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EFFECT OF GATED PIPES IRRIGATION SYSTEM ON COTTON YIELD AND WATER USE EFFICIENCY

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ABSTRACT: The field experimental works were conducted at the experimental farm of Sakha Agricultural Research Station, Kafr El-Sheikh Governorate during two successive seasons of 2013/ 2014 in clay soil to evaluate the performance of utilizing gated pipes technique for cotton crop production. The objective of this research was to study surface irrigation system performance through using gated pipes under different furrows irrigation lengths L_{75} (75m). L_{100} (100m), and L_{125} (125m) comparing with the traditional irrigation system. Also to study the effects of irrigation system and land slope technique under different furrows lengths on cotton crop production, total water applied, water use efficiency and water application efficiency under prevailing condition in Egyptian old valley. Results showed that: The maximum value of seed cotton yield was 1846.3 kg/fad., achieved by using gated pipes under furrow length treatment L_{125}. On the other hand, the minimum value was 1472.8 kg/fad., was achieved in case of traditional irrigation method at L_{125} furrow length treatment. The maximum value of the total water applied saving was achieved in case of using gated pipes irrigation system at Laser land leveling technique of 0.1% land slope under furrow length treatment L_{75} and its value was 1472 m^3/fad./season or 34.33% of the average values of the total water applied of traditional irrigation system during the first and second seasons. Generally the results showed that the best water use efficiency was obtained in case of irrigation using gated pipes irrigation system at any treatments compared to traditional irrigation methods and increases the water use efficiency with treatment L_{100} furrow length. The maximum value of water application efficiency for the irrigation with gated pipes irrigation was achieved in the case of treatment L_{125} and its value was 85.7% under land slope of 0.10%. The results showed that using gated pipes irrigation system with Laser land leveling technique of 0.1% in three cases of furrows lengths saving irrigation water by about 33% compared to traditional irrigation method.

Key words: Cotton crop, surface irrigation, gated pipes, water saving.

INTRODUCTION

Irrigation water consumes about 80% of the water budget for cultivating approximately 7.1 million faddans, with an annual crop area of about 12 million faddans. About 5.05 million faddans, is old land irrigated by surface irrigation methods.

Surface irrigation is the oldest most used method of irrigation in Egypt, at least from 4000 years ago. In surface irrigation, basin, border, or furrows are the primary methods of applying water, and the field has to be cut into rather narrow strips by numerous field ditches run that is convey water from the source to fields. Because a great amount of water runs through canal wasted by seepage, deep percolation and evaporation. The surface irrigation has a disadvantage as gated pips efficiency (Hassan, 1998).

The use of gated pipes system is claimed to be one of the ways to improve the efficiency of surface irrigation method (border and furrow), (Morcos *et al.,* 1994).

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The total cotton cultivated area reached about 300 thousand faddans wherein surface irrigation system is used. It is considered a highly water consuming crop in Egypt especially under the conventional irrigation method. The applied irrigation water for cotton is estimated to be 5000 m^3/fad./year.

The future will require even greater improvements as competition for limited water supplies continues to increase. Now the saving of irrigation water is considered a strategically target of Egypt. Economic use of irrigation water is vital problem that confronts agriculture scientists in irrigated areas.

Now, the saving of irrigation water is considered a strategic target of Egypt. Lower application efficiency is one of the surface irrigation disadvantages. El-Sherbeny *et al.* (1997) mentioned that irrigated agriculture faces a number of difficult problems in the future. One of the major concerns is the generally poor-efficiency with which water resources have been used for irrigation. A relatively safe estimate is that 40 percent or more of water diverted for irrigation is wasted at the farm level through either deep percolation or surface runoff.

The irrigation application efficiency and irrigation distribution efficiency were increased to 72.5 percent and 92 percent, respectively by using gated pipes system through furrow irrigation.

Booher (1974) described the gated pipes are available in diameters ranging from 10 to 30 centimeters. The outlets on gated pipe operate as sharp-edge or long-tube orifices. The outlets on gated pipe 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 valve are usually spaced along the buried pipeline so that not more than 30 meters of gated pipe need be connected to each hydrant.

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.

General Administration of Agricultural Economics (2004) reported that the system application in Egypt is perforated pipes and gated pipe irrigation. These applications an aboveground pipeline or buried pipeline replaces these types of furrow irrigation in which the conventional head ditch and siphons.

Awad and Gomaa (2004) studied the effect of different long-strip and furrow length 50, 100 and 150 m for corn under laser-leveling field compared with traditional land leveling on the amount of the applied water, the water application efficiency, water use efficiency and economic evaluation of studied treatment. El-Awady *et al.* (2002) mentioned that the gated pipes are convenient means of distributing water to surface irrigated crops. Irrigation water flows from gates, which are regularly spaced along the pipeline.

The objective of this research was to study surface irrigation performance through using gated pipe system technique under different furrows irrigation lengths treatments L_{75} (75m). L_{100} (100m), and L_{125}(125m) comparing with the traditional irrigation methods and their effects on total water applied, yield, water application efficiency and water use efficiency for cotton crop.

MATERIALS AND METHODS

Materials

The pumping unit

The experimental field pumping unit operated by a diesel motor. The pump was connected through connecting tubes, spools, elbows, tees and other pipe fitting. The pump was equipped with an individual suction pipe and 5 inch hose ending with a trash screen and non- return valve. The discharge side of the pumping unit was connected to the inlet of tested gated pipe having 30 gates at 0.60 m spacing between each gate through a discharge valve, flow-meter, pipe having no holes and the gated pipes. The pumps drawn water from lining canal. The specifications of the pumps and engines are shown in Table 1.

The utilized pipes for the gated pipes system

Six inch diameter, 6 meter length UPVC pipes were used for the gated pipes system. The pipes were connected together using rubber ring jointing system.

Table 1. The specifications of the pump and diesel engine

Type of pump	Pump made	Motor power kw (hp)	Rpm	Max. discharge (m^3/hr.)	Max. operating pressure (bar)	Suction pipe diameter (Inch)	Delivery pipe diameter (Inch)
Centrifugal	Locally-Diesel Shobra	7.8	1460	130	1.0	6	6

Flow rate and pressure head measuring devices

The flow meter

A six inch flow meter was used to measure the flow entering the inlet of the gated pipes. The rate was obtained by dividing the recorder water quantity passed in the flow meter at a certain time by that time.

Spirit bubble level

Spirit bubble level was used to assure that the gated pipe was kept, as much as possible, in a horizontal position.

A stop watch

Whenever time was concerned, it was measured using a stopwatch.

Steel tape scale

A steel tape scale was used to measure the height of water in the water hose manometers.

Linen scale tape

The linen scale tape of 50-m long was used to measure the land dimensions.

Air release valve

The air release valve attached to the connection of the pumping unit before six inch valve was used to exhaust air under various pressure head conditions during normal pipeline operation while restricting the outflow of water.

Methods

The experimental field was conducted at the experimental farm of Sakha Agricultural Research Station, Kafr El-Sheikh Governorate, Egypt, cultivated by cotton (Giza 85 variety) during two successive seasons of 2013/2014 in clay soil.

The soil texture of the experimental site according to Black *et al.* (1965) was classified as clay soil as shown in Table 2.

Field Experimental Test Procedure

Field experimental work was conducted to study the effect of irrigation system and land leveling technique under different furrow lengths on the cotton crop production, water application efficiency and water use efficiency under prevailing condition in Egyptian old valley. Also, its effects on the total water applied.

An experimental area plot was about 3.4 fad. The experimental plot was divided into 2 sub-plots each of 1.7 fad., as shown in Fig. 1. The first sub-plot was leveled at zero slope and irrigated by traditional irrigation method. The second sub-plot leveled at 0.1% slope as Hassan (2004) by laser technique and irrigated by gated pipes irrigation system. Each sub-plot was divided into three treatments *i.e.*, 75 meters furrow length (L_{75}), 100 meters furrow length (L_{100}) and 125 m furrow length (L_{125}). The width of the field test for each treatment *i.e.,* was 18 m and 1-m strip of untilled land was thus left between adjacent treatments. Also, 2-m strip of untilled land was thus left between adjacent sub-plots. The first area sub-plot was irrigated with traditional irrigation method by pumping irrigation water through 6-inch flow meter into a concrete canal to flow from the canal to the furrows. The second experimental area sub-plot was irrigated by 6- inch diameter PVC gated pipes. The distance between two consecutive furrows was to be 0.60 m. Each treatment was serving by 6- inch gated pipe having 6-m length and the required gates. The flow rate recommended per meter width in clay soil was about 2 l/sec., as (Hassan, 1998).

Table 2. Some physical and chemical properties of the soil

Soil depth (cm)	Soil moisture characteristic			Soil type	pH	Ec. (ds/m)	Basic Inf. (cm/hr.)
	Fc (%)	Wp (%)	Bd (g/cm^3)				
0-15	50.3	17.5	1.3	Clay	8.2	3.85	1.2
15-30	51.7	18.2	1.46	Clay	8.3	4.20	1.0
30-45	52.3	18.5	1.57	Clay	8.3	4.50	0.9

Fc: Field capacity, Wp: Wilting point, B d: Bulk density.

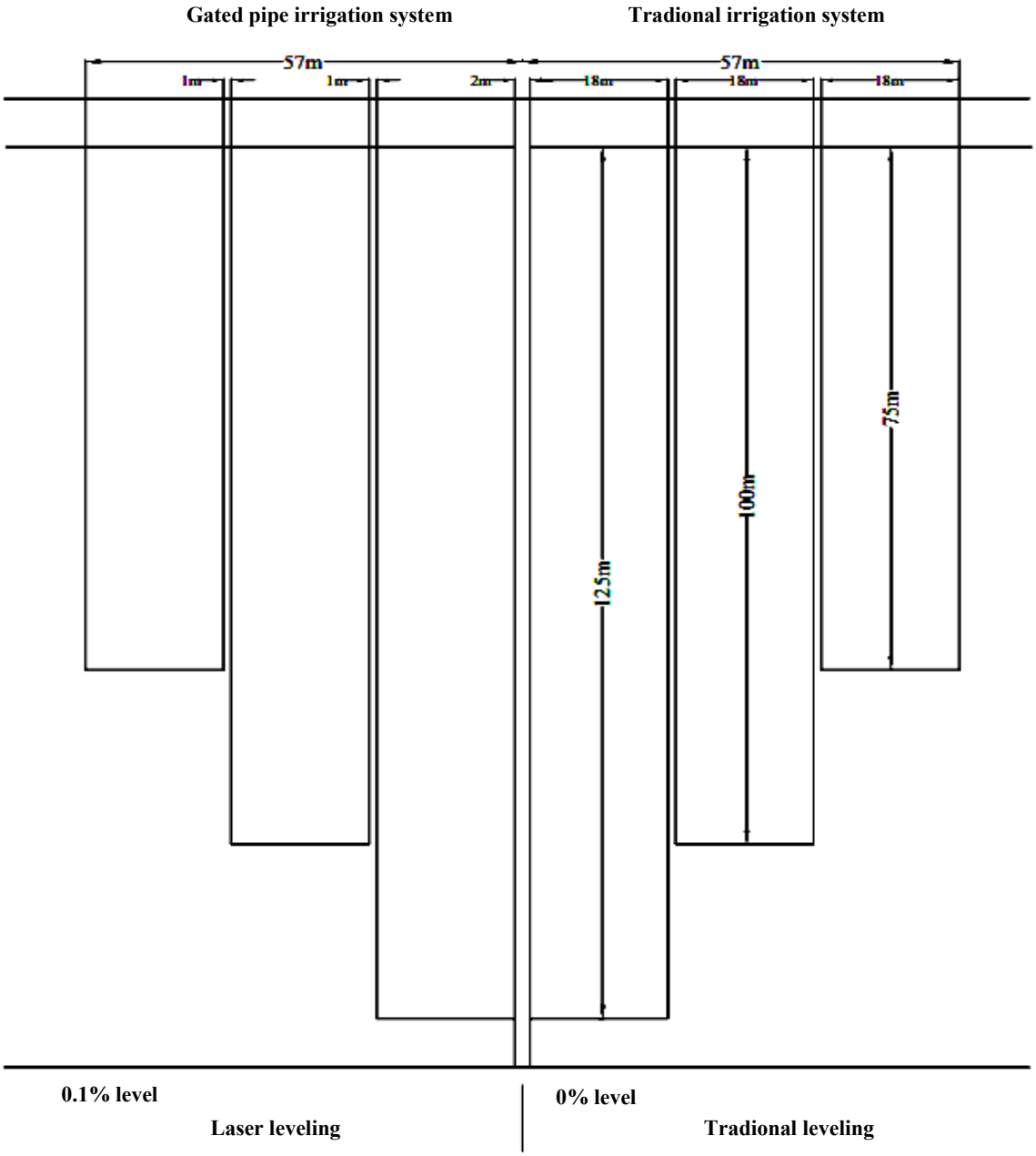

Fig. 1. Experiment layout

The water irrigation applied for each treatment was measured by 6 inches flow meter connecting with pumping unit. Water application efficiency and water use efficiency were determined. Also, estimating the water saving.

The water application efficiency (WAE)

Jensen (1980) stated that the water application efficiency is the ratio of the average depth of the irrigation water infiltrated and stored in the root zone to the average depth of water applied according to Hassan (1998) as follows:

$$WAE = \frac{\text{Average depth of water infiltrated and stored into root zone}}{\text{Average depth of water applied}} \times 100. \quad (1)$$

Water use efficiency (WUE)

Water use efficiency (WUE) values were calculated according to Jensen (1983) as follows:

$$WUE = \frac{\text{Cotton yield (kg/fad.)}}{\text{Applied irrigation water (m}^3\text{/fad.)}} \quad (2) \ (\text{kg/ m}^3)$$

RESULTS AND DISCUSSION

Effect of the Irrigation Methods on the Water Applied Under Different Treatments of Furrow Lengths

The results of the average values of the total water applied during two seasons through each treatment using gated pipe system under Laser land leveling technique at 0.1% lands slopes and different furrow lengths L_{75}, L_{100} and L_{125} compared to the traditional irrigation method under different furrow lengths of L_{75}, L_{100} and L_{125} were shown in Fig. 2.

Fig. 2 show that the average values of the total water applied for traditional irrigation methods at 0.0% land slope through replicates under different treatments of furrow lengths L_{75}, L_{100} and L_{125} were 4288, 4365 and 4436 m^3/fad., respectively and the average values of the total water applied through gated pipes irrigation system under Laser land leveling technique at 0.1% lands slope and different treatments of furrow lengths L_{75}, L_{100} and L_{125} were 2816, 2942 and 3018 m^3/fad., respectively.

Generally, the results revealed that the traditional irrigation methods received more applied of irrigation water per faddan per season than gated pipes irrigation system in three cases of furrows 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 Abou El-Soud (2009).

At the same trend of the traditional irrigation methods, the average total water irrigation applied received by cotton plants per faddan through gated pipes irrigation system with Laser land leveling technique at 0.1% lands slopes under different treatments of furrow lengths L_{75}, L_{100} and L_{125} increased as furrow length increased due to increase the water opportunity time as furrow length increased, thus water losses with seepage and run off increased.

The results showed that using gated pipe irrigation system with Laser land leveling technique at 0.1% in three cases of furrow lengths saving irrigation water by about 33% compared to traditional irrigation method.

Effect of the Irrigation Methods on the Water Saving Under Different Treatments of Furrow Lengths

The results of the average values of the total irrigation water applied saving of irrigated cotton plants during two seasons through each treatment using gated pipe irrigation system under Laser land leveling technique at 0.10% land slopes and different furrow lengths of L_{75}, L_{100} and L_{125} compared to the traditional irrigation method at 0.0% land slope under different furrow lengths of L_{75}, L_{100} and L_{125} were shown in Fig. 3.

Fig. 3 show that the average values of the total irrigation water applied saving of irrigated cotton plants for traditional irrigation methods at 0.0% land slopes through replicates under different treatments of furrow lengths of L_{75}, L_{100} and L_{125} were 148.0, 71.0 and 0.0 m^3/fad./ season, respectively or by about 3.34, 1.6 and 0.0%, respectively than the average values of the total water applied of traditional irrigation system during the first and second season at 0.0 lands slopes under different treatments of furrow lengths of L_{75}, L_{100} and L_{125}, respectively.

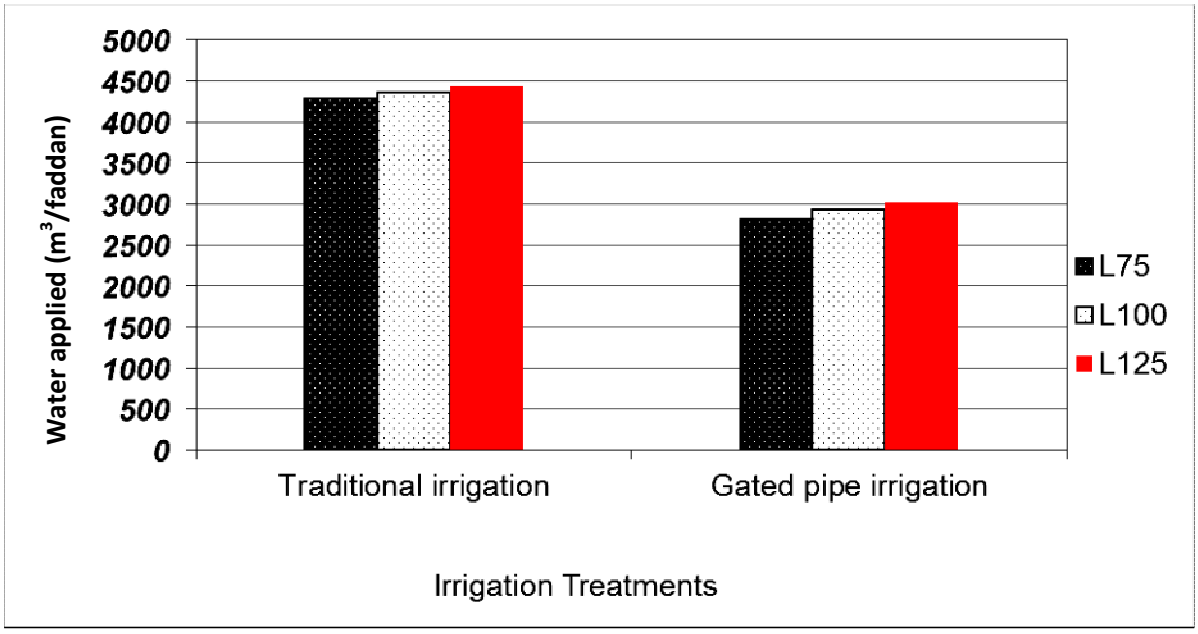

Fig. 2. Effect of traditional and gated pipes irrigation systems on total water applied under different furrow lengths

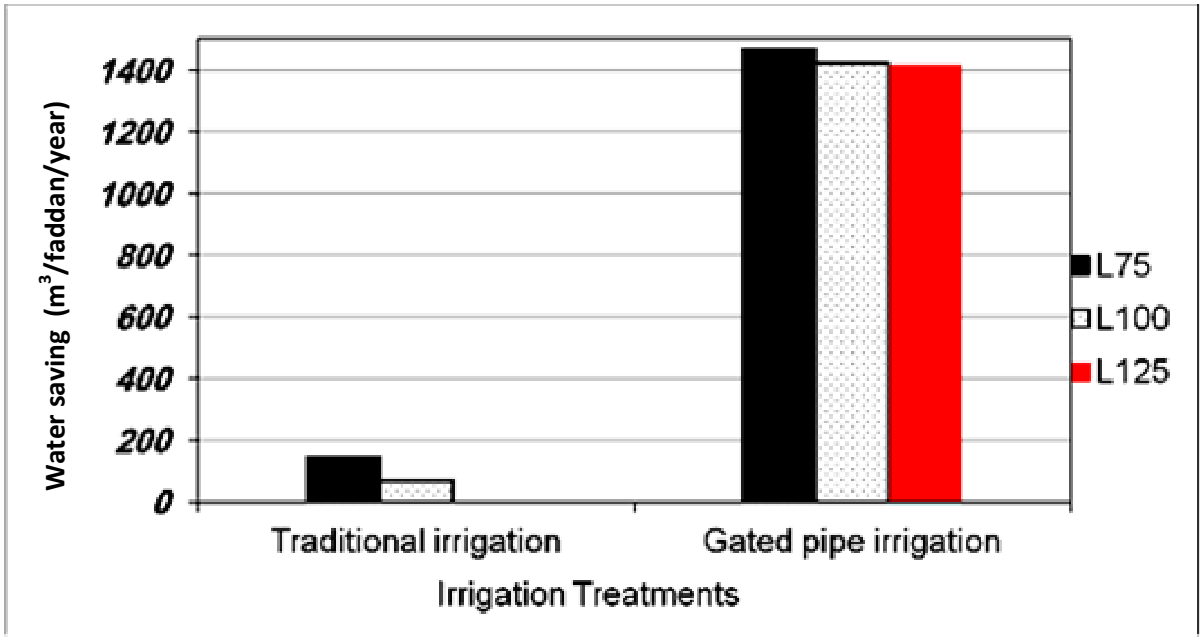

Fig. 3. Effect of traditional and gated pipes irrigation systems on water saving under different furrow lengths

On the other hands, the average values of the total water applied saving of irrigated cotton plants through gated pipes irrigation system at Laser land leveling technique of 0.1% lands slopes under different treatments of furrow lengths of L_{75}, L_{100} and L_{125} were 1472, 1423 and 1418 m^3/fad./season.

The maximum average values of the total water applied saving of irrigated cotton plants was achieved in case of using gated pipes irrigation system at Laser land leveling technique of 0.1% lands slopes under furrow length L_{75} and its value was 1472 m^3/fad./season or 34.33% of the average values of the total water applied of traditional irrigation system during the first and second seasons at the same furrow lengths.

As general conclusion using gated pipes irrigation system saved average values of the total irrigation water appled by about 33.0% in average than traditional irrigation system under different treatment of furrow lengths and lands slope and its value was about 2925.33 m^3/fad., season.

Effect of the Irrigation Methods on the Water Application Efficiency under Different Treatments of Furrow Lengths

Concerning the average actual furrows depths of irrigation water applied through traditional irrigation method at 0.0% lands slopes were 102.1, 103.93 and 105.62 cm under different treatments of furrow lengths, L_{75}, L_{100} and L_{125}, respectively.

On the other hand, the average values of the actual furrow depths of irrigation water applied through irrigation using gated pipes irrigation system under Laser land leveling technique at 0.1% lands slopes were 67.05, 70.05 and 71.86 cm under different treatments of furrow lengths of L_{75}, L_{100} and L_{125}, respectively was shown in Fig. 4.

Fig. 4 show that the average values of the water application efficiency for traditional irrigation methods at 0.0% lands slopes through replicates under different treatments of furrow lengths of L_{75}, L_{100} and L_{125} were 48.3, 45.1 and 41.6%, respectively.

The results showed that the highest average value of the water application efficiency for the traditional irrigation method was achieved in the case of treatments L_{75} and its value was 48.3%, also, the minimum average value of water application efficiency was achieved in the case of treatments L_{125} and its value was 41.6% due to increasing the advance time, consequently increasing the opportunity time and causing increased water losses by deep percolation, run off and evaporation.

On the other hands, the average values of water application efficiency through gated pipe irrigation system under Laser land leveling technique at 0.1% lands slopes and different treatment of furrow lengths of L_{75}, L_{100} and L_{125} were 81.3, 84.3 and 85.7 %, respectively.

The maximum value of water application efficiency for the irrigation with gated pipes irrigation was achieved in the case of treatment L_{125} and its value was 85.7% under lands slopes 0.10%, also the minimum average value of water application efficiency was achieved in the case of treatment L_{75} and its value was 81.3% due to decreases the water irrigation losses by deep percolation.

Average values of water application efficiency through gated pipe irrigation system under Laser land leveling technique at 0.1% lands slopes under different treatments of furrow lengths of L_{75}, L_{100} and L_{125} and traditional irrigation methods at 0.0% lands slopes under the same different treatments of furrow lengths of L_{75}, L_{100} and L_{125} were displayed together in Fig. 4.

To facilitate the discussion, Fig. 4 show that the average value of water application efficiency for irrigation with gated pipe irrigation system were more than the average value of water application efficiency achieved by traditional irrigation under the three treatments of furrow lengths of L_{75}, L_{100} and L_{125} due to increased total irrigation water applied consumed per faddan at the same condition of using gated pipes irrigation system.

The average values of water application efficiency increased as a lands slope increased under the three cases of treatments L_{75}, L_{100} and L_{125} due to decrease both advance time and opportunity time resulting decreased the water losses by both deep percolation and run off and also reduce the time needed to irrigation.

Fig. 5 show that in three cases of furrow lengths for gated pipes irrigation system, the

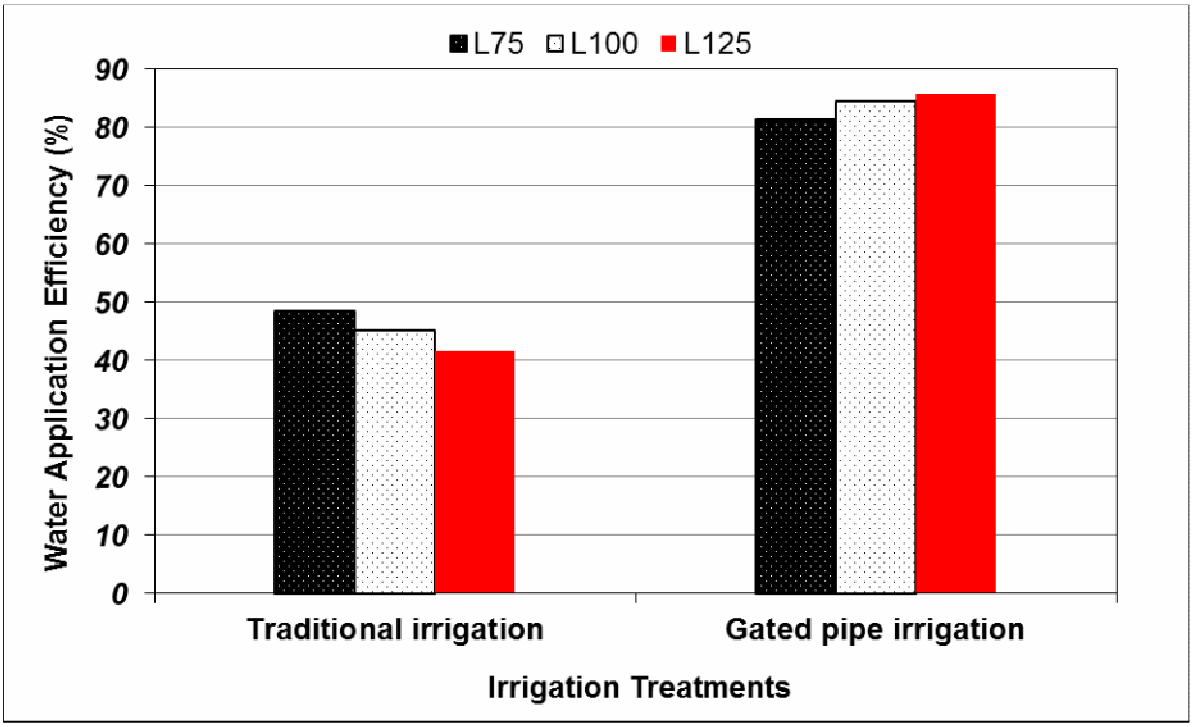

Fig. 4. Effect of traditional and gated pipes irrigation systems on water application efficiency under different furrow lengths

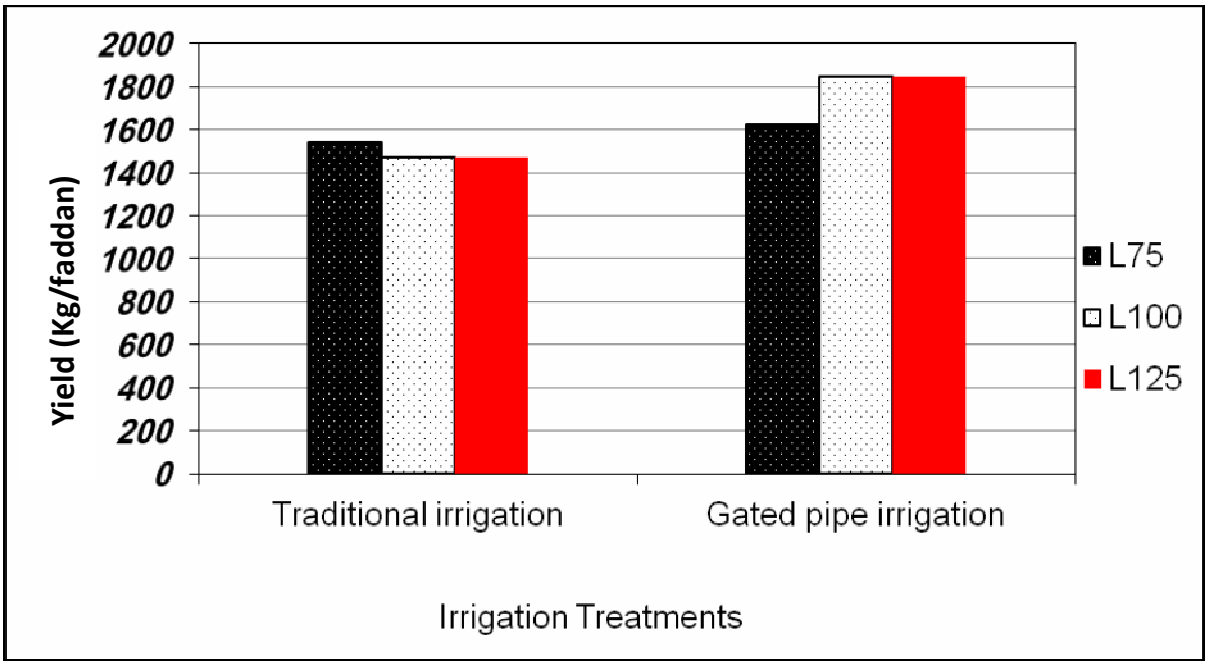

Fig. 5. Effect of traditional and gated pipes irrigation systems on crop production under different furrow lengths

average value of water application efficiency increased as furrow length increased due to decrease the water losses by deep percolation and run off, this result agreed with Abo Soliman *et al.* (2002).

Effect of the Irrigation Methods on the Cotton Crop Production Under Different Treatments of Furrow Lengths

The values of the cotton crop production of traditional irrigation system and gated pipes irrigation system were determined actually on the field.

Dealing with the figure representing the average values of the seed cotton yield per fad., through gated pipe irrigation system at Laser land leveling technique of 0.1% land slopes under different treatments of furrow lengths of L_{75}, L_{100} and L_{125} and traditional irrigation methods under the same different treatments of furrow lengths of L_{75}, L_{100} and L_{125} were displayed together in Fig. 5 to represent the effect of irrigation method on the average values of cotton seed yield per fad.

The results revealed that the maximum value of the cotton seed yield for traditional irrigation methods was1541.6 kg/fad., achieved with treatment L_{75}. Also, the minimum value was 1472.8 kg/fad., achieved with treatment L_{125}.

The maximum value of the cotton seed yield for the irrigation with gated pipes system was achieved in laser land leveling technique at 0.10% land slopes under furrow lengths of L_{125} and its value was 1846.3 kg/fad. On the other hands, the minimum average values of the cotton seed yield production was 1686.2 kg/fad., achieved with furrow length of L_{75} .

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.

Effect of the Irrigation Methods on the Water Use Efficiency Under Different Treatments of Furrow Lengths

In the herein research trial, field water use efficiency means kg/fad., of the economical yields of the cotton seed with applying m^3 amount of irrigation water. Concerning water use efficiency, which considered as the evaluation parameter of the capability of converting irrigation water to seed cotton yield. The water use efficiency was considered a tool for maximizing crop production per each unit of water applied were shown in Fig. 6.

The results revealed that the maximum value of water use efficiency for traditional irrigation methods was 0.36% achieved in case of treatment L_{75} due to the total water consumptive use increased than other treatments *i.e.,* L_{100} and L_{75} due to increase water irrigation losses by deep-percolation and runoff. Also, the minimum value of water use efficiency was 0.33% achieved with furrow length L_{125}.

The maximum value of water use efficiency for the irrigation with gated pipes system was 0.61 achieved in case of Laser land leveling technique at 0.10% lands slopes under furrow length L_{125}. On the other hands, the minimum value of water use efficiency was 0.60% achieved in case of Laser land leveling 0.10% lands slopes under furrow length of L_{75} and due to increase the water irrigation amount consumed and also increased the water irrigation losses by deep-percolation and run off as increased the irrigation run.

The average values of water use efficiency increased as lands slopes increased under any furrow length due to decrease both advance time and opportunity time as increased lands slopes resulting decreased the water losses by both deep percolation and run off and also reduce the time needed to irrigation, thus water losses with seepage and run off decreased.

Concerning the effect of irrigation systems on the water use efficiency, the results showed that the best water use efficiency obtained in case of irrigation using gated pipe system at any treatments than traditional irrigation methods. due to the good uniformity of water application from the gates along the gated pipe irrigation system gives good water distribution along the furrows on the upper part of the field. Also, as a lands slopes increased decreased both advance time and opportunity time by good land leveling in 0.1% lands slopes resulting decreased the water losses by both deep percolation and run off and also reduce the time needed to irrigation.

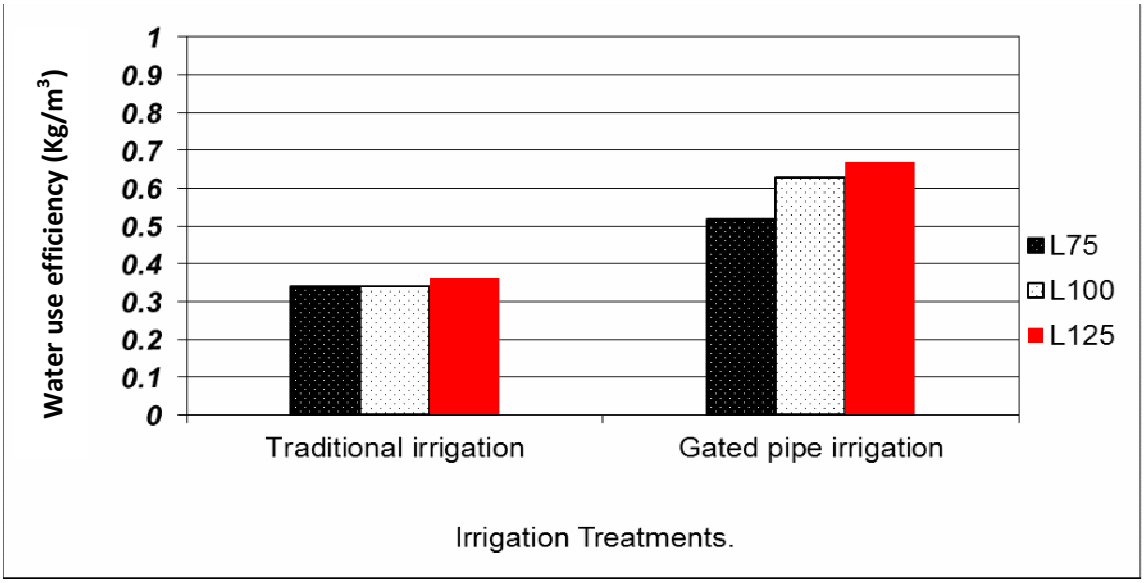

Fig. 6. Effect of traditional and gated pipes irrigation systems on water use efficiency under different furrow lengths

The results showed that the average values of water use efficiency through gated pipes irrigation system at 0.10% lands slopes under different treatments of furrow lengths of L_{75}, L_{100} and L_{125} increased than the average values of the cotton water use efficiency through traditional irrigation methods under the same different treatments of furrow lengths of L_{75}, L_{100} and L_{125} by about 75.73% in average.

Generally the results showed that the best water use efficiency obtained in case of irrigation using gated pipes irrigation system at any treatments than traditional irrigation methods and increases the water use efficiency with treatment L_{100} furrow length under different lands slopes. These results are in harmony with Sonbol *et al.* (2009).

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تأثيـــر نظـــام الـــري بالأنـــابيب المبـــوبـــة علـــى محصـــول القطـــن وكفـــاءة استخـــدام الميـــاه

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أجريت التجارب بمحطة بحوث سخا -مركز البحوث الزراعية- محافظة كفر الشيخ- خلال موسمي ٢٠١٣، ٢٠١٤ في أرض طينية القوام، على محصول القطن، لدراسة أداء نظام الري السطحي من خلال إضافة المياه باستخدام الرى بالأنابيب المبوبة، تحت أطوال مختلفة للخطوط، مقارنة بنظام الري التقليدي تحت نفس الظروف والمعاملات والتأثيرات المتتالية لهذه الطرق علي إجمالي كمية مياه الري المضافة والإنتاجية وتوفير المياه وكفاءة الاستخدام المائي، وقد أوضحت النتائج التالي: أعلى إنتاجية لمحصول القطن الزهر كانت ١٨٤٦,٣ كجم/فدان وتحققت باستخدام نظام الرى بالأنابيب المبوبة تحت المعاملةL_{125} وكانت اقل إنتاجية لمحصول القطن الزهر ١٤٧٢,٨كجم/ فدان وتحققت باستخدام نظام الرى التقليدى تحت المعاملة L_{125}، أعلى توفير للمياه تحقق تحت نظام الرى بالأنابيب المبوبة وتسوية ليزر بانحدار ٠,١% تحت معاملة L_{75} وقيمته كانت ١٤٧٢م^3/فدان/الموسم أو ٣٤,٣٣% متوسط كمية المياه المتوفرة بالمقارنة بالرى التقليدى خلال الموسمين تحت المعاملةL_{75} ، أوضحت النتائج أن أفضل استخدام للمياه تحت نظام الرى بالانابيب المبوبة تحت أى من المعاملات مقارنة بالرى التقليدى الذى أعطى أعلى كفاءة أستخدام عند معاملة L_{100} ، أعلى قيمة لكفاءة إضافة المياه تحت نظام الرى بالأنابيب المبوبة تحقق تحت معاملة L_{125} وإنحدار ٠,١% وكانت قيمتها ٨٥,٧%، أوضحت النتائج أن أستخدام الرى بالأنابيب المبوبة مع التسوية بالليزر على إنحدار ٠,١% فى الثلاث حالات لأطوال الخطوط توفر مياه الرى بنسبة تصل إلى ٣٣% مقارنة بالرى التقليدى.

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