EFFECT OF DISTANCE BETWEEN LINES OF DRIP IRRIGATION ON CORN YIELD IN SANDY SOILS

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Abstract

This study aims at determining the effect of drip lateral spaces and the full and deficit irrigation on corn yield, The water use efficiency under new land conditions during summer season of 2016 was evaluated. The experiment was conducted in privet farm (green revolution Km31Egypt-Alexandria road after the intelligent village). The farm has the latitude of 30°04'37.0N the longitude of 30°59'53.5E. Single hybrid (Giza /131) corn was used in this study. Irrigation treatments consisted of three different lateral spacing as (A: 0.60m, B: 1.20 m, and C: 1.80 m) and two water level (I_1=100%, I_2=70%) of water requirements.The study reveal that: The highest seasonal water use was determined in the full irrigation ($I_{1\ 100}$%), level (607 mm/season) , and the lowest water use was found in the deficit irrigation ($CI_{2\ 70}$ %), level (428 mm/ season). The hig.A.S.S[1]hest grain yield was obtained under (BI_{1100}%) treatment with (4912 kg / Fe), and the lowest yield was found in the plant row (1.80 m) away from the drip lateral in (C I_{270}%) treatment with (2504 kg /Fe. Yield from the 1.20 m) spacing with full irrigation treatment BI_{1100}% was significantly higher than in the other two spacing as (A=60cm, C=180cm). According to the research results, preferable lateral spacing for corn plant was found to be 1.20 m. The highest water use efficiency (WUE) was found in BI_{170}% (1.89 kg / m^3) and the lowest one was found in the plant row 90 cm away from the drip lateral in $CI_{2\ 70}$% (1.39 kg / m^3). Thus a lateral spacing of 120 cm (one drip lateral per two crop rows), flow rate 8 L/h/m, (dripper flow rat 4l/h. dripper spaced 0.50 m) was recommended for drip-irrigated corn under the Egyptian climatic conditions.

Keywords: Drip irrigation, Deficit irrigation, Preferable lateral spacing, Water use efficiency.

INTRODUCTION

Irrigation is today the primary consumer of fresh water on earth (Shiklomanov, 1998) but the increasing populations and expanding development are pushing our water resource management systems to be more productive with less water. Despite limited water resources in the world. Water management must be improved in order to fully solve it, or to reduce the severity of water shortage. Thus, agriculture has the greatest potential to solve the problem of global water scarcity. (Longo and Spears, 2003). Drip irrigation has been used for agricultural production for about the past 35 years. Drip irrigation has advantages over more traditional practices

such as surface and sprinkler irrigation due to reduced labor requirements and its ability to conform to irregularly shaped fields. It is also much more efficient than sprinkler or surface irrigation (Camp, 1998). The reasons for the growing popularity of drip irrigation are several. Drip irrigation offers improved yields, requires less water, decreases the cost of tillage, and reduces the amount of fertilizer and other chemicals to be applied to the crop. Because drip irrigation makes it possible to place water precisely where it is needed and to apply it with a high degree of uniformity at very low flow rates, it lessens both surface runoff and deep percolation. These features make drip irrigation potentially much more efficient than other irrigation methods, which can translate to significant water savings (Hanson *et al.*, 1994). Since the initial installation costs for drip irrigation are high, it has not been considered a viable economic option for field row crops, such as corn. However, increasing the spacing of dripline laterals would be one of the most significant factors in reducing the high overall investment costs of drip irrigation (Lamm *et al.*, 1997). (Liu *et al* 2018) at least 14% of more maize production could be achieved through drip-irrigation systems in Heilongjiang Province compared to rainfed conditions. Sub-humid region drip-irrigation is increasingly applied in maize production. It is important to quantify irrigation requirements during different growth stages under different climatic conditions. Lamm *et al.* (1997) carried out a 2-year study on a Keith silt loam soil in northwest Kansas to determine the optimum drip line lateral spacing for irrigated corn using subsurface drip lines installed at a depth of 40–45 cm in a direction parallel to the corn rows. Average corn yields were 13.6, 12.8, and 12.2 Mg /ha for drip line spacing of 1.5, 2.3, and 3.0 m, respectively for a seasonal-irrigation amount of 462 mm. Yields decreased to 10.8 and 9.3 Mg/ ha when irrigation was reduced by 33 and 50% for the wider 2.3 and 3.0 m drip line spacings, respectively. The highest yield, highest water use efficiency, and lowest year-to-year variation was obtained by the 1.5 m dripline spacing. Spurgeon and Manges (1991) reported no significant differences in corn yields among spacing treatments ranging from 0.75 to 3.0m in a wet season (1989) at Garden City, Kansas. However, there was a 1.3–3.8 Mg/ ha range in yields 1990 and 1991, respectively (Spurgeon and Makens, 1991). The drip lines in this study were perpendicular to the corn rows. As a result, a corn plant could be as much as 1.5m from a drip line for the 3.0m dripline spacing. (Sefer *et al.*, 2011).Found that the average corn grain yields varied from 1.93 to 10.4 t /ha and the highest water use efficiency (1.77 kg /m^3). Hussein and Dewidar (2018) shown that the adoption of modern irrigation systems combined with deficit irrigation strategies can improve both the irrigation water use efficiency and quality of tomato fruits. Kruse and Israeli (1987) examined subsurface drip irrigation using a 1.5 m dripline spacing for corn

production in Colorado. They found considerable yield variation with distance from the dripline, and they concluded that it was important to center drip lines between corn rows to assure good production. Corn is one of the most important crops in Egypt. Common irrigation methods used for corn production in this region are wild flooding, furrow and sprinkler irrigation. In general, the farmers over irrigate, resulting in high water losses and low irrigation efficiencies, thus creating drainage and salinity problems (Yazar *et al.*, 2002). The objectives of this study were to determine the effects of different lateral spacings and the full and deficit irrigation on yield and water use efficiency and reduce the cost of drip irrigation network materials of corn under sandy soil conditions. El-Hendawy and Schmidhalter, (2010). said that, the water application rates needed to achieve maximum yield and IWUE under limited water applications require the establishment of optimal soil water contents around the emitters without moving the water beyond the active rooting zone or failing to meet the water requirement of the plant. In addition, maize yields under drip irrigation are generally a linear function of the seasonal ET and yields are usually lower if ET is less than optimal. For example, El-Hendawy *et al.* (2008) found that the decreases in the grain yield of maize drip irrigated for 0.80 and 0.60 ET com-pared to 1.00 ET were approximately 18.0 and 60.0%, respectively. This also indicated that applying water below the full crop-water requirement under the drip irrigation system requires further approaches to mitigate the adverse effects of this water deficit. A potential approach to reduce water deficit-induced crop losses is the exogenous application of osmolytes that do not interfere with enzymatic functions. Kresović *et al.*, 2016. Therefore, reducing irrigation level and improving water use efficiency are critically important to sustainable agriculture. Water-saving irrigation measures can influence crop growth, yield, and WUE. Many techniques have been suggested for improving the yield, WUE and economic return of maize. Some scholars have discussed various water-saving irrigation technologies for reducing agricultural water use. Karasu *et al.*, 2015. Told that, irrigation regimes affect evapotranspiration and maize grain yield. Some studies have suggested that maize yield is a linear function of seasonal evapotranspiration . Liu, *et al*. 2017 show that by simulated the sensitivity of maize to water at varied stages and the simulation results indicated that the descending order was pollen shedding and silking, tasse lling, jointing, initial grain filling, germination, middle grain filling, late grain filling, and end of grain filling Wang *et al*. 2014,remmber that Inrecent years, drip irrigation has widely been applied to maize production in sub-humid regions like North China Plain Chen *et al.*, 2015 show that Drip irrigation, whereby water is frequently applied to a small area near growing plants, generally

results in strong crop development while limiting soil evaporation and percolation depth Lifeng Z *et al*. 2018 said that, the effect of lateral spacing on yield and WUE were influenced by irrigation amounts. Under high irrigation amounts (i.e. 550–700 mm), grain yield and WUE first increased and then decreased as the lateral spacing increased, which showed a higher yield and under lateral spacing of 1.5 m than that of under 0.7 m and 2.1 m. Under low irrigation amounts (i.e. 300 mm), grain yield and WUE were decreased as the lateral spacing increased. Layout and spacing of drip irrigation laterals has been shown to influence the distribution of soil water content and nitrate, yield formation, and net profits in dripped irrigation systems. Closer lateral spacing usually gives a greater horizontal water content distribution uniformity, crop yield, and water use efficiency (WUE) Chen *et al.*, 2015.

The aim of this study is to determined the effect of drip lateral spaces and the full, and deficit irrigation on corn yield.

MATERIALS AND METHODS

Experimental Layout

The experiment was conducted in privet farm (green revolution Km31Egypt-Alexandria road. The farm has the latitude of 30°04'37.0N the longitude of 30°59'53.5E. Some physical and chemical properties of the soil given in Table (1). The soil of the experimental site is sand. soil pH values ranged from 6.62 to 6.78, soil water tension at the field capacity (0.1 bar) and at wilting point (15 bar), respectively. Mean bulk density varies from 1.4 to 1.6 g / cm^3.

The drip irrigation system consisted of a control unit and distribution lines Fig (1). The control unit of the system contained a disk filter, control valves, pressure gauges and a water flow meter. Distribution lines consisted of polyethylene pipe manifolds for each plot. Drip laterals of 16 mm in diameter had in-line emitters spaced 0.50 m apart, each delivering (4 L/ h) at the pressure of 1 Bar. Each manifold had removable end caps for flushing. The experimental design in three replications.

Irrigation management treatments consist of three different lateral spacings (A: 0.60 m, B: 1.20 m, C: 1.80 m) and two water level ($I_{1\ 100}$ %, $I_{2\ 70}$ %). In A, one drip lateral was laid out at the center of two subsequent crop rows; in B, one lateral at the center of alternative rows; and in C, one drip lateral served three crop rows Fig(1). For deficit irrigation treatment I_{70} 30% less water was applied as compared to I_{100} treatment plots. The plot dimensions were 60m by 70m. A layout of the experimental plots is shown in Fig (1). Plant and soil water measurements and observations were started 18 days after planting, and were terminated on the harvest date. Commercial farm equipment was used for agronomic practices. The experimental field was planted

with a four-row planting machine at 60 cm row spacing. Single hybrid (Giza /131) corn was used in this study planted on 2 June 2016.
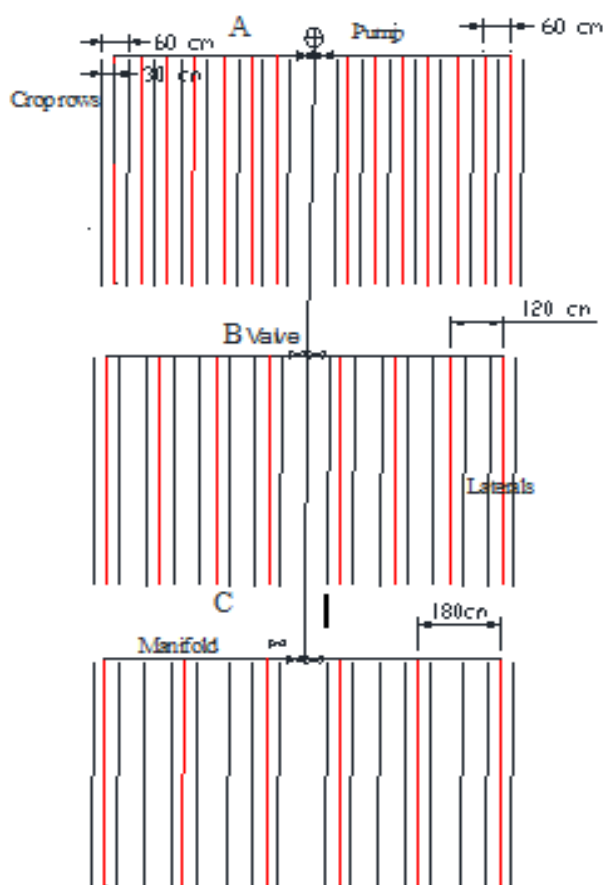

Fig. 1. Experimental Layout

Table1. Physical and Chemical properties of different soil layers of the experimental field.

Soil depth	Sand %	Silt %	Clay %	F.C %	W.P %	Ece Ds/m	PH	Cations				Anions		
								Ca^{++}	Mg^{++}	Na^+	K^+	Hco^-_3	$So4^{-2}$	CL^-
0-30	58	12	12	40	1.19	1.13	6.68	1.62	0.53	0.63	0.10	1.79	0.4	0.62
30-60	55	19	26	40	1.16	0.17	6.62	1.79	0.74	0.70	0.07	1.5	1.17	0.59
60-90	28	18	54	41	1.15	0.11	6.78	2.71	0.85	0.74	0.05	1.53	1.93	0.69

Crop water requirement·s parameters

Table 2 showing the following value .

Table 2. Crop Water Requirements (CWR), Irrigation Crop Water requirements (ICWR), References Evapotreanspiration(ET_O), Evapotreanspiration(ET_C) and Crop factor(K_C)

Month	ET_o mm/day	K_c	ET_c mm/day	CWR (m^3/fed./day)		ICWR (m^3/fed./day)	
				100%	70%	100%	70%
June	6.5	0.55	3.6	15	10.5	16.8	11.76
July	5.1	0.95	4.8	20.3	14.21	22.4	15.68
August	4.4	1.1	4.8	20.1	14.07	22.4	15.68
September	4.7	1.0	4.7	19.7	13.79	22.0	15.33

Reference evapotranspiration (ET0, mm/day) was calculated according to the Penman-Monteith (PM) equation as specified by the FAO protocol (Allen *et al*., 1998) for irrigation scheduling.

As crop evapotranspiration ETc can be calculated as:

$$ETc = Kc \times ET_0$$

Where:-

ETc = Crop evapotranspiration (mm/day),

Kc = Crop coefficient ranged,

ET_0 = Reference crop evapotranspiration (mm/day).

In turn the Grass water requirement (GWR), is calculated by multiplying the reference crop evapotranspiration, ET_0, by a crop coefficient, Kc following (Allen *et al*., 1998).

CWR= ETc×4.2

ICWR=CWR×LR

**LR= Leaching Requirements (Assumed 12%of total applied water)

Calculating water use efficiency (WUE): Water use efficiency WUE) was computed as the ratio of corn grain yield to seasonal water use (Howell *et al*., 1995).

$$(\mathbf{WUE})Kg/m3 = \frac{Yield\,(Kg)}{Water\,use\,(m3)} \times 100$$

Fertlization: Fertilizer applications were based on soil analysis results and all the plots received the same amount of fertilizer. total 150 Kg/Fed. of Super phosphate 150 Kg/unit area of Potassium Sulfate 150 Kg of Ammonium Sulfate , which was applied in banding along the rows and then incorporated into the soil.

Dripper Evaluation

Table (3) and Fig (2): showing the dripper evaluation (bilt in drip)

Table 3. showing the Dripper Evaluation

Dripper	X ponent	CV%	EU	Classification according to ASABE		
			%	X ponent	C.V%	EU%
GR	0.50	1.49	93	Turbulent	excellent	excellent

CV : Manufacturers coefficient of emitter variation

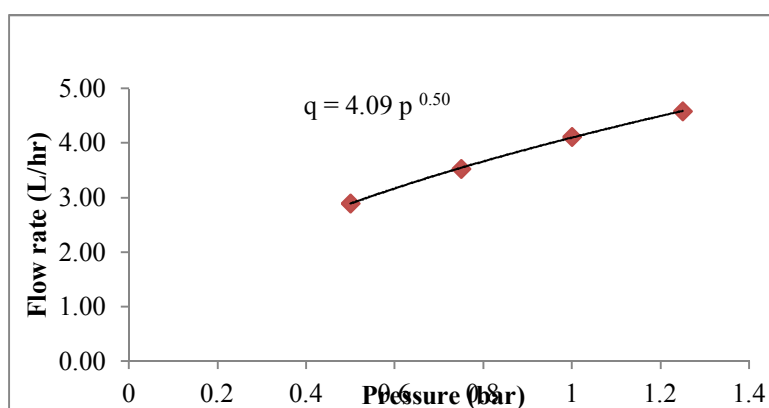EU : the emission uniformity %.

Fig. 2. Flow rate (q) with pressure for GR drippers (4 L/h) performance curve.

RESULTS AND DISCUSSION

Table (4) and Fig (3,4,5): showing the following: Dry matter yield, Corn grain yield, Water use, Water use efficiency (WUE) also, show that the highest grain yield was observed in B $I_{1\ 100}$% treatment as 4916 kg/ fed and the lowest yields was found in the plant row 0.90 m away from the drip lateral in C $I_{2\ 70}$ % treatment as 2504 kg/ fed. These results indicate that, the preferable lateral spacing for corn plant was found to be 1.2 m. The yield from the wider (C= 1.80 m) dripline spacing with full irrigation C $I_{1\ 100}$ % (3738 Kg/Fed) was lower, than the yield from the propose dripline spacing B $I_{1\ 100}$% (4916 Kg/Fed) 1.2 m by 23.9 %, while closer dripline spacing (60 cm) with full irrigation (A $I_{1\ 100}$%) 3612 Kg /Fed, reduced the yield by 26.5 % as compared to yield from the superior spacing(1.2 m) . The yield was reduced when the irrigation levels was reduced. Also the data revealed that the grain yield from the corn rows adjacent to the drip lateral (60 cm) in full irrigation A $I_{1\ 100}$% (3612 Kg/Fed) treatment plots were higher than the deficit irrigation plots A $I_{1\ 70}$ % (3192 Kg/Fed).Also the grain yield a way from the drip line 180 cm C$I_{2\ 70}$% (2504 Kg/Fe) were lower than the yields from corn rows adjacent to the lateral in the deficit irrigation plots A$I_{2\ 70}$% (3192 Kg/Fe) this can be attributed to in the deficit irrigation treatment plots (I_{70}), degree of the water stress gradually increased towards the end of the growing season and resulted in reduced crop yields.

This result indicated that one lateral per three rows is not suitable for corn production under the study conditions since insufficient irrigation water is supplied to crops 0.90 m away from the drip lateral, the lateral spacing of 1.20m resulted in higher grain yields than the other two spacings (0.60 and 1.80 m). These findings is agree with Yazar *et al*. (2002), reported that the highest average corn grain yield obtained in the full irrigation treatment using trickle irrigation method was 11,920 kg/ha.

Total dry matter varied from 9324 to 13188 kg/ Fed , the highest dry matter was observed in $A1_{I\ 100}$% (13188 kg /Fed) and the lowest in $C_{2\ 70}$%(9324 kg/ Fed). The dry matter production under the full irrigation was higher than that under the deficit irrigation treatment. The highest dry matter production was observed in the treatment of one lateral per corn row, this can be attributed to the wetter soil water conditions, which enhanced the vegetative development. Also, Fig (3): show that treatment $CI_{2\ 70}$% was the lowest in receiving irrigation water use 1796 m^3/Fed/ seasonal (428 mm/ seasonal) in deficit irrigation in compare with the other (A $I_{1\ 100}$%) 2551 m^3/Fed/ seasonal (607 mm/ seasonal) in non- stress plot (full irrigation).

Table 4. Dry matter yield, Corn grain yield, Water use, Water use efficiency (WUE).

Treatment	Period month	water use m^3/Fed	ET_c	Water use month m3	Operation time min	Corn grin Kg/Fed	Dray mater Kg/Fed	Water use seasonal m3	Water use seasonal mm	W.U.E Kg/m3
$AI_{1\ 100}$ %	June	16.8	15	504	18	3612	13188	2551	607	1.41
	July	22.4	20.3	694.4	24					
	August	22.4	20.1	694.4	24					
	September	22	19.7	658	24					
$AI_{2\ 70}$%	June	11.8	15	352.8	13	3192	11424	1796	428	1.77
	July	15.7	20.3	491.7	17					
	August	15.7	20.1	491.7	17					
	September	15.3	19.7	460	17					
$BI_{1\ 100}$ %	June	16.8	15	504	36	4916	11130	2551	607	1.92
	July	22.4	20.3	694.4	48					
	August	22.4	20.1	694.4	48					
	September	22	19.7	658	47					
$BI_{2\ 70}$ %	June	11.8	15	352.8	25	3360	11422	1796	428	1.87
	July	15.7	20.3	491.7	34					
	August	15.7	20.1	491.7	34					
	September	15.3	19.7	460	33					
$CI_{1\ 100}$%	June	16.8	15	504	55	3738	10248	2551	607	1.46
	July	22.4	20.3	694.4	74					
	August	22.4	20.1	694.4	74					
	September	22	19.7	658	73					
$CI_{2\ 70}$%	June	11.8	15	352.8	38	2502	9324	1796	428	1.39
	July	15.7	20.3	491.7	52					
	August	15.7	20.1	491.7	52					
	September	15.3	19.7	460	51					

Water use in the rows next to the lateral in the treatment C $I_{2\ 70}$ was higher than the water use at distant rows (0.90 m from the lateral). This result indicated that

one lateral per three rows is not suitable for corn production under the study conditions since insufficient irrigation water is supplied to crops 0.90 m away from the drip lateral.

Fig. 3. Corn grin Kg/Fed Via Tretment
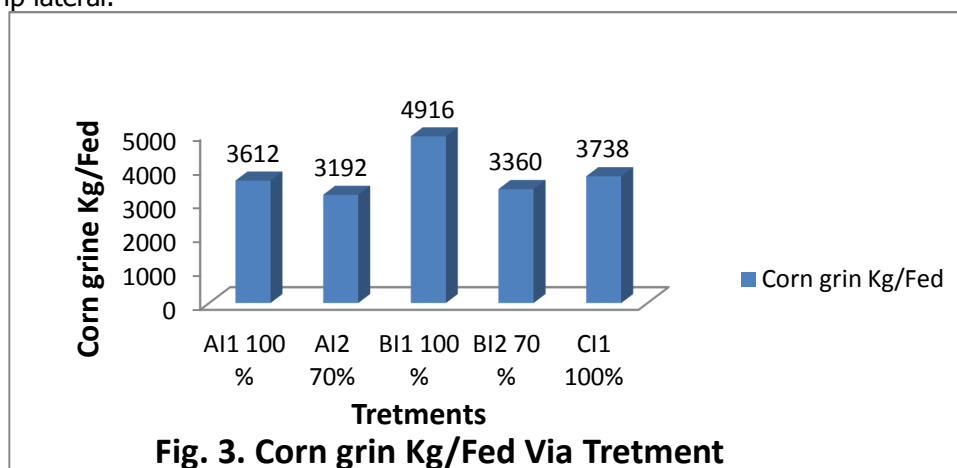
The date in Fig. 4 :showing that the highest water use efficiency (WUE), 1.87 kg/m^3, was obtained in treatment B $I_{2\ 70}$ %while the lowest one was found in treatment C $I_{2\ 70}$ % (1.39 kg/m^3). In general, WUE values decreased with increasing water use.

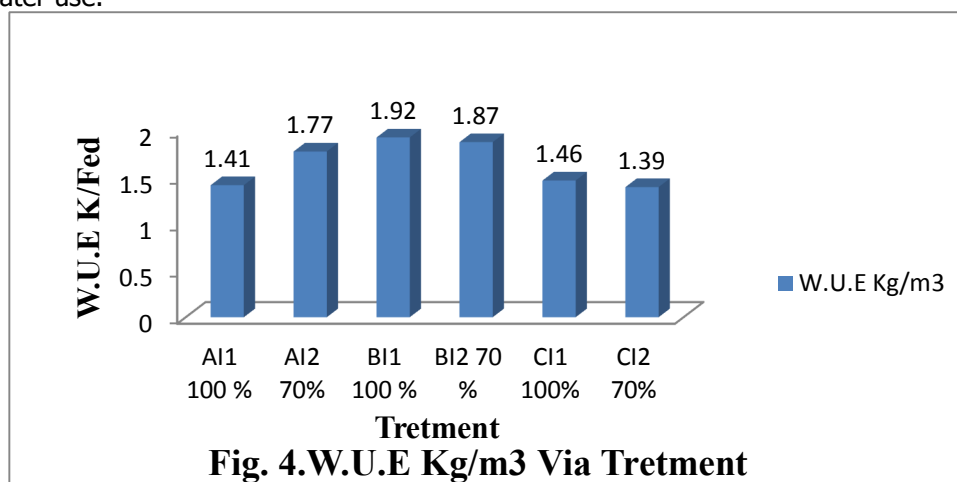**Fig. 4.W.U.E Kg/m3 Via Tretment**

Fig. 5 shows the relationship between operating hours and treatments. From the figure it is be observed that the operating hours of treatments C $I_{1\ 100}$% and $CI_{2\ 70}$ % were higher than the rest of the treatments (A $I_{1\ 100}$%, A $I_{1\ 70}$%, B $I_{1\ 100}$% and B $I_{1\ 70}$%) in order to reach the actual water needs of the plant. On the margin of research the highest grain yield per cob was observed in $B_{1\ 100}$ at 184.8 g, and the lowest was found in $C_{2\ 70}$ at 143.1 g. The highest grain number per cob was observed in $B_{1\ 100}$ (482), and the lowest was found in $C_{2\ 70}$ (501). The research indicated that the grain

yield per cob and grain number per cob was found to be relatively higher in full irrigation treatments as compared to the deficit irrigation cases.

Fig. 5. Operation time min Via Tretment
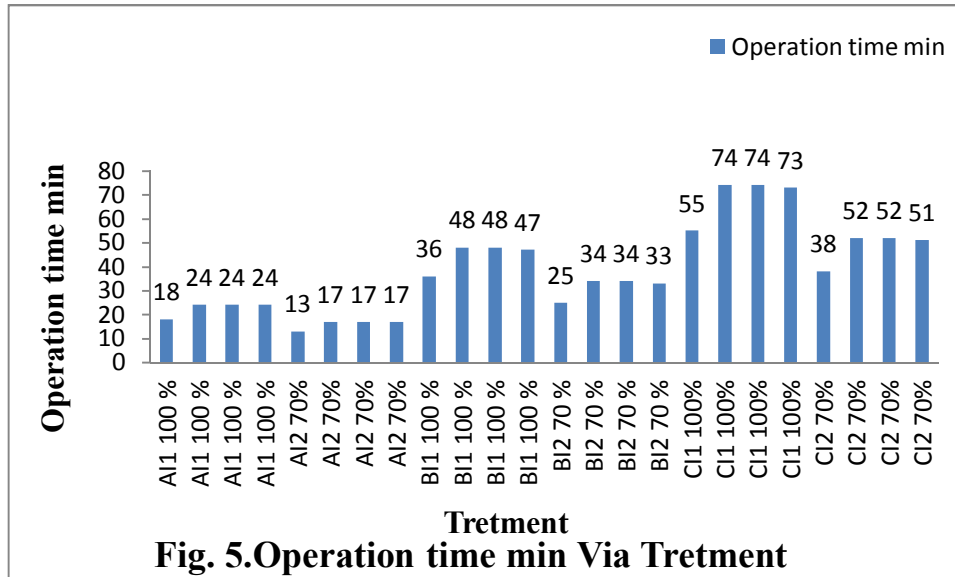
CONCLUSION

This study was carried out to evaluate the effects of full and deficit irrigation and different lateral spacing on yield and yield components of corn. According to results, preferable lateral spacing for corn plant was found to be 1.20 m, which produced the maximum yield of 4912 kg / Fed. In other words, flow rate 8 L/h/m, one drip lateral laid out at the center of two crop rows is recommended for the corn producers in the region. Grain yields away from the drip line (o.90 m) were lower than the yields from corn rows adjacent to the lateral both in the full and deficit irrigation plots. Non-uniformity of grain yield increased with deficit irrigation in the wider lateral spacing. Considering that the cost of the pipes (all tubing and laterals included) is about 40% of the total cost, one drip lateral per two crop rows would result in considerable saving in total installation cost of a drip system. The research results also revealed that a lateral spacing of 1.80 m (one lateral per three corn rows) is not suitable for the drip irrigated corn production under the Egyptian climatic conditions.

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تاثير المسافة بين خطوط الرى بالتنقيط
على محصول الذرة فى الاراضى الرملية

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معهد بحوث الهندسة الزراعية _ مركز البحوث الزراعية _ دقي _ جيزة _ مصر

هذه الدراسة تم تنفيذها لتقدير تاثير المسافة بين خطوط الرى بالتنقيط على محصول الذرة فى الاراضى الرملية فى حالة الرى الكامل والناقص على الانتاجية وكفاءة إستخدام المياة وتقليل تكاليف خامات شبكة الرى بالتنقيط عام 2016. تمت التجربة فى مزرعة خاصة 5Eُ --30°04'37.0N 30°59'53.   (مزرعة الثورة الخضراء الكيلو 32 طريق مصر أسكندرية الصحراوى). على صنف ذرة هجين فردي 131.

وكان تخطيط التجربة علي النحو التالي : ثلاث مسافات بين خطوط التنقيط (A=60، 120 ،B=180،C=180 سنتيمتر) وكميات مياة I_1=100%، I_2=70% من الاحتياجات المائية والرى يوميا. أظهرت الدراسة أن أعلى أستخدام للمياة فى الموسم تحقق من المعاملة (AI_{1100}%) وقدرت ب 607mm وأقل كمية كانت مع المعاملة (CI_{270}%) وقدرت ب428   mm.

اما بالنسبة لتاثير المسافة بين خطوط المنقطات أظهرت عن إختلافات فى الانتاجية إلى حد كبير وقدرت أعلى إنتاجية (4916 كجم /فدان) للمعاملة BI_{1100}% (120 cm مسافة بين خطوط المنقطات) وأقل إنتاجية (2604 كجم / فدان) للمعاملة CI_{270}% (180 cm مسافة بين خطوط المنقطات).

و كانت اعلي انتاجية مع الرى الكامل (BI_{1100}%) مع مسافة بين خطوط المنقطات 120 cm و يليها A60cm ، C180 cm .

و لذلك تبين ان انسب مسافة بين خطوط المنقطات لمحصول الذرة 120 cm .وان أعلى كفاءة لاستخدام المياة هي 1.77 كجم/ m^3 كانت للمعاملة BI_{270}% . وأقل كفاءة لاستخدام المياة 1.39 كجم m^3/ للمعاملة AI_{1100}% . وعلية فإن المسافة بين خطوط المنقطات 120 cm (خط تنقيط بين صفين زراعة للذرة) مع تصرف 8/للمتر الطولى /ساعة (50 سنتيمتر بين النقاطات وتصرف نقاط 4 لتر / ساعة) يوصى بها لاستخدام الرى بالتنقيط لمحصول الذرة فى الاراضى الرملية تحت الظروف المصرية.