Gated Pipes Irrigation System for Optimum Water Productivity of Sugar cane in Egypt

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Abstract: In Egypt, water scarcity is one of the main challenges that hinder agricultural expansion and development. Also, sugar cane is the principal crop for the sugar industry and is the sole source for molasses, in addition, it provides many essential industries with raw materials. Sugarcane is well-known as one of the freshwater-guzzling crops, where one feddan (0.42 ha) planted by sugar cane in old lands need to more of irrigation water around 10800m^3 than other field crops in Egypt. Therefore, optimization of water use of sugar cane involves getting the maximum value output for minimum amount of water consumed. Consequently, two field experiments during seasons (2015 and 2016) were conducted at three region at El – Minia (middle Egypt), Luxor (begin of Upper Egypt) and Aswan (end of Upper Egypt) experiment stations. Gated pipes irrigation system compared with conventional flood irrigation for irrigating sugar cane ***(Saccharum officinarum L.)*** were examined under two different planting methods (raised-beds and furrows) for the resulting differences in yield, water applied, actual water consumptive use, water saving, total irrigation efficiency, irrigation time and irrigation costs. Results indicated that the irrigated sugar cane crop by gated pipes system and planting in beds leads to an increase in productivity with rate equals 11.82%, 14.04 % and 16.03 %, saving of water by 32.35 %, 33.10% and 35.67 %, decrease the irrigation time about 36.90%, 37.95 % and 38.19 % % and rising the total irrigation's efficiency about 75.78%, 75.10% and 74.83 % compared with conventional treatment (flood irrigation and planting in furrow) for El-Minia, Luxor and Aswan regions respectively. Result indicated that (from view point of water) when we use the best irrigation system (irrigated by gated pipes and planting in beds) we can save water irrigation about 1,035420270, 1,25400762 and 1,992858540 Millar m3/area in Egypt for same regions respectively. This quantity saving water enough to cultivate different areas from field and horticulture crops under Egypt conditions. It could be recommended to application gated pipes in beds to produce high yield and quality with less amount of water applied under different soil texture and weather conditions in Egypt.

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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 policy 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 gated pipe system provided many benefits of which increasing crop yields and providing controllable, consistent and accurate delivery of water right.

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

Hassan (1998) reported that there are many methods for improving the performance of surface irrigation, but all of them 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, and avoid loss of water by seepage and evaporation. 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.

Osman (2000) 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.

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.

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 (2010) found that irrigation in beds leads to an increase in productivity and also more water saving with equals 20 % m^3/fed. per year, decreasing the costs of the product's materials, decreasing the irrigation time, and rising the total irrigation's efficiency.

Abo Soliman et al.(2008)found that the lowest amount of water applied water consumptive use, water losses %, the highest values of field water use crop water use efficiencies (kg/ m^3) and water application efficiency % were obtained under gated pipes, 60 m border length and 12 m border width. They added that gated and concrete pipes could save irrigation water by 9.2 and 6.82 % for wheat crop, while these values were 12.52, 5.81 % for soybean crop, respectively, compared to traditional. field ditch. They also added water application efficiency was higher under gated pipes (79.37 %) followed by concrete pipes (72.66 %) while traditional field ditch was the lowest on (66.85 %). it was expected that water application efficiency would be improved with gated and concrete pipes due to uniform water distribution from the outlets compared to traditional field ditch, which reduces the percolation losses

Abou El-Soud (2009).showed that gated pipes is 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. 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 79.5ad 71.7% for gated pipes and traditional surface irrigation systems, respectively.

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.

Abdel – Fattah (2011), showed that gated pipes technique is a promising practice in improving surface irrigation, the convenient irrigation method in Egypt several advantages could be obtained by using gated pipes.

- Good uniform distribution of irrigation water.
- Low energy needed in its irrigation operations.
- High water saving
- Gained about 10 % from cultivated lands.

Ndeketeya ***et al. (2014)*** reported that there was a significant difference in the sugar-cane fresh yield and sucrose content of furrow irrigated and drip irrigated plots with the former having better results. ln 2009, there was a slight increase in fresh weight of 2.0t and l.25t for drip and furrow systems, respectively. Sucrose content increased slightly by 0.l5t for drip, and 0.2t for furrow system. For both treatments benefit cost ratio was greater than zero and net present value was positive, showing that they are profitable and viable projects.

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. The aim of this work is to study the effect of development irrigation system by gated pipe on water consumptive use, yield, saving water and total irrigation efficiency for sugar cane crop

2. Materials and methods

Two field experiments were carried out for two seasons 2015 and 2016 at regions El-Minia Governorate, Luxor, Aswan under different texture soils and weather. The present research was carried out to study the effect of irrigation system and planting methods on water consumptive use, water applied, and water use efficiency, yield and quality of sugar cane crop and compare it with common conventional cultivation practiced in these region. 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:

TAble (1): Some physical properties of the experimental soil before the growing season in the two studied season in three regions.

El Minia Region									
Soil depth (cm)	Particle size distribution			Texture	infiltration rate (Cm/hours)	Bulk density (g/cm^3)	Soil moisture characteristics		
	Sand%	Silt %	Clay %				Field capacity %	Wilting point %	Available water %
0-15	7.96	36.80	55.24	Clay	0.80	1.17	43.40	18.00	5.4
15-30	14.24	30.80	54.96	Clay		1.24	38.21	17.50	20.71
30-45	17.78	29.77	52.45	Clay		1.29	36.90	17.10	19.80
45-60	23.49	26.72	49.79	Clay		1.30	35.50	16.90	18.60
60-90						1.73	31.99	16.50	15.49
Luxor region									
Soil depth (cm)	Particle size distribution			Texture	infiltration rate (Cm/hours)	Bulk density (g/cm^3)	Soil moisture characteristics		
	Sand%	Silt %	Clay %				Field capacity %	Wilting point %	Available water %
0-15	39.20	49.90	10.9	Salty clay	1.10	1.03	40.47	17.00	23.47
15-30	34.50	45.22	20.28	Salty clay		1.24	38.59	16.40	22.19
30-45	33.20	42.20	24.60	Salty clay		1.27	37.05	15.80	21.25
45-60	32.16	39.88	27.96	Salty clay		1.34	33.59	14.59	19.00
60-90	-	-	-			1.40	31.85	13.50	18.35
Aswan region									
Soil depth (cm)	Particle size distribution			Texture	infiltration rate (Cm/hours)	Bulk density (g/cm3)	Soil moisture characteristics		
	Sand%	Silt %	Clay %				Field capacity %	Wilting point %	Available water %
0-15	77.45	10.25	12.30	Sand loam	5.60	1.45	23.52	10.01	13.51
15-30	78.12	9.88	12.00	Sand loam		1.49	19.40	9.97	9.43
30-45	78.22	9.80	11.98	Sand loam		1.60	17.00	8.70	8.30
45-60	79.49	8.87	11.64	Sand loam		1.76	16.75	8.61	8.14
60-90			-	-		1.85	14.78	8.32	6.46

Table (2): Some chemical properties of the experimental soil before the growing season in the two studied season in three regions.

El Minia region														
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	2.2	8.19	.60	6.70	.70	2.26	1.79	-	3.20	7.01	1.40	0.43	8.85	272.50
15-30	1.80	8.23	0.67	6.91	0.84	2.32	1.93	-	3.95	7.02	1.80	0.40	7.95	270.20
30-45	1.78	8.40	0.69	7.00	0.99	2.40	2.25	-	4.50	7.49	2.80	0.36	6.55	268.30
45-60	1.70	8.42	0.78	7.00	1.10	2.53	2.40	-	5.56	7.8	3.01	0.30	5.94	260.99
Luxor region														
Soil depth (cm)	OM %	PH*	EC** dSm^{-1}	Soluble cations ($meqL^{-1}$)				Soluble anions ($meqL^{-1}$)				Available N mg/kg soil	Available P & K`	
				Na^-	K^+	Ca++	Mg++	CO^-	HCO_4^-	CL^-	SO_4^-		P (ppm)	K (mg/kg)
0-15	1.30	8.15	1.5	4.12	0.26	8.39	2.74	-	3.25	4.90	4.40	18.55	7.92	190.30
15-30	1.20	8.20	1.53	4.20	0.24	8.40	2.75	-	3.30	4.92	4.55	18.70	7.85	180.24
30-45	1.18	8.23	1.60	4.40	0.23	8.45	2.80	-	3.8	4.7	4.60	19.20	7.70	172.20
45-60	1.07	8.25	1.62	4.45	0.20	8.48	2.80	-	4.20	5.01	4.67	19.35	7.50	170.85
Aswan region														
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	0.38	7.75	0.94	2.85	1.41	6.52	1.20	-	2.20	3.84	3.40	.019	11.10	174
15-30	0.40	8.1	1.03	3.10	1.49	6.70	1.27	-	2.49	4.11	3.96	0.020	11.29	179
30-45	0.45	8.1	1.12	3.20	1.50	6.90	1.39	-	2.90	4.60	4.34	0.020	11.32	182
45-90	0.51	8.2	1.14	3.35	2.02	733	1.43	-	3.12	4.81	5.01	0.025	11.77	190

The bulk density was determined using the undistributed core samples according to ***Klute 1986*** as shown in Table (1). The Field capacity (F.C %) was determined by field method according to (Klute 1986) as shown in Table (1). Permanent wilting point was determined by using a pressure membrane apparatus (***Klute 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 **blocked furrow infiltromter (Salazar.1977).**

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).

Soil - water relationships

Recorded data:

Irrigation Water Measurements

Improved surface irrigation (gated pipes) the quantity of water applied was measured by water meters during every irrigation, ***(Brater and King, 1976*** On the other hand surface irrigation the quantity of water applied was measured in studied area by using a rectangular sharp crested weir. The discharge was calculated using the following formula.

$Q = CLH^{3/2}$ *(Masoud, 1967*).

Where

Q: The discharge in cubic meters per second.

L: The length of the crest in meters.

H: The head in meters.

C: An empirical coefficient that must be determined from discharge measurements.

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. Calculation of CU was repeated for all irrigation until the harvesting date.

Water consumptive use per faddan (4200m2) was obtained by the following equation.

$$CU = \frac{\theta_2 - \theta_1}{100} \times b.d \times \frac{depth}{100} \times area\ (4200m^2)$$

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)

Application efficiency (Ea):

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)**

$$E_a = \left(\frac{Ws}{Wd} \times 100\right)$$

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):

Calculated according to **Jame (1998)** as follow:=

$$E_{wd} = (1- \frac{y}{d}) \times 100$$

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 (Es):

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 1991).**

$$E_s = \left(\frac{W_s}{W_m} \times 100\right)$$

Where:

E_s = water storage efficiency (%).

W_s = water storage in the root zone (m3/fed.)

W_m= the amount of irrigation water that must be added before irrigation (m3/fed.)

Total irrigation efficiency = $E_a \times E_s \times E_{wd}$

Total yield (ton/fed)

Millable cane yield (ton/fed):

1. Single stalk weight (kg): was calculated by the following equation:

Stalk weight (kg) = Weighed cane yield per plot (kg)/number of Millable stalk per plot (kg).

2. Number of millable stalks/fed: was recorded.
3. Millable cane yield: was calculated as (Cane yield per plot/plot size) x 4200

Saving of irrigation time (minuets/fed) and irrigation costs (LE/fed)

Saving of irrigation time and irrigation costs between the best treatment and other treatments were estimated during irrigation and at the end of two studied seasons average total time irrigation (min/fed) and total costs irrigation (LE/fed) were estimated ***(Abd El Ati et. Al 2014).***

Quality determination

1- **Millable cane yield (ton/fed):** cane stalks of the four inner rows were harvested topped, cleaned, weighed and cane yield was calculated as ton/fed.

2- **Recoverable sugar yield (ton/fed)** was estimated according to the recoverable sugar yield (ton/fed)=Millable cane yield(ton/fed)xPurity% Pol%

3- **Purity % juice** was calculated as in **Satisha et al. (1996)** using the follow formula:

Purity %=Surose %x100 ÷ TSS % (Total soluble solids) was determined using "Brix hydrometer" standardized at 20C as in **A.O.A.C. (1995**).

4- **Pol % cane** of cane stalks was calculated y the following equation after determination of sucrose % in the cane juice using succharometer according to **A.O.A.C (1995).**

Pol% = {Brix % -(Brix % -sucrose %)0.4} 0.73

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.

Results and discussion

1- **Total yield (ton/fed):**

Total yields (ton/fed.) as well as its quality properties expressed as pol % cane and purity % juices % as influenced by the irrigation system and different planting methods and were presented in Table (3) and (4) the results in Table (4) show that system irrigation and the planting method had a significant effect on millable cane and recoverable sugar cane crop. Data in table (3) show that the highest values of milleble cane sugar yields were obtained from treatment A_2b_2 (gated pipes in beds) (50.625, 49.635 and 54.560 ton/fed.) for El-Minia, Luxor and Aswan regions respectively. While the lowest values of millable cane and recoverable sugar yields of sugar cane were obtained from conventional method (surface irrigation in furrowA_1b_1 (common method in experimental regions) (45.260, 43.525 and 47.025 ton/fed) for El-Minia, Luxor and Aswan regions respectively. These results are in agreement with those reported by ***El- Monoufi et al 1993 and Abd El Rheem 2010*** In general, the improving irrigation by gated pipes (furrow & beds) produced highest values of total yield and recoverable sugar yield, so planting the sugar cane by irrigation by gated pipes solves the problem of decreasing of the productivity, This might be due to increase the cultivated area of land instead of sub canals of irrigation, reduce the spread of weed and diseases. In general, it could be concluded development irrigation system becomes very important for obtaining a high productivity where conventional irrigation practiced by the farmers usually leads to low irrigation efficiency, water logging and high losses of water and fertilizer so the proper water management not only accurate determination of crop water requirements but also helps to know how, when and how much water

Table (3): Mean values of productivity (ton / fed.) as affected by irrigation system and planting methods for each regions (El-Minia – Luxor –Aswan) in the two studied seasons.

Irrigation systems (A)	Regions								
	El-Minia			Luxor			Aswan		
	(B) planting method			(B) planting method			(B) planting method		
	(B_1)in furrow	(B_2) in beds	Mean (A)	(B_1)in furrow	(B_2) in beds	Mean (A)	(B_1)in furrow	(B_2) in beds	Mean (A)
A1	**45.280**	**47.125**	**46.203**	**43.525**	**44.875**	**44.200**	**47.025**	**47.975**	**47.500**
A2	**47.700**	**50.625**	**49.163**	**48.225**	**49.635**	**48.930**	**49.900**	**54.560**	**52.230**
Mean (B)	**46.490**	**48.875**	**47.683**	**45.875**	**47.225**	**46.665**	**48.463**	**51.268**	**49.865**
LSD									
5%	**0.476**	**0.451**	**0.637**	**0.322**	**0.450**	**0.637**	**18.997**	**14.633**	**20.694**
1%	**0.875**	**0.683**	**0.966**	**0.591**	**0.682**	**0.965**	**34.865**	**22.175**	**31.354**

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

Table (4): Mean values of quality for sugar can crop for each regions (El-Minia- Luxor – Aswan) as affected by irrigation systems and plating methods in the two studied seasons

Quality Properties	Irrigation System(A)	Regions								
		El-Minia			Luxor			Aswan		
		(B) planting method			(B) planting method			(B) planting method		
		(B_1)in furrow	(B_2) in beds	Mean (A)	(B_1)in furrow	(B_2) in beds	Mean (A)	(B_1)in furrow	(B_2) in beds	Mean (A)
1 Sugar yield (ton/fed)	A1	**5.33**	**5.70**	**5.52**	**5.01**	**5.46**	**5.24**	**4.87**	**5.25**	**5.06**
	A2	**5.95**	**6.44**	**6.20**	**5.82**	**6.28**	**6.05**	**5.81**	**6.95**	**6.38**
	Mean (B)	**5.64**	**6.07**	**5.86**	**5.42**	**5.87**	**5.65**	**5.34**	**6.10**	**5.72**
	LSD	**A**	**B**	**AB**	**A**	**B**	**AB**	**A**	**B**	**AB**
	5%	**0.51**	**0.58**	**0.82**	**0.089**	**0.091**	**0.129**	**0.096**	**0.93**	**0.131**
	1%	**0.093**	**0.088**	**0.124**	**0.163**	**0.139**	**0.196**	**0.176**	**0.140**	**0.199**
2-Tss %	A1	**19.50**	**19.80**	**19.65**	**19.33**	**19.65**	**19.49**	**17.100**	**17.800**	**17.30**
	A2	**20.22**	**21.15**	**20.68**	**20.30**	**21.18**	**20.74**	**18.30**	**19.800**	**19.150**
	Mean (B)	**19.86**	**20.47**	**20.16**	**19.82**	**20.42**	**20.12**	**17.70**	**18.800**	**18.23**
	LSD	**A**	**B**	**AB**	**A**	**B**	**AB**	**A**	**B**	**AB**
	5%	**0.2**	**0.077**	**0.109**	**0.101**	**0.50**	**0.071**	**0.266**	**0.100**	**0.142**
	1%	**0.396**	**0.117**	**0.165**	**0.186**	**0.076**	**108**	**0.414**	**0.152**	**0.214**
Sucrose %	A1	**16.56**	**16.99**	**16.77**	**16.37**	**16.76**	**16.57**	**14.29**	**15.17**	**14.60**
	A2	**17.39**	**18.30**	**17.84**	**17.44**	**18.40**	**17.92**	**16.01**	**18.00**	**17.09**
	Mean (B)	**16.97**	**17.64**	**17.30**	**16.91**	**17.58**	**17.25**	**15.15**	**16.59**	**15.85**
	LSD	**A**	**B**	**AB**	**A**	**B**	**AB**	**A**	**B**	**AB**
	5%	**0.040**	**0.067**	**0.095**	**0.101**	**0.40**	**0.057**	**0.124**	**0.012**	**0.017**
	1%	**0.073**	**0.102**	**0.144**	**0.186**	**0.061**	**0.086**	**0.227**	**0.019**	**0.026**
Purity %	A1	**84.95**	**85.80**	**85.37**	**84.70**	**85.28**	**84.99**	**83.600**	**85.250**	**84.40**
	A2	**86.00**	**86.85**	**84.42**	**85.90**	**86.70**	**86.30**	**87.50**	**90.900**	**89.20**
	Mean (B)	**85.47**	**86.32**	**84.89**	**85.30**	**85.99**	**85.65**	**85.55**	**88.08**	**91.30**
	LSD	**A**	**B**	**AB**	**A**	**B**	**AB**	**A**	**B**	**AB**
	5%	**0.509**	**0.319**	**0.450**	**0.081**	**0.072**	**0.101**	**0.084**	**0.059**	**0.083**
	1%	**0.934**	**0.483**	**0.683**	**0.148**	**0.108**	**0.163**	**0.155**	**0.089**	**0.126**
Pol %	A1	**13.85**	**14.10**	**13.97**	**13.60**	**13.95**	**13.78**	**12.40**	**13.09**	**12.75**
	A2	**14.50**	**14.66**	**14.58**	**14.25**	**14.59**	**14.42**	**13.30**	**14.01**	**13.65**
	Mean (B)	**14.17**	**14.38**	**14.27**	**13.93**	**13.27**	**14.10**	**12.85**	**13.55**	**13.20**
	LSD	**A**	**B**	**AB**	**A**	**B**	**AB**	**A**	**B**	**AB**
	5%	**0.230**	**0.234**	**0.331**	**0.030**	**0.041**	**0.068**	**0.056**	**0.068**	**0.096**
	1%	**0.422**	**0.355**	**0.501**	**0.055**	**0.062**	**0.088**	**0.103**	**0.103**	**0.146**
Sugar recovery %	A1	**11.87**	**12.10**	**11.92**	**11.53**	**11.89**	**11.71**	**10.37**	**11.14**	**10.75**
	A2	**12.47**	**12.72**	**12.59**	**12.24**	**12.66**	**12.45**	**11.64**	**12.73**	**12.10**
	Mean (B)	**12.17**	**12.41**	**12.25**	**11.89**	**12.28**	**12.08**	**11.01**	**11.94**	**11.43**
	LSD	**A**	**B**	**AB**	**A**	**B**	**AB**	**A**	**B**	**AB**
	5%	**0.084**	**0.119**	**0.169**	**0.017**	**0.041**	**0.058**	**0.115**	**0.037**	**0.053**
	1%	**0.155**	**0.181**	**0.256**	**0.032**	**0.062**	**0.088**	**0.212**	**0.057**	**0.080**
Reducing sugar %	A1	**0.32**	**038**	**0.37**	**0.34**	**0.36**	**0.35**	**0.37**	**0.39**	**0.38**
	A2	**0.45**	**0.48**	**0.47**	**0.40**	**0.45**	**0.43**	**0.42**	**0.46**	**0.44**
	Mean (B)	**0.38**	**19.24**	**0.42**	**0.37**	**0.41**	**0.39**	**0.40**	**0.43**	**0.41**
	LSD	**A**	**B**	**AB**	**A**	**B**	**AB**	**A**	**B**	**AB**
	5%	**0.019**	**0.026**	**0.037**	**0.032**	**0.021**	**0.029**	**0.069**	**0.020**	**0.028**
	1%	**0.036**	**0.039**	**0.056**	**0.060**	**0.031**	**0.044**	**0.126**	**0.030**	**0.043**

should be applied to get high efficiency of each unit of water applied. So improving irrigation by gated pipes is responsible for obtaining a high productivity of sugar cane with least possible amount of water ap1plied.

Also, data in Table (4) show that the treatment A_2b_2 (development surface irrigation by gated pipes and planting in beds is preferable under the Egyptian conditions for sugar cane because it is gave higher values of millable cane, recoverable sugar yield, pol% cane and purity % juice of sugar cane.In addition there was a positive correlation between both millable cane and recoverable sugar yields of sugar cane for all regions.

2- Seasonal irrigation water applied:

Average of the amount of applied water delivered (m^3/fed) to different treatments for each region of sugar cane crop shown in Table (5). It is obvious that the lowest values of water applied was 6692.76, 7995.90 and 11335.47 m^3/fed obtained from treatment A_2b_2 (development irrigation system by gated pipes and planting in beds). while the highest values were. 9744.100, 11951.76 and 17622.09 m^3/fed. obtained from surface irrigation in furrow (A_1b_1) for El-Minia, Luxor and Aswan regions respectively.

It is clear from data the quantity of water applied different from region to other this is due to the difference in the number of irrigations for sugar cane crop as a result of the different soil texture and weather conditions for each region for other.

Table (5): Mean values of the quantity of water applied for three regions for sugar cane crop in the two studied seasons.

Treatments	Irrigation system (A)				
	Surface irrigation A1		Improving irrigation by gated pipes A2		
	Planting method				
	Furrow B1	Beds B2	Furrow (B1)	Beds(B2)	No. of irrigation
(1) El-Minia Region					
Water applied (m3/fed)	9744.100	8558.42	7689.77	6692.76	17
(2) Luxor Region					
Water applied (m3/fed)	11951.76	9916.38	8873.31	7995.90	19
(3) Aswan region					
Water applied (m3/fed)	17622.09	14639.95	13205.20	11335.47	26

3- Water saving (m3/area):

Data in Table (6) show that average quantity of water saving (m^3/fed.) which obtained when comparison conventional irrigation treatment with other treatment in each region.

The obtained results show that when the best method using (irrigation system by gated pipes and planting in beds A_2b_2) the irrigation water is saved more than the surface irrigation in furrow (common method in region A1b1) by about 32.53, 33.10 and 35.67 for El-Minia, Luxor and Aswan regions respectively. The results show that, the amount of water irrigation which can be saved (for average area cultivated plant sugar cane crop in Egypt) by about 1,035420270, 1,254007620 and 1,992858540 Millar m^3/area for El-Minia, Luxor and Aswan regions respectively compared to conventional treatment (surface irrigation and planning in furrow A_1b_1). This amount of saving water enough to cultivate area about (generally) 161784.4, 195938.7 and 311384.1 feddan for the same regions respectively or cultivate different area of horticulture and field crops according to water requirements in each region.

These results reflex how much irrigation water can be save to produce the highest yield with least possible amount of water applied where the farmer's practices in sugar cane can be (conventional irrigation treatment) utilized much water without giving higher productivity and high losses of water and fertilizer.

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

Daily monthly and seasonal water consumptive use values for each region were presented in Table (7). The data obtained indicated that the highest values of seasonal of water consumptive use were 172.24, 197.35 and 272.17 cm/season for El-Minia – Luxor – Aswan region respectively obtained from surface irrigation in furrow (A_1b_1), while the lowest values of seasonal of water consumptive use were 122.24, 146.98 and 177.80 cm/season for the same regions respectively obtained from development irrigation by gated pipes in beds (A_2b_2). Generally it clear that the surface irrigation in furrow have high values of actual water consumptive use cm/seasons. while, the irrigation system by gated pipes in beds gave lowest values of actual water consumptive use for each region. 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 sugar cane crop for all regions.

Table (6): Average of water saving (m3/fed.) as affected by comparison conventional irrigation treatment (A_1b_1) with other treatments for sugar can for each region in the two studied season.

Treatments	Increase of yield		% of increase in yield	Water applied (m3/fed)	Saved water		Average area cultivated plant sugar cane crop in Egypt	To total of water saving Milliar m3/area	*The area (fed.) of old land which can be cultivated as a resulting of saving water
	Ton/fed	Ton/fed.			m3/fed	%			
El-Minia region									
Surface irrigation in furrow (common method in region)	45.280	5.35	11.82	9919.10	3266.31	32.53	317000	1035420270	161784.4
Irrigation by gated pipes in beds	50.625			6692.76					
Luxor region									
Surface irrigation in furrow (common method in region)	43.525	6.11	14.04	11951.76	3955.86	33.10	317000	1254007620	195938.7
Irrigation by gated pipes in beds	49.635			7995.9					
Aswan region									
Surface irrigation in furrow (common method in region)	47.025	7.54	16.03	17622.09	6286.62	35.67	317000	1992858540	311384.1
Irrigation by gated pipes in beds	54.560			11335.47					

*** The area (fed.) of old land which can be cultivated as a resulting of saving water calculate on the basis that the average water requirements/fed in general in the old lands 6400 m3/fed**

Table (7): Average values of actual water consumptive use (daily, monthly and seasonal) for sugar cane plants as affected by irrigation systems and planting methods for each region. In the two studied seasons.

Months	actual water consumptive use															
	Surface irrigation in furrow (A1b1)				Surface irrigation in beds(A1b2)				Gated pipes in furrow(A2b1)				Gated pipes in beds(A2b2)			
	mm/day	mm/month	Cm/month	m^3/fed	mm/day	mm/month	cm/month	m^3/fed	mm/day	mm/month	cm/month	m^3/fed	mm/day	mm/month	cm/month	m^3/fed
El-Minia																
March	1.8	90	0.9	37.8	1.72	8.6	0.86	36.12	1.52	7.6	0.76	31.92	1.38	6.9	0.69	28.98
April	5.72	171.60	17.16	720.72	5.71	171.30	17.13	719.46	4.98	149.4	14.94	627.48	4.59	137.7	13.77	578.34
May	6.27	149.37	19.44	816.48	5.73	177.63	17.76	745.92	5.36	166.16	16.62	698.04	4.98	154.38	15.44	648.48
June	8.88	266.40	26.64	1118.88	7.04	211.20	21.13	887.46	6.33	189.9	18.99	797.58	5.94	178.2	17.82	748.44
July	9.04	280.24	28.02	1176.84	7.16	222	22.20	932.4	6.79	210.49	21.08	884.1	6.41	198.71	19.87	834.54
August	7.95	246.45	24.65	1035.3	6.17	191.30	19.13	803.46	6.13	190.03	19.00	798	5.75	178.25	17.83	748.86
Sept	5.98	179.4	17.94	753.48	4.63	138.90	13.89	583.38	3.92	117.6	11.76	493.92	3.53	105.9	10.59	444.78
Oct.	3.87	119.79	11.98	503.16	30.70	114.70	11.47	481.74	3.33	103.23	10.32	433.44	2.95	91.45	9.15	384.3
Nov.	3.38	101.4	10.14	425.88	2.96	88.80	8.89	373.38	2.58	77.40	7.74	325.08	2.19	65.7	6.57	275.94
Dec.	2.27	70.37	7.04	295.68	2.42	75.02	7.50	315	2.04	63.24	6.32	265.44	1.66	51.46	5.15	216.3
January	1.96	60.76	6.08	255.36	1.57	48.67	4.87	204.54	1.52	47.12	4.71	197.82	1.18	36.58	3.66	153.72
Febr.	1.5	22.5	2.25	94.5	1.43	21.45	2.15	90.3	1.33	19.95	1.99	83.58	1.13	16.95	1.7	71.4
Total			172.24	7234.08			146.98	6173.16			134.2	5636.4			122.24	5134.08
Luxor																
March	2.84	69.88	1.99	83.58	2.84	19.88	1.99	83.58	2.79	19.53	1.95	81.9	2.69	18.83	1.88	78.96
April	6.79	185.7	18.56	779.52	5.6	168.00	16.80	705.6	4.70	141	14.1	592.2	4.43	132.9	13.29	558.18
May	6.83	211.73	21.17	889.14	5.93	183.83	18.38	771.96	5.05	156.5	15.65	657.3	4.79	148.49	14.85	623.7
June	9.08	272.4	27.24	1144.08	8.5	255.00	25.50	1071	7.25	217.5	21.75	913.5	6.98	209.4	20.94	879.48
July	9.33	289.23	28.92	1214.64	8.76	271.56	27.16	1140.72	7.55	234.05	23.41	983.22	7.29	225.99	22.60	949.2
August	7.81	242.11	24.21	1016.82	6.66	206.46	20.65	867.3	6.45	199.95	19.99	839.58	6.19	191.89	19.89	835.38
Sept	6.32	189.6	18.96	796.32	6.04	181.2	18.12	761.04	5.06	151.80	15.17	637.14	4.79	143.7	14.37	603.54
Oct.	5.36	166.16	16.62	698.04	4.67	140.10	14.01	588.42	3.64	112.84	11.28	473.76	3.38	104.78	10.48	440.16
Nov.	4.51	135.3	13.52	567.84	3.92	117.6	11.75	493.5	3.55	106.5	10.65	447.3	3.28	98.40	9.84	413.28
Dec.	4.04	125.24	12.52	525.84	3.53	109.43	10.94	459.48	3.07	95.17	9.52	399.84	2.82	87.42	8.74	367.08
January	3.29	101.99	10.20	428.4	2.58	79.98	7.99	335.58	2.65	82.15	8.22	345.24	2.38	73.78	7.38	309.96
Febr.	1.72	34.40	3.44	144.48	1.48	29.6	2.96	124.32	1.23	24.6	2.46	103.32	1.01	20.2	2.02	84.84
Total			197.35	8288.7			176.25	7402.5			154.15	6474.3			146.28	6143.76
Aswan																
March	6.63	26.52	2.65	111.3	4.98	19.92	1.99	83.58	4.75	19.0	1.90	79.8	4.63	18.52	1.85	77.7
April	8.07	242.10	24.21	1016.82	6.66	199.8	19.98	839.16	6.12	183.36	18.36	771.12	4.69	145.39	14.54	610.68
May	10.26	318.06	31.81	1336.02	8.43	261.33	26.13	1097.46	7.91	245.21	24.52	1029.84	6.68	207.08	20.71	869.82
June	11.23	336.4	33.69	1414.98	9.39	281.70	28.17	1183.14	8.87	266.10	26.61	1117.62	7.95	238.50	23.86	1002.12
July	11.55	358.05	35.82	1504.44	9.73	301.63	30.17	1267.14	9.20	285.20	28.52	1197.84	8.26	256.06	25.61	1075.62
Agust	10.13	314.03	31.40	1318.8	8.64	267.84	26.78	1124.76	8.12	251.72	25.17	1057.14	7.23	224.13	22.41	941.22
Sept	9.49	284.70	28.48	1196.16	7.94	238.20	23.82	1000.44	7.42	222.60	22.26	934.92	6.47	194.10	19.41	815.22
Oct.	8.88	275.28	27.54	1156.68	7.38	228.78	22.89	961.38	6.87	212.97	21.30	894.6	5.65	175.15	17.52	735.84
Nov.	6.40	192.00	19.20	806.4	5.30	159.00	15.90	667.8	4.44	133.2	13.32	559.44	3.94	118.20	11.82	496.44
Dec.	5.96	184.76	18.47	775.74	4.78	148.18	14.82	622.44	4.06	125.86	12.59	528.78	3.52	109.12	10.92	458.64
January	4.73	144.63	14.66	615.72	3.57	110.67	11.07	464.94	3.05	94.55	9.45	396.9	2.15	66.65	6.66	279.72
Febr.	2.83	42.45	4.24	178.08	2.16	32.4	3.24	136.08	1.77	26.55	2.66	111.72	1.66	24.90	2.49	104.58
Total			272.17	11431.14			224.96	9448.32			206.66	8679.72			177.8	7467.6

Irrigation efficiencies:

Irrigation efficiency for different treatments of sugar cane for each region are shown in Table(8) It is obvious that the highest values of total irrigation efficiency (75.78, 75.10 and 74.83 %) were obtained from irrigation system by gated pipes in beds for El-Minia, Luxor and Aswan region respectively. While the lowest values (54.67, 53.85 and 48.80%) were obtained from surface irrigation in furrow for same region respectively (common method in region). So it could be concluded that when irrigation system by gated pipe used in beds average total irrigation efficiency increased from (52.44%) to (75.20%) compared with the conventional method for all regions where the over irrigation practiced by the farmers usually lead to low irrigation efficiency and high losses of irrigation water.

Table (8): Average values of total irrigation efficiency's (%) for different treatments for sugar cane crop in the two studied seasons.

El-Minia					Luxor					Aswan				
No.	Surface irrigation irrigation		Gated piped		No.	Surface irrigation irrigation		Gated piped		No.	Surface irrigation irrigation		Gated piped	
	Furrow	Beds	Furrow	Beds		Furrow	Beds	Furrow	Beds		Furrow	Beds	Furrow	Beds
1	53.92	64.90	69.90	75.57	1	51.49	62.1	70.62	74.45	1	50.76	63..80	69.59	74.19
2	54.88	65.77	71.22	74.74	2	53.83	61.74	71.23	74.36	2	50.61	63.32	69.20	74.20
3	54.99	67.60	70.75	75.48	3	55.04	61.3	71.44	74.24	3	50.99	61.63	68.95	73.05
4	56.35	68.30	69.45	76.89	4	53.57	58.17	70.73	74.37	4	48.35	62.23	68.61	73.03
5	51.66	66.81	70.41	74.98	5	52.53	61.3	72.35	75.02	5	47.40	64.22	68.92	74.18
6	56.13	68.41	70.01	75.46	6	53.57	62.50	71.66	75.22	6	47.26	64.77	69.72	74.34
7	54.35	66.40	70.26	75.83	7	53.47	63.08	72.31	75.25	7	46.44	64.95	70.53	75.18
8	54.92	68.68	69.82	76.54	8	54.42	61.93	73.1	75.32	8	47.99	65.05	70.93	75.82
9	55.75	67.68	67.86	76.23	**9**	54.33	62.10	70.24	75.18	**9**	48.41	64.15	71.30	74.70
10	55.62	68.37	70.77	76.50	10	54.40	61.90	71.52	75.37	10	47.95	65.52	70.87	75.22
11	55.40	63.84	70.13	75.97	11	52.49	62.1	71.62	75.45	11	48.57	66.14	71.04	75.19
12	55.93	65.90	69.90	75.57	12	54.83	62.74	72.23	75.36	12	48.70	64.12	70.24	75.13
13	54.88	65.77	71.22	74.74	**13**	56.04	62.3	72.44	75.24	**13**	49.37	63.42	71.34	75.25
14	54.99	67.60	70.75	75.48	**14**	52.57	59.17	71.73	75.37	**14**	51.76	64.80	70.59	75.19
15	56.35	68.30	69.45	76.89	**15**	55.04	59.75	72.84	75.17	**15**	51.61	64.32	70.20	75.20
16	51.70	68.79	69.45	74.83	**16**	52.85	61.44	69.92	75.52	**16**	53.99	63.63	70.95	75.05
17	53.12	65.50	71.73	76.63	**17**	54.00	61.27	73.90	75.25	**17**	51.35	64.23	70.61	75.03
18	——	——	——	——	**18**	54.58	61.86	70.42	75.34	**18**	48.40	65.22	70.92	75.18
19	——	——	——	——	**19**	54.11	62.37	71.360	75.37	**19**	47.26	65.77	90.72	75.34
20	——	——	——	——	**20**	——	——	——	——	**20**	46.44	64.95	70.53	75.18
21	——	——	——	——	**21**	——	——	——	——	**21**	47.99	65.05	70.93	75.82
22	——	——	——	——	**22**	——	——	——	——	**22**	48.41	64.15	71.30	74.70
23	——	——	——	——	**23**	——	——	——	——	**23**	46.88	64.69	70.89	75.17
24	——	——	——	——	**24**	——	——	——	——	**24**	45.74	95.91	70.96	74.00
25	——	——	——	——	**25**	——	——	——	——	**25**	48.40	64.39	71.80	75.22
26	——	——	——	——	**26**	——	——	——	——	**26**	47.82	65.68	71.04	75.12
Average	54.76	66.98	70.18	75.78		53.85	61.53	71.67	75.10		48.80	65.69	71.26	74.83

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

Saving of irrigation time and irrigation costs as influenced by irrigation systems and planting methods were presents in Table (9 and 10) The results of the Table (9) show that (from view point of water and economic) when we use the best irrigation system A_2b_2 (gated pipes in beds) we can save irrigation time about 36.90 %, 37.95 5 and 38.19 % and saving of costs irrigation (oil and diesel) about 36.27 %, 34.04 %, 35.63 % for each region El Minia, Luxor and Aswan respectively compared with the conventional irrigation in region A_1b_1 (surface irrigation in furrow).From these results it could be concluded that the using gated pipe system in beds decreased irrigation time and irrigation costs which lead to reduction in the overall of production requirements for sugar cane crop compared with traditional irrigation method.

Table (9): Mean values of time saving of irrigation (minute/fed& %) under surface irrigation A_1b_1 with different treatments for sugar cane crop for each region in the two studied seasons.

Treatments	El-Minia region			Luxor region			Aswan region		
	Irrigation time (min/season)	Saving of irrigation time		Irrigation time (min/season)	Saving of irrigation time		Irrigation time (min/season)	Saving of irrigation time	
		(min/season)	%		(min/season)	min/season %		(min/season)	min/season %
Surface irrigation in furrow (common method in region) Surface irrigation in beds	6417	1219	19.00	7115	1323	18.59	9860	1765	17.90
	5198			5792			8095		
Surface irrigation in furrow (common method in region) Irrigation by gated pipes in furrow	6417	1764	27.49	7115	2027	28.49	9860	2870	29.11
	4653			5088			6990		
Surface irrigation in furrow (common method in region) Irrigation by gated pipes in beds	6417	2368	36.90	7115	2700	37.95	9860	3766	38.19
	4049			4415			6094		

Table (10): Mean values of costs saving of irrigation (L.E/fed& %) under surface irrigation A1b1 with different treatments for sugar cane crop for each region in the two studied seasons.

Treatments	El-Minia region			Luxor region			Aswan region		
	Irrigation costs (L.E/season)	Saving of irrigation costs		Irrigation costs (L.E/season)	Saving of irrigation costs		Irrigation costs (L.E/season)	Saving of irrigation costs	
		(L.E/season)	%		(L.E/season)	%		(L.E/season)	%
Surface irrigation in furrow (common method in region) Surface irrigation in beds	510	93	18.24	570	104	18.25	870	156	17.93
	417			466			714		
Surface irrigation in furrow (common method in region) Irrigation by gated pipes in furrow	510	128	27.41	570	147	25.79	870	220	25.29
	370.20			423			650		
Surface irrigation in furrow (common method in region) Irrigation by gated pipes in beds	510	171	36.27	570	194	34.04	870	310	35.63
	325			376			560		

Irrigation machine used in the three areas has been standardized and are similar in disposition rate(4 inches)

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 labors. 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.

At the end of this study the obtained results indicate that recommended by application gated pipes in beds method to produce high yield and quality with the least possible amount of water applied for all study regions under different soil texture and weather conditions in Egypt.

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