank floor is 50 mm. The previous slots then connected with PVC pipes to work as Piezometers. These pipes are installed on the tank wall vertically (Fig.2), and connected to the copper pipes which are buried inside the soil. The length of each of pipe is 0.8 m, along the tank, and copper pipes were wrapped with wool glass to work as filter to prevent clogging from soil particles (Fig. 2).

Irrigation system

Three parallel lines of plastic pipe with 32 mm diameter installed along the length of the tank at three different heights (0.2, 0.3, 0.4 m) from the floor of the tank, in order to study the effect of impermeable layer on the distribution of water inside the tank. Every line is equipped with eight slots for irrigation; the distance between each two slots is 0.5 m, equipped with a valve at each slot entrance, these tube lines connected to the subsurface irrigation pipes inside the soil profile. When the system turned on, the valves used to determine the distance between the subsurface irrigation pipes. The irrigation lines subsequently are connected to water source with a valve to control the amount of water flowing into the system, and used as pressure scale. When using treated wastewater, an external tank filled with treated wastewater connected to 0.5-horse pump-to-pump water from external tank to the irrigation lines in the soil tank.

Drainage system

Drainage systems consist of five holes with 13 mm diameter installed in the tank to empty the tank when needed. It also used to control the level of ground water during the measurement of the permeability and experiences porous exchange test. One of these holes in in the tank floor, and the others installed on the side of the tank in different depth (0.2, 0.3, 0.4, 0.6 m) from the floor of the tank (Figure 3).

Water and Soil collection and analysis

After establishing the simulation tank and the instillation of the irrigation and drainage system, the next step was to select and prepare the soil for the experiment. The sandy soil was selected to fill this tank. The selection based on some criteria, that can make the movement of water during irrigation and drainage process and do not cause clogging nozzles or drippers on irrigation pipes. In This study, two types of water were used, fresh, treated wastewater. Chemical analysis for these two types were done in the laboratory of the Riyadh National Research Center of the Ministry of Agriculture and Water, the result of the water analysis are presented in Table 1.

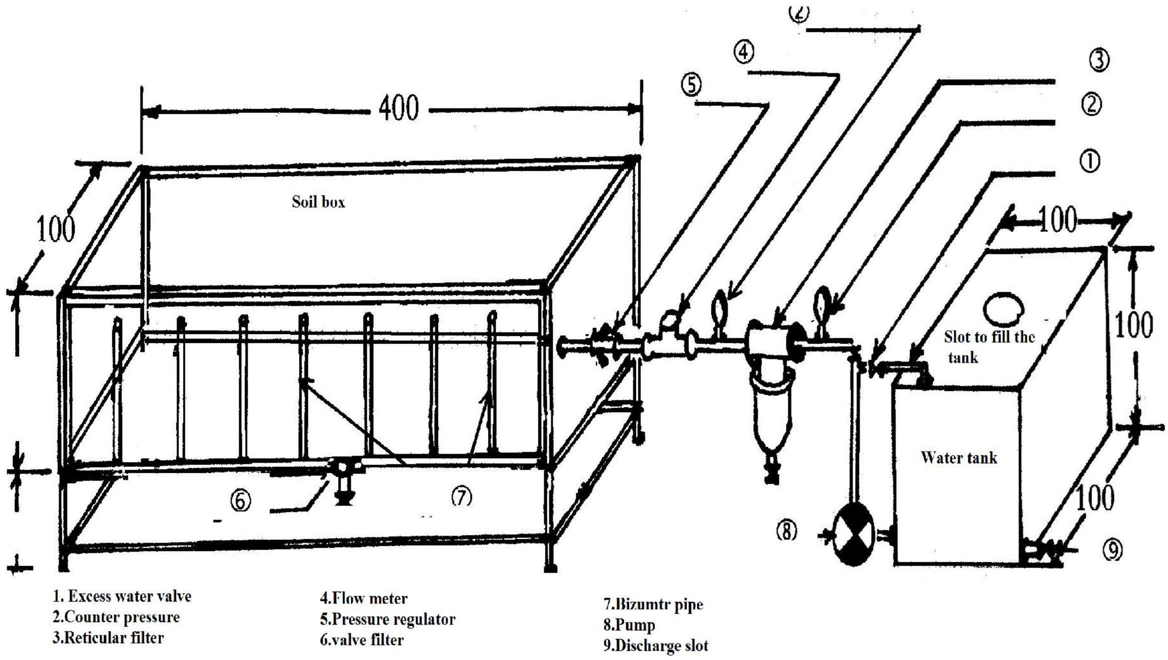

Figure 1. Schematic sketch illustrating parts of the soil tank

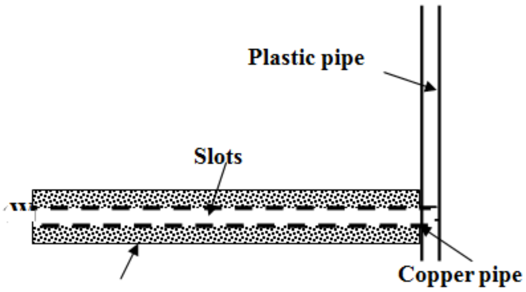

Figure 2. Section shows piezometer parts inside the soil tank

Figure 3. Drainage System

Table 1. Water chemical analysis

Treated wastewater		Fresh water		Parameter
%	ppt	%	ppt	
8.54	68.00	13.45	39.00	Ca
12.19	97.00	15.52	45.00	Na
0.38	3.00	0.69	2.00	K
15.08	120.00	13.10	38.00	Cl
0.63	5.00	-	-	Mg
0.01	0.08	-	-	B

Irrigation pipes

In this study two types of irrigation pipes were used (1) Pipes with built in emitters: It is a polyethylene pipe made from, with outer diameter 16 mm and internal 13.5 mm. Equipped with emitter every 0.20 m, this emitters were calibrated before the experiment, the rate of discharge found to be 4.7 l / s at one air pressure and it's largest of the designed discharge by 9%. (2) Perforated pipes: PVC pipes, outer diameter 16 mm and internal 13.5 m, equipped with 2 mm slots every 0.1 m in three rows. The actual discharge of these pipes was 38 l/h at one air pressure. Subsurface irrigation Pipes installed inside the tank with Humidity measuring device. To make the comparison between the two systems somewhat clear we fixed the irrigation depths for all states and for the two types of pipes at 0.3 m. This depth was selected because it represent the actual root depth, so it can be used to measure the taken time for water to go down to the root zone. EL Tantawy *et al.*, 2004 reported that subsurface irrigation is much preferred at this depth.

Methodology

The experiment done for the two types of pipes at different depth and pressure as follow: The subsurface irrigation system operated at the following depths (0.2, 0.3, 0.4 m) from the impermeable layer. Then starting Pumping the fresh-water for the first experiment using built in pipes at different depths with 0.5 m a distance between pipes and 0.5 bar operating pressure. In the first half hour, the measurement taken every 5 min at the middle of the distance between every two pipes for every depth. In the second half, the measurement taken every 10 min and so on until the soil being saturated and then irrigation system closed. After taking the required measurement the water drained from the soil box using the drainage system this presses took 48 h to drain all the water from the tank. This experiment were repeated three times using the same pipe at constant depth and different pressure (1, 1.5 bar). Then the experiment repeated again at the same depth and pressure as the previous conditions but at different distance between the pipes 1.5 m not 0.5 m. The second experiment was done using the second type of pipes, running the same experiment to measure the effect of different pressure, and different subsurface irrigation depths from the impermeable layer and the distance between the irrigation lines.

RESULTS AND DISCUSSION

Fig 4 (A, B, C) shows that the time required to raise the water level to 0.3 m decreased when you increase the distance between endocrine and irrigation pipes. For example, when the pressure 1.0 and 1.5 bar (Figure 10 b, c) changed savings time ratios to 50, 65, 147%, and 28, 67.113%, when we increased the endocrine layer depth of 0.2-0.3, 0.3-0.4, 0.2-0.4, respectively.

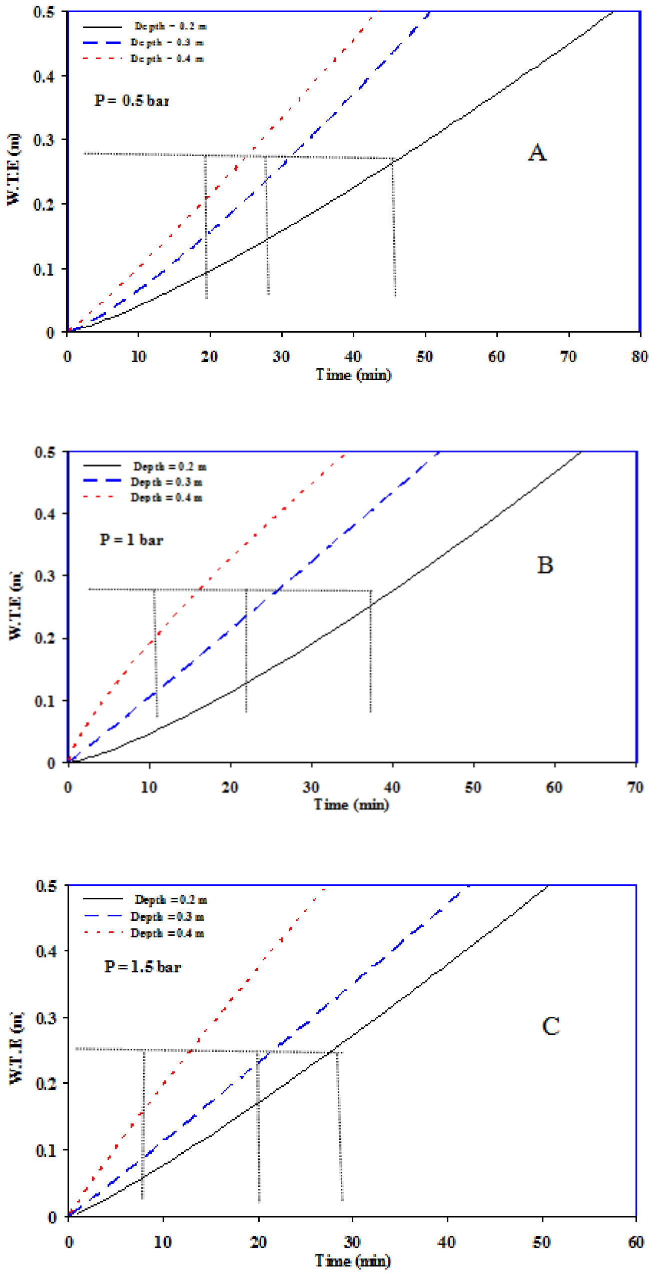

Figure 4. The relation between rising soil water and time in built in pipes, (L= 0.5 meters

Fig (5 and 6), also shows the relation between rising soil water and time in built in pipes for the same irrigation pipes, but the distance between them was 1 m (Figure 5 b) and 1.5 m (Figure 6c). These figures are also evident that the time it takes for the water to rise in the soil tank at least with the increase on depth of the layer endocrine, for example, in Figure (5a) notes that the proportion of savings in time, up to 35, 15, 54% when changing endocrine layer depth of 0.2-0.3, 0.3-0.4, 0.2-0.4, respectively

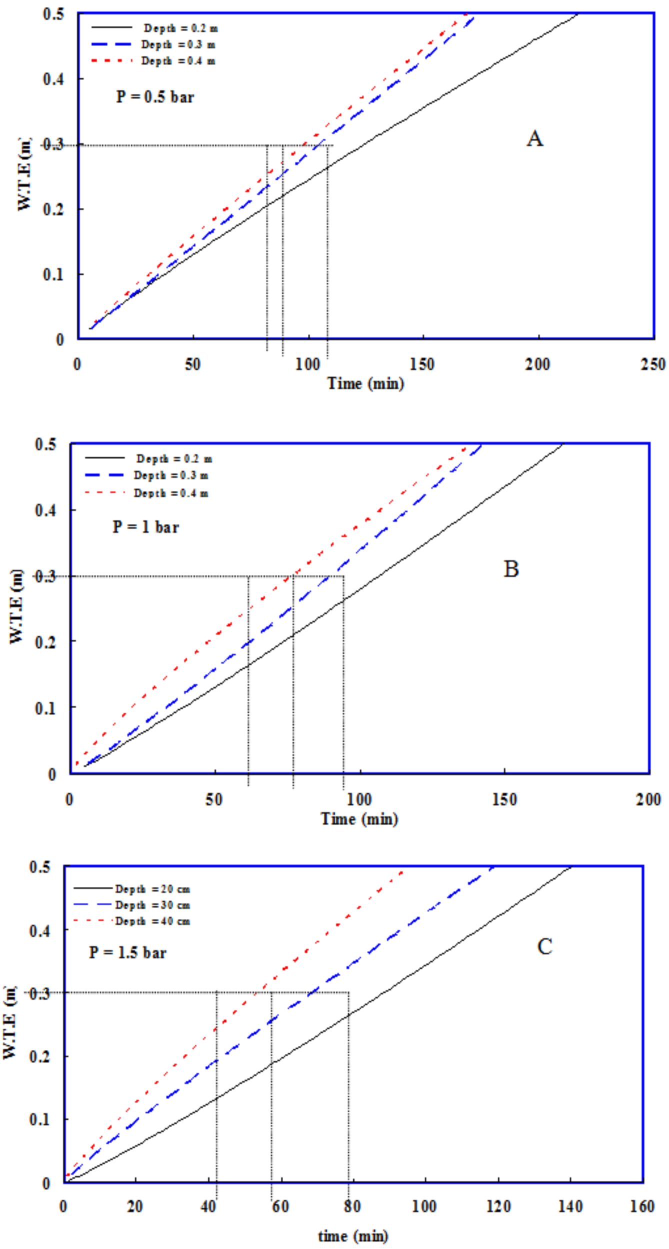

Figure 5. The relation between rising soil water and time in built in pipes, (L= 1.5 m)

Table 2 shows the Timesaving ratios between the different cases of endocrine layer depths. From this table it is clear that the rate of savings in time is equal to 18, 60, 88% in the case of the irrigation system by pressing 1 bar (Figure 5B). While equal to 17, 29, 50% in the case of the operating pressure of 1.5 bar (Figure 5 c). It is clear also that the rates of savings in time when the distance intra 1.5 m follow the same pattern

Table 2. Timesaving ratios between the different cases of endocrine layer depths

Endocrine depth m	Time to rise water to 0.3 m (min)	Save Ratio. %	Time diff.	L	P (bar)	Notes
0.2	50	47	16	0.5	0.5	Fig 5A
0.3	34	26	7			
0.4	27	*85	*23			
0.2	42	50	14	0.5	1.0	Fig 5B
0.3	28	65	11			
0.4	17	*147	*25			
0.2	32	28	7	0.5	1.5	Fig 5C
0.3	25	67	10			
0.4	15	*113	*17			
0.2	74	35	19	1.0	0.5	Fig 6A
0.3	55	15	7			
0.4	48	*54	*26			
0.2	64	18	24	1.0	1.0	Fig 6B
0.3	40	60	6			
0.4	34	*88	*30			
0.2	45	17	10	1.0	1.5	Fig 6C
0.3	35	29	5			
0.4	30	*50	*15			
0.2	125	16	17	1.5	0.5	Fig 7A
0.3	108	20	18			
0.4	90	*39	*35			
0.2	110	22	20	1.5	1.0	Fig 7B
0.3	90	20	15			
0.4	75	*47	*35			
0.2	90	32	22	1.5	1.5	Fig 7C
0.3	68	31	16			
0.4	42	*73	*38			

before. In (Figure 12 a, b, c) and Table (2) notes that the ratios savings in the time required to increase the water level up to 0.3 m in the soil at increasing the endocrine depth and the pressures of 0.5, 1.0, 1.5 bar were 16, 20, 39% and 22, 20, 47% and 32, 31 and 73%. In general, in the previous cases, at least the time required whenever endocrine class moved away from ground pipe, that is the inverse relationship, and this is similar to the findings of the study in the case of the tube type equipped. It is clear from the results that the savings rate in the relationship of time with increase endocrine layer depth counterproductive, as it is not written in all cases. As concluded that the depth of the endocrine is an effective influence on the speed of water movement and the rise within the soil profile. Which means that whenever you depart

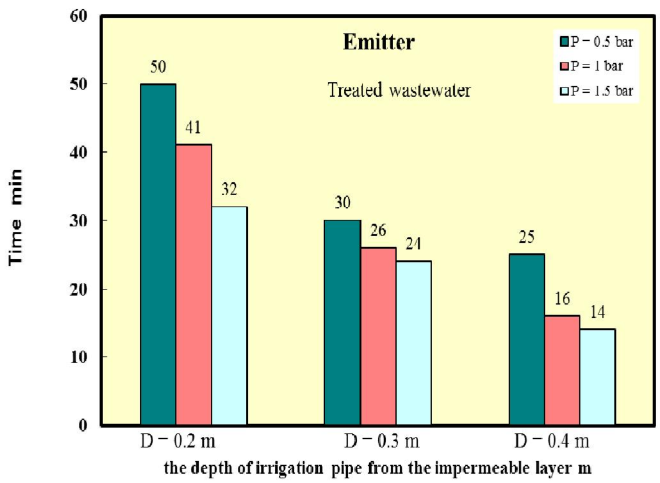

Figure 6. The required time for water to reach 0.3 m depth in the soil when using built in pipes with 0.5 m space between irrigation pipes

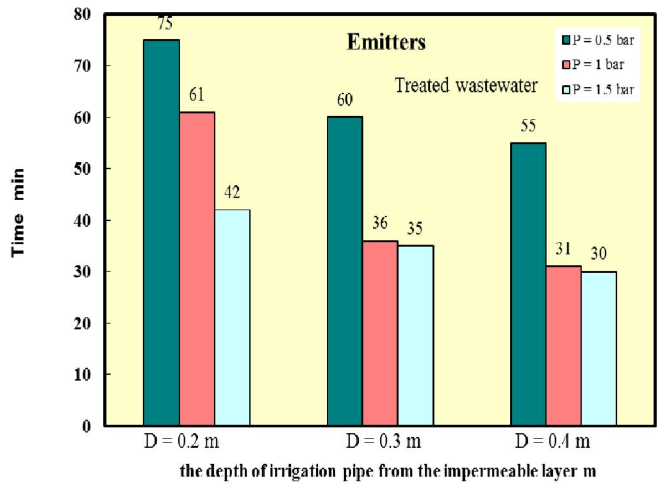

Figure 7. The required time for water to reach 0.3 m depth in the soil when using built in pipes with 1 m space between irrigation pipes

endocrine layer from ground irrigation pipes, it helped to increase the speed of water movement. regardless of the type of pipe used in irrigation, can interpret the reason for this is to increase the lengths of lines flow paths within the soil, which often lead to the reduction of energy losses resulting from the crowd starting slots water pipes. Figures from (6) to (7) show the relation between required time for water to reach 0.3 m depth in the soil using built in pipes and the distance between the Irrigation pipe and impermeable layers (0.2, 0.3, 0.4) and at different pressure (0.5, 1, 1.5 bar) using treated wastewater. The Figures from (9) to (10) show the relation between required time for water to reach 0.3 m depth in the soil using perforated pipes and the distance between the Irrigation pipe and impermeable layers (0.2, 0.3, 0.4) and at different pressure (0.5, 1, 1.5 bar).

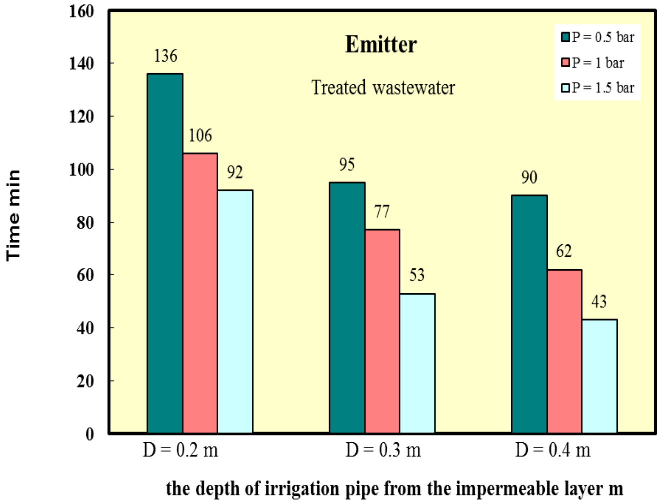

Figure 8. The required time for water to reach 0.3 m depth in the soil when using built in pipes with 1.5 m space between irrigation pipes

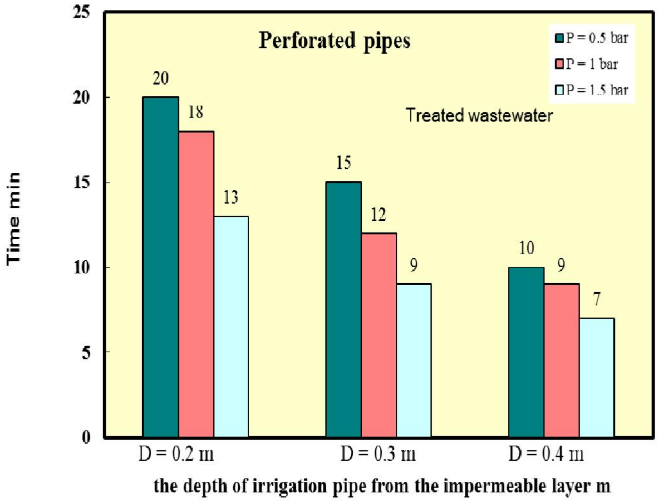

Figure 9. The required time for water to reach 0.3 m depth in the soil when using perforated pipes with 0.3 space between irrigation pipes

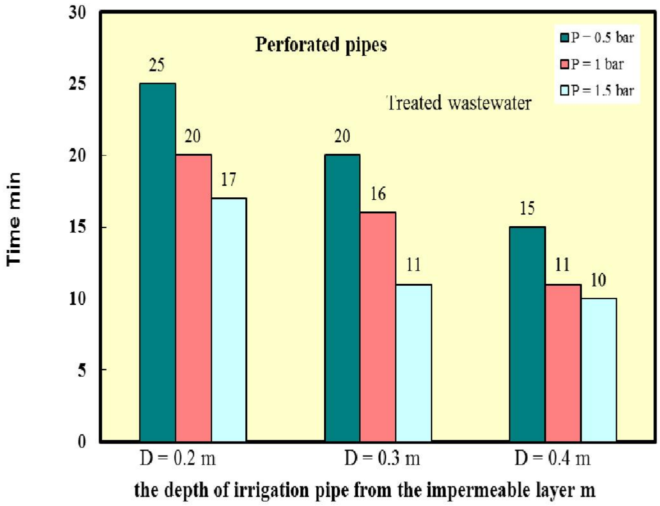

Figure 10. The required time for water to reach 0.3 m depth in the soil when using perforated pipes with 1 space between irrigation pipes

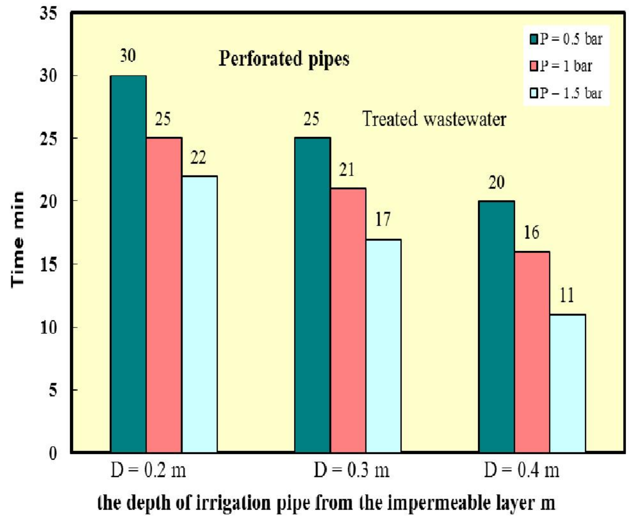

Figure 11. The required time for water to reach 0.3 m depth in the soil when using perforated pipes with 1.5 space between irrigation pipes

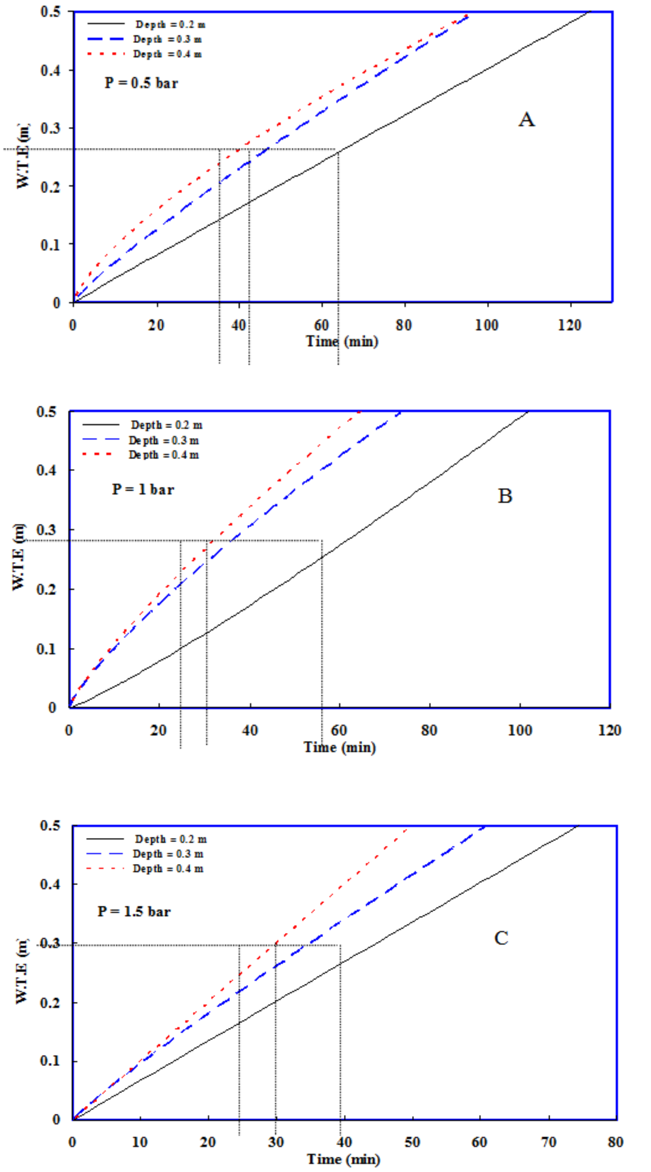

Figure 12. The relation between rising soil water and time in built in pipes, (L= 1 m)

In case of built in pipes, the required time for water to rise in the soil tank depend on the depth of impermeable layer, Pressure and the distance between irrigation pipes. It show that when the inter distance between the Irrigation lines was 0.5 m the water take 32, 41, 50 min to rise to 0.3 m in middle distance between irrigation pipes when the depth of impermeable layer was 0.2 below the irrigation pipes at operating pressure (0.5, 1, 1.5) Respectively. In the other case the water take 24, 26, 30 min and 14, 16, 25 min when the depth of the impermeable layer were 0.3 and 0.4 Respectively and at the same pressure as in case one. i.e., the time will be less when the pressure increased if the depth of the impermeable layer was constant. And the time will be less to if the impermeable layer depth increased. From this result it is clear that the percent of time saving for water to reach the depth 0.3 m when distant between the pipes was 0.5 and the pressure 0.5 bar with the increase in impermeable layer depth from 0.2 – 0.3, 0.3 – 0.4 and 0.2 – 0.4 equal 40, 17, 50 % Respectively. This conclusion, which refers to a provision in the time it takes to raise the water level due to increasing the depth of the endocrine that's compatible with the modern concept of irrigation water management. Which is the field as a single system integrated, where all processes are interrelated, and not only the soil humidity, but also it is a function of the relationship of the overlap between the plant, soil and climate. The system also were more flexible than the previous regime. which was based in irrigation scheduling on the moisture content of the soil at field capacity and wilting point, in the modern concept of irrigation scheduling can modify the irrigation system so that commensurate with the circumstances and nature of the soil and the depth of the layer endocrine in the case of presence within the soil profile. This makes maintaining more favorable conditions for soil water and bring it up to the optimum water level at the lowest possible time. This in turn leads to water conservation, improve growth, and increase production.

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