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Performance Assessment of Some Developed Surface Irrigation Methods

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Abstract - Irrigation development is a gateway to increased agricultural, water and land productivity, increased household and national food security. However, irrigation development has been a major challenge in many developing countries, including Egypt. The overall objective of this study is to detect the influence of different irrigation systems on water-use efficiency, crop and soil salinity in highly soil salinity. Two techniques were applied in experiment, the first technique was siphon irrigation, and the second one was pipeline with gates. The monitored parameters were water table depth, water and soil salinity and crop yield. The total leaching water requirements was given to control the salinity and the crop production. The study revealed that the cotton crop yield was higher by 17% with gate pipeline treatment compared to siphon irrigation treatment. The total soil salinity increased in both treatments. The siphon method gives highest value of total salinity at all seasons. This method increased the salinity by 2.7% while the pipeline with gate increased the salinity by 12.9%. Convergence the value of the crop coefficient in all relations used in most stages of growth, except Penman relationship which gave the highest values.

Keywords : *siphon irrigation method, pipeline with gate irrigation method, subsurface drainage, water-table management, water-table salinity, soil salinity, and crop yield.*

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Keywords : siphon irrigation method, pipeline with gate irrigation method, subsurface drainage, water-table management, water-table salinity, soil salinity, and crop yield.

I. Introduction

As water is becoming more and more a scarce resource all over the world, proper management of the available water is essential. For an optimal use of the available water resources, water management strategies have to be developed. Soil salinity problems generally occur in arid and semiarid regions and reduce crop production at different levels. Salinity is also a major limiting factor for crop yield in poorly drained soils [1, 2, 3, and 4]. [5] recommend that national governments should formulate and hold sound irrigation development strategies and encouraged to partner with public and private institutions in defining and implementing such comprehensive strategies for sustainable irrigation development. [6] notes agriculture has dominated the Zimbabwean economy despite contributing only 15-20% to Gross National Product. It provides income to over 75% of the population of 12 million. In most years, 95% of all food beverages have been locally produced and agriculture accounted for 30% of formal sector employment and over 40% of total national exports. Manufacturing is dependent on agriculture as a source of raw materials with most consumer expenditure on products derived from agriculture. Moreover, about 80% of the rural population lives in Natural Regions III, IV and V where rainfall is erratic and unreliable, making dry-land cultivation a risky venture. Climatic conditions are largely sub-tropical with one rainy season, between November and March. Rainfall reliability decreases from north to south and also from East to West. Only 37% of the country receives rainfall considered adequate for agriculture. This makes irrigation development a prerequisite in these areas. [7] recommend a proper field preparation, including for instance a laser-guided land leveling is necessary before bed making to facilitate a uniform distribution of irrigation water; a suitable bed height, i.e., 10-15 cm height, is needed for efficient salt leaching; adequate soil moisture content needs to be ensured during planting to obtain a proper plant stand; the use of appropriate herbicides for weed control is advantageous; the use of appropriate machinery to drill seed and fertilizer at the proper depth is compulsory; a reshaping of beds during planting, if necessary; the use of short-maturing crop varieties is advantageous. [8] Abdel Ghaffer, and Wahba studied the sub-irrigation method to manage the water table and the effect of method on wheat crop.

II. Methodology

a) Experimental Site

The experiments were carried out in a farm in western Delta, Egypt. The experimental area is divided into lines where each line 200m in length and 0.75m in width and has a sandy silt loam to clay loam texture, The field hydraulic conductivity was measured using the auger hole method and the average value is 2.0 m/day. The main source of the irrigation water is supplied from field canal. The site is served by a subsurface drainage system. The collector drains (PVC corrugated plastic pipe) have been installed at about 1.5 m depth and all laterals drains (PVC corrugated plastic pipe covered by synthetic envelope materials) have been installed at a depth of 1.2 m with an average space of 80 m. The lateral drains were sloped at 10% and exit directly to the main collector through a manhole. Figure 1 shows the experimental study.

Observation wells network with 10cm in diameter and 2m in depth were installed in the

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experiment to measure the water table fluctuation. The wells were placed above the subsurface drains and between them.

b) Subsurface Drainage / Irrigation Operation and Management

Irrigation water is applied to the study area from branch canal to the tank at inlet of field canal at the beginning of the gate pipe and siphons, Figure 1, then flowed to all laterals (field drains) and upward to root zone by capillary flow. The outlet of the collector has drained to main drain. The study has been done by two surface irrigation systems, first by the gate pipes and second by Siphons. The water duty is given for 75% of field capacity.

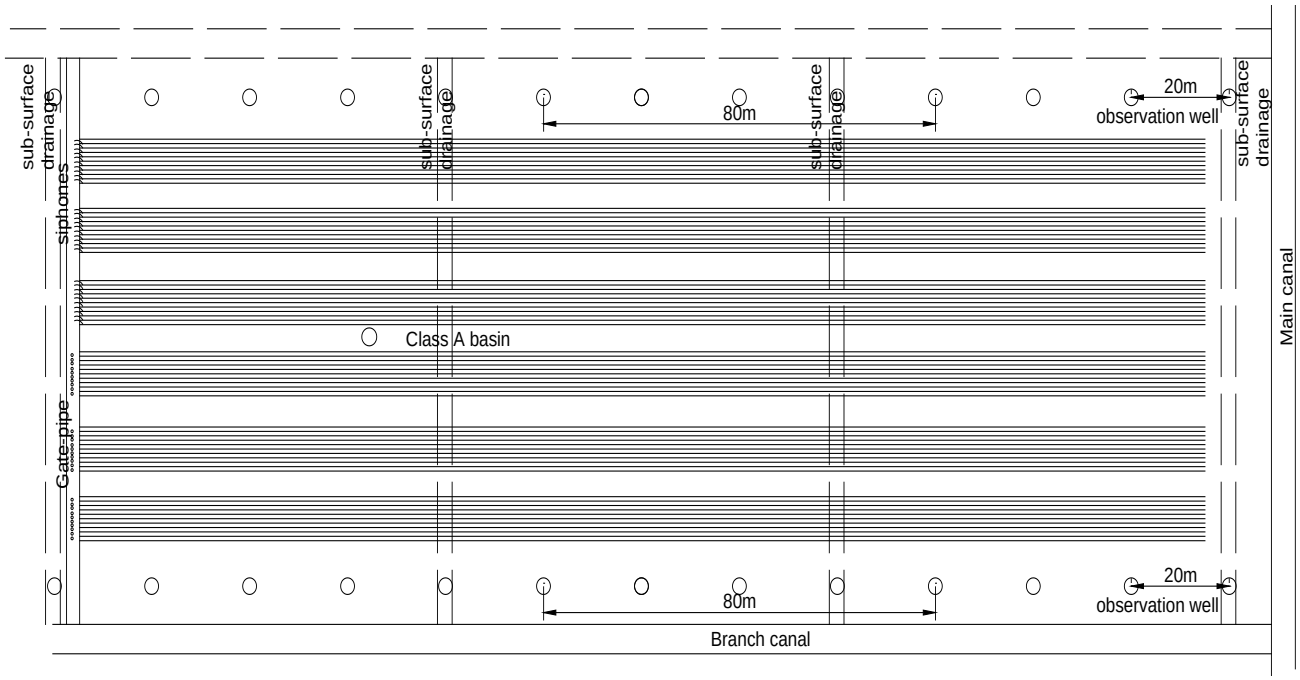

Figure1 : The layout of experimental

c) The Gate Irrigation Pipe

The pipes are 6m in length, 150mm in diameter and with distance holes 0.75m which can communicate with each. The pipe holes can be changed to give the flow required by using the equation 1. Pipe connected with the basin to secure the appropriate pressurized by counter discharge.

$$Q = 2.109d^2 * h^{0.5} \quad (1)$$

Where Q is the flow "m^3/sec", d is opening diameter "m", h is the water head above the opening center "m"

d) The Siphons System

The siphons with 0.037m in diameter and 1.5 to2.0 m. the equation 2 is used to calculate the flow of siphons

$$Q = K * A * \sqrt{2gh} \quad (2)$$

Where Q is the flow "m^3/sec", A is cross section area of siphon "m^2", g is gravity acceleration "m^2/sec", h is water head "m", K is correction factor.

The water velocity and the water slope were measured at the middle line at each 20m and Parshall flume with 5cm contraction at 3m to 5m from the start line. The class A basin with 121.5cm in diameter and 25cm in height rested on wooden block used to measure the evaporation. Figure 1 shows the layout of the experimental site. The water drained by subsurface drainage 10cm in diameter with spacing 80m and depth 150cm.

e) Measurements

Measurements included water table depth, irrigation and water table salinity, rainfall, temperature and soil salinity.

f) Irrigation water salinity

It was measured before each irrigation gift by a handheld electrical conductivity meter in (dS/m). The equation 3 is used for determine the sodium ratio.

$$SAR = \frac{Na^+}{\sqrt{\frac{Ca^{++} + Mg^{++}}{2}}} \quad (3)$$

Where SAR is sodium adsorption ration "%", Na^+ is the sodium "meg/L", Ca^{++} is the calcium ratio "meg/L", Mg^{++} is the Magnesium ratio "meg/L".

The equation 4 is used for determine the total salinity dissolved in water.

$$TDS = 640EC_w \quad (4)$$

Where TDS is the total dissolved salts in water "ppm", EC_w is the electrical conductivity "dS/m".

Irrigation water salinity varied from 0.83 to 2.74 with average of 1.78dS/m and sodium adsorption ratio is 2.96% and salts total dissolved salts in water varied from 2331 to 2754 with rate of 2542ppm.

g) Water Table Level

Water table level was measured daily in a set of 26 wells that installed and distributed in between and above the subsurface drainage in the experimental field for both treatments.

h) Soil Salinity

Table (1) shows the average soil salinity for both treatments (siphon and gate pipe) along the soil depth, The table shows that the pattern of soil salinity started with low value of 1.7 dS/m at the upper layer and increases with depth to a value of 3.9 dS/m and this result is confirmed with the logical, where the irrigation water passes through the subsurface drainage system upward by capillary flow.

Table 1 : Soil Salinity

Depth (cm)	E.C (dS/m)	Ca Co3 (meg/L)
0-35	1.7	24.25
35-47	2.95	28
47-105	3.3	22.5
105-125	3.9	22.75

i) Weather Temperature

Weather has been observed daily during the study period and Figure 2 shows the temperature in the study area during the experiment.

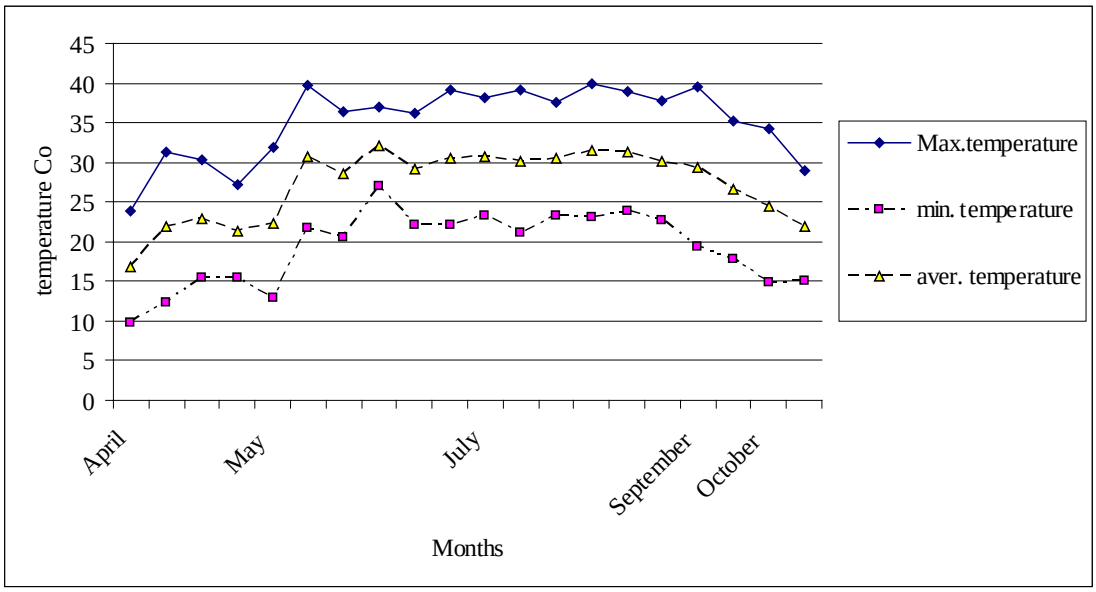

Figure 2 : The weather temperature

j) Crop Yield

The study area were planted in lines 75cm in distance between them and 15cm to 17cm between the plants. Observation of cotton growth was followed and four crop samples were taken from each treatment at harvest time to determine the average cotton crop yield.

III. Results and Discussion

a) Soil Salinity

Table (2) shows the soil salinity for two treatments in all season. The siphon method gives highest value of total salinity at all seasons as shown in Figure 3. This treatment increased the salinity by 2.7% while the pipeline with gate increased the salinity by 12.9%

Table 2 : Soil Salinity for Both Treatments

Treatment		EC_e dS/m	P.H.	Ca mmeq/L	Mg mmeq/L	Na+ mmeq/L	Cl mmeq/L	HCo_3 mmeq/L	So_4 mmeq/L
Siphon	Before Season	4.244	7.65	16.83	14.85	24.11	29.6	0.48	25.7
	Mid Season	4.61	7.6	19.87	16.84	15.85	18.07	0.37	34.15
	After Season	4.36	7.57	14.04	14.89	17.44	20.46	0.37	25.47
Gate pipe	Before Season	3.84	7.7	15.21	12.48	17.04	16.61	0.41	28.85
	Mid Season	4.357	7.51	20.73	15.48	17.39	26.34	0.48	26.81
	After Season	4.336	7.52	15.69	15.11	15.94	19.33	0.37	27.03

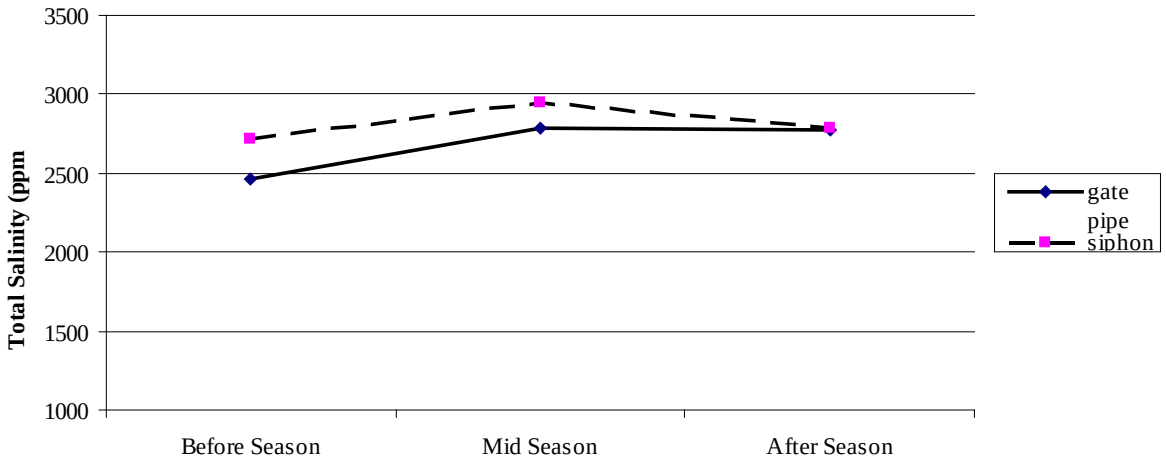

Figure 3 : The total soil salinity

Sodium adsorption ratio (SAR) decreased for all treatment as shown in Figure 4. The pipeline with gate treatment gives lower percentage. The siphon method gives the highest value equal to 24% before season and the lowest one is 17% after season. It decreased the sodium ratio by 27%. The pipe gate decreased the SAR by 6.7%.

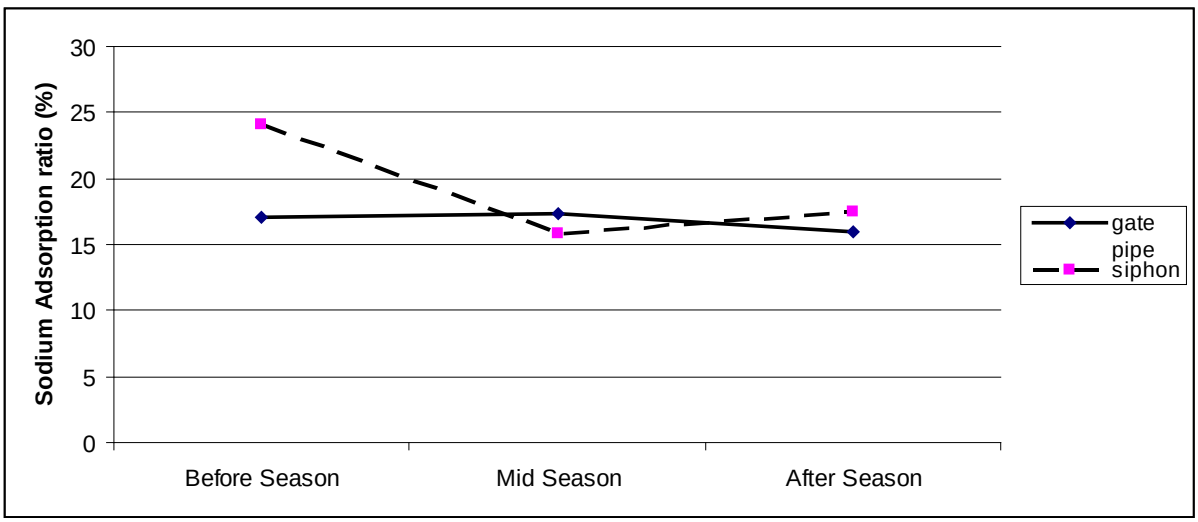

Figure 4 : The sodium ratio for both treatments

Toxic salts (sodium sulfate, sodium chloride and magnesium chloride) changed from 1.8058mS/m before planting to 1.8376 mid agriculture then 1.9695mS/m the end of the season for the treatment of

pipeline with gate. And it decreased from 2.2323mS/m before planting to 1.9113mS/m at mid agriculture then increased to 1.9622mS/m after season for siphon treatment.

Non-toxic salts (calcium bicarbonate and calcium Sulfate) changed from 1.0638 before planting to 1.4366mS/m mid season then 0.9142mS/m the end of the season for the treatment of pipeline with gate. And it increased from 1.1675mS/m before planting to 1.3758mS/m at mid agriculture then increased to 0.8838mS/m after season for siphon.

The probability of producing alkaline soil in all transactions out of the question because the value of $\frac{K+N_a}{Ca+Mg}$ is less than 1. as shown in table (3)

Table 3 : alkaline probability

Season	siphon	Pipe gate
Before Season	0.761	0.61
Mid- Season	0.432	0.48
After Season	0.603	0.453

b) Water Table Salinity

The water table salinity for both treatments was represented in Figure 5. It ranges from 2.45 to 5.37 dS/m with an average value of 4 dS/m for gate pipe treatment while the water table salinity for siphon treatment ranges from 2.3 to 5.25 dS/m with an average value of 3.9 dS/m. It is obvious from these results that there is no difference between the water table salinity for both treatments.

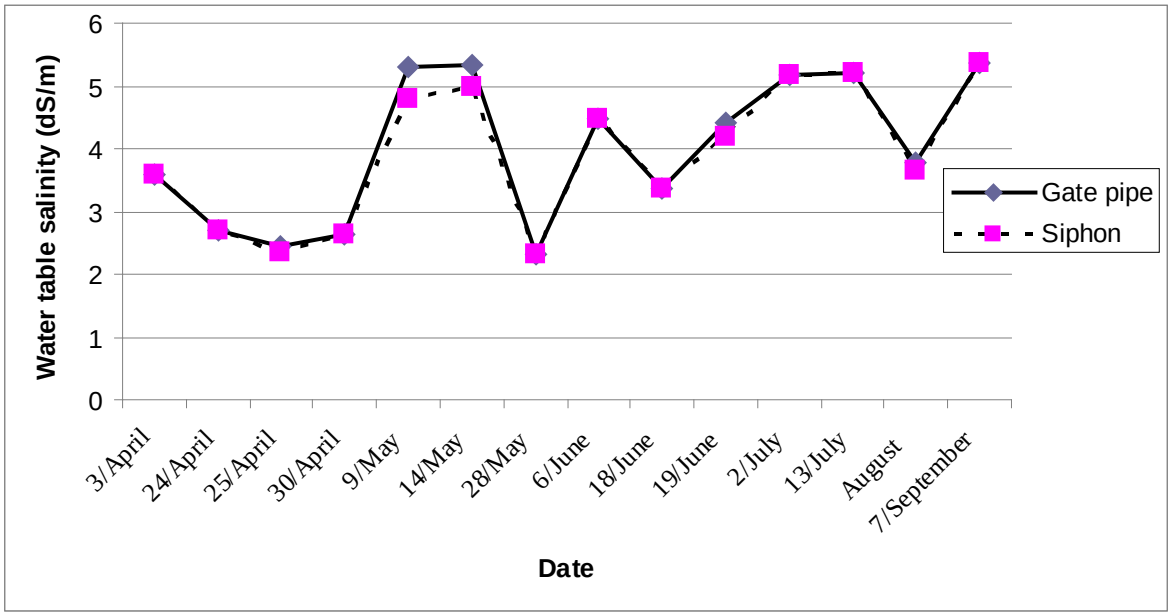

Figure 5 : Water table salinity for both treatments

c) Water table level

The average water table level for both treatments (Siphon and pipeline) along the cotton season are represented in Figure 6.The figure shows that the average water table in gate pipeline is less than in the siphon.

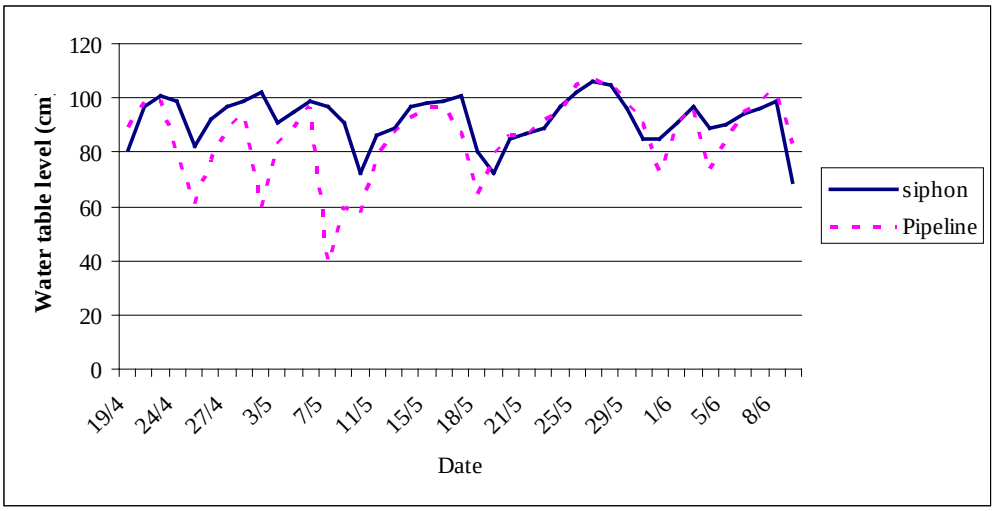

Figure 6 : Water table level

d) Water Consumption

For the gate pipe the water consumption during the flowering phase and form roots gives the largest amount which gives 4200 m^3/hectare (42.4% from the total amount). The germination stage gives 2327m^3/ hectare (23.5% from the total amount), While the water consumption during the floral buds gave the minimum amount. But for the siphon the water consumption during the flowering phase and form roots gives the largest amount which gives 3534m^3/hectare (36.61% from the total amount). The germination stage gives 2340m^3/hectare (24.2% from the total amount), While the water consumption during the floral buds gave the minimum amount equal 893m^3/hectare (9.2%). As shown in Figure 7. The total water consumption for the treatment of pipe gate is 9903 which exceed than siphon by 2.5%.

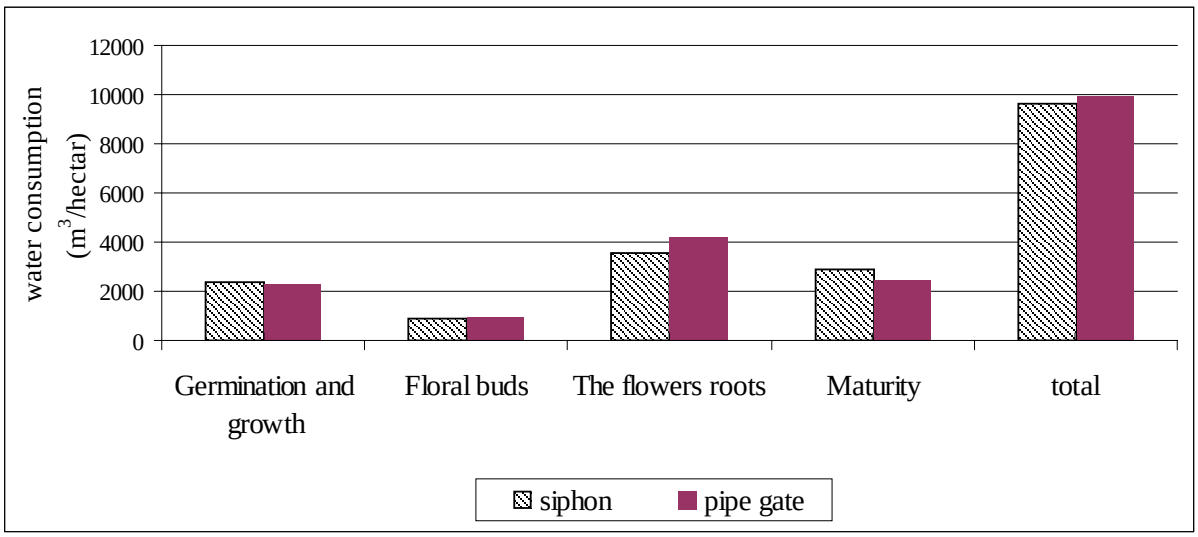

Figure 7 : The water consumption for each treatment

e) Water Irrigation Efficiency

The value of the additional water efficiency was measured by using equation (5) which gives that working in siphons is higher than in the pipeline as shown in table 4.

$$E_a = \frac{D_s}{D_A} \qquad (5)$$

Where E_a is the additional water efficiency "%", D_s is the stored water depth in root zone "cm", D_A is the additional water depth "cm"

Table 4 : Irrigation addition efficiency

Phases	Pipeline	siphon
Germination	56	66
Floral buds	59	67
Flowers	51	66
Maturity of the plant	55	52
Average	55.25	62.75

The water distribution efficiency is higher in siphon 80% than in gate pipeline 72%. The storage coefficient for pipeline is 100% and 99% for the siphon.

f) Time progress

Figure 8 shows the time progress inside the filed. The siphon treatment gives less time than the gate pipeline. The applied time for the treatment of gate pipe is 223 minutes but in siphons is 191 minutes.

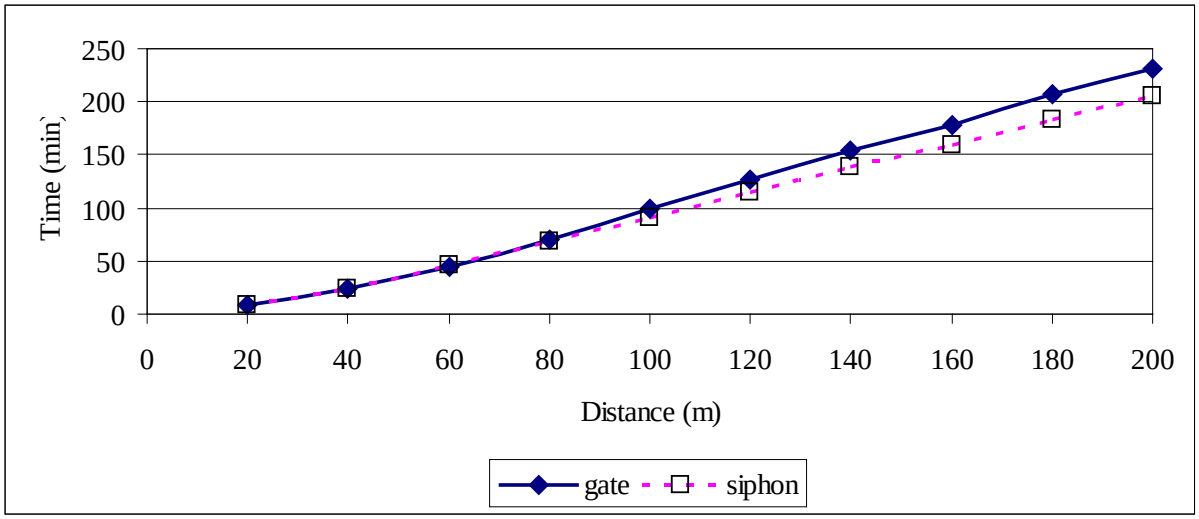

Figure 8 : Time progress in both treatments

g) Crop Production

The crop water need (ET crop) is defined as the depth (or amount) of water needed to meet the water loss through vapor-transpiration. In other words, it is the amount of water needed by the various crops to grow optimally. Convergence the value of the crop coefficient in all relations used in most stages of growth, except Penman relationship which gave the highest values. Figure 9 and Figure 10 show the relation between the crop coefficient and in all stages for gate pipe and siphon respectively.

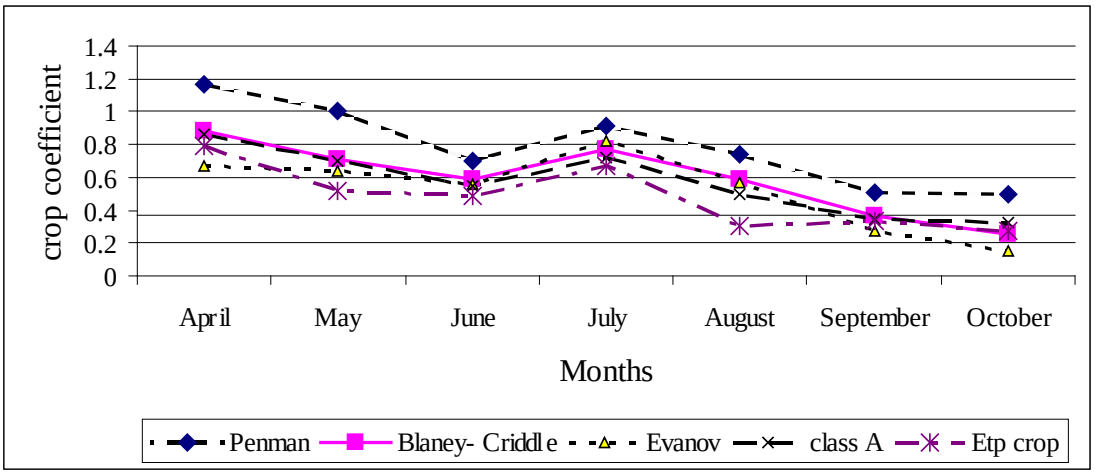

Figure 9 : The relation between the crop coefficient and in all stages for gate pipe

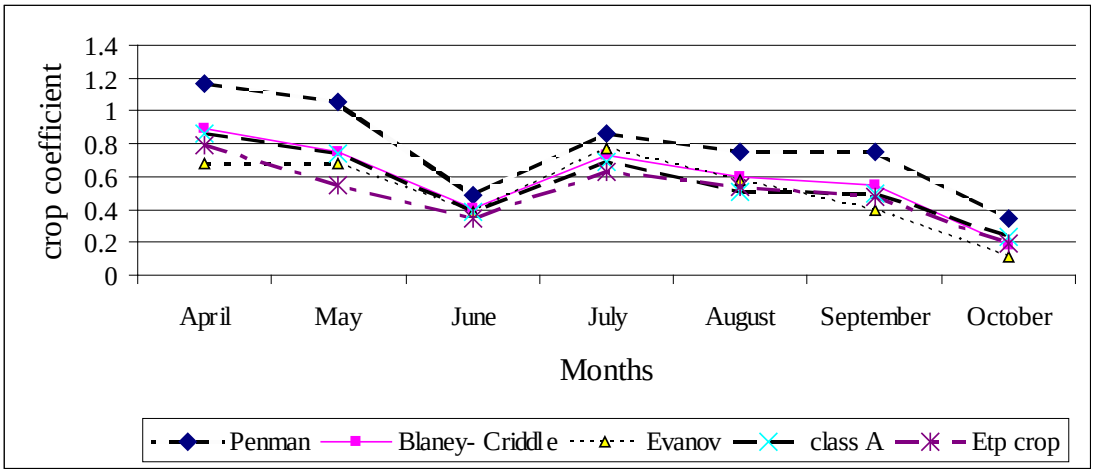

Figure 10 : The relation between the crop coefficient and in all stages for siphon

Table (5) Shows the comparison between the average of the crop coefficient in pipe line with gate and in siphon.

Table 5 : The average crop coefficient

	Penman	Blaney-Criddle	Evanov	class A	Etp crop
$\overline{kc}pipe$	0.79	0.59	0.53	0.57	0.48
$\overline{kc}$ *siphone*	0.78	0.59	0.52	0.56	0.50

Figure 11 shows the average cotton yield for both siphon irrigation and pipeline with gate treatments. In case of gate pipeline treatment, the cotton yield was 2.581ton/ha; this exceeds the yield of siphon irrigation treatment by 17%.

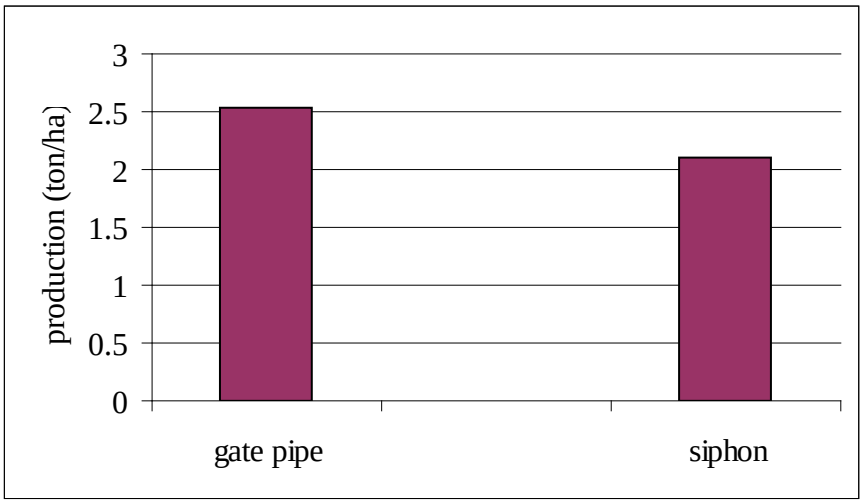

Figure 11 : Crop Production

Figure 12 shows the average cotton length for both siphon irrigation and pipeline with gate treatments. In case of siphon treatment, the average cotton length was 74cm; this exceeds the length of pipeline treatment by 14%.

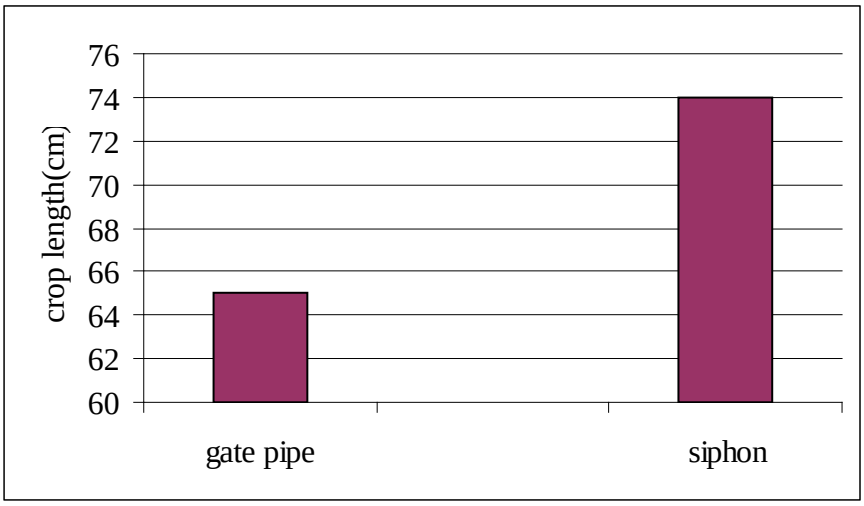

Figure 12 : Crop Length

IV. Conclusion

The total soil salinity increased both treatments. The siphon method gives highest value of total salinity at all seasons which increased the salinity by 2.7% while the pipeline with gate increased the salinity by 12.9%. Sodium Adsorption ratio decreased for both treatments. The pipeline with gate treatment gives lower percentage. The siphon treatment decreased the sodium ratio by 27% and the pipe gate decreased the sodium ratio by 6.7%. The pipeline with gate increased the toxic salts by 9.07% and non-toxic salts by 14% while the siphon decreased toxic salts by 12% and increase the non-toxic by 24%. The probability of producing alkaline soil in both treatments is out of the question. Convergence the value of the crop coefficient in all relations used in most stages of growth, except Penman relationship which gave the highest values. The siphon treatment need water consumption less than gate pipeline by 2.5%. The water distribution efficiency is higher in siphon 80% than in gate pipeline 72%. The storage coefficient for pipeline is 100% and 99% for the siphon. The cotton grains yield in case of gate pipeline treatment was greater than that of siphon irrigation by 17% and equal to 2.581ton/ha. In case of siphon treatment, the average cotton length was 74cm; this exceeds the length of pipeline treatment by 14%.

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