PERFORMANCE EVALUATION OF LOW-HEAD MICROIRRIGATION SYSTEMS IN MAIZE FIELDS

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ABSTRACT

The effect of the emitter type and lateral length of low-head microirrigation systems in maize fields were determined on discharge uniformity, water use efficiency (WUE) and cost analyses. Five different emitters (manufactured on-line 'Em_1, Em_2; Em_3', in-line 'Em_4' and microtube 'Em_5') were evaluated with different lateral lengths (15, 20, 25 and 30 m) at operating pressure of 50 kPa. The results indicated that the coefficient of uniformity (CU) decreased with increasing lateral length. The WUE as well as return of water unit (RWU) increased by increasing the uniformity. Em_4 was the highest values of yield consequently WUE and RWU, but Em_5 was the highest net seasonal income (NSI) and BC ratio, due to it has a lowest total cost. The cost analysis take into account the effect of inflation rate (Inf.) increasing by 5 or 10%. NSI and RWU were increased by the same ratio of Inf. increasing, but BC ratio remain in the same values.

Keywords: *Low-head, Microirrigation, Uniformity, Water use efficiency, Cost analyses.*

INTRODUCTION

The main goal of the irrigation process is to achieve optimal agricultural production and maximum economic return **(Merriam and Keller, 1978)**. Among all irrigation methods, microirrigation is a very efficient method of applying water and nutrients to crops. Microirrigation has a slow rate of water application at discrete locations with operating pressure about 10 m **(Ngigi, 2008)**. The success of microirrigation is possible if the system is correctly designed with filtration unit. In general, the variable costs are related to the amount of water pumped. The fixed costs will occur regardless of amount of water used and will generally be the depreciation and interest costs based upon the amount of investment **(Charles *et al.*, 1999)**.

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Uniformity is an important parameter in the design and evaluating of microirrigation systems (**Li *et al.*, 2012**). In Egypt, the new reclaimed areas must be use modern irrigation systems; since the traditional surface irrigation has low water use efficiency (**Ragab and Prudhomme, 2002**). Most of the Egyptian farmers who are living in the new reclaimed areas are small holder and facing poverty. Low head microirrigation systems (less than 10 m) with short lateral lengths were recently introduced depending on unfiltered water (**Ngigi, 2008**). This system is greatly affected by pressure distribution inside a lateral or manifold as a result of the friction and pipe laying slope.

Maize (*Zea mays L.*) is considered one of the most important cereal crops in Egypt after wheat and rice. The cultivated maize area reached about 1.99 million feddans yearly with productivity about 6.84 million ton of grains **(FAO, 2014)**. Therefore, microirrigation systems could be suggested for maize cultivation, the crop always planted in the overlap of wetting pattern zones. The wetting volume is affected by some factors, including emitter discharge rate, water application, emitter spacing and various soil texture **(Shan *et al.*, 2011). El-Sayed *et al.* (1994)** studied two drip irrigation regimes under conditions of old lands in Egypt. The first regime is one lateral per one row of maize while the second regime is one lateral per two rows of maize. They found that the first irrigation regime is more efficient and reliable, in the soil profile compared to the second one, where the obtained grain yield was 4220 and 2980 kg/fed with water use efficiency of 1.20 and 0.90 kg/m^3 for the first and second irrigation regimes, respectively.

The main objective of this work was to determine the effect of different emitters and lateral lengths on discharge uniformity, water use efficiency and economic feasibility of the low-head microirrigation systems in maize field.

MATERIALS AND METHODS

Laboratory Experiment

The experimental work of the present study was conducted at the Hydraulic Laboratory and the Farm of Faculty of Agriculture, Suez Canal University, Ismailia. The laboratory hydraulic experiment of subunit was carried out to determine the highest discharge uniformity and the optimum length of lateral. Five emitters were tested in these subunits with four lateral lengths (15, 20, 25 and 30 m) and operating pressure of 50 kPa.

Under different operating pressure heads h_i (m), the emitter flow rate q (ℓ/h) and the coefficient of variation (C_v) of every emitter tested in this study were estimated and classified as unacceptable (> 0.15), poor (0.11 to 0.15), marginal (0.07 to 0.11), average (0.05 to 0.07), excellent (< 0.05) according to the following two equations emphasized by **ASABE EP 405.1 (2008)**:

$$q = k\, h_i^{\,x} \tag{1}$$

$$C_v = \frac{S}{\overline{X}} \tag{2}$$

where, k is a dimensionless constant of proportionality that characterizes each emitter, x is a dimensionless emitter discharge exponent that is characterized by the flow regime and $\overline{X}$; S are the mean discharge and standard deviation of emitters.

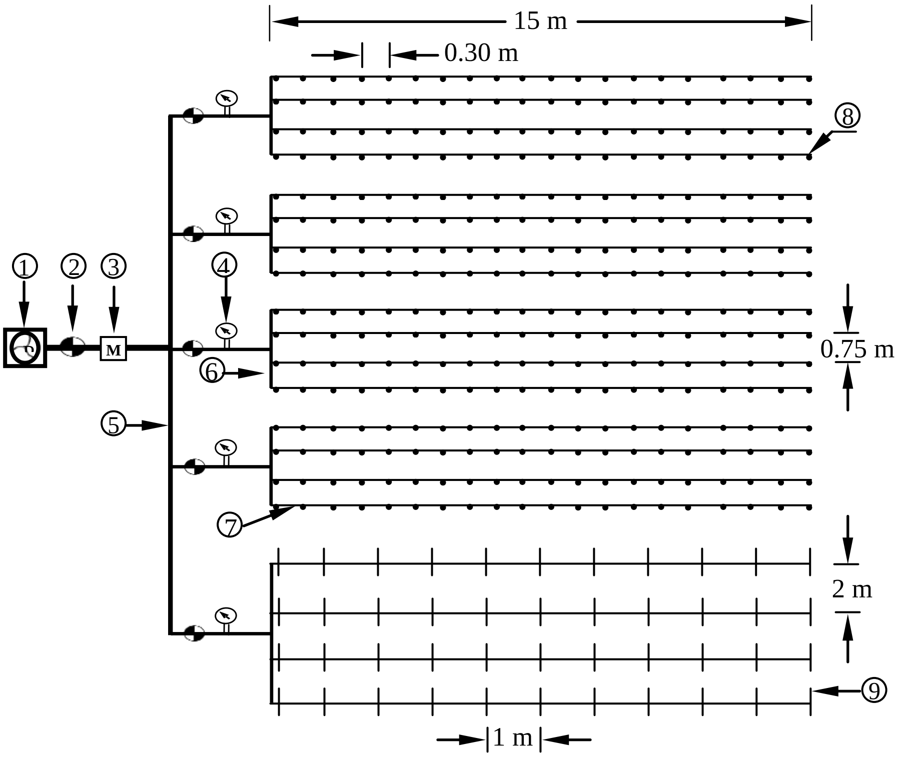
Because, the coefficient of uniformity (CU) is a better way of expressing the variation in discharge along lateral lines, it was classified as below 60 %, from 60 to 70 %, 70 to from 80 %, from 80 to 90 %; above 90 % is referred to as low, poor, fair, good; excellent uniformity, respectively, and calculated using the following equation **(Christiansen, 1942 and ASAE EP 458.0, 1999)**:

$$CU = 100\left(1 - \frac{\sum_{i=1}^{i=n} \left|q_i - \overline{q}\right|}{n\,\overline{q}}\right) \tag{3}$$

where, $\sum_{i=1}^{i=n} \left|q_i - \overline{q}\right|$ is the summation of absolute values of deviation from the means of emitter discharge, q_i is the individual discharge of each emitter (ℓ/h), $\overline{q}$ is the mean of emitter discharge (ℓ/h) and n is the number of collectors measured. Combined analysis of variance (ANOVA) was estimated using CoStat software version 6.311 according to **Steel and Torrie (1984).** The significance of differences was determined among the examined emitters with different lateral length.

Field Experiment

Studying the effect of different emitters on maize yield and water use efficiency will help in estimating the water saving as well as cost analysis. The field experimental work was conducted under Egyptian conditions at the Research Farm of Faculty of Agriculture, Suez Canal University, Ismailia, Egypt. As shown in Figure (1), the setup of field experiment consists of water source from Ismailia canal (branched from Nile River), pump unit of the farm, main line with outer diameter (*OD*) of 75 mm, submain line having 63 mm out diameter, manifold lines with 50 mm branched from the submain, control valves, flow meter, pressure gauge (0 - 250 kPa) with scale accuracy of 10 kPa distributed through the submain unit to control the flow and pressure. Lateral lines made from polyethylene (*PE*) with internal diameter (*ID*) of 13.6 mm were



1- Water pump 2- Valve 3- Water meter 4- Pressure gauge 5- Submain line
6- Manifold line 7- Lateral line 8- Emitter 9 - Microtube

Figure (1): Schematic diagram of the field experiment.

connected with manifold line. Five emitters from the local market were tested under constant pressure of 50 kPa with lateral length of 15 m. As shown in Table (1), the tested emitters were divided into three categories: on-line manufactured (Em_1, Em_2, Em_3) where Em_1 and Em_2 were global manufacturer but Em_3 was local manufacturer, in-line manufactured (Em_4) and microtube (Em_5). The internal distance between laterals was 75 cm with emitter spacing of 30 cm. Microtube (Em_5) has a length of 50 cm and 3.80 mm (*ID*) at a spacing of 100 cm distributed by head to head system on the laterals which designed at internal distance of 200 cm.

Table (1): Emitter types symbols and nominal discharge at 100 kPa.

Emitter types (trademark)	Symbol	Nominal discharge "ℓ/h"
Eden	Em_1	4.0 ℓ/h
Euro-key	Em_2	4.0 ℓ/h
Metallic	Em_3	4.0 ℓ/h
GR*	Em_4	4.0 ℓ/h
Microtube (3.80 mm *ID*)	Em_5	Unknown

*In-line emitter device

The irrigations system was installed in the maize field located at 13 m elevation above sea level, Latitude angle of 30° 58′ N and Longitude angle of 32° 23′ E. The maize crop (*Zea mays L.*) was a yellow variety of Three Way Cross 352 (*T.W.C. 352*) planted on 1st May to 28th August during the summer season of 2012. This crop was cultivated in a sandy soil with about 25 - 30 cm distances between plants. Full water requirements and recommendation of Egyptian Agriculture Ministry for cultivation and fertilization practices were applied. Soil samples were collected to determine some physical and chemical characteristics of soil depths from 0 to 60 cm at root depth according to **Black (1969).** The analysis showed that at this depth the soil is considered to be homogeneous layer (Table (2)).

Water Saving

The daily evapotranspiration (ET_c) through agriculture season was calculated using CROPWAT software version 8.0 based on Penman-Monteith equation which recommended by FAO **(Allen *et al.*, 2011).** Application efficiency as 85 % was constant for this study.

Table (2): Some physical characteristics of the experimental field.

Depth (cm)	Particle size distribution				Texture Class	Soil moisture content			DBD g/cm^3
	Sand (%)		Silt (%)	Clay (%)		FC (%)	PWP (%)	AW (%)	
	Coarse	Fine							
0 - 30	80.1	15.1	1.8	3.0	Sandy	9.10	1.79	7.31	1.63
30 - 60	80.3	15.2	1.7	2.8	Sandy	9.00	1.80	7.20	1.61

FC: Field capacity (- 0.1 atm), *PWP*: Permanent wilting point (- 15 atm), *AW*: Available water, *DBD*: Dry bulk density.

The irrigation interval can be determined by identifying the maximum water that can be stored in the soil and the consumptive use of crops as follows (**Keller and Karmeli, 1974; Keller and Bliesner, 1990**).

$$D_n = \frac{FC - PWP}{100} \times p \times Z_r \times DBD \tag{4}$$

where, D_n is the maximum net depth of each irrigation application (mm), *FC* is field capacity (%), *PWP* is permanent wilting point (%), *p* is fraction of available moisture depletion allowed, Z_r is the root depth (mm) and *DBD* is relative density of soil (g/cm^3).

The irrigation interval (*F*) in days depends on the rate at which water is consumed by the plants and the depth of irrigation applied by each cycle. To obtain the irrigation interval based on water stored in root zone the following two relations were used (**Keller and Karmeli, 1974**):

$$F = \frac{D_n}{ET_c} \tag{5}$$

$$ET_c = ET_o . k_c \tag{6}$$

where, ET_c is crop evapotranspiration (mm/day), ET_o is the reference evapotranspiration (mm/day) and k_c is the crop coefficient.

The operating time *t* (h) of each emitter during irrigation process was estimated using the following equation (**Merriam and Keller, 1978**) based on plant area *A* (m^2), application efficiency *Ea* (decimal) and the emitter discharge *q* (ℓ/h).

$$t = \frac{ET_c \times A \times F}{Ea \times q} \tag{7}$$

The water use efficiency (*WUE*) (kg/m^3) as an indicator of effectiveness usage of irrigation water for increasing maize crop yield *Y* (kg/fed), was calculated according to **Bilalis *et al.* (2009)** using the following formula based on the total water applied W (m^3/fed):

$$WUE = \frac{Y}{W} \tag{8}$$

Cost Analysis

Cost analysis was carried out by using the current prices for equipment and installation according to 2012 price level and maize production cost. The effect of emitter type on total cost and net return of maize production was then evaluated. The total cost per one feddan area is divided into: fixed costs and variable or operating costs. The estimated fixed costs were the depreciation, interest on investment, taxes and insurance costs. Meanwhile, the estimated variable costs were repair and maintenance, energy and the other costs. The following equations were used to calculate the cost analysis as shown in Table (3).

Table (3): Equation were used to calculate the cost analysis.

Cost type	Equation	Parameters
Depreciation costs, *D*, LE/fed/season	* $D = \frac{P_m - S}{L_m}$	**P_m** : the cost new (LE), **S** : salvage value price (0.1 P_m) (LE). **L_m** : total expected life (year)
Interest on the investment costs, *I*, LE/fed/season	* $I = \frac{P_m - S}{2} \times i$	**i** : interest rate as compounded annually 10 % (decimal)
Fixed costs, *F.C*, LE/fed/season	* $F.C = D + I + T_i$	**T_i** : taxes and insurance costs were assumed to be 1.5 % of the purchase price of the unit (P_m)
Repair, maintenance costs, R_m	* $R_m = (3\%\ new cost)$	
Energy cost, *E.C*, LE/fed/season	** $E.C = Bp \times T \times P_r$ ** $B_p = \frac{Q \times TDH}{C \times E_{overall}}$	**B_p** : the brake power (kW), **T** : the annual operating time (*hr*), **P_r** : cost of electrical power (0.125 LE/kW), **Q** : the total discharge rate (ℓ/s), **TDH** : the dynamic head (m) **C** : the conversion coefficient (C = 102); **$E_{overall}$** : overall efficiency (67.5 % for pump derived by electric motor)
Variable costs, *V.C*, LE/fed/season	* $V.C = R_m + E.C + O$	**O** : the other costs (mechanization, maize seeds, fertilization per feddan, pesticides, labor, harvesting and transportation)
Total costs, *T.C*, LE/fed/season	* $T.C = F.C + V.C$	
The economical net seasonal income, *P*, LE/fed	*** $P = (Y_t \times Y_p) - T.C$	**Y_t** : the total yield (kg/fed), **Y_d** : the yield price (LE/kg);

***El-Awady *et al.*, 1988, **Clark *et al.*, 2007; ***Younis *et al.*, 1991**

RESULTS AND DISCUSSION

Hydraulic Characteristics of Subunit

The discharge versus operating pressure relationship plays a vital role in the characterization of emitters. It is one of the key factors in selecting an emitter type and system design. Table (4) shows the nominal and measured discharge, emitter discharge equation constants (k, x), flow regime and the manufacturer's coefficient of variation (C_v). Great differences between nominal and measured discharges were observed with emitter (Em_3). The emitter exponent x showed that its classification lies between pressure compensating and turbulent flow. The results indicated that the C_v values classification of Em_1, Em_2 and Em_4 emitters were excellent, due to emitter the higher quality of these emitters than others. Meanwhile, Em_3 was classified poor and Em_5 was classified as marginal, maybe due to the lowest initial price.

Table (4): Average of discharge (ℓ/h), emitter constants (k, x), flow regime and manufacturing coefficient of variation (C_v) for emitters at 50 kPa.

Emitter	discharge "ℓ/h"	constants		Flow regime	"C_v"	
		"k"	"x"		Value	Classi.*
Em_1	4.23	2.52	0.12	Pressure compensating	0.03	Excellent
Em_2	5.35	1.33	0.32	Partially pressure compensating	0.02	Excellent
Em_3	15.28	2.04	0.50	Fully turbulent	0.12	Poor
Em_4	2.68	0.61	0.38	Partially turbulent	0.02	Excellent
Em_5	86.0	7.82	0.63	Partially turbulent	0.10	Marginal

*Classification of the manufacturing coefficient of variation

The uniformity plays an important role in water use efficiency (WUE). The coefficient of uniformity (CU) of different lateral lengths indicated that the highest significant value of CU was obtained at lateral length 15 m regardless the emitter type as shown in Table (5). Generally, water distribution uniformity was decreased by increasing lateral length with all emitters which agreed with **(Ngigi, 2008).** CU values were significantly higher at lateral length of 30 m for Em_1, Em_2; Em_4 and was good at lateral length of 15 m for Em_3; Em_5. Maximum value of CU was obtained with

Em_4, meanwhile minimum value was obtained with Em_3. The results revealed that *CU* was a variable relationship with emitter types, due to the differences in C_v classifications, its found that *CU* was increased by improvement C_v classification agreed with **(Amer, 2001 and Tagar, *et al.*, 2010)**.

Table (5): Coefficient of uniformity (*CU*) with different lateral lengths at operating pressure 50 kPa for different emitters.

Emitter type	Coefficient of uniformity (*CU*, %)			
	Length of lateral, m			
	15	20	25	30
Em_1	96.77^{ab}	96.57^{ab}	96.15^{ab}	95.49^{a}
Em_2	94.67^{b}	94.47^{b}	94.05^{b}	93.39^{a}
Em_3	81.69^{d}	79.80^{d}	75.04^{c}	70.21^{c}
Em_4	97.86^{a}	97.83^{a}	97.28^{a}	96.17^{a}
Em_5	90.18^{c}	84.29^{c}	77.44^{c}	75.82^{b}

Values with the same column with different superscript (a, b, c; d) are significantly different ($p < 0.05$).

Water Use Efficiency

Generally, water use efficiency (*WUE*) is the ratio of grain yield to the total crop water use. The results indicated that *WUE* were 1.47, 1.45, 1.30, 1.29 and 1.11 kg/m^3 for Em_4, Em_1, Em_5, Em_2 and Em_3 emitters, respectively as shown in Figure (2). It is clear from the obtained results that the highest value of *WUE* was achieved at Em_4 emitter, which could be recommended for microirrigated maize in sandy soil. As shown in Table (5), the values of *WUE* increased by increasing the uniformity of different emitters except for Em_2 and Em_5. Although C_v and *CU* of Em_5 less than Em_2 but the *WUE* significantly increased with Em_5. This exception may be attributed to increasing crop cultivation intensity of Em_5 than Em_2 as a result of different discharges.

Wetted Diameter

The results showed that the overlap between emitters wetted diameter was increased the crop yield. Also, the wetted diameter (*WD*) was increased by increasing emitter discharge as shown in Figure (3) agreed with (**Shan *et al.*, 2011**). Therefore, the highest value of *WD* (100 cm) was recorded with Em_5 and the lowest (46 cm) with Em_4. It clear that the wetted diameter overlap happened between emitters at the laterals, and no effect for examined lateral distances of all emitter types on overlap between its wetted diameter. So the lateral distance in the experiment didn’t effect on the crop yield.

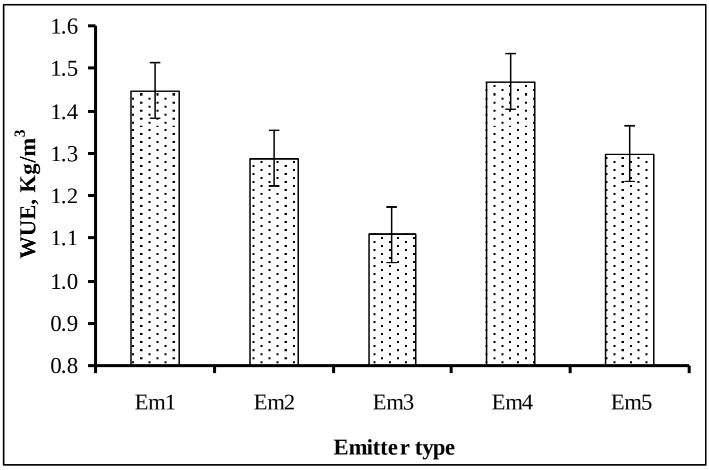


Figure (2): Water use efficiency (*WUE*) for emitter types.

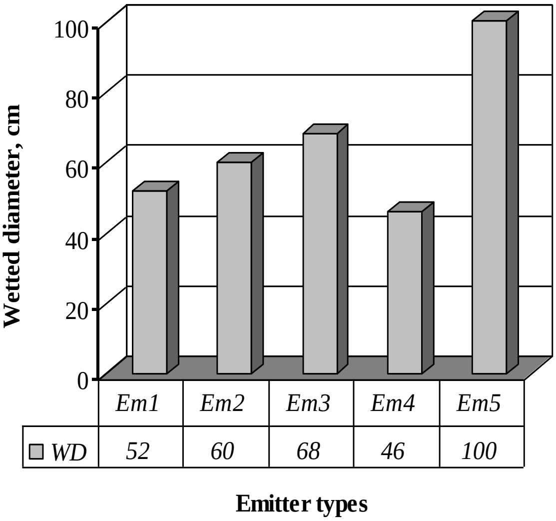


Figure (3): The relationship between emitter types and wetted diameter.

Economic Return

Table (6) shows the difference in fixed costs (depreciation, interest on investment; taxes and insurance costs) and operating or/variable costs (repair and maintenance, electrical energy costs and others) for each

Table (6): The economic return of different emitters in 2012 year with inflation rate (Inf.) of 5 or 10 %.

Cost measures	**Em_1**			**Em_2**			**Em_3**			**Em_4**			**Em_5**		
	2012	Inf. 5 %	Inf. 10 %	2012	Inf. 5 %	Inf. 10 %	2012	Inf. 5 %	Inf. 10 %	2012	Inf. 5 %	Inf. 10 %	2012	Inf. 5 %	Inf. 10 %
New network cost (N)	**14679**	**15413**	**16147**	**11889**	**12484**	**13078**	**7406**	**7776**	**8147**	**10001**	**10501**	**11001**	**6161**	**6469**	**6777**
1. Fixed costs:	**1153**	**1194**	**1254**	**881**	**924**	**971**	**480**	**503**	**530**	**707**	**741**	**779**	**405**	**424**	**446**
a) Depreciation	885.3	928.8	974.8	676.0	709.1	744.6	352.3	369.2	388.6	534.4	560.4	588.9	298	312.2	328.3
b) Interest on investment	232.6	230.8	242.7	178.3	186.9	196.7	111.1	116.3	122.7	150.0	157.2	165.5	93.2	96.7	101.9
c) Taxes and insurance	34.9	34.6	36.4	26.8	28.0	29.5	16.7	17.4	18.4	22.5	23.6	24.8	14.0	14.5	15.3
2. Variable costs:	**3429**	**3608**	**3790**	**3402**	**3578**	**3757**	**3361**	**3533**	**3708**	**3378**	**3552**	**3729**	**2509**	**2637**	**2767**
a) Repair, maintenance	146.8	161.8	177.6	118.9	131.1	143.9	74.1	81.7	89.6	100.0	110.3	121.0	61.6	67.9	74.6
b) Electrical energy	36.82	38.66	42.53	37.81	39.70	43.67	42.06	44.16	48.58	32.92	34.57	38.02	11.96	12.56	13.81
c) Others	3245	3407	3570	3245	3407	3570	3245	3407	3570	3245	3407	3570	2435	2557	2679
3. Total cost (1+2).	4581	4802	5043	4283	4502	4728	3841	4036	4237	4085	4293	4508	2914	3061	3212
4. Applied water, m^3/fed/season	2800	2800	2800	2800	2800	2800	2800	2800	2800	2800	2800	2800	2800	2800	2800
5. Yield production	4058	4058	4058	3611	3611	3611	3095	3095	3095	4126	4126	4126	3652	3652	3652
6. Selling price, LE/kg/season	2.10	2.21	2.31	2.10	2.21	2.31	2.10	2.21	2.31	2.10	2.21	2.31	2.10	2.21	2.31
7. Total return, (5x 6)	8521	8947	9373	7582	7961	8340	6499	6824	7149	8665	9099	9532	7669	8052	8435
8. NSI, (7-3)	3939	4145	4329	3299	3459	3613	2658	2788	2911	4580	4805	5024	4755	4992	5223
9. *RWU*, (7/4)	3.04	3.20	3.35	2.71	2.84	2.98	2.32	2.44	2.55	3.09	3.25	3.40	2.74	2.88	3.01
10. *BC* ratio, (7/3)	1.86	1.86	1.86	1.77	1.77	1.76	1.69	1.69	1.69	2.12	2.12	2.11	2.63	2.63	2.63

operating conditions of emitters and lateral lengths. The electrical energy costs were estimated which had values of 36.82, 37.81, 42.06, 32.92 and 11.96 LE/fed/season for Em_1, Em_2, Em_3, Em_4 and Em_5, respectively in 2012 year. The Em_5 provided the lowest electrical energy cost, due to the minimum operating hours.

Em_1 was recorded the highest total cost of 4581.40 LE/fed/season, since it was the highest initial price. Also, Em_5 was recorded the lowest total cost (2913.74 LE/fed/season) with highest net seasonal income (*NSI*) of 4755.02 LE/fed/season, due to relatively long internal distance between laterals and emitters, in addition to a low initial price of this emitter and the free irrigation water in Egypt. Meanwhile, the lowest net seasonal income was Em_3, although it has the lowest initial price, due to a low yield production as a result of a lowest C_v and *CU*.

The highest return of water unit (*RWU*) could be arranged in the following descending order ($Em_4 > Em_1 > Em_5 > Em_2 > Em_3$) with values of 3.09, 3.04, 2.74, 2.71 and 2.32 LE/m^3/season, respectively. The seasonal benefit cost (*BC*) ratio arranged in the following descending order ($Em_5 > Em_4 > Em_1 > Em_2 > Em_3$) with values of 2.63, 2.12, 1.86, 1.77 and 1.69, respectively. Despite of Em_4 was the highest values of yield consequently *WUE* and *RWU*, but Em_5 was the highest net seasonal income *and BC* ratio, this may be due to it has a lowest total cost.

The suggested scenario for cost analysis takeing into account the effect of the changes in input and output prices of maize yield that maybe will occur in the next years, if inflation rate (*Inf.*) increases by 5 or 10 %. The net seasonal income (*NSI*) and return of water unit (*RWU*) were increased by the same ratio of inflation rate (*Inf.*) increasing. Although *NSI* and *RWU* were increased by the same ratio of *Inf.* increasing, but *BC* ratio remain in the same values.

CONCLUSIONS

Maize (*Zea mays L.*) is considered as one of the most important cereal crops in Egypt. The examined emitters divided into manufactured on-line (Em_1, Em_2; Em_3), in-line (Em_4) and microtube (Em_5) were evaluated with four lateral lengths (15, 20, 25 and 30 m) at operating pressure of 50 kPa.

The result showed that the *CU* values was excellent at lateral length of 30 m for Em_1, Em_2; Em_4 emitters and was good with lateral length of 15 m for Em_3; Em_5 emitters. Water use efficiency (*WUE*) consequentially return of water unit (*RWU*) is increased by increasing the uniformity of different emitters. The results indicated that the values of *WUE* and *RWU* were 1.47 kg/m^3 and 3.09 LE/m^3/season for Em_4. Em_4 was the highest yield consequently *WUE* and *RWU*, but Em_5 was the highest net seasonal income (*NSI*) *and* seasonal benefit cost (*BC*) ratio, due to relatively long internal distance between laterals and emitters, in addition to a low initial price of this emitter. The suggested scenario for cost analysis take into account the effect of inflation rate increasing by 5 or 10%. *NSI* and *RWU* were increased by the same ratio of inflation rate increasing, but *BC* ratio remain in the same values.

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الملخص العربي

تقييم أداء نظام للري الدقيق منخفض الضاغط لحقول الذرة

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أجريت هذه الدراسة بالمعمل الهيدروليكي لقسم الهندسة الزراعية ومزرعة كلية الزراعة، جامعة قناة السويس، بالإسماعيلية خلال موسم صيف ٢٠١٢. وكان هدفها الرئيسي تقييم أداء نظم ري دقيق منخفضة الضاغط (ضغط تشغيل ٥٠ ك باسكال) وكفاءتها في زراعة الذرة فى مصر فى الحفاظ على المياه واقتصاديا. وفيها تم تحديد تأثير أنواع مختلفة من المنقطات المركبة على الخط الجانبي ($Em_1, Em_2; Em_3$)،

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والمصنعة كوحدة واحدة مع الخط الجانبي (Em_4) والأنابيب الدقيقة المركبة على الخط الجانبي (Em_5) مع أطوال مختلفة من الخطوط الجانبية (١٥، ٢٠، ٢٥ و٣٠ م) عند مسافة بينية بين الخطوط الجانبية ٠,٧٥م لجميع المنقطات فيما عدا Em_5 كانت على مسافات ٢,٠م، على توفير المياه والجدوى الاقتصادية. ولقد أظهرت النتائج أنه بزيادة طول خط المنقطات تقل قيمة معامل انتظامية توزيع المياه (CU). وكان الترتيب التنازلي لقيم كفاءة استخدام المياه (WUE) هي ١,٤٧، ١,٤٥، ١,٣٠، ١,٢٩ و١,١١ كجم/م^{٣}، وقطر البلل لجميع المنقطات حدث بينها تداخل على الخط الجانبي فى حين أنها لم تتداخل فيما بينها على الخطوط الجانبية المتجاورة، لذا لم يكن هناك تأثير للمسافات مابين الخطوط الجانبية على المحصول فى حين كان تأثيرها الاقتصادي واضح. وقيم العائد المادي لوحدة المياه لعام ٢٠١٢ م (RWU) هي ٣,٠٩، ٣,٠٤، ٢,٧٤، ٢,٧١ و٢,٣٢ جنية/م^{٣}/موسم للمنقطات الآتية Em_4، Em_1، Em_5، Em_2 وEm_3 على التوالي. وكان الترتيب التنازلي لقيم نسبة الفائدة للتكاليف هي ٢,٦٣، ٢,١٢، ١,٨٦، ١,٧٧ و١,٦٩ للمنقطات Em_5, Em_4، Em_1، Em_2 وEm_3 على التوالي. وخلصت الدراسة أن Em_4 كان أعلى قيمة فى كفاءة استخدام المياه والعائد المادي لوحدة المياه، فى حين حقق Em_5 أقل تكاليف كلية وأعلى صافى ربح ونسبة فائدة للتكاليف (BC)، ويرجع ذلك إلى ما يتميز به من سعر منخفض ومسافات بينية كبيرة نسبياً ما بين الخطوط الجانبية والمنقطات على الخط الجانبي. التحليل الاقتصادي أخذ في الاعتبار تأثير ارتفاع معدل التضخم بنسبة ٥ أو ١٠٪. وأظهرت النتائج زيادة صافى الربح (NSI) والعائد المادي لوحدة المياه (RWU) بنفس نسبة ارتفاع معدل التضخم، مع بقاء نسبة فائدة للتكاليف (BC) ثابتة.