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Development of Irrigation Management by Gated Pipes Under Newly Reclaimed Lands Conditions

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Abstract

This investigation was carried out during two successive summer seasons of 2021 and 2022 on maize (*Zea mays L.*) crop, grown in sandy loam under modified surface irrigation by gated pipes in a private farm located at Wady Elmollak Ismaillia Governorate Egypt. to evaluate the performance of using gated pipes compared with traditional surface irrigation method on total water applied, water use efficiency and maize crop production under different furrows irrigation lengths 30 m (L_{30}) and 60 m (L_{60}) at three levels of cut-off irrigation as Q1: when the applied water was reached the end of furrow, Q2: when the applied water was reached 90% of furrow length and Q3: when the applied water was reached 80% of furrow length. The treatments were arranged in a split–plot design with four replicates. The main results in this study can be summarized as follows: The maximum average value of maize yield was 3565 kg/fed., achieved by using a gated pipes irrigation system under 60 m furrow length when cut-off irrigation 90% of furrow length. On the other hand, the minimum average value was 2589 kg/fed., achieved by traditional irrigation method at 60 m furrow length when cut-off irrigation 80 % of furrow length. The maximum average value of the saved irrigation water was35.04 % of the average values of the total water applied, achieved in the case of using a gated pipes irrigation system at 30 m furrow length when cut-off irrigation 80 % of furrow length. The best water use efficiency was 0.72 kg/m^3, obtained by using a gated pipes irrigation system at 60 m furrow length when cut-off irrigation 90 % of furrow length compared to traditional irrigation method.

Keywords: Surface irrigation management, Gated pipes, Maize crop, Water use efficiency.

Full length article *Corresponding Author, e-mail: farh17976@gmail.com

1. Introduction

Egypt is mainly an agricultural country where irrigation technologies play an important role in supporting the national economy. Irrigation water consumes about 80% of the country's water budget for cultivating approximately 9 million feddans (feddan = 0.42 hectare), and about 6 million is irrigated by traditional surface irrigation methods with low on-farm water application efficiency (40-60%) [1]. Surface irrigation is the most widely used system, a conventional practice by Egyptian farmers. Despite this progressive water shortage, farmers continue to use surface irrigation systems. Poor management, uniformity, and water distribution have been cited as the most frequent problems of surface irrigation systems, which cause waterlogging, salinization, and less water use efficiency. Furrow irrigation is one of the oldest known techniques of surface irrigation, water is conveyed through small channels with a gentle slope towards the downstream end. The spacing of these channels generally corresponds to the spacing of the crop to be established. This method is popular for the irrigation of row crops [2]**.** The gated pipes technique become one of the ways to improve water use efficiency for surface irrigation methods, **[3]** Gated pipes are available in pipes diameter ranging from 10 to 30 centimeters. The outlets on gated pipe operate as sharp-edge or long-tube orifices. The outlets on gated pipes may be circular or rectangular orifices. The available pressures of 30 to 200 centimeters of water are usually required at the hydrant to operate the gated pipe. Flows ranging from 0.15 L/sec., to 6 L/sec., can be obtained from each outlet. The risers and outlet valves are usually spaced along the buried pipeline so that not more than 30 meters of gated pipe need to be connected to each hydrant. [4] Gated pipes system provides uniform water distribution, reduce the irrigation water quota, and conserves energy without affecting crop yields. However, the gated pipes irrigation technique is easy to understand, and the system is movable and convenient to operate. This is very important for the system acceptance [5]. Using gated pipes saved irrigation water by about of 12 and 29.24% for cotton and wheat, respectively. He also added that using gated pipes as an irrigation technique gave the highest yield of cotton and wheat compared with traditional furrow irrigation systems.

Surface irrigation efficiency is maximum when systems are managed to minimize deep percolation and runoff while meeting irrigation requirements [6] there are many engineering factors affecting the water infiltrated depth along the furrow and the uniformity in surface irrigation systems such as inlet flow and furrow slope [7]. Precision land leveling, furrow length, and irrigation water discharge are the main factors affecting directly the irrigation efficiency of surface irrigation systems. Laser leveling increases field irrigation efficiency, saves water, increases yield, and consequently increases crop-water use efficiency [8,9] indicated that Cut-off irrigation at 80% from furrow length with 0.1% ground surface slope decreased seasonal applied water, water consumptive use and water stored in the effective root-zone by 20.11, 12.11 and 10.90%, respectively compared with cut-off irrigation at 100% of furrow length. Also, the highest mean values of water application efficiency, and water consumptive use efficiency (71.65, 67.84%) respectively were obtained when Cut-off irrigation at 80% from furrow length with 0.1% ground surface slope. [10] indicated that alternate partial root-zone irrigation (APRD) is a water-saving irrigation technique being intensively studied in many regions of the world on a wide range of crops. Partial root-zone drying and regulated deficit irrigation techniques have proven the efficiency in improving the irrigation water use efficiency and fruit quality and dry fruit yield as compared with control irrigation. [11] reported that using improved management practices IMP (leveling soil surface using LASER technique for longitudinal slope 0.10 %, Long narrow borders irrigation system, and addition of mature compost plant residues) under conditions of the studied farms resulted in enhanced water distribution uniformity, saved irrigation water and maximized the irrigation water use efficiency compared with traditional management practices [12]. Studied surface irrigation performance by a using gated pipe system technique under different furrow irrigation lengths treatments 75, 100, and 125 m compared with the traditional irrigation methods. The average values of cotton seed yield under gated pipes irrigation system were increased than the average values of cotton crop production under traditional irrigation system by about 9.38, 20.34 and 25.36% under different treatments of furrow lengths of L75, L100, and L125, respectively.

Corn crop (*Zea mays L.*) is one of the most important cereal crops grown principally during the summer season. Great attention has been paid to increasing total corn production [13]. In Egypt, maize cultivated area is expected to be extended to more than 1.79 million feddans [14]. Considering all other factors of production at their optimum level, crop response is defined as a crop yield decreased constantly by decreasing the quantity of water applied into the root zone in deficit irrigation [15,16] indicated that maize yield decreases by increasing deficit irrigation for all treatments, the maximum yield of maize is obtained by adding full water requirements to the plant (100% Etc.). The maize production was acceptable by adding 80% Etc. because the soil water was not exposed to high stress. As the maize plant is classified as drought-sensitive crop, the application of 60% Etc. resulted in the lowest yield.

The objective of the present work is to study surface irrigation performance by using the gated pipe system technique under different furrow irrigation lengths treatments compared with the traditional irrigation methods and their effects on total water applied, water saving, yield, and water use efficiency.

2. Materials and Methods

2.1. Site description

The field experiment was carried out during two successive summer seasons of 2021 and 2022 on maize (*Zea mays* L.) crop at a private farm located at The geographical coordinates of the farm were (latitude 30º, 44´ 44.25" N, longitude 31, 82´ 44.57" E), some physical and chemical properties of experimental soil are shown in Table1.

Table1: Some physical and chemical properties of experimental soil

Soil Depth (cm)	Particle size distribution (%)				Texture Class	Db (g cm^{-3})	$^{*}K_{Sat.}$ (cm h^{-1})	F.C. (W%)	W.P (W%)	A.W (W%)	EC (dS m^{-1})	pH	$CaCo_3$ (%)	(OM) (%)
	C. Sand	F. Sand	Silt	Clay										
0 - 20	48.20	31.89	9.16	10.75	Sandy loam	1.54	3.54	20.73	10.25	10.48	1.5	7.12	9.24	0.34
20-40	56.15	27.91	7.64	8.30	Sandy loam	1.56	4.24	19.15	9.88	9.27	1.6	7.45	8.68	0.31
40-60	45.45	35.38	10.25	8.92	Sandy loam	1.58	3.64	18.04	10.65	7.39	1.6	7.51	10.16	0.24

$k_{sat.}$= Saturated hydraulic conductivity, Db= Bulck density, W.P= Permanent wilting point at 15 bar,
. A. W= Available water, (OM) = Organic matter

2.2. Materials

2.2.1. The pumping unit

The experimental field pumping unit is operated by a diesel engine. The pump was connected through connecting tubes, spools, elbows, tees, and other suitable pipe fitting. The pump was equipped with an individual suction pipe and a 6-inch hose ending with a trash screen and non-return valve. The discharge side of the pumping unit was connected to the inlet of the tested gated pipe having 36 gates at 0.70 m spacing between each gate. The specifications of the pumps and engine are shown in Table2.

Table 2: some specifications of the pump and engine

Type of pump	Motor power (hp)	RPM	Average discharge (m^3 /h.)	Max. operating pressure (bar)	Suction pipe diameter (Inch)	Delivery pipe diameter (Inch)
Centrifugal	10	1460	120	1.5	6	6

2.2.2. The utilized pipes for the gated pipes system and tools

Six-inch diameter, 6-meter length UPVC pipes were used for the gated pipes system. The pipes were connected together using a rubber ring jointing system. A six-inch flow meter was used to measure the water flow entering the inlet of the gated pipes. The rate was obtained by dividing the recorded water quantity passed at a certain time. A two-inch air release valve attached to the pumping.

2.2.3. Methods

The experimental area was about 3000 m^2 divided into 2 sub-plots as shown in Fig. (1). The first sub-plot was about 1500 m^2 leveled at 0.1% slope as [17] by laser technique and irrigated by gated pipes irrigation system where the second sub-plot was about 1500 m^2 leveled at zero slope and irrigated by traditional method. Each sub-plot was divided into two main treatments i.e., 30 meters furrow length (L_{30}) and 60 meters furrow length (L_{60}).

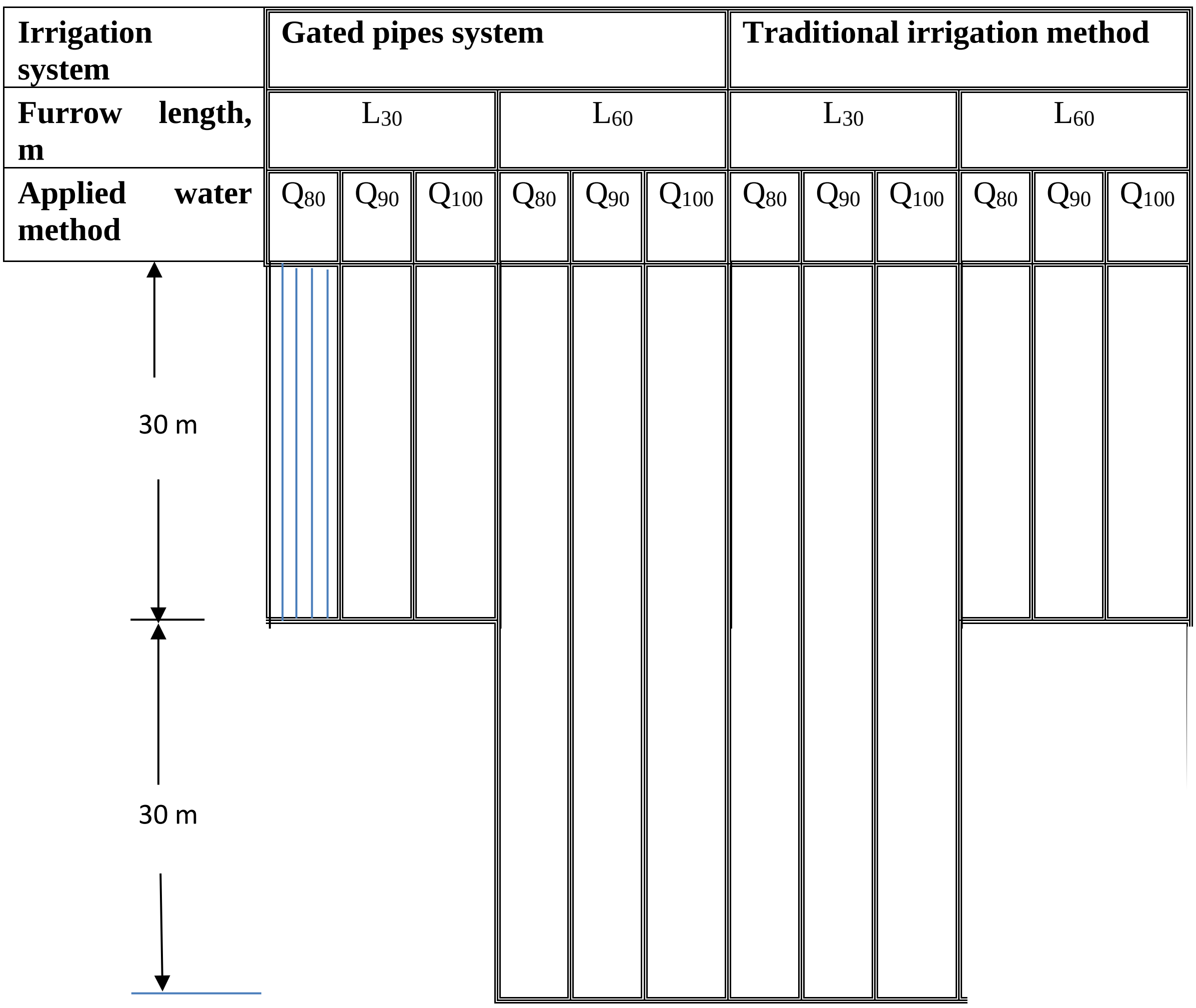

Fig. 1: Experiment layout

Each main treatment of furrow length was divided into three sub-treatments of cut-off irrigation (Cut-off irrigation is the practice of cutting off the inflow of water onto a field just as (or before) the surface wetted front reaches the lower end of the field or section of field to be irrigated) i.e., Q_{100}: cut-off irrigation when the applied water has reached the end of the furrow, Q_{90}: cut-off irrigation when the applied water was reached 90% of furrow length and Q_{80}: cut-off irrigation when the applied water was reached 80% of furrow length, 1-m strip of untilled land was thus left between adjacent treatments. Also, a 2-m strip of untilled land was thus left between adjacent subplots. The treatments were arranged in a split–plot design with 4 replicates.

The first area sub-plot was irrigated by six-inch diameter PVC gated pipes. Plastic saddles were used to connect the ball valves to the gated pipe at 70 cm spacing. The ball valves can be adjusted to handle the desired inflow rate to the furrows. The flow rate out of each gate is controlled by the percent of opening the ball valve according to the recommended flow rate of about 180 l/min. [18]. The second experimental area sub-plot was irrigated as a traditional irrigation method by pumping irrigation water through 6-inch flow meter into an excavated canal to the furrows. The average flow rate was checked by volumetric methods during several irrigation events, according to [19]. The maize (*Zea mays* L.) seeds were planted on 20th April 2021 for the first season and on 15th April for the 2nd season, the plants received 10 irrigations through the growing seasons, the irrigation interval was each 9 days. After 90 days from planting in both seasons, the irrigation was stopped. The experimental treatments received the same agricultural practices as usual in the area.

2.2.3.1. Amount of water applied

According to [20] the discharge was measured by direct method using volume and time. This is one of the simplest and most accurate methods.

$$Q = v\, t^{-1} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (2)$$

Where:

Q: discharge (.$m^3\, h^{-1}$)

V: volume (m^3)

t: time (h)

2.2.3.2. The saved irrigation water

The saved irrigation water percentage were calculated by compare each treatment with the reference treatment (when using traditional irrigation method and 60 m furrow length at cut-off irrigation 100% from furrow length).

2.2.3.3. Water use efficiency

Values were calculated according to [21] as follows:

$$WUE= [\ Y/V_m)\ (m^3\ /fed.) \quad \ldots\ldots\ldots\ldots\ldots\ldots \quad (7)$$

Where:

WUE: Water use efficiency, kg/ m^3.

Y: yield, kg/fed.

V_m: Applied irrigation water, m^3/fed

3. Results and Discussion

3.1. Effect of furrow lengths and cut-off irrigation on total water applied

The average values of the total water applied during two seasons through each treatment using a gated pipes system under different furrow lengths (L_{30} and L_{60}) at different cut-off irrigation (Q_{100}, Q_{90} and Q_{80}) and compared to the traditional irrigation method at the same treatments were shown in Fig. (2).

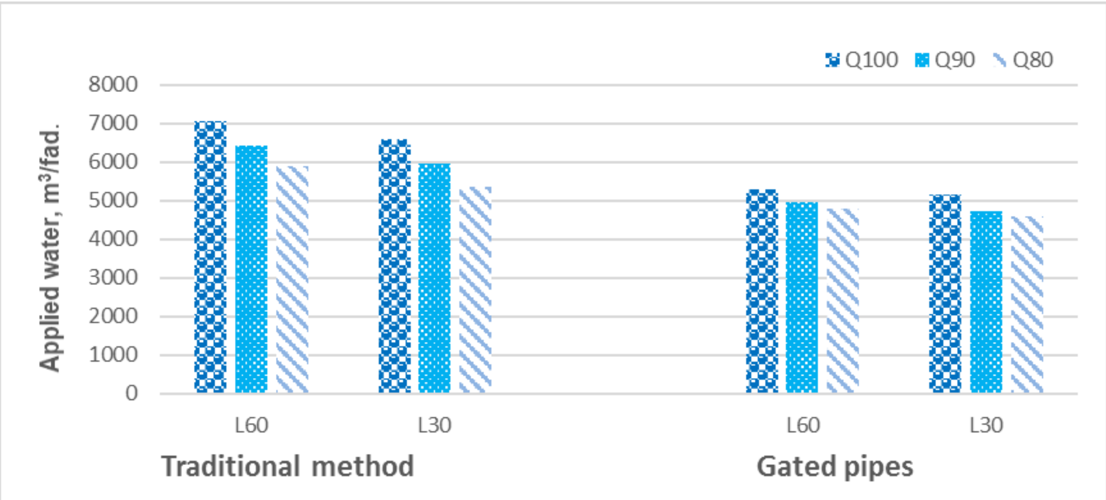

Fig. 2: Effect of furrow lengths and water cutting time on total water applied under different irrigation systems

Generally, the results revealed that the average total water irrigation applied increased as furrow length increased from 30 m to 60 m at different treatments whereas the average total water irrigation applied decreased as cut-off irrigation decreased from 100% to 80% at different irrigation methods. The highest values of seasonal water applied were 7065 m^3/fed. Recorded when using the traditional irrigation method and 60 m furrow length at cut-off irrigation 100% from furrow length where the lowest values of seasonal water applied were 4589 m^3/fed. Recorded when using the gated pipes irrigation method and 30 m furrow length at cut-off irrigation 80% from furrow length

Presented data in Fig. (2) Clearly showed that the traditional irrigation methods received more applied irrigation water than the gated pipes irrigation system in three cases of cut-off irrigation at different furrow lengths due to the good uniformity of water application from the gates along the gated pipes irrigation system gives good water distribution along the furrows on the upper part of the field. These results are similar to those recorded by [9,12].

3.2. Effect of furrow lengths and cut-off irrigation on water-saving

The effect of furrow lengths and water cutting time on water saved percentage was illustrated in Fig. (3). Values of the saved irrigation water percentage were calculated based on the reference treatment (when using traditional irrigation method and 60 m furrow length at cut-off irrigation 100% from furrow length) as shown in Fig. (3). The maximum average values of the total water applied saving of irrigated maize plants was 2476 m^3/fad./season achieved in the case of using a gated pipes irrigation system at furrow length L_{30} under Q_{80} cut-off irrigation and its percentage value was35.04 % where the minimum average value was 649 m^3 /fad./season achieved in the case of using traditional irrigation method and L_{60} furrow length under Q_{90} cut-off irrigation and its percentage value was 9.18%.

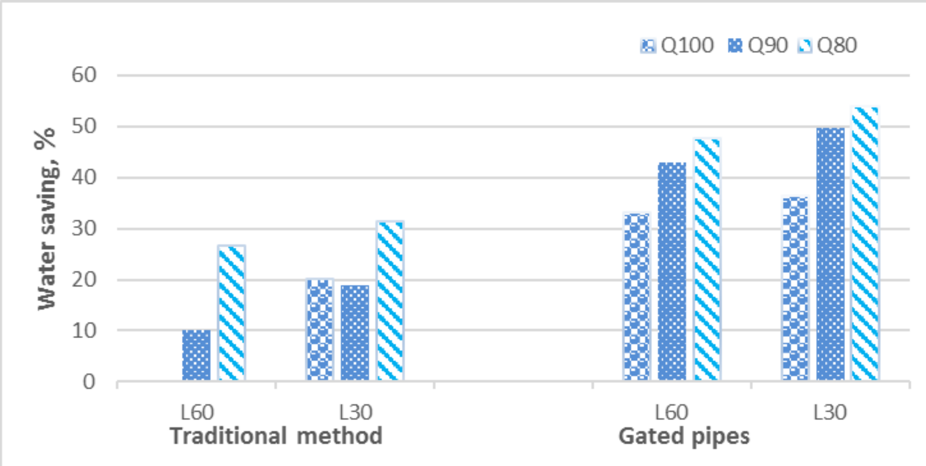

Fig. 3: Effect of furrow lengths and water cutting time on water saved percentage under different irrigation systems

Generally, using a gated pipes irrigation system saved average values of the total irrigation water applied by about24.86 % on average than traditional irrigation systems under L_{60} furrow lengths and Q_{100} cut-off irrigation. The closed-end of the long furrows caused accumulation of water at the end of the field, increasing the deep losses, so saved amounts of water were attributed to using improved irrigation systems with good water distribution through the field for the maize crop during the growing season and reducing water losses through reducing deep percolation.

3.3. Effect of furrow lengths and water cutting time on grain yield

It can be indicated that values of maize grain yield for traditional irrigation method and irrigation using gated pipe system were affected by different furrow lengths and different cut-off irrigation as shown in Fig. (4).

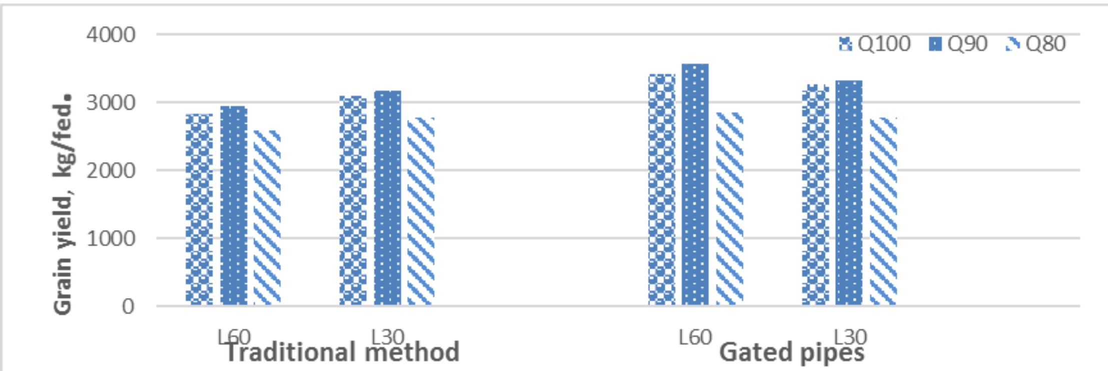

Fig. 4: Effect of furrow lengths and water cutting time on Grain yield under different irrigation systems

The results demonstrated that for traditional irrigation methods in case of increasing furrow length from 30 m to 60 m, the average values of grain yield were decreased for all treatments. Therefore, the furrow length L_{30} treatment at cut-off irrigation Q_{90} gave the best value of water grain yield compared to the other treatments, it was 3168 kg/fed also, the minimum average value of grain yield was 2589 kg/fed achieved in the case of using traditional irrigation method at furrow length L_{60} under cut-off irrigation Q_{80}. On the other hand, by increasing furrow length from 30 m to 60 m under using gated pipes irrigation, the average values of grain yield were increased for all treatments. Therefore, the maximum average value of grain yield when using gated pipes irrigation was 3565 kg/fed. Achieved in the case of treatment L_{60} under cut-off irrigation Q_{90}, also the minimum average value of grain yield when using gated pipes irrigation was 2788 kg/fed achieved in the case of treatment L_{30} at cut-off irrigation Q_{80}. In general, it could be noticed that the maize yield decreases by increasing deficit irrigation (cut-off irrigation) when deficit irrigation by cut-off irrigation from Q_{90} to Q_{80} maize yield decreases for all tested treatments because the soil water was not exposed to high stress as the maize plant is classified as drought sensitive crop, while by increasing deficit irrigation when cut-off irrigation from Q_{100} to Q_{90} maize yield increases for all tested treatments due to reducing water irrigation losses by deep percolation, also the good uniformity and distribution of irrigation water along the furrows. These results are similar to those recorded by [20,9**]**.

3.4. Effect of furrow lengths and water cutting time on Water use efficiency

Water use efficiency is an important indicator for measuring and determining crop production per unit of applied water. The obtained values of water use efficiency (WUE) of maize yield for traditional irrigation method and irrigation using gated pipe system were affected by different furrow lengths and cut-off irrigation as shown in Fig. (5).

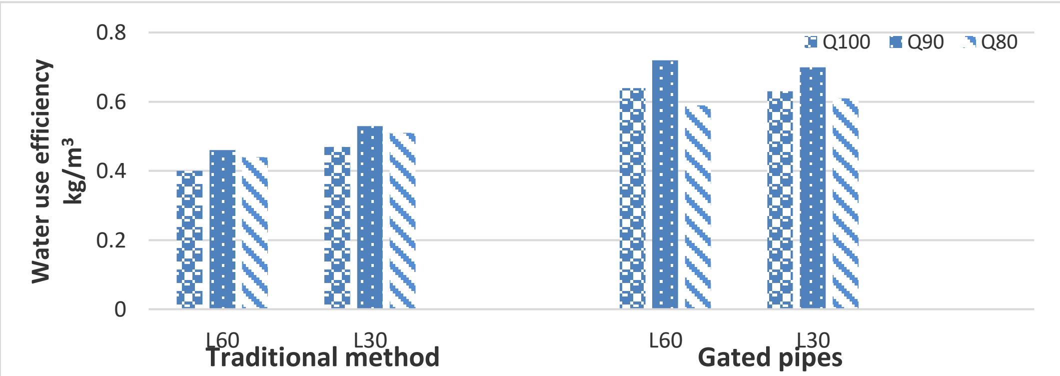

Fig. 5: Effect of furrow lengths and water cutting time on Water use efficiency under different irrigation systems

The results revealed that the maximum average value of WUE for traditional irrigation was 0.53 kg/m^3 achieved in the case of treatment L_{30} when cut-off irrigation Q_{90}, while the minimum value of WUE was o.40 kg/m^3 achieved in the case of using traditional irrigation method at furrow length L_{60} under cut-off irrigation Q_{100}. However, the maximum average value of WUE for the irrigation with a gated pipe system was 0.72 kg/m^3 achieved in the case of treatment L_{60} when cut-off irrigation Q_{90}. While the minimum value of WUE using a gated pipes system was 0.59 kg/m^3 achieved at furrow length L_{60} under cut-off irrigation Q_{80}.

The results showed that the irrigation by gated pipe system with a furrow length of 60 m increased WUE by 60, 56.52, and 34.10 % under treatments Q_{100}, Q_{90}, and Q_{80}, respectively compared with the traditional irrigation method at the same treatments. The results revealed that cut-off irrigation when the irrigation water reaches 90 % from furrow length treatment Q_{90} achieves the best values of WUE at all treatments compared with Q_{80} and Q_{100} due to decreased water irrigation losses by deep percolation, evaporation and runoff by good land leveling, closed pipe to carry water to the field and good water distribution along the upper part of the field through gated pipe system which achieves improvement in crop yield.

Generally, the results showed that the best water use efficiency was obtained in the case of irrigation using a gated pipes irrigation system and 60 m furrow length under cut-off irrigation when the irrigation water reached 90 % from the furrow length as compared to traditional irrigation methods at the same treatments. These results are in harmony with [22].

4. Conclusions

If it is necessary to use a surface irrigation system in newly reclaimed lands, it is recommended to use developed surface irrigation by gated pipes system and long furrow about 60 m length at cut-off irrigation when the irrigation water reaches 90 % of furrow length to save irrigation water by29.62% and achieve best water use efficiency 0.72 kg/m^3 of maize crop compared to traditional irrigation method at the same conditions.

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