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Effect of using trailing perforated pipe on irrigation efficiency for maize production

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ABSTRACT

The present study aimed to evaluate the trailing perforated pipe effect on irrigation efficiency and maize production using UPVC pipe with 200 mm inside diameter. The orifices were located at 75 cm spacing (the same spacing between furrows) with a circular orifice (25mm D) attached with a 2 m plastic hose. trailing perforated pipe is a new method to be used to reduce the soil erosion, directing the exit of irrigation water towards the irrigation furrows, can be using the system on irrigating any kinds of crops planting through any furrows spacing, distribute water into furrow irrigated fields based and water. The results revealed that the average values of the water a dvance, recession and opportunity times for gated pipe and trailing perforated pipe at 0.1% lands leveling slopes and furrows lengths 100 m were 88, 268 and 180 minutes and 84, 264, and 180 minutes respectively, the highest water amount applied was found at gated pipe irrigation system (2766m^3/feddan). Water distribution efficiency were 95.8% for gated pipe and 97.2% for trailing perforated pipe. The highest value of crop production was 3695 kg/feddan/year in case of using the trailing perforated pipe. The results showed that the average values of maize water use efficiency increased at using trailing perforated pipe irrigation system of 1.37 kg/m^3 than the gated pipe irrigation system by 1.32 kg/m^3. From the above-mentioned results, it can conclude that, the trailing perforated pipe irrigation system is better than the gated pipe for improving irrigation efficiency and maize productivity.

1. Introduction

As the world becomes increasingly dependent on the production of irrigated lands, irrigated agriculture is facing serious challenges that threaten its sustainability. Economic use of irrigation water is avital problem, which confronts agriculture scientists in irrigated areas. Irrigated agriculture will require innovative mergers of managerial and technological the skill to survive as an economically viable and environmentally acceptable venture.

The state has tended to develop surface irrigation such as gated pipe irrigation and trailing perforated pipes to control water use, reduce water requirements, reduce water losses, increase yields, and finally increase irrigation efficiency.

Using gated pipe irrigation increased the values of yield by 24.4 % and 16.3 % respectively, the WUE by 26.5 % and 16.7% respectively and reduced both soil (EC) and (pH) for wheat and maize compare with traditional surface irrigation system (**Farag, et al. 2019)**

Trailing perforated pipes irrigation system reducing the soil erosion under the outlets along with the system, directing the exit of irrigation water from the opening towards the irrigation furrows, can be using the

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system on irrigation any kinds of crops planting through any furrows spacing, give higher uniformity distribution than a gated pipe irrigation system, Economic studies showed that the trailing perforated pipe system was less than the gated pipe irrigation system in costs (**Abdel-hady 2018)**.

Laser land leveling saves farm inputs like water and fertilizers, improves crop stand **(El-Behery and El-Khatib, 2001)**. The use of laser land leveling increases yields and saves irrigation water as compared to traditional method of leveling in different cropping systems **(Naresh et al., 2014)**.

The main objective of the herein research trial is to evaluate surface irrigation system performance through using trailing perforated pipe system compared with gated pipe system under furrows irrigation lengths of 100 m at land slope of 0.1 %.

2. Materials and methods

Research field experimental work was conducted at a private farm in shibin al kom - El Menoufia Governorate. Lower Egypt on maize variety (Hi Tech Hybrid 301) during two successive seasons in 2020/2021 from 1/4 to 25/7 for the two seasons. Field experiment was conducted to study the effect of trailing perforated pipe and gated pipe under furrow lengths of 100m on water (Advance – recession – opportunity), total water amounts, water distribution efficiency, crop production, water use efficiency for maize crop under Egyptian condition.

The soil texture of the experimental site according to **(Black 1965)** was classified of Silty Clay Loam soil as shown in Table 1.

Pumping unit with the specifications of the pumps and engines are shown in Table 2.

Table 1
some physical and mechanical analysis of the soil

Depth (cm)	Particle size distribution				Texture Class	F.C (%)	W.P (%)	B.D (g/cm³)
	Sand		Silt (%)	Clay (%)				
	C.S (%)	F.S (%)						
0 – 15	0.91	12.96	54.08	32.05	Silty Clay Loam	32.40	14.17	1.21
15 – 30	0.69	10.80	57.85	30.66		32.55	14.86	1.29
30 – 45	0.96	17.38	48.63	33.03		35.90	16.35	1.37
45 – 60	0.76	17.18	48.72	33.34		35.58	16.72	1.40

Table 2
The specifications of the pump

Type of pump	Pump made	Motor Power (hp)	Pump speed (rpm)	Max. discharge (m^3/h)	Max. operating pressure (kPa)	Suction pipe diameter (mm)	Delivery pipe diameter (mm)
Centrifugal	Diesel Shobra	13 hp	1460	172	100	150	150

The utilized pipe for investigated system is 8-inch (203mm) diameter, 6 m length UPVC pipes were used for the trailing perforated pipe irrigation system. The pipes were connected together using rubber ring jointing system.

2.1. Flow rate and pressure head measuring devices.

The flow meter was used to measure the flow entering the inlet of the trailing perforated pipe. The rate was obtained by dividing the recorder water quantity passed in the flow meter by that time. The Spirit bubble level was used to assure that the trailing perforated pipe was kept, as much as possible, in a horizontal position.

Also, A glass mercury thermometer was used to measure the temperature of the water passing in the gated pipe during the performed experiments, while A stopwatch was used to determine the time of the discharge.

A galvanized bucket of 15-liter capacity was used to collect the water discharge from each gate. The gate flow rate was obtained by dividing the capacity of the bucket by the time. A steel tape scale was used to measure the height of water in the water hose manometers. The linen scale tape of 50-m long was used to measure the land dimensions. The pumping unit discharge head was measured using a pointer pressure gauge fixed just before the flow- meter. Its reading range was from 0 to 0.6 bar (60 kPa) with 10 cm increment and fixed one at each pipe just before the inlet pipe.

Hand-made pure plastic hose manometers were locally manufactured using 8 mm inside diameter plastic tubes connected with plastic hoses. Each piezometer was fixed on a meter wooden board. The plastic hose of each piezometer was connected to the opening existing in the gated pipe by a plastic fitting. The purpose of using these piezometers was to measure the flow gauge pressure at each connection of the pipe. The air release valve was attached to the connection exhaust air under various pressure head conditions during normal pipeline operation while restricting the outflow of water**.** Iron elbow 8 inch (203 mm) to put it on the discharge side of the pumping unit to connect with an 8-inch flexible hose**.** A pure plastic hose with 25 mm diameter with 2 m length was used to direct the water to the line**.** An 8inch (203mm) diameter of an end line was used to close the end of the pipeline. Black Fitch with an internal diameter of 14 mm and 18 mm outside diameter with a length of 12 mm was used to fix the plastic connection on the vertical hole on the pipe. 24 wooden telescopic stands were locally manufactured to keep the gated pipe system horizontal.

The field experimental work was conducted at Menoufia Governorate. during successive seasons in 2020/2021 as shown in Figure 1. The pressure gauges were attached to the pumping unit before and after the 8inch (203mm) orifice valve at the inlet of the trailing perforated pipe system to determine the inlet pressure head of the trailing perforated pipe. Also, a pressure tube piezometer fixed at each orifice on the top of the pipe to determine the pressure head at each orifice and at dead end pipe. All the experiments were conducted at about water irrigation temperature, 20^{o}C to 21^{o}C.

2.2. Field experiment procedure

Experimental field was conducted to study the effect of irrigation system technique under furrows lengths of 100 m on water advance, recession, opportunity, total water amounts, water distribution efficiency and crop production for maize crop. An experimental area plot was about two plots was planted by maize as shown in figure(1). The first sub-plot was leveled at 0.1% slope and irrigated by gated pipe irrigation system. The second sub-plot was leveled at 0.1 % slope (**Hassan 2004)** by laser technique and irrigated by trailing perforated pipe irrigation system. The width of the field test for each treatment was 24 m and 1-m strip of untilled land was thus, left between adjacent treatments. The first area sub-plot was irrigated with the gated pipe irrigation system by pumping irrigation water through an 8-inch flow meter into a concrete canal to flow from the canal to the furrows. The second sub-plots experimental area sub-plot was irrigated by an 8-inch diameter UPVC trailing perforated pipe irrigation system. The distance between two consecutive furrows was to be 0.75 m. The stream of irrigation was cut off at 100 % of the irrigation run (as traditional dominat). The amount of irrigation water for each treatment was measured by an 8-inches flow meter connected to the pumping unit as shown in Fig. 1.

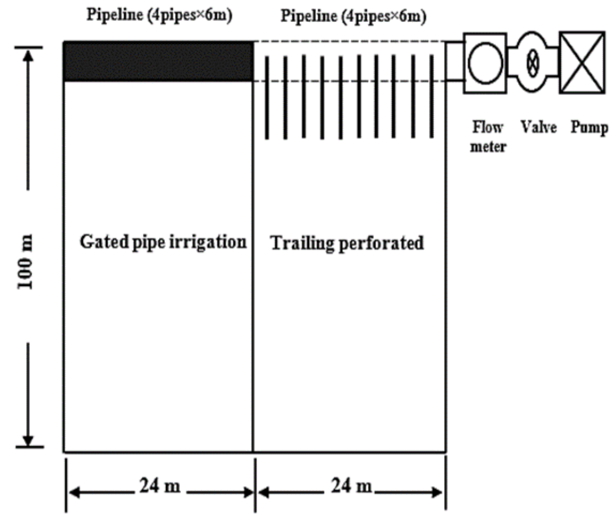

Fig.1. The experiments Layout.

2.3. The trailing perforated pipes irrigation system calibration and test procedure

The trailing perforated pipe system designed for testing on the field was locally manufactured. The main objective of the experimental test procedure was to evaluate a portable trailing perforated pipe system manufactured using UPVC pipe with 203 mm outside diameter. Each pipe had 8 orifices. Therefore, a 24-meter length of 203mm outside pipe diameter was used with closed end having 32 orifices. The connecting pipes, elbows, and fittings for the pumping unit were also locally manufactured, and the system was equipped with the required valves, flowmeter, pressure gauge and piezometers. It was compared to traditional irrigation method performance.

The flow rate recommended per meter width in silty clay loam soil was about 2 l/s **(Hassan 1998).** Therefore, the pumping unit discharge rate was adjusted to be as close as possible to the pumping discharge rate.

2.4. The system performance Evaluation

The experimental work covered the evaluation of the trailing perforated pipe irrigation system performance pumping unit discharge rate 172 m^3/h and pressure head inlet 75 cm.

From the actual experimentally measured flow rates from each orifice along with the trailing perforated pipe irrigation system (q_m), l/s and the actual orifice pressure head (h_m) along the trailing perforated pipe irrigation system measured by using piezometers.

2.5. The flow rate variation (qvar)

The flow variation along the gated pipe irrigation system was computed according to the following equation.

$$q_{var}(\%) = \frac{q_{max} - q_{min}}{q_{max}} \times 100 \quad ...\ [1]$$

where:

q_{var}: The gate flow variation, (%),
q_{max}: The maximum gate flow along the lateral line, (l/s), and
q_{min}: The minimum gate flow along the lateral line, (l/s).

2.6. Water uniformity distribution

The water uniformity distribution was computed as:

$$\text{Water uniformity distribution} = 100\% - q_{var}$$

2.7. Irrigation efficiencies

2.7.1. Water distribution efficiency (WDE)

Water distribution efficiency indicates the extent to which water is uniform distribution along the run. **(Israel Sen and Hansen 1962)** as defined it:

$$WDE = [1.0 - (\sum|Y_i - d|/(N \times D)] \quad ...\ [2]$$

where**:**

WDE: Water distribution efficiency, (%),
d: Average depth of water stored along the run during the irrigation,
$|Y_i - d|$: Average of absolute numerical deviation from d, and
N: Number of readings.

2.7.2. Water use efficiency (WUE)

The field water use Efficiency (kg/m^3) was measured to clarify the variations of crop production due to water amount m^3 of irrigation. Water use efficiency (WUE) values were calculated according to **(Jensen 1983)** as follows:

$$WUE\ (kg/m^3) = \frac{\text{Maize yield (kg/fed,)}}{\text{Applied irrigation water } (m^3/\text{fed,})} \quad ...\ [3]$$

3. Results and discussions

3.1. Trailing perforated pipe irrigation system performance Evaluation:

The flow variation through trailing perforated pipe irrigation system was about 9.5 %. Therefore, the water uniformity distribution along the 24 meters apart of the 8-inch trailing perforated pipe irrigation system was about 90.5 % as show in Fig. 2.

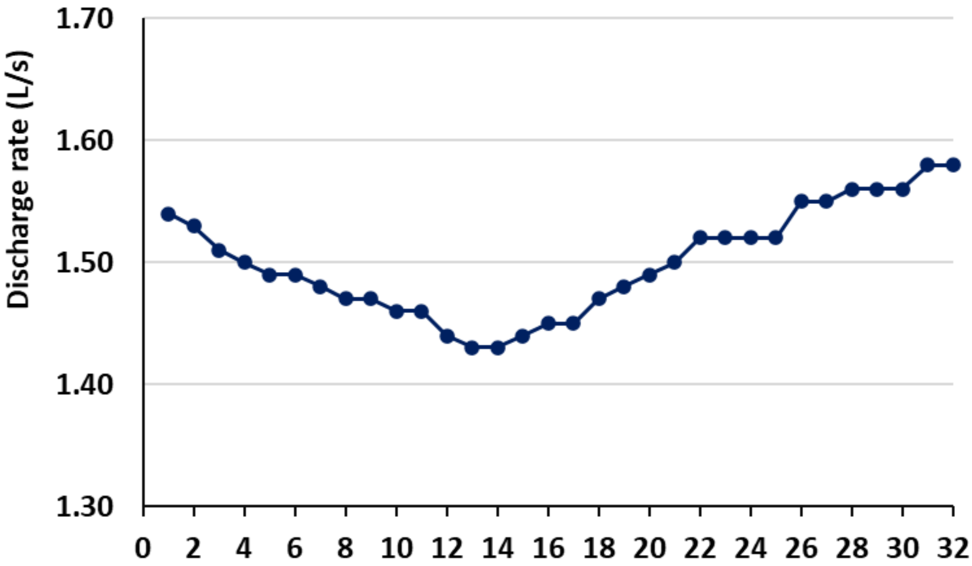

Fig.2. Trailing perforated pipe irrigation system performance evaluation.

3.2. Advance, recession, and opportunity times

The advance of water in surface irrigation plays an important role in the application of the soil land and the distribution of water in the soil root zone. The water advance and recession times were recorded at equal distance along each plot. The difference between recession and advance time at each station gives the infiltration opportunity time for each station. The average values of advance, recession and opportunity times using gated pipe irrigation system and trailing perforated pipes irrigation system under furrow lengths 100 m at lands slopes 0.1% were shown in Figs 3 and Fig. 4.

Fig. 3 showed that the average values of the water advance, recession and opportunity times for gated pipe irrigation system were 88, 268, and 180 minutes respectively.

Fig. 4 showed that the average values of the water Advance, recession and opportunity times for trailing perforated pipe irrigation system through replicates at 0.1% lands slopes and furrows lengths 100 m were 84, 264 and 180 minutes respectively.

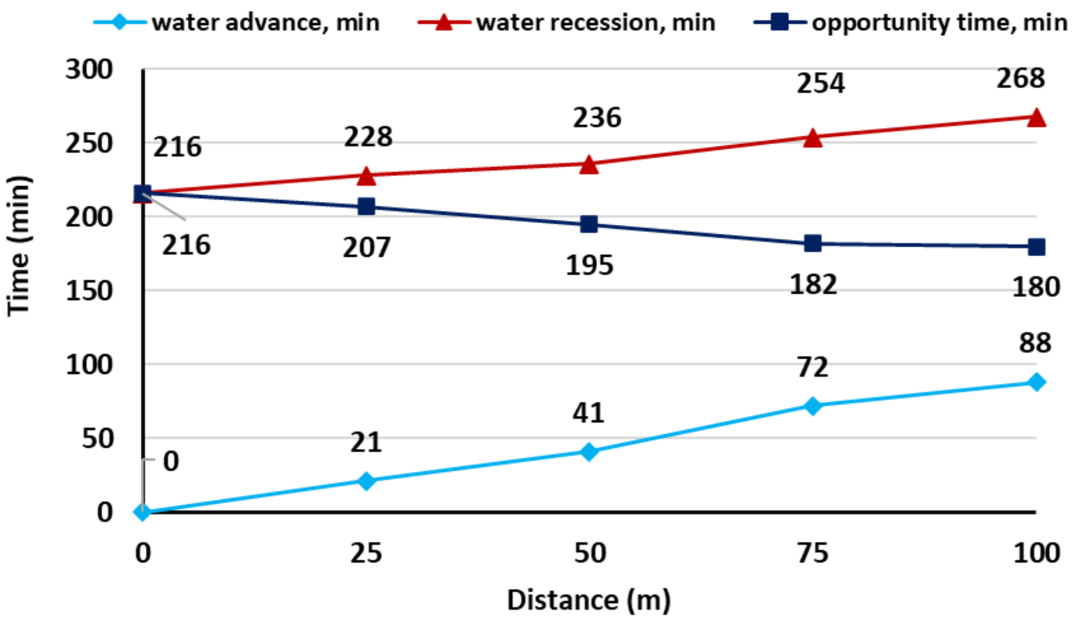

Fig.3. Advance, recession and opportunity times curves for the gated pipe irrigation system.

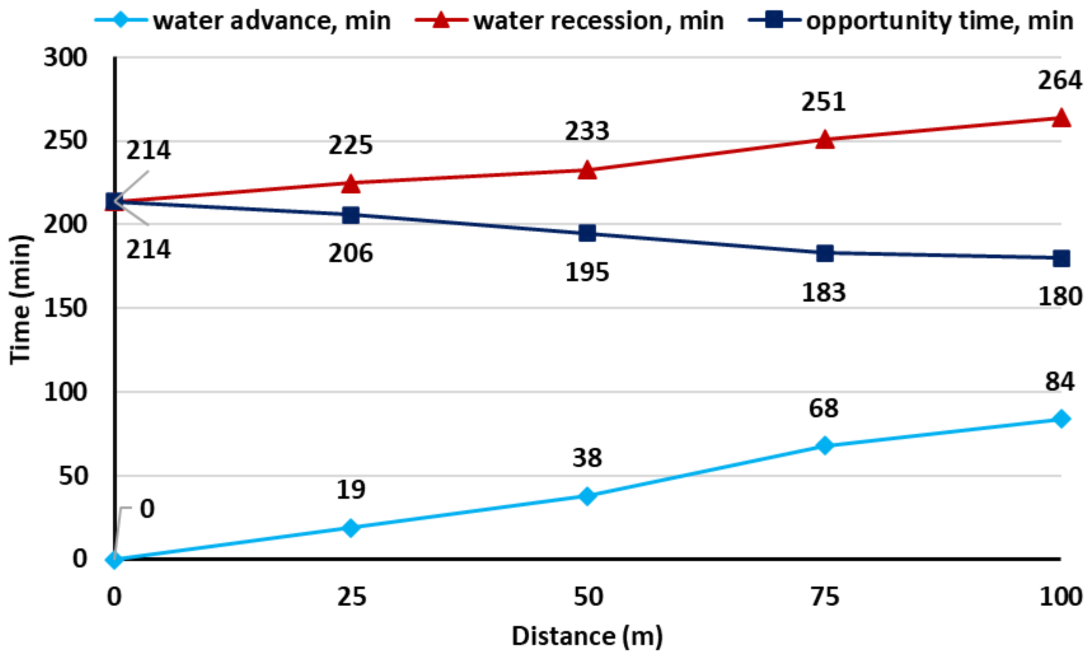

Fig. 4. Advance recession and opportunity times curves for the trailing perforated pipe irrigation system.

On the other hand, the average values of water advance time, water and recession time were increased in the case of gated pipes irrigation system compared with trailing perforated pipes irrigation system while both of them equal in opportunity time at 180 min due to the good irrigation water distribution by the trailing perforated pipe irrigation system.

The results showed that the average values of water advance time, water recession time, and opportunity time decreased as lands slope increased through each treatment using gated pipes irrigation system or trailing perforated pipe irrigation system under furrow length L100 m.

3.3. Water irrigation amounts

The maximum average values of the total water irrigation amount received by maize plants were achieved in the case of using a gated pipe irrigation system and, increased by 2.56% than the total water irrigation amount under gated pipe irrigation system as shown in Fig. 5.

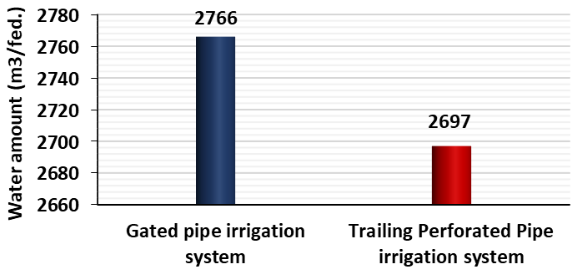

Fig.5. Water amounts.

3.4. Water distribution efficiency

The results showed that the average values of the water distribution efficiency were 97.2 for trailing perforated pipe irrigation system as shown in Fig. 6.

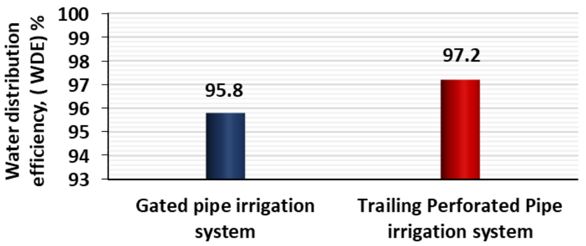

Fig. 6. Water distribution efficiency affected by irrigation system.

3.5. Maize crop production affected by irrigation system

The average values of maize crop production per feddan through gated pipe irrigation system comparing with trailing perforated pipe irrigation system were 3664 and 3695 kg/ feddan/season, respectively as shown in Fig. 7.

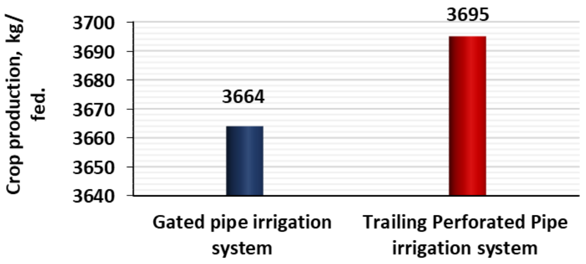

Fig. 7. Crop production

3.6. Water Use Efficiency

The average values of the maize water use efficiency through gated pipe irrigation system through replicates compared with trailing perforated pipe irrigation system were 1.32 and 1.37 kg/m^3 respectively as shown in Fig. 8.

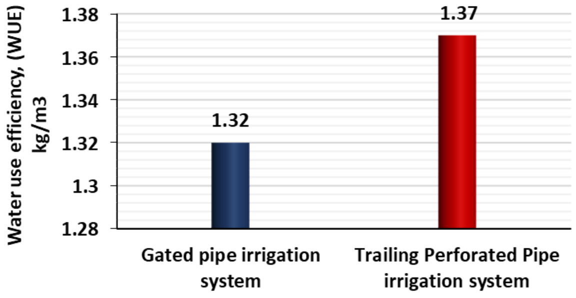

Fig. 8. Water use efficiency.

4. Conclusions

The results concluded that the trailing perforated pipe irrigation system technique is better than gated pipe for improving water irrigation efficiency and maize productivity.

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تأثير استخدام الأنابيب المثقبة ذات الخراطيم المتدلية على كفاءة الري لإنتاج الذرة

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الملخص العربي

تهدف الدراسة الحالية إلى تقييم تأثير الأنابيب المثقبة ذات الخراطيم المتدلية على كفاءة الري وإنتاجية محصول الذرة باستخدام مواسير بقطر خارجي ٢٠٠مم. تقع الفتحات على مسافات متساوية ٧٥ سم (نفس المسافة بين خطوط الزراعة). الفتحات دائرية الشكل بقطر ٢٥ مم ومثبت عليها خراطيم بلاستيكية بأطوال ٢ م.

وتُعد طريقة الري بالأنابيب المثقبة ذات الخراطيم المتدلية طريقة جديدة تعمل على تقليل النحر الحادث تحت الفتحات على طول خط الأنابيب، توجيه المياه الخارجة من الفتحات باتجاه الخطوط، يمكن استخدامها لجميع أنواع المحاصيل التي تُزرع على مسافات مختلفة بين الخطوط، كما تفيد في انتظامية توزيع المياه الخارجة من الفتحات. **وأوضحت النتائج ما يلي:**

- القيمة المتوسطة لزمن تقدم وانحسار والتلامس للمياه للأنابيب المبوبة والأنابيب المثقبة ذات الخراطيم المتدلية بتسوية بالليزر على منسوب ٠,١٪ واطوال خطوط ١٠٠م كانت ٨٨، ٢٦٨، ١٨٠ دقيقة و٨٤، ٢٦٤، ١٨٠ دقيقة على الترتيب.
- سجلت أعلى كمية من المياه المستخدمة بنظام الري بالأنابيب المبوبة وبلغت (٢٧٦٦ م^{٣} / فدان).
- بلغت كفاءة توزيع المياه ٩٥,٨٪ للأنابيب المبوبة و٩٧,٢٪ للأنابيب المثقبة ذات الخراطيم المتدلية.
- أعلى قيمة لإنتاجية المحصول ٣٦٩٥ كجم / فدان / سنة في حالة استخدام نظام الري بالأنابيب المثقبة ذات الخراطيم المتدلية.
- متوسط كفاءة استخدام المياه للذرة ازدادت في حالة استخدام نظام الري بالأنابيب المثقبة ذات الخراطيم المتدلية بلغت ١,٣٧ كجم / م^{٣} عن نظام الري بالأنابيب المبوبة والتي بلغت بمقدار ١,٣٢ كجم / م^{٣}.

واستُخلص من النتائج المُشار إليها سابقاً إلى أن تقنية نظام الري بالأنابيب المثقبة ذات الخراطيم المتدلية أفضل من الأنابيب المبوبة لتحسين كفاءات الري وإنتاجية الذرة.