Optimizing Water Use Efficiency for Sugar Cane Crop

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Abstract: Two field experiments were carried out at Mallawy Water Requirements Research station – El Minia, Governorate; Egypt Water Management Research Institute – National Water Research Center during seasons 2012 and 2013 seasons. The present research was carried out to study the effect of irrigation system by gated pipes on water use efficiency, yield, saving of water and economic evaluation for sugar can crop (Saccharum *officinarum* L) and compare it with common conventional cultivation practiced in this region. Four treatments were arranged in a spilt-plot design. Two of them system irrigation by gated pipes and the others planting method (furrows and beds). Results indicated that the planting sugar cane crop by gated pipes in beds leads to an increase in productivity with rate equals 20.42% and to more water saving about by 42.99% per year, decrease both the costs of irrigation by about 45.8 % and the irrigation time by about 45.01% and rising the total irrigation's efficiency by 75.31%. It also saving water by about 1.310850629 billion m3/area (Average area cultivated by sugar cane in Egypt) compared with the traditional method in this region. The results indicated also from the economic view point that, the gated pipes in beds recorded the highest values of field and crop water use efficiencies (10.26 and 16.06 kg/m^3) respectively. The highest values of total income, production, financial benefits **(**L.E/ area), net return of each and water irrigation **(**L.E/m^3**)** and economic efficiency were gained with it. Therefore, the economics of irrigation water becomes very important for planting irrigation management project where the over irrigation practices by farmers usually lead to low irrigation efficiency, water logging and high losses of water. It could be recommended to application gated pipes in beds to produce high yield with less amount of water applied under El-Minia province conditions.
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1. Introduction

Agricultural sector plays an important role in the economic development in Egypt. It is considered one of the national economy basis, and the main income source for more than half of Egypt's population. Agriculture is responsible for satisfying the consumers' needs for clothing and food. In addition, it provides the industry sector with raw materials needed for various industries. The extension of this role requires achieving the economic development which is derived from two main sources: horizontal and vertical agricultural expansion. Horizontal agricultural expansion depends on the availability of the production resources. In arid regions, water resources are considered the scarcest element among other economic production resources. Consequently, it is not only one of the man determinants but also the strategic one which determines the horizontal expansion through reclamation of new lands.

The optimal use of water is the corner stone of the agricultural development sector because the present water sources available in Egypt are not enough for the future horizontal agricultural expansion, in the scope of the present techniques and irrigation practices. Comprising the 21th century challenges arises under conflicts on water shares of Egypt, and the attempt to continue the poliy of agricultural horizontal expansion, it gets worst. This matter shows the necessity of achieving the maximum efficiency of water sources in Egypt through some parameters which can be used in achieving the best use of the available water sources in Egypt.

Sugar cane (*Saccharum officinarum L.*) is considered to be one of the most important sugar crops all over the world. In Egypt, sugar cane production faces some problems which developed by time. The main problems, nowadays, are the limited freshwater supply and increasing of crops water requirements due to the climate change (**El-Sharfai 1996; Moursi and Nour El-din 1977; Chapman and Egan, 1997; CCSC, 2003 and ESST, 2006**). Comparing with other field crops, sugar cane and rice crops require a highest amount of water for growth. As result, lately some voices have risen up asking for the replacement of sugar cane with sugar beet which has relatively less water requirements.

In this connection ***Smith et. al. (1997)*** indicated that using gate pipe system provided many benefits.

1-Demonstrated that water applied more evenly and more efficiently could increase crop yields.

2-Provided controllable, consistent, and accurate delivery of the water right.

3-Reduced the need to divert 5.5 acre-feet per acre from the Clear-water ditch to 3.3 acre-feet per acre.

4-Improved water quality in the Lostine River by reducing tail water return flows and reducing sediment yield.

Hassan (1998) reported that there are many methods for improving the performance of surface irrigation, but all of then depend up on the main factors related to soil characteristics, leveling and application method. they stated that the use perforated pipe system instead of ditches for conveying and distributing the irrigation water over the entire field may improve the surface irrigation, avoid weed problems, avoid loss of productive land, avoid loss of water by seepage and evaporation. And also decreases the irrigation water losses up to 25 % during distributing the irrigation water

El-Tantawy et al.(2000) stated that developed surface irrigation means using perforated pipe system and precision land leveling on sugarcane area in old valley in Egypt.

Abou El-Soud (2009). showed that gated pipes is an aluminum or PVC pipe (6 inches diameter) and an orifice gated are distributed along the pipes with 75 cm spacing. Gated pipes are connected directly with a water pump to convey and distribute the water to the head of the irrigated fields (furrows or basins method). Gated pipes are easy to be used by the farmer and have low cost. The conveyance efficiency, application efficiency and distribution uniformity are relatively high with gated pipes. He also found that Traditional surface irrigation is used in most of field crops at North Delta as a conventional practice of irrigation at the Egyptian farmers. Developed surface irrigation using gated pipes and drip irrigation (Surface or subsurface) are new methods to be used for irrigation not only in the new land but also in Nile Delta and Valley areas as strategy based on water saving. This tendency is very important because Egypt is becoming more water poor country.

Abo Solimam, et al (2002) found that using gated pipes could save irrigation water by 16.94% for maize crop compared to traditional surface furrow irrigation.

Osman (2002) stated that using gated pipes, led to saving water by about (29.64%, 29.9%, 14.5% and 19.7%) in cotton, wheat, corn and rice respectively compared with traditional (flooding) system.

Abou El-Soud (2009) also found that water application efficiency value increase as the amount of water applied with each irrigation decreases. The values of irrigation application efficiency for maize are 82.2 and 75.5% with gated pipes and traditional surface irrigation systems, respectively., while the values of water application efficiency for sugar beet are 79.5 and 71.7% for gated pipes and traditional surface irrigation systems, respectively.

Kholeif et. al. (1997) showed that, modern irrigation systems in sugar under Upper Egypt conditions gave highest cane yield and quality.

Osman (2002) showed that using gated pipes increased the mango yield by 377.2% and saved irrigation water by 19.8% compared with traditional system. Also, water utilization efficiency by using improved surface irrigated mango with gated pipes was increased by 70.7% compared with traditional methods.

Abo Soliman et al. (2008) reported that the grain yield of wheat and soybean crops were significantly increased with gated and concrete pipes and with shorter border length and width.

Sonbol et al. (2010) found that the irrigation by gated pipes system and surface drip irrigation (single lateral) systems achieved the highest values of water distribution efficiency. It can be recommended to use gated pipes as modified surface irrigation method to irrigate heavy clay soils especially under condition of salt affected soils, while subsurface drip irrigation can be used properly in case of water shortage. They also found that the highest root, sugar yield, sucrose percentage and quality of juice were produced when sugar beet plants were irrigated by gated pipes. While the lowest root and sugar yield were achieved with irrigation by double line of subsurface drip irrigation.

Osman (2002) showed water utilization efficiency by using improved surface irrigated mango with gated pipes was increased by 70.7% compared with traditional methods.

***Jibin and Foroud* (2007)** found that the gated pipes gave a water saving of 25-28% and 19-29% increase in water use efficiency and 25% of electricity energy saving compare to conventional basin irrigation.

Abd El- Rheem et.al 2007, Abd El- Rheem et. al 2008, and Abd El- Rheem 2010 found that irrigation in beds leads to an increase in productivity and also more water saving with equals 20 % m3/fed. per year, decreasing the costs of the product's materials, decreasing the irrigation time, and rising the total irrigation's efficiency.

Also project by Ministry of Agriculture and ARC, for improving Sugar Cane irrigation efficiency, and productivity, had implemented "aluminum" gated pipes with laser land – leveling into more than 1265 fed (2003). The obtained results highlighted significant positive yield response to controlled irrigation (gated pipes). Productivity, for sugar cane had increased under gated pipes irrigation system by an average value of 9 to 19% depending on application rates and openings' size during years 1998 to 2000. Crop water use efficiency also had increased

by amount varied between 24% to 55%, depending openings' size and application rates.

So the use of improving surface irrigation by using gated pipe and planting in beds has a positive effect on increasing agricultural production, both vertically and horizontally. Vertically by increasing yield per unit area, and horizontally by saving water in order to irrigate more new lands. Consequently, due to the considerable initiative costs, the introduction of this technique lies primarily on the shoulder of government's institutions, cooperatives, and large companies. In future, upon its benefits, the gated pipes' system and planting in beds will be widely spread in Egypt.

2. Materials and methods

Two field experiment were carried out for two seasons summer and winter of 2012 and 2013 seasons, at Mallawy, Water Requirements Research Station – El Minia Governorate; Water Management Research Institute- National Water Research Center. The present research was carried out to study the effect of irrigation system an planting methods on water consumptive use, water applied, water use efficiency, economic evaluation, yield and quality of sugar cane crop.

The experiments were included two irrigation systems (A) (surface irrigation & improving surface by gated pipes) and two planting method (B) (furrow & beds) with four replication so that experiment was arranged in split plot design. The treatments of irrigation systems were randomly distributed in the main plots and planting method treatments were randomly distributed in the sub-plots.

Soil Physical analysis:

* The bulk density was determined using the undistributed core samples according to ***Klule 1986*** as shown in Table (1).

* The Field capacity (F.C%) was determined by field method according to (Klule 1986) as shown in Table (1).

*Permanent wilting point was determined by using a pressure membrane apparatus (***Klule 1986)*** as shown in Table (1).

*The available water (A.W.) was calculated as the difference between the F.C and PWP as shown in Table (1).

*Infiltration rate (IR): It was determined using double cylinder infiltrometer as described by ***Garcia (1978).***

* Some chemical properties of the experiments soil before soil preparation were estimated according to the procedures outlined by ***Jackson (1967)*** are shown in Table (2).

Table (1): Some physical properties of the experimental soil before the growing season in the two studied seasons

Soil depth (cm)	Particle size distribution			Texture	infiltration rate (mm/hours)	Bulk density (g/cm^3)	Soil moisture characteristics		
	Sand%	Silt %	Clay %				Field capacity %	Wilting point %	Available water %
0-15	16.91	25.25	57.84	clay	10	1.17	43.40	22.30	21.10
15-30	17.91	26.51	55.59	clay		1.24	38.90	21.10	17.80
30-45	19.31	27.41	53.28	clay		1.33	36.51	19.51	17.00
45-60	20.98	28.3	50.72	clay		1.37	33.99	18.09	15.90
Average	18.78	26.87	54.36	clay		1.28	38.2	20.25	17.95

Table (2): Some chemical properties of the experimental soil before the growing season

Soil depth (cm)	OM %	PH*	EC** dSm^{-1}	Soluble cations (meqL^{-1})				Soluble anions (meqL^{-1})				Total N (%)	Available nutrients (ppm)	
				Na^-	K^+	Ca++	Mg++	CO^-	HCO_4^-	CL^-	SO_4^-		P	K
0-15	1.50	8.10	1.62	11.53	0.69	1.75	3.57	0	3.75	8.02	7.20	0.39	23.8	415.00
5-30	1.35	8.22	1.84	13.05	0.85	1.85	4.09	0	3.90	8.52	7.80	0.32	23.20	410.9
30-45	1.33	8.26	2.70	15.29	0.89	1.94	4.82	0	4.10	9.01	8.03	0.29	22.90	40280
45-60	1.10	8.29	2.85	16.40	1.08	2.01	6.51	0	4.24	9.30	9.01	0.28	21.70	392.00

*PH was determined in soil water suspension (1:2.5). **EC was determined in saturated soil paste extract.

Oil- water relationships

Recorded data:

Water Measurements

The quantity of water was measured in studied area by cut throat Flume size (20 x 90 cm) where applied water was added during each irrigation and at the end of each growth season the total quantity of water applied was estimated (m^3/ fed.) **(Early 1975).**

*Improved surface irrigation (gated pipes) the quantity of water applied was measured by water meters during every irrigation, **(Brater and King 1967).**

Water consumptive use (CU):

The quantities of consumptive use were calculated for the 60 cm soil depth which was assumed to be the depth of the root zone as reported by many investigators.

Monthly and seasonal water consumptive use were calculated by the summation of water consumed for the different successive irrigation through the whole growth season (**Serry et al. 1980).** Calculation of CU was repeated for all irrigation until the harvesting date.

Water consumptive use per feddan (4200m^2) can be obtained by the following equation.

CU=$\frac{\theta 2 - \theta 1}{100}bd\frac{\text{depth}}{100}$ area (4200m^2) which described by **Israelsen and Hansen, (1962)**

Where:

CU= Amount of water consumptive use.

θ_2 = Soil moisture content % by weigh after irrigation.

θ_1= Soil moisture content % by weigh before the next irrigation

B.d = Bulk density (g/ cm^3)

Crop water use efficiency (C.W.U.E)

The crop water use efficiency is the weight of marketable crop produced per unit volume of water consumed by plants or the evapotranspition quantity. It was computed for the different treatments by dividing the yield (kg / fed) on units of evapotranspiration expressed as cubic meters of water per fed. (**Abd El- Rasool et al. 1971)** It was calculated by the following formula.

$$\textbf{C.W.U.E} = \frac{\textbf{Yield (kg / fed.)}}{\textbf{Water consumptive use (m3 / fed.)}} = \textbf{(kg/ m}^3\textbf{)}$$

Field water use efficiency (F.W.U.E.)

Field water use efficiency is the weight of marketable crop produced per the volume unit of applied irrigation which was expressed as cubic meters of water (**Michael**, 1978).

It was calculated by the following equation:

$$\textbf{F.W.U.E} = \frac{\textbf{Yield (kg / fed.)}}{\textbf{Water applied (m3 / fed.)}} = \textbf{(kg/ m}^3\textbf{)}$$

Application efficiency (E_a):

The values of application efficiency (E_a) in percent for each treatment were obtained by dividing the total consumptive use on the applied irrigation water (**Downy, 1970)**

$$\textbf{E}_a = \frac{\textbf{Ws}}{\textbf{Wd}} \textbf{ x 100}$$

Where:

Ea = Water application efficiency. (%)

Ws = Water stored in the root zone. ($m^{3/}$ fed.)

Wd= Water applied to the field plot. ($m^{3/}$ fed.)

Water distribution efficiency (Ed):

It was calculated according to **Jame (1998)** as follow:

E_d = (1- y) x 100 d

where:

E_d = Water distribution efficiency (%)

d-Average of soil water depth stored in long the furrow during the irrigation.(cm)

y = Average numerical deviation from d (cm)

Storage efficiency (E_s):

Values of storage efficiency (E_s) in percent for each treatment were obtained by dividing the total water storage on the amount quantity of irrigation water that must be added before irrigation **(Sharl Sh. S. 1991).**

$$\textbf{Es} = \frac{\textbf{Ws}}{\textbf{Wm}} \textbf{ x 100}$$

Where:

E_s = water storage efficiency (%).

W_s = water storage in the root zone (m^3/ fed.)

W_m= the amount of irrigation water that must be added before irrigation (m^3/fed.)

Economic efficiency:

The economic efficiency refers to the combination of inputs that maximize individual or social objectives. Economic efficiency is defined in terms of two conditions: necessity and sufficiency. Necessary conditions are met in the production process when they are is producing the same amount with fewer inputs or producing more with the same amount of inputs. But, the sufficient condition encompasses individual or social goals and values **(John and Frenk 1987)** It was calculated by the formula:

$$\text{Economic efficiency} = \frac{\text{Net profit (L.E/ fed)}}{\text{Total costs (L.E /fed)}}$$

Statistical analysis:

The proper statistical analysis of all data was carried out according to **Gomez and Gomez (1984).** Homogeneity of variance was examined before combined analysis the differences between means of the different treatments were compared using the least significant difference (LSD) at 5% level.

3. Results and discussion

1-Total yield (ton/ fed):

Total yield (ton / fed) as influenced by different irrigation system and planting methods were presented in Table (3). The results show the system irrigation and planting methods had a significant effect on mill able cane crop. The highest values of mill able cane of

sugar cane was obtained from irrigation system by gated pipes in beds (56.900 ton/fed.) This might be due to increase the cultivated area of land instead of irrigation canals, reduce the spread of weed and diseases while the lowest values of mill able cane of sugar cane was obtained from surface irrigation in furrow 47.250 ton/fed. (conventional method in region).

This results are in agreement with those reported by Abdel Rheem et 2008, abdel Rheam 2010. It is obvious from data that treatment (A_2b_2) irrigation system by gated pipes in beds is responsible for obtaining high productivity of sugar cane.

So it can be concluded that this method is preferable under the water Egyptian conditions for sugar cane because gives higher values of yield with least possible amount of water applied.

Table (3): Productivity as affected by irrigation systems and planting methods combined between 2012 and 2013 seasons

Treatments	B_1	B_2	Mean
A_1	47.250	48.750	48.00
A_2	55.500	56.900	56.200
Mean	51.375	52.825	52.100
	A	**B**	**AB**
LSD5%	0.227	0.122	0.173
LSD1%	0.416	0.185	0.262

Where; *A_1= surface irrigation* *A_2=Improving surface irrigation by gated pipes* *b_1= irrigation the furrow* *b_2= irrigation in beds.*

2-Seasonal irrigation water applied:

Average of the amount of applied water delivered (m3/ fed) to different treatments of sugar cane crop shown in Table (4). The irrigation water applied for sugar cane plants were 9731.67, 7727.35 m3/fed for irrigation surface under (furrow & beds) respectively while, were 6799.82 and 5547.06 m3/fed for irrigation system by gated pipes under (furrow & beds) respectively. It is obvious that the lowest values of water applied was 5547.06 m3/fed obtained from irrigation system by gated pipes in beds (A_2b_2), whereas the highest values were 9731.67 m3/fed. Obtained from surface irrigation in furrow (A_1b_1).

Table (4): Average of the quantity of water applied for different treatments during the two studied seasons for sugar cane crop.

No. of irrigation	Surface irrigation		Irrigation by gated pipes	
	Irrigation in furrow	Irrigation in beds	Irrigation in furrow	Irrigation in beds
1	680.85	555.00	462.80	407.93
2	489.80	389.05	329.80	278.9
3	625.38	488.38	438.88	366.38
4	710.85	560.75	489.59	410.85
5	640.59	538.37	450.59	367.60
6	663.95	531.95	450.90	360
7	780	630.00	547	437.58
8	630.70	500.75	445.49	360.38
9	650.22	505.32	490	410.00
10	600	465	440	345.00
11	580.20	455.00	400	300.00
12	533.60	420.50	370.50	260.95
13	494.70	387.85	345.75	245.50
14	490	385	380.22	305
15	580	454	382.55	350.00
16	580.83	460.43	375.75	340.99
Total / season	**9731.67**	**7727.35**	**6799.82**	**5547.06**

3-Water saving (m3/ area):

Data in Table (5) show the average quantity of water saving (m3/fed.) which obtained when comparison conventional irrigation treatment with other treatment.

The obtained results in present study show that when the best method is use (irrigation system gated pipes in beds) the irrigation water is saved more than the service irrigation in furrow (common method in region) by about 42.99%. The results show also that, the amount of water irrigation which can be saved (as average) by about 1.318152100 milliard m^3/ area compared to normal planning in furrow. This amount of saving water enough to cultivate area about (generally) 2059612.66 feddan in old land or cultivate different areas of horticulture and field crops under El-Minia conditions. These results reflex how much irrigation water can be saved when using the transplanting method. In general, it could be concluded that water fast becoming an economically scarce resource in many area of the world. So, the use of irrigation system by gated pipes in beds is very important to save water. The best method to plant sugar cane should give favorable crop yield and optimum amount of irrigation water. Therefore, estimating economic of irrigation water becomes very important for planning irrigation management where the over irrigation by the farmers usually leads to low irrigation efficiency and high loss of water and fertilizer. These results reflex how much irrigation water can be save to produced the highest yield with least possible amount of water applied where the farmer's practices in sugar can be (conventional irrigation treatment) utilized much water without giving higher productivity.

4-Daily, monthly and seasonal actual water consumptive use:

Daily monthly and seasonal water consumptive use values are presented in Table (6) The data obtained indicated that mean values of seasonal water consumptive use were 137.44, and 115.92) cm/season for surface irrigation in (furrow & beds), respectively while were (96.12 and 82.79) cm/ season for irrigation system by gated pipes in furrow and beds respectively. Generally it clear that the surface irrigation in furrow have high values of actual water consumptive use (137.44) cm/ seasons.

While, the irrigation system by gated pipes in beds gave lowest values of actual water consumptive use which (82.79) cm/ seasons. It could be noticed from the data that water consumptive use starts with small amount because the needs small amount of water plants at initial growth stage, therefore, soil moisture are mainly affect by evaporation from soil surface at this time, with the advance with plant age, evapotranspiration increase and consequently the monthly consumptive use increased as plant foliage develops. The monthly water consumptive use reaches its peak value in the middle off growing (May – August) season which is considered the critical period in water demands of sugarcane crop.

5-Irrigation efficiencies:

Irrigation efficiency for different treatments of sugar cane are shown in Table(7) It is obvious that the highest values of total irrigation efficiency (75.31 %) were obtained from irrigation system by gated pipes in beds while the lowest values (54.85%) were obtained from surface irrigation in furrow (common method in region). So it could be concluded that when irrigation system by gated pipe used in beds the total irrigation efficiency increased from (54.85 %) to (75.31 %) compared with the conventional method in region where the over irrigation practiced by the farmers usually lead to low irrigation efficiency and high losses water.

6-Water use efficiency (WUE):

The water use efficiency is obtained by evaluating the two parameters of total yield per unit of water applied and water consumptive use. WUE is a tool for maximizing crop production per each unit of water irrigation. Effect of the different planting methods and system irrigation on WUE is presented in Table (8). From the presented data, it is clear that values of WUE of sugar cane differed from one treatment to another.

That highest values of field and crop water use efficiencies (10.26 and 16.36 kg/m^3 respectively) were obtained using the treatment A_2b_2 (gated pipe in beds) respectively. This is mainly due to the higher yield of sugar cane and decrease water applied and water consumptive use in the this treatment compared with the other treatments. While the lowest value of and crop water use efficiencies (4.88 and 8.23 kg/m^3 respectively) were obtained from treatment A_1b_1 (surface irrigation furrow). These results indicated that the using irrigation system by gated pipes in beds is the best treatment from the view point of water management for sugar cane yield.

7-The Economic Evaluation:

Total costs, production and total income (L.E / fed.)

Data in Table (9) illustrated that values of total cost, production, total income (L.E / fed.) and net return from unit of irrigation water (L.E/ m^3) as influenced by irrigation systems and different planting methods of sugar cane in both studied seasons.

The maximum values of total income and net profit (L.E / fed.) and return from a unit of irrigation water applied and consumptive were 20484, 10377, 1.87 and 2098 respectively obtained from plants which grow with gated pipes in beds (A_2b_2). While, the lowest values of total income (L.E/fed), net profit and net return from a unit of irrigation water (applied and consumptive use) were17010, 6756, 0.69 and 1.17 respectively obtained from the surface irrigation in furrow (A_1b_2).

From these results it could be concluded that the improving surface irrigation by gated pipes in beds lead to increase in total income, not profit and net return of irrigation water. The data in Table (9) show also that the highest values of yield (56.900 ton/ fed) were obtained from improving surface irrigation by gated pipes in beds. Moreover the results indicated that the maximum values of total cost / fed obtained from conventional method in experimental region surface irrigation in furrow (10254 L.E/fed.) while, using gated pipes in beds can be decreased it by about 1.51 % from production requirements for sugar cane crop compared to conventional method (surface irrigation in furrow). These results reflex how much irrigation water can be saved to produce the highest yield with least possible amount of water applied.

Table (5): Quantity of water saving (m3/fed.) which obtained when comparison conventional irrigation treatment with other treatments for sugar can crop during the both studied seasons.

Treatments	Increase of yield		% of increase in yield	Water applied (m3/fed)	Saved water		Average area cultivated plan cane crop in Egypt	To total of water saving m3/million /area	The area (fed.) of old land which can be cultivated as a resulting of saving water
	Ton/fed	Ton/fed.			m3/fed	%			
Surface irrigation in furrow (common method in region)	47.250	1.5	3.17	9731.67	2004.32	20.59%	315000	631.360800million	98650.125
Surface irrigation in beds	48.750			7727.35					
Surface irrigation in furrow (common method in region)	47.250	8.25	17.46	9731.67	2931.85	30.13%	31500	923.532750	144301.99
Irrigation by gated pipes in furrow	55.500			6799.82					
Surface irrigation in furrow (common method in region)	47.250	9.65	20.42	9731.67	4184.61	42.99%	31500	1.318152100	205961.266
Irrigation by gated pipes in beds	56.900			5547.06					

Table (6): Average values of actual water consumptive use (daily, monthly and seasonal) for sugar cane plants as affected by irrigation regime and planting methods (furrow & beds) (average of both seasons)

Months	actual water consumptive use															
	Surface irrigation in furrow				Surface irrigation in beds				Gated pipes in furrow				Gated pipes in beds			
	mm/day	Mm/month	cm/month	m³/fed	mm/day	mm/month	cm/month	m³/fed	mm/day	mm/month	cm/month	m³/fed	mm/day	mm/month	cm/month	m³/fed
March	1.50	22.5	2.25	94.5	1.27	19.05	1.90	79.80	0.95	14.25	1.42	59.64	0.4	12.4	1.24	52.08
April	4.53	135.90	13.60	571.20	3.65	109.5	10.95	459.90	2.83	84.90	8.49	356.58	2.16	64.8	6.48	272.16
May	5.51	170.80	17.08	717.36	4.65	144.15	14.41	605.22	3.74	115.94	11.60	487.20	3.21	99.51	9.95	417.90
June	6.17	185	18.50	777	5.30	159.0	15.90	667.80	4.40	132	13.21	554.82	3.74	112.2	11.22	471.24
July	6.69	207.40	20.74	871.08	5.83	180.73	18.07	758.94	4.91	152.21	15.22	639.24	4.44	137.64	13.76	577.92
August	7.03	218.00	21.80	915.60	6.16	190.9	19.10	802.20	5.22	161.82	16.20	680.4	4.72	146.32	14.63	614.46
September	5.14	154.20	15.42	647.64	3.92	117.6	11.76	493.92	3.43	102.9	10.3	432.60	2.77	83.10	8.31	349.02
October	4.30	133.30	13.33	559.86	3.23	100.13	10.01	420.42	2.58	79.98	8.00	336.0	2.03	62.93	6.30	264.60
November	2.99	89.70	8.97	376.74	2.52	78.12	7.81	252.42	2.47	74.1	6.41	269.22	1.96	58.8	5.88	246.96
December	2.18	67.60	6.76	283.92	1.94	58.2	5.82	4745.58	1.70	527	5.27	221.34	1.62	50.22	5.02	210.84
Total			137.44	5772.48			115.73				96.12	4037.04			82.79	3477.18

Source: Actual field measurements

Table (7): Average values of irrigation efficiency's (%) (application storage and distribution efficiency) and total irrigation efficiency for different treatments for sugar cane crop in both studied seasons.

No. of irrigation	Irrigation efficiency's (%)															
	Irrigation surface in furrow				Irrigation surface in beds				gated pipe in furrow				Gated pipe in beds			
	E_a%	E_s%	E_{wd}%	Total irrigation efficiency	E_a%	E_s%	E_{wd}%	Total irrigation efficiency	E_a%	E_s%	E_{wd}%	Total irrigation efficiency	E_a%	E_s%	E_{wd}%	Total irrigation efficiency
1	62.97	78.3	96.5	47.58	77.3	84.55	99.5	65.00	81.00	88.9	99.7	71.8	80.9	90.80	99.80	73.31
2	62.17	82.48	96.23	49.34	77.20	84.90	99.6	65.28	81.90	89.1	99.8	72.8	82.4	91.50	99.85	75.28
3	64.94	72.72	97.52	46.00	78.4	87.10	99.60	68.01	80.77	88.20	99.6	70.95	81.88	91.25	99.9	74.64
4	64.5	81.84	98.2	51.83	77.94	86.5	99.7	67.15	80.30	87.95	99.70	70.41	83.7	91.55	99.9	76.55
5	68.2	77.36	99.7	52.60	77.15	87.30	99.6	67.08	82.0	88.1	99.77	72.07	82.90	90.77	99.80	75.10
6	68.96	81.33	99.10	55.58	76.98	83.69	99.8	64.29	79.9	88.50	88.90	70.57	80.30	90.3	99.9	72.40

7	69	82.4	99.5	56.6	77.2	84.00	99.6	64.6	82.10	89.9	99.9	73.7	83.09	90.1	99.8	74.70
8	68	82.45	99.3	55.63	75.9	84.8	99.8	64.23	82.5	88.95	99.8	73.09	82.7	91.77	99.8	75.74
9	68.2	84.3	99.6	57.20	78.2	89.4	99.8	69.8	80.66	88.87	99.9	71.61	83.9	92.5	99.9	77.53
10	69.5	84.00	99.7	58.20	77.5	89.0	99.9	68.91	80.46	88.95	99.9	71.50	82.8	91.4	99.9	75.60
11	68	84.1	99.6	57.80	78.2	87.9	99.8	68.6	80.01	89.90	99.7	71.70	82.6	90.9	99.8	74.93
12	69.64	83.3	99.6	57.70	78.0	87.0	99.7	67.65	80.00	89.00	99.7	70.98	83.41	9.51	99.9	75.42
13	67.00	83.3	99.7	55.64	77.53	87.2	99.8	67.4	79.44	88.3	99.7	70.00	82.5	89.8	99.9	74.00
14	68.23	84.2	99.6	57.23	78.32	88.2	99.5	68.71	81.00	89.95	99.9	73.50	82.4	89.9	99.9	79.00
15	69.31	85.2	99.2	58.6	76.9	87.4	99.4	68.50	79.6	88.4	99.6	70.1	83.76	89.70	99.9	75.50
16	67.2	84.1	98.9	55.89	77.1	87.2	99.60	66.96	80.2	88.49	99.7	70.75	83.9	89.8	99.9	75.3
Average	54.85			54.59				67.01				71.59				75.31

Source: Actual field measurements $E_{a=}$ application efficiency E_s = storage efficiency $E_{wd=}$ water distribution efficiency

Table (8): Values of total yield (kg/ fed.) of sugar cane crop, water applied (m^3/fed), water consumptive use (m^3/fed.), field and crop water use efficiencies in the two studies seasons.

Treatments		Water applied (m3/fed)	Total yield (kg/ fed.)	Field water use efficiency (kg/ m3)	Water consumptive use (m3/fed)	Crop water use efficiency (kg/m3)
Surface irrigation	In furrow b_1)	9731.67	47.500	4.88	5772.48	8.23
	In beds (b_2)	7727.35	48.750	6.31	4845.54	10.06
Improving surface irrigation by (gated pipes)	In furrow(b_1)	6799.85	55.500	8.16	4037.04	13.75
	In beds(b_2)	5547.06	56.900	10.26	3477.18	16.36

Table (9): Average values of total costs, production, total income (L.E) and net return per cubic meter a water (L.E /m3) (for both studies seasons) by different planting methods and irrigation system for sugar cane crop.

Treatments		The total costs (L.E)													Yield (ton /fed)	Total return L.E / fed.			*Water issues L.E/m3*			
		Land preparation	Irrigation *network	Leveling by laser	harvest and the transfer of seed	seed	Cultivate Labors	Rent	Chemical fertilizer	Service & tillage Labors	Fuel (oils + diesel	Furrow opener by conventional plow	Irrigation labors	Pesticides	Total costs	Average total yield	Market price	Total income	Net profit	Water consumptive use (m3/fed)	Net return from unit water consumptive use	Water applied m3/fed	Net return from unit water applied L.E/m3
Surface irrigation (A_1)	In furrow (b_1)	110	-	-	142	432	270	5000	1700	1000	400	250	800	150	10254	47.250	360	17010	6756	5772.48	1.17	9731.67	0.69
	In bests (b_2)	110	-	-	142	432	270	5000	1700	1000	313	250	800	150	10167	48.750	360	17550	7383	4845.54	1.52	7772.35	0.95
Gated pipes (A_2)	In furrow	86	320	54	142	432	270	5000	1700	800	276	250	800	100	10230	55.500	360	19980	9759	4037.04	2.41	6799.85	1.43
	In bests	86	257	54	142	432	270	5000	1700	800	216	250	800	100	10107	56.900	360	20484	10377	3477.18	2.98	5547.06	1.87

Calculated the costs of network of irrigation gated pipes covered annually based on the life span for irrigation network is ten years

8-*The economic efficiency:*

Increasing net return or profit for crops refers to the decreasing of production costs or for increasing crop production. So the economic efficiency index refers to agricultural and irrigation activities, which can gave the highest return from each L.E unit which can spend on crop production.

The economic efficiency data, presented in Table (10). From these results it could be concluded that the lowest values of economic efficiency was obtained from surface irrigation in furrow (0.66) for each Egyptian pound (L.E) Spend for production while, the highest economic efficiency (1.02) was obtained from Improving surface irrigation by gated pipes in beds. These increases in economic efficiency due to the enhancement of net profit in the improving surface irrigation by gated pipes in beds compare with other treatments.

Table (10): Average values of the economic efficiency under lifting irrigation system for various treatments of sugar cane crop per feddan in both studied seasons.

Treatments		Total return	Total cost LE/fed	Net profit (L.E/fed.)	Economic efficiency
Surface irrigation	In furrow	17010	10254	6756	0.66
	In beds	17550	10167	7383	0.73
Improving surface irrigation (gated pipes)	In furrow	19980	10230	9770	0.95
	In beds	20484	10107	10343	1.02

Saving of irrigation time (minute/fed) and irrigation costs (L.E / fed)

Saving of irrigation time and irrigation costs as influenced by irrigation system and planting methods were presents in Table (11 and 12). The results in Table (11) show that irrigation time decreased by 22.25%, 32.35% and 45.01% by surface irrigation in beds, gated pipes in furrow an gated pipes in beds compared with the conventional irrigation in region (surface irrigation in furrow) respectively. Also the results in Table (12) show that when we using the gated pipes in beds the irrigation costs / decreased from 25.L.E/fed to 13.55 L.E/fed equal about (45.8%) compared with the common conventional irrigation (surface irrigation in furrow in the region). From these results it could be concluded that the using gated pipes system in beds decreased irrigation time and irrigation costs /fed which will lead to reduction in the overall costs of production requirements for sugar cane crop compared with traditional irrigation method.

Table (11) Comparison between the time saving of irrigation (minute / fed.) under surface irrigation and time saving of irrigation by development irrigation (gated pipes) for different treatments for sugar cane crop in the two studies seasons.

No. of irrigation	Time saving	Time saving of irrigation (minute / fed & %)								
	Surface irrigation in furrow (the common method in region) minute /fed. (A_1b_1)	surface irrigation in beds (A_1b_1)			gated pipes in furrow (A_2b_1)			gated pipes in beds (A_2b_2)		
		minute /fed	minute /fed	%	minute /fed	minute /fed	%	minute /fed	minute /fed	%
1	420	328	92	21.9	280	140	33.33	238	182	43.33
2	355	278	77	21.69	250	105	29.58	197	158	44.50
3	375	292	83	22.13	245	130	34.66	194	181	48.26
4	367	290	77	20.98	255	112	30.51	199	168	45.77
5	390	304	86	22.05	265	125	32.05	210	180	46.15
6	360	275	85	23.61	240	120	33.33	188	172	47.77
7	37	285	85	22.9	254	116	31.35	197	173	46.75
8	390	302	88	22.56	250	140	35.89	210	180	46.15
9	360	276	84	23.30	240	120	33.30	207	153	42.5
10	375	290	85	22.67	255	120	32.00	210	165	44
11	335	265	70	20.89	230	105	31.34	195	140	41.79
12	330	255	75	22.72	226	104	31.51	195	135	40.90
13	320	250	70	21.87	224	96	30.00	180	140	43.75
14	332	257	75	22.59	231	101	30.42	185	147	44.27
15	375	294	81	21.6	250	125	33.33	197	178	47.46
16	340	264	74	21.76	230	110	32.35	181	159	46.76
Average	**362.12**	**281.56**	**80.43**	**22.25**	**245.31**	**116.81**	**32.25**	**198.93**	**163.19**	**45.01**

Table (12) Comparison between the costs saving of irrigation (L.E / fed.) under surface irrigation and costs saving of irrigation by development irrigation (gated pipes) for different treatments for sugar cane crop in the two studies seasons.

No. of irrigation	cost	costs saving of irrigation costs saving (L.E / fed. & %)								
	Surface irrigation in furrow (the common method in region) (L.E/fed.) (A_1b_1)	surface irrigation in beds (A_1b_1)			gated pipes in furrow (A_2b_1)			gated pipes in beds (A_2b_2)		
		L.E/fed.	L.E/fed.	%	L.E/fed.	L.E/fed.	%	L.E/fed.	L.E/fed.	%
1	25	19.95	5.05	20.2	17.60	7.4	29.6	13.85	11.15	44.60
2	25	19.52	5.48	21.92	16.70	8.3	33.2	13.40	11.60	46.4
3	25	19.50	5.50	22	16.99	8.01	32.04	13.00	12.00	48.00
4	25	19.75	5.25	21.00	17.4	7.50	30.0	13.55	11.45	45.8
5	25	19.5	5.50	22	17.00	8.00	32.0	13.45	11.55	46.2
6	25	19.00	6.00	24	16.67	8.33	33.32	13.00	12.00	48.00
7	25	19.25	5.75	23	17.16	7.84	31.36	13.30	11.70	46.8
8	25	19.50	5.50	22	17.00	8.00	32	13.50	11.50	46.00
9	25	19.20	5.80	23.2	17.33	7.67	30.68	13.37	11.63	46.52
10	25	19.32	5.65	22.6	16.98	8.02	32.08	13.70	11.30	45.2
11	25	19.80	5.20	20.8	17.65	7.35	29.4	14.55	10.45	41.8
12	25	19.32	5.68	22.72	17.50	7.50	30.0	13.63	11.37	45.48
13	25	19.55	5.45	21.80	17.71	7.29	29.16	14.00	11.00	44.12
14	25	19.50	5.50	22.00	17.70	7.30	29.20	14.10	10.9	43.6
15	25	19.60	5.40	21.8	17.66	7.34	29.36	13.13	11.87	47.48
16	25	19.42	5.58	22.32	17.15	7.85	31.4	13.30	11.70	46.8
Average	**25**	**19.48**	**5.51**	**22.085**	**17.26**	**7.73**	**30.92**	**13.55**	**11.44**	**45.8**

Table (13): The total of finical benefits (L.E/ area) when the best methods (gated pipes in beds $A_2b_{2)}$ using and compare it with conventional method (A_1b_1) in experimental region.

Treatments	Saving of water L.E / area						Saving of yield LE/area					Saving of irrigation time (L.E/are)					Saving of irrigation costs (oils + diesel) (L.E/ area)				
	Water applied (m3/fed)	*Saving of water (m3/fed)*	*Average area cultivate sugarcane in Egyptfed/area*	*The total of water saving (m3 million/area)*	**The cost of transporting cubic meter water*	*The total of water saving (million L.E/area)*	*Total yield (ton/fed)*	*Increase in yield (ton/fed*	*Market price ton/fed.*	*Saving of yield (L.E/fed.)*	*Saving of yield(billion L.E/area)*	*The time fir each irrigation(minute /irrigation)*	*Saving time of (minute / irrigation)*	*The total of saving time of irrigation (minute / season)*	*total of finical benefits(L.E/fed.)*	*total of finical benefits(L.E/area)*	*The cost fir each irrigation(L.E /irrigation)*	*Saving of irrigation costs L.E/ irrigation)*	*Saving of irrigation costs L.E/ fed.)*	*Total saving of irrigation costs(L.E / area)*	*The total offinical benefits(L.E billion /area)*
Surface irrigation in furrow (A_1b_1)	9731.67	4184.61	315000	1.318152150	.037	48.771629	47.250	9.65	360	3474	1.094310000 billion	362.12	198.93	198.93 x 16=3182.88	315	99.225000	25	13.60	217.60	68.544000	1.310850629 billion
Gated pipes in beds (A_2b_2)	5547.06						56.900					163.19					11.44				

- Resource: Egypt: study on cost Recovery in the irrigation and Drainage sector, Ministry of irrigation and water Resources (KFW.) September 2004 Cairo.

9-The financial benefits (LE/ area)

Data in Table (13) show that the values of financial benefits (L.E/ area) as a result of saving of water, yield, irrigation costs and irrigation time (L.E/ area). From these results it could be concluded that using the best method (Improving surface irrigation by gated pipes in beds A_2b_2) get total of financial benefits as a result of saving water by about (48771629 L.E mullion/area) + saving of yield (1.094310000 billion L.E /area) + saving of irrigation costs (68.544000 L.E million / area) + saving of irrigation time (99.225000 L.E million/ area) =(1.310850629 billion L.E / area).

Conclusion

Considering the previous discussion and the use of gated pipes in beds has a positive effect on increasing agricultural production in both vertically and horizontally; vertically by increasing yield per unit of land area, horizontally by saving water in order to irrigate more old or new lands. Thus the method becomes very important in saving water and obtaining high yield where this not need requires well trained skilled lab our. Therefore, the introduction of this method lies primarily on the shoulder of government institutions, cooperatives and large companies then in the future the improving surface irrigation by gated pipes in beds will started to be widely introduced in Egypt. So we have search for applicable solutions and how to limit the sugar cane consumption of water and keep the planted land as it is, and to expand the producing sugar from sugar beet in new lands. One of these solutions is the point of our study which study the effect of gated pipes in beds on water consumptive use and the water use efficiency for the crop in order to have a high yield and good quality with least quantities of water.

The improving surface irrigation by gated pipes in beds decrease irrigation water requirements by about 42.99s% and increases yield by about 20.42 % Economic analysis show that the using gated pipes in beds the total costs fed. decreased by about 1.51 % compared with irrigation surface in furrow. At the end of this study the obtained results indicate that it may be recommended by application gated pipes in beds m method to produce high yield and quality with the least possible amount of water applied under El-Minia province conditions.

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