

DEVELOPMENT A COMPUTER MODEL TO DETERMINE THE OPTIMUM LATERAL LENGTH OF MICROIRRIGATION SYSTEMS

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ABSTRACT

This study was carried out for developing a computer model to determine the optimum length of lateral in microirrigation systems. The model was designed to obtain a flow variation (q_{var}) of 10, 15 and 20 % and/or coefficient of uniformity (CU) greater than 85 %. The model was then validated by a hydraulic experiment which measure CU of five emitters. The examined emitters were in-line (Em_3), on-line ($Em_1, Em_2; Em_4$) and Em_5 was microtube (a 3.80 mm inside diameter with a length of 50 cm), at four lateral lengths, under seven operating pressures. The theoretical model and the validation experiment were compared indicating that there was a strong relationship with coefficient of determination (R^2) more than 0.95 between the measured and predicted CU for Em_1, Em_2 and Em_3 , while this relationship was decreased with R^2 about 0.80 for Em_4 and Em_5 at different treatments.

Keywords: Computer modeling, Lateral, Pressure, Uniformity, Microirrigation system.

INTRODUCTION

Microirrigation includes any localized irrigation method such as trickle, spray and/or bubbler that slowly and frequently provides water directly to the plant root zone. The slow rate of water application at discrete locations with certain operating pressure at only a portion of the soil volume in the field can result in a relatively low cost water delivery systems, with a higher uniformity coefficient, as well as reductions in water diversions compared to other irrigation methods (Lamm *et al.*, 2007, ASABE Standard, 2008 and Ngigi, 2008). Microirrigation is a technique that enables us to save water and energy while economical, less laborious and more efficient irrigation can be achieved. The success of microirrigation is possible if the system is

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appropriately designed and managed. The first step in the design process of microirrigation system is to determine the optimum lateral lengths allow equal water distribution along the laterals. The characteristics of emitters and the friction losses along the lateral for a new produced microirrigation lateral are the main data for optimum lateral lengths (**Yurdem *et al.*, 2011**).

Generally, the design of microirrigation systems is essentially depend on the assumption that the flow rates of emitters are the same along the laterals. Due to friction losses, some variations occur in flow rates. The selection of the appropriate flow rate, spacing and emitter types is the major role in designing an ideal microirrigation system. For instance, based on a desirable 90 % of uniformity, **Hanafy (1995)** developed design charts that could be used in to selecting the optimum lateral lengths and diameter of the drip lateral line under the effect of total friction loss, emitter spacing and line slope. Generally, the pressure variation along the lateral line is determined by energy drop due to friction and energy gain or loss due to slope. The distribution uniformity substantially decreases at slopes steeper than 30 % (**Hassan, 2007**). However, the successful design is usually a compromise between the choice of high uniformity and small cost of the installation.

There are significant differences in finding the frictional losses between the theoretical calculations using both the Darcy-Weisbach or Hazen-Williams equations and the data obtained in the laboratory (**Demir and Uz, 1995; Allen, 1996 and Demir, 1999**). For this reason, researchers try to attain the data in the laboratory and to determine the friction losses (**Pitts *et al.*, 1986**). In addition to these, some studies using dimensional analysis were carried out recently in order to develop some empirical models for predicting the friction losses (**Demir *et al.*, 2007 and Yildirim, 2010**).

Because uniformity is an important parameter in the design and operation of microirrigation systems (**Li *et al.*, 2012**) several classification standards for microirrigation uniformity have been developed in different countries. Microirrigation uniformity classifications, ranging from excellent to unacceptable, were recognized by the American Society of Agricultural Engineers (**ASAE Standard, 1999**) for point source

emitters. Uniformity below 60 %, from 60 to 70 %, 70 to from 80 %, from 80 to 90 %, and above 90 % is referred to as low, poor, fair, good and excellent uniformity, respectively. Also, manufacturer's coefficient of variation C_v is one of the significant factors affecting the overall uniformity of the microirrigation system. Classification C_v is unacceptable (> 0.15), poor (0.11 to 0.15), marginal (0.07 to 0.11), average (0.05 to 0.07), excellent (< 0.05) and these guidelines have been stated in Standards of American Society of Agricultural and Biological Engineering (**ASABE Standards, 2003 and 2008**).

Although there is already available software in the market for designing microirrigation systems, there is no software to define the optimum technical properties of new designed emitters and estimating the appropriate length of laterals. Hence, the main objective of this study was to develop a computer model to determine the optimum lateral length for different emitters, which improve the hydraulic performance of the subunit. The study also aimed to validate the results obtained from the model by verification in a laboratory hydraulic experiment.

MATERIALS AND METHODS

Mathematical model

In this study, a mathematical model depending on a set of algebraic equations of the microirrigation system was proposed and a program written in *MATLAB* version 10.0 (*The Mathworks Inc., Natick, MA, USA*) was developed for solving such equations to predict uniformity, discharge, number of emitters and optimum lateral length. The program was then tested and verified according to the data obtained from a laboratory experiment.

Under different operating pressure head h_i (m), the emitter flow rate q (ℓ/hr) and the coefficient of variation (C_v) of every emitter tested in this study could be obviously estimated according to the following two equations emphasized by **ASABE Standards (2003 and 2008)** and suggested by many researchers (**Keller and Karmeli, 1974 and 1975; Wu and Gitlin, 1974**):

$$q = k h_i^x \quad (1)$$

$$C_v = \frac{S}{\bar{X}} \quad (2)$$

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 \bar{X} ; S are the mean discharge and standard deviation of emitters.

In this study, the prediction of the friction losses between two microtube devices can also be made possible without testing friction losses in the laboratory by using the mathematical model. Thus, the Darcy-Weisbach and Blasius equation can be used to calculate the friction head loss for small diameter and smooth pipes (**Keller and Bliesner, 1990, Demir, 1995 and El-Meseery, 1999**) as:

$$h_f = f \frac{LV^2}{d2g} \quad (3)$$

where, h_f is the friction loss in the pipe (m), L is the pipe length (m), d is the pipe's internal diameter (m), V is the velocity of the flow inside the emitter (m/s), g is the acceleration of gravity (9.81 m/s^2), and f is the friction coefficient calculated as:

$$\text{For laminar flow} \quad f = 64/Re \quad Re \leq 2000 \quad (4)$$

$$\text{For turbulent flow} \quad f = 0.3164/Re^{0.25} \quad 4000 \leq Re \leq 100000 \quad (5)$$

As, the Reynolds number (Re) is controlled by the internal diameter of the flow cross-section d (m) and the kinematics viscosity of water ($\nu = 1.004 \times 10^{-6} \text{ m}^2/\text{s}$ at 20°C), it could be utilized to characterizes the flow regime and the discharge Q (m^3/sec) passing through it to estimate the velocity of the flow inside the emitter V (m/s) as:

$$Re = \frac{Vd}{\nu} \quad \text{with} \quad V = \frac{4Q}{\pi d^2} \quad (6)$$

Accordingly, the friction loss in the pipe h_f (m) can be calculated as follow for laminar and turbulent flow:

$$\text{For laminar flow} \quad h_f = \frac{1.16 L_i Q}{D^4} \quad (7)$$

$$\text{For turbulent flow} \quad h_f = \frac{0.471 L_i Q^{1.75}}{D^{4.75}} \quad (8)$$

Because the total head losses h_m (Δh_n) at any delivery location on lateral line is the accumulation of losses occurred along the line, following steps were followed to calculate the total head losses:

$$\begin{aligned}
 h_{f1} &= \Delta h_1 \\
 h_{f2} &= \Delta h_1 + \Delta h_2 \\
 &\downarrow \\
 h_{fn} &= \sum_{n=1}^N \Delta h_n \tag{9}
 \end{aligned}$$

On the other hand, the head losses between each two successive emitter could be calculated from the following equation that differs slightly from equation (7) and (8) (noticing that at first microtube $L_i = S$).

For laminar flow $h_{fn} = 1.16 S (Q_n) D^{-4}$ (10)

For turbulent flow $h_{fn} = 0.471 S (Q_n)^{1.75} D^{-4.75}$ (11)

Where, S is the distance between two successive emitter (m), and Q_n is the lateral line discharge at any emitter location (just before delivery inlet) (ℓ/hr).

In addition, the lateral line discharge at the first delivery (Q) equals the discharge of all delivery as follows:

$$Q = q_1 + q_2 + q_3 + \dots \dots \dots q_n \tag{12}$$

Assuming that for equal delivery discharge

$$q_1 = q_2 = q_3 = q_4 = \dots \dots \dots q_n$$

Thus, the lateral discharge will decrease subsequently after every emitter by a value equal to microtube (Em_s) discharge (q):

$$\begin{aligned}
 Q_1 &= Nq \\
 Q_2 &= Nq - q = q (N-1) \\
 &\downarrow \\
 Q_n &= Nq - (n-1) q = q (N - n + 1) \tag{13}
 \end{aligned}$$

From equations 7 to 13 the friction head losses between each two successive emitters can be deduce as:

For laminar flow $h_{fn} = 1.16 S q D^{-4} (N - n + 1)$ (14)

For turbulent flow $h_{fn} = 0.471 S q^{1.75} D^{-4.75} (N - n + 1)^{1.75}$ (15)

Considering two emitters (microtubes) at each single outlet leads to the following two equations for calculating the friction head losses h_{fn} (m) in both laminar and turbulent flows, respectively:

For laminar flow $h_{fn} = S \left[1.16 (2q) D^{-4} \sum_{i=1}^N (N - n + 1) + \delta_s \right]$ (16)

$$\text{For turbulent flow } h_{f_n} = S \left[0.471 (2q)^{1.75} D^{-4.75} \sum_{i=1}^N (N-n+1)^{1.75} + \delta_s \right] \quad (17)$$

where, q is the discharge through emitter (ℓ/hr), D is the internal diameter of lateral line (mm), S is the distance between microtubes (m), δ_s is the slope, N is the total number of emitter and n is the number of estimated emitters.

In case of the in-line devices (Em_3), the friction loss between emitters is given by the following equation (Demir *et al.*, 2007 and Yurdem *et al.*, 2011):

$$h_{fn} = 5.885 \times 10^{-5} Q_i^{1.725} D^{-2.203} S^{0.742} d^{-3.074} l_e^{0.066} \quad (18)$$

where, h_{fn} is friction head loss (m), Q_i is the flow rate in lateral section (m^3/s), D is the pipe internal diameter (m), S is the emitter spacing (m), d is the emitter internal diameter (m) and l_e is the emitter length (m).

The in-line friction loss model is valid for the following ranges; $0.2 \leq S \leq 1$ m, $12.53 \leq D \leq 13.77$ mm, $11.33 \leq d \leq 12.05$ mm, $31.53 \leq l_e \leq 68.68$ mm and $3591 \leq Re \leq 23688$.

On the other hand, for on-line emitter devices the friction loss between two emitters are given by the following equation:

$$h_{f_n} = 8859.16 Q_i^{1.789} D^{-3.904} S^{0.635} A_e^{1.153} \quad (19)$$

Where, A_e is emitter devices barb protrusion area ($A_e = (x+y) \times z/2$) (m^2).

The on-line friction loss model is valid for $0.2 \leq S \leq 1$ m, $12.01 \leq D \leq 13.68$ mm, $27.51 \leq A_e \leq 36.06$ mm^2 and $4047 \leq Re \leq 22215$.

Accordingly, the pressure effective head (h_n) at the emitter was calculated as:

$$h_n = H_I - h_{f_n} \quad (20)$$

Determinations of the optimum length of the microirrigation laterals is not a straightforward task due to the fact that the laterals are not only smooth pipes but also have multiple outlets depending upon the emitter device and spacing. Since emitters discharge water along the lateral line, the total flow rate decreases and the pressure changes in the lateral line with respect to the length as shown in Figure (1). For this reason, pressure and flow rate relations are considered in order to determine the optimum lateral lengths and water distribution uniformity from emitters along the lateral line.

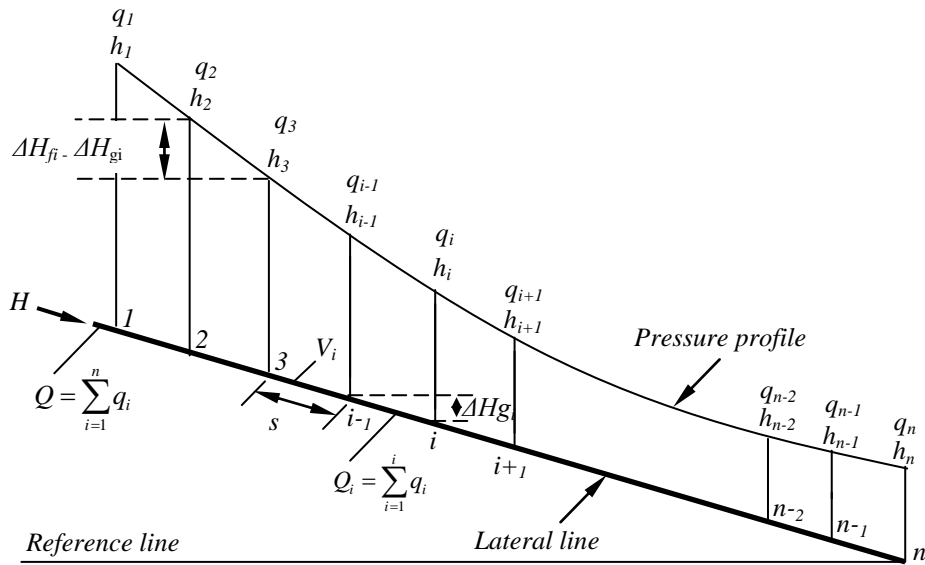


Figure (1): The pressure and flow rate distribution along the microirrigation lateral line (Yurdem *et al.*, 2011).

As the emitter flow rates along the lateral for each emitter could be estimated by using equation (1), the inlet pressure h_i in the abovementioned equation was calculated as:

$$h_i = h_{i-1} - \Delta H_f \pm \Delta H_g \quad (21)$$

where, h_i is inlet pressure head at i emitter (m), h_{i-1} is inlet pressure head at $i-1$ emitter (m), ΔH_f is the friction loss between emitter i and emitter $i-1$ (m), and ΔH_g is the elevation between emitter i and emitter $i-1$ (m).

Design criterias were computed simultaneously in a back-propagation manner in the developed program. Several criteria were used to calculate the optimum length of the laterals in order to obtain uniform water distribution and force the program to stop running. The coefficient of discharge uniformity (CU) was a better way of expressing the hydraulic performance of the subunit. The uniformity of irrigation could be determined by Christiansen (1942).

$$CU = 100 \left(1 - \frac{\sum_{i=1}^{i=n} |q_i - \bar{q}|}{n \bar{q}} \right) \quad (22)$$

where, $\sum_{i=1}^{i=n} |q_i - \bar{q}|$ is the summation of absolute values of deviations from means of emitter discharge, q_i is individual of discharge of an

emitter (ℓ/hr), \bar{q} is the mean of discharge of an emitter (ℓ/hr) and n is the number of estimated emitters. The optimum lateral length was then estimated based on the aforementioned equations in order to meet the limitations of CU greater than 85 %.

Another criterion is the emitter flow variation (q_{var}) and it is defined by **(Jiang and Kang, 2010)** equation as:

$$q_{var} = \frac{q_{max} - q_{min}}{q_{max}} \times 100 \quad (23)$$

where, q_{max} and q_{min} are the maximum and minimum emitter discharge rate (ℓ/hr). Several researchers suggested a uniformity coefficient of trickle irrigation about 97.5 % equivalent to q_{var} of 10 % and a uniformity coefficient of about 95.0 % equivalent to q_{var} of 20 % **(Bralts and Wu, 1979)**. The output data of the computer model (predicted values of uniformity, discharge, number of emitters and optimum lateral length) were then computed and compared with those obtained from the experimental works (the real measured values). The flowchart of the equations used in the model is given in Figure (2).

Model validation

Firstly, laboratory experiment was carried out to test the hydraulic characteristics of examined emitter devices. These characteristics were discharge exponent constants x and coefficient of manufacturer's variation C_v . five types of emitters (Em) purchased from the local market included two emitters from local manufacturers (Em_4) were tested. The emitters were divided into manufactured in-line (Em_3), on-line (Em_1 , Em_2 ; Em_4) and microtube Em_5 (3.80 mm ID with a length of 50 cm) as shown in Figure (3, a, b; c) were tested under seven operating pressures from 20 to 120 kPa.

Secondly, validation of the model was carried out by comparing the measured with predicted coefficient of uniformity at different lengths of lateral (15, 20, 25 and 30 cm) and different operating pressures (from 20 to 120 kPa) under Egyptian conditions with five emitter devices. Emitter discharges were calculated by dividing water volume in catch cans

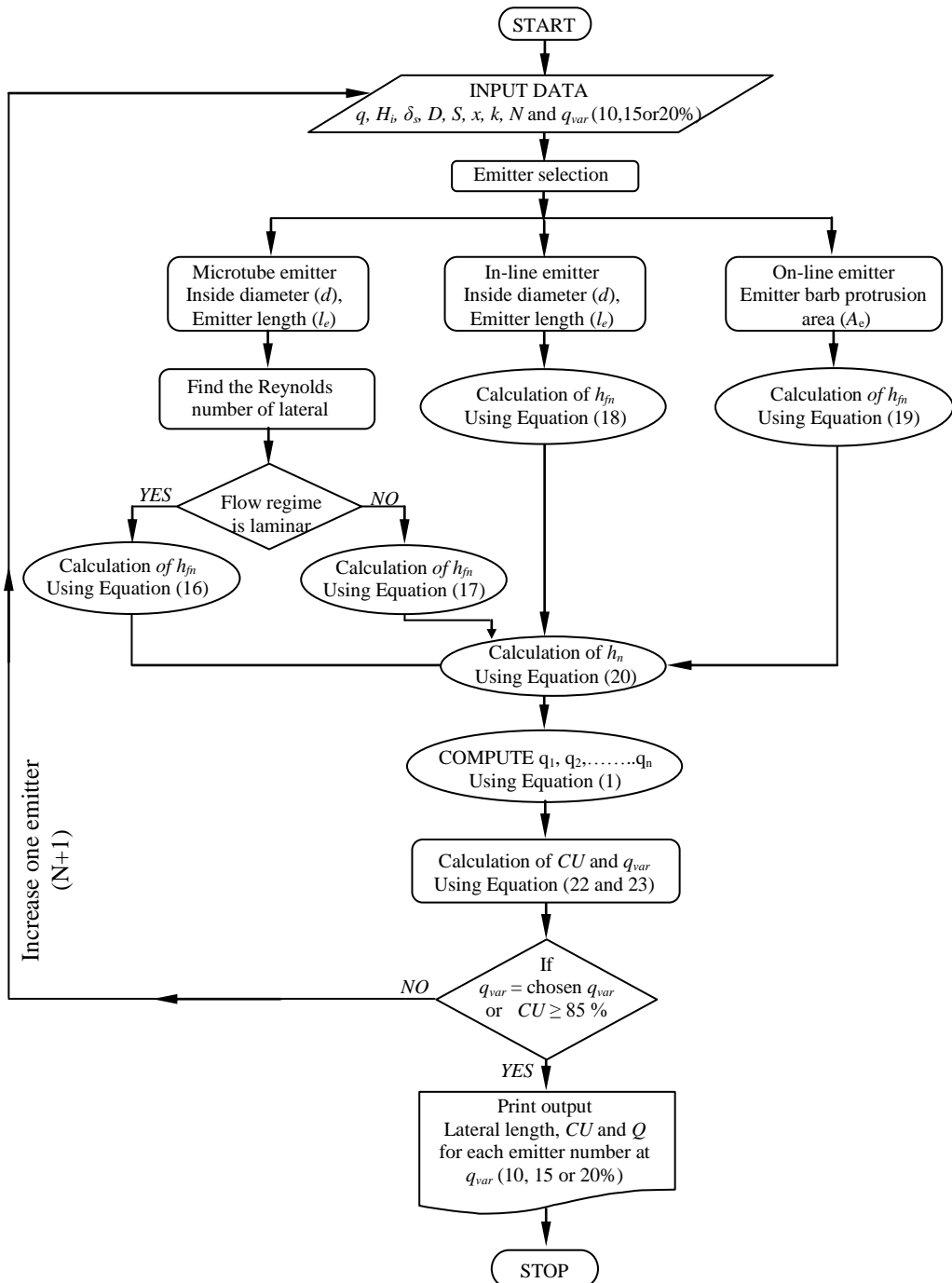


Figure (2): Schematic representations of the flowchart of the all involved steps and equations used in estimating the optimum length of microirrigation laterals.

180 x 140 mm to collect the emitted water were placed along the lateral line directly below the emitters on a specified time under operating pressures. Drippers were selected on each emitter line at four locations (at the inlet, 1/3 of the length, 2/3 of the length and at the end of emitter line) as shown in Figure (4).

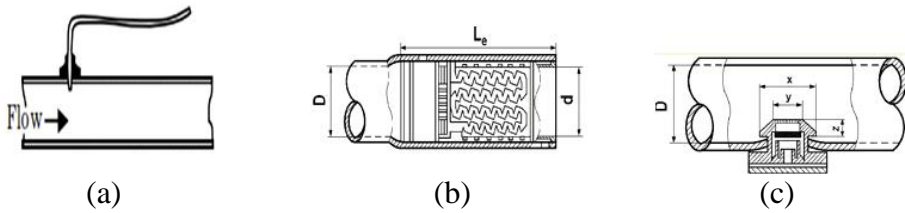
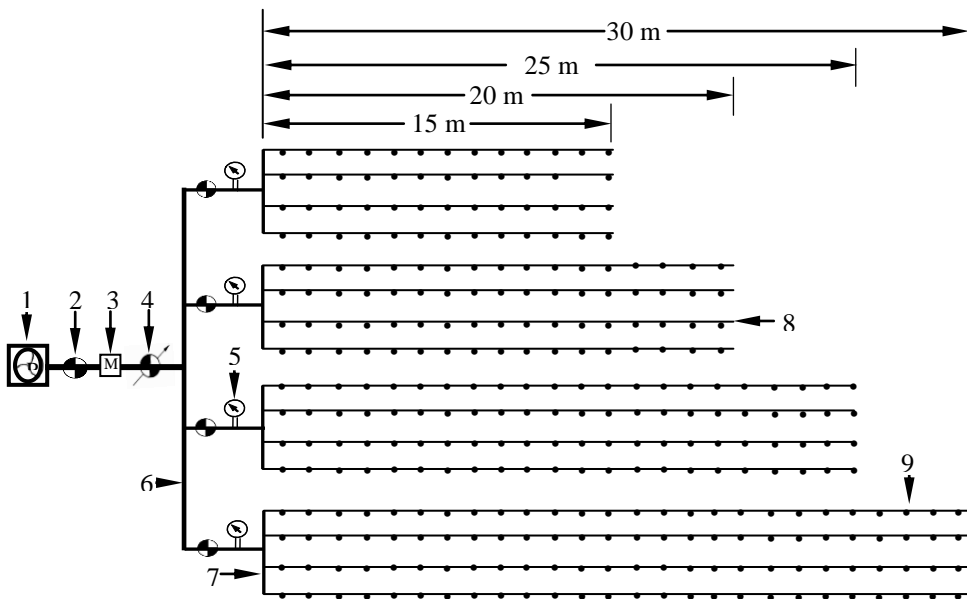


Figure (3): Schematic diagram of the tested emitter devices (a) microtube, (b) in-line and (c) on-line emitters. (a)



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

Figure (4): Schematic diagram of the hydraulic subunits of different lateral lengths.

RESULTS AND DISCUSSION

Characterization of emitters

As one of the key factors in selecting an emitter type and system design, the flow rate versus operating pressure relationship plays a vital role in the characterization of emitters in microirrigation systems. Table (1) shows the nominal and the measured flow rate, emitter discharge equation constants (k and x), flow regime, the manufacturer's coefficient of variation C_v and the overall classification of the tested emitters. The data show that there were great differences between nominal and measured discharges for Em_4 emitter, which commonly handled types (un-published data about emitters by manufacturer). Also, the nominal flow rate of emitter Em_5 was unknown. Generally, the results indicated that the discharges of tested emitter types were highly affected by operating pressure.

Table (1): Average of flow rate (ℓ/h), emitter constants (k , x), flow regime and manufacturing coefficient of variation (C_v) for tested emitters at 100 kPa.

Emitter (trademark)	discharge " ℓ/h "		Difference Percentage "% "	Emitter constants		Flow regime	Coefficient of variation " C_v "	
	Nominal	Measured		" k "	" x "		Value	Class **
Eden (Em_1)	4.0	4.36	9.0	2.52	0.12	Pressure compensating	0.02	Excellent
Euro-key (Em_2)	4.0	5.60	40.0	1.33	0.32	Partially pressure compensating	0.02	Excellent
GR* (Em_3)	4.0	3.95	-1.25	0.61	0.38	Partially turbulent	0.03	Excellent
Metallic (Em_4)	4.0	20.56	414.0	2.04	0.50	Fully turbulent	0.10	Marginal
Microtube (Em_5)	-	102.0	-	7.82	0.63	Partially turbulent	0.23	Unacceptable

* In-line emitter device. ** Classification according to ASABE standards (2008).

The highest difference percentage of measured than nominal discharge was 414.0 % for Em_4 , while the lowest percentage -1.25 % was obtained with Em_3 . The emitters' exponent x showed that its classification lies between pressure compensating and turbulent. The measurements also indicated that the Em_1 , Em_2 and Em_3 emitters were classified as excellent emitters based on C_v values; meanwhile Em_4 was marginal and Em_5 was classified as unacceptable emitter. Due to the simple design of Em_4

emitter and their low C_v , they recorded high difference between nominal and measured discharge. Emitter Em_4 was just selected for the model validation experiment to represents the cheap and commonly used types in the local market.

Mathematical model

The developed programmed model in this study was used to determine uniformity, maximum discharge, ideal number of emitters, discharge of lateral, friction losses and the optimum length of lateral under different operating pressures and flow rate variations q_{var} (i.e. 10, 15 and 20 %). The model was tested to estimate these parameters for different emitters as shown in Table (2). The results indicated that lateral length proportionally related with the operating pressures for all manufactured emitter, while it has no relationship with microtube (Em_5). All emitters discharge had a proportional relationship with operating pressures. Although CU values decreased by increasing the variations in flow rate q_{var} , Em_1 , Em_2 , Em_3 and Em_4 emitters still classified as excellent emitters under all operating pressures. While CU value of the microtube (Em_5) inversely proportional with discharge, its classification was decreased from excellent to good when the variations of flow rate q_{var} increased from 10 to 20 % at all operating pressures.

Model validation

The coefficient of uniformity (CU) was determined at different levels of lateral length and operating pressure. The relationship between operating pressure and coefficient of uniformity for five emitters types at different lateral lengths is shown in Figure (5). It could be divided the emitters into two groups, the first group includes the manufactured emitters Em_1 , Em_2 , Em_3 and Em_4 emitters and the second group includes Em_5 as a microtube. Generally, for all manufactured emitters the CU increased with increasing pressure until the maximum value with 100 kPa and decreased again at all lateral lengths. Meanwhile, the CU of microtube emitter Em_5 was decreased with increasing pressure at all lateral lengths. For all tested emitters, the reduction in CU by increasing the lateral length could be attributed to the pressure losses (Amer, 2001, and Tagar, *et al.*, 2010).

Table (2): Prediction of optimum lateral length, total lateral discharge and coefficient of uniformity under different operating pressures and flow rate variations (q_{var} : 10, 15 and 20 %) for emitters.

Emitter type	P (kPa)	Optimum lateral length								
		Flow variation								
		10 %			15 %			20 %		
		L_{max} (m)	Q (ℓ/h)	CU (%)	L_{max} (m)	Q (ℓ/h)	CU (%)	L_{max} (m)	Q (ℓ/h)	CU (%)
Em_1	20	19.8	248.2	98.37	28.8	361.0	97.05	35.4	443.7	95.75
	40	33.0	448.8	98.36	50.1	681.4	97.09	61.2	832.3	95.76
	50	35.1	494.9	98.58	57.0	803.7	97.24	71.4	1006.7	95.94
	60	44.7	639.2	98.39	68.4	978.1	97.07	84.0	1201.2	95.79
	80	74.7	1070.7	97.63	97.5	1397.5	96.36	112.2	1608.2	95.21
	100	96.3	1399.6	97.33	120.6	1752.7	96.11	136.5	1983.8	94.99
	120	116.1	1710.5	97.15	142.2	2095.1	95.11	159.3	2347.0	94.86
Em_2	20	24.0	256.8	97.55	45.3	484.7	96.12	63.0	674.1	94.68
	40	53.1	810.7	99.25	65.7	1003.0	98.38	78.6	1200.0	96.88
	50	60.0	1070.0	98.18	66.0	1177.0	97.35	83.1	1482.0	95.33
	60	63.0	1142.4	97.80	66.3	1202.2	96.57	85.2	1545.0	95.10
	80	69.3	1279.7	96.61	77.1	1423.8	95.22	102.0	1883.6	93.82
	100	86.7	1618.4	96.48	112.2	2094.4	95.10	134.7	2514.4	93.69
	120	111.3	2125.8	95.62	135.9	2595.7	94.28	157.8	3014.0	92.89
Em_3	20	64.0	395.6	99.08	84.8	524.2	97.38	117.8	728.2	96.17
	40	96.7	764.8	98.66	141.9	1122.3	97.24	201.0	1589.7	95.75
	50	99.0	804.0	98.21	157.7	1280.7	97.81	210.9	1712.8	95.35
	60	100.0	957.6	99.58	162.7	1558.0	98.16	217.8	2085.6	96.66
	80	132.0	1416.0	99.68	173.9	1865.5	98.27	222.8	2390.0	96.76
	100	133.0	1592.0	99.72	200.0	2393.9	98.35	260.7	3120.5	96.81
	120	123.8	1523.1	99.27	196.7	2420.0	97.86	210.9	2594.7	96.35
Em_4	20	45.0	1407.0	98.00	57.9	1810.3	96.59	86.4	2701.4	95.16
	40	52.5	2339.8	98.21	75.0	3342.5	96.79	92.4	4118.0	95.33
	50	54.9	2796.2	98.76	69.9	3560.2	97.32	89.4	4553.4	95.86
	60	72.9	3837.0	97.30	90.0	4737.0	95.91	105.0	5526.5	94.47
	80	70.5	4368.7	97.78	87.9	5446.9	96.36	104.1	6450.7	94.94
	100	77.4	5304.5	97.79	94.5	6476.4	96.70	108.9	7463.3	94.61
	120	100.2	7004.0	95.75	113.1	7905.7	94.42	124.2	8681.6	93.08
Em_5	20	16	1312.0	90.99	17	1394.0	88.52	19	1558.0	87.08
	40	16	1984.0	90.15	17	2108.0	88.83	18	2232.0	87.37
	50	15	2580.0	90.25	14	2408.0	88.75	15	2580.0	87.52
	60	14	2464.0	90.11	15	2640.0	88.06	16	2816.0	87.32
	80	15	2925.0	90.08	16	3120.0	88.29	17	3315.0	87.79
	100	15	3060.0	88.71	16	3264.0	87.30	17	3468.0	86.14
	120	15	3600.0	87.64	16	3840.0	86.03	17	4080.0	86.06

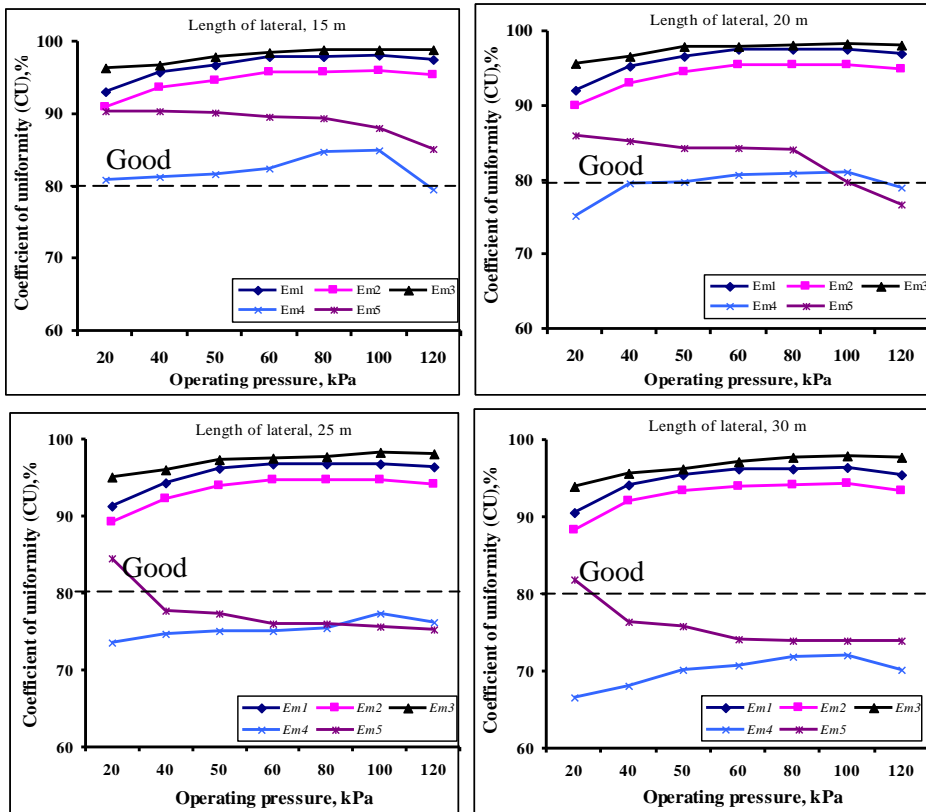


Figure (5): Relationship between operating pressure and coefficient of uniformity at different lateral length for different emitters.

The results indicate that the highest value of *CU* was obtained at operating pressure of 100 kPa and lateral length of 15 m for all tested ranges of operating pressures. The maximum values of *CU* were 98.85, 98.01, 95.91 and 84.94 % for the *Em*₃, *Em*₁, *Em*₂ and *Em*₄ emitters, respectively. The *CU* values excellent classifications was achieved at lateral length of 30 m for *Em*₁, *Em*₂; *Em*₃ emitters and lateral length of 15 m for *Em*₄; *Em*₅ emitters were good as it was above 80 %. Emitter *Em*₄ represent an exception in which the increase in lateral length changed the *CU* classification from good to poor according to **ASABE standards (2008)**. However, the operating pressure of 20 kPa and lateral length of 15 m for *Em*₅ as a microtube gave a *CU* value of 90.43%. Therefore, it can be concluded that the highest coefficient of uniformity could be achieved at operating pressure of 100 kPa and length of lateral 15 m for the first group emitters and using 20 kPa at the same lateral length for *Em*₅ microtube.

Model evaluation

The equations solved by the developed model resulted in optimum values of microirrigation system design parameters (i.e. uniformity, maximum discharge of lateral, friction losses, ideal number of emitters and the optimum length of lateral). The model was then evaluated by comparing the values estimated by the model with those measured in the hydraulic experiment. The comparison between the measured and the predicted values is very important in order to check out how far the simulated results from the measured ones to evaluate the capability of the programmed model in analyzing new designed emitter devices. Coefficient of determination (R^2) were approximately constant values about 0.96, 0.95 and 0.97 between measured and predicted CU for different lateral lengths of emitters Em_1 , Em_2 and Em_3 , respectively as shown in Table (3).

There is an inverse relationship between the coefficient of determination and lateral length for Em_4 and Em_5 . R^2 values were decreased from 0.88 to 0.80 and from 0.93 to 0.81 with Em_4 and Em_5 , respectively at different lateral lengths from 15 to 30 m. These differences between R^2 of local and imported emitters may be attributed to its C_v values. The C_v classification of Em_1 , Em_2 and Em_3 were classified as excellent, while C_v value of Em_4 and Em_5 was classified as marginal and unacceptable, respectively as shown in Table (1). The theoretical model and the validation experiment were compared indicating that there was a strong relationship between the measured and predicted CU at different treatments.

Table (3): Coefficient of determination (R^2) at different lateral lengths and emitters.

Emitter type	Coefficient of determination (R^2)			
	Length of lateral, m			
	15	20	25	30
Em_1	0.9638	0.9603	0.9629	0.9559
Em_2	0.9539	0.9544	0.9525	0.9507
Em_3	0.9725	0.9717	0.9707	0.9634
Em_4	0.8845	0.8573	0.8136	0.8066
Em_5	0.9395	0.8644	0.8377	0.8169

CONCLUSION

A computer model was developed by Matlab version 10.0 to determine optimum lateral length of microirrigation systems. The model was validated by hydraulic experiment for different emitters and lateral lengths (15, 20, 25 and 30 m) under operating pressures (from 20 to 120

kPa). The emitters were divided into in-line (Em_3), on-line (Em_1 , Em_2 , Em_4 ; Em_4) and microtube (Em_5). The model was designed to obtain a q_{var} of 10, 15 and 20 % and/or CU greater than 85 %. CU was inversely proportional with lateral length, the best results was obtained under 100 kPa for all manufactured emitters and 20 kPa for microtube. The comparison between measured and predicted CU at different lateral lengths and operating pressures for emitters, indicates a strong correlation with coefficient of determination (R^2) more than 0.95 for Em_1 , Em_2 and Em_3 , while this relationship was decreased with R^2 about 0.80 for Em_4 and Em_5 at different treatments.

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المخلص العربي

تطوير نموذج حاسوب لتحديد أفضل طول خط جانبي لنظم الري الدقيق

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الهدف من هذه الدراسة هو تطوير نموذج حاسوب يحدد أفضل طول مناسب لخط جانبي بنظم الري الدقيق. وفي هذا النموذج تم إستخدام نظام محاكاة لحساب انتظامية توزيع المياه وتحديد أفضل طول مناسب للخط الجانبي عند معامل اختلاف التصريف (q_{var}) (١٠، ١٥ و ٢٠%) أو معامل انتظامية توزيع المياه ($CU \geq 85\%$). وقد تم عمل تجربتين بكلية الزراعة جامعة قناة السويس بالإسماعيلية لإثبات صحة القيم المتنبأ بها من البرنامج. وفي التجربة الأولى تم دراسة الخصائص الهيدروليكية (معدل تصرف، معامل اختلاف التصنيع وأس تصرف المنقط) لستة أنواع مختلفة من المنقطات المتاحة في السوق المحلي. وتم تقسيم المنقطات إلى منقطات مصنعة كوحدة واحدة مع الخط الجانبي (Em_3)، ومنقطات مركبة على الخط الجانبي (Em_1 ، Em_2 ، Em_4) والأنابيب الدقيقة المركبة على الخط الجانبي (Em_5). وفي التجربة الثانية تم اختبار الأداء الهيدروليكي للوحدة التحت رئسيه للري الدقيق لأفضل المنقطات التي اختيرت من التجربة الأولى وذلك تحت تأثير سبع ضغوط تشغيل (٢٠، ٤٠، ٥٠، ٦٠، ٨٠، ١٠٠ و ١٢٠ ك باسكال)، وأربع أطوال من الخطوط الجانبية ذات قطر ١٦ مم (١٥، ٢٠، ٢٥ و ٣٠ م). ولقد أظهرت النتائج أن أعلى قيم لمعامل انتظامية توزيع المياه هي ٩٨،٨٥٪ للمنقط (Em_3) وتم الحصول عليها عند ضغط تشغيل ١٠٠ ك باسكال وطول خط جانبي ١٥ م، بينما كانت أعلى قيمة لمعامل انتظامية توزيع المياه للأنابيب الدقيقة (Em_5) ٩٠،٤٣٪ عند ضغط تشغيل ٢٠ ك باسكال وطول خط جانبي ١٥ م. وكان معامل الارتباط (R^2) أعلى من ٠،٩٥ لكل من المنقط (Em_1 ، Em_2 ، Em_3)، وقلت قيمة R^2 لتصل ٠،٨٠ للمنقط (Em_4 ، Em_5) بين القيم المحسوبة والقيمة المتنبأ بها لمعامل انتظامية توزيع المياه.

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