PERFORMANCE EVALUATION OF LOW PRESSURE DRIP-SUBUNIT UNDER DIFFERENT EMITTER TYPES AND DESIGN PARAMETERS

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ABSTRACT

Two experiments were conducted to evaluate the hydraulic performance of drip irrigation subunit designs using three emitter types (Em_1, Em_2; Em_3). Each subunit consisted from one of three lateral lengths (20, 30 and 40m) which connects in open loop (OL) and close loop (CL). The results revealed that shortening the lateral length and close loop increase flow distribution uniformity (DU) for all emitter. There is a different effect of emitter types on the hydraulic performance of each loop at the three lateral lengths. Despite CL improves the hydraulic performance than OL, the effect was always limited. The main influence is attributable to the lateral length and emitter type.

Keywords: *Low Pressure, Drip, Hydraulic Performance, Emitter, Uniformity.*

1. INTRODUCTION

Egypt is an arid area with low rainfall and high evaporation rates. Water is the main factor for the country development. Agriculture is mainly depending on irrigation, call for 50 to 85% of the total water use **(Capra and Scicolone, 2004)**. The drip irrigation method is considered as the most efficient method requiring only 20 to 30% of water as compared to conventional methods **(Tagar et al., 2010)**. Partial wetting of the soil volume, superior emission uniformity and a high level of control over water application facilitate efficient utilization of the limited water resources.

Drip systems are typically designed to operate at 100 kPa. Most rural communities in Egypt consist of smallholder farmers whose low income hinders adoption of a complex technology. However, most of drip irrigation systems in Egypt were using low-pressure to save energy **(Harby and Hans-Heinrich, 2013)**.

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The combination of laterals and manifold pipe constitute a hydraulic subunit. The design process is used to reduce the friction-induced pressure changes in the lateral to achieve an acceptable level of emitter discharge variation **(Phocaides, 2000)**.

Small differences between emitters may result in significant discharge variations **(Kirnak et al., 2004)**. The selection of emitters is difficult because there are a variety of emitter characteristics to be considered in relation to crop, soil and topography, emitter price and hydraulic performance of the system **(Rashad, 2006)**. Therefore, the objective of this study was to improve the hydraulic performance of low pressure drip irrigation subunit under Egyptian conditions.

MATERIALS AND METHODS

Two experiments were carried out in agriculture faculty, Suez Canal University to calibrate emitters' hydraulic characteristics and to evaluate the hydraulic performance of subunit designs.

Emitter Hydraulic Evaluation:

The first experiment was to calibrate hydraulic characteristics of a three commonly used emitters in the local market (table 1). The emitters Em_1 and Em_2 were globally used with relatively high prices, where Em_3 was locally manufactured and commonly used by the farmers in Egypt, due to its cheap price. The three emitters discharge were measured at five operation pressures of 20, 50, 80, 100 and 120kPa in three replications. The test bench was closed system and constructed to allow testing of 40 emitters simultaneously by using fresh water. The equation for Pressure-flow relationship that has been used by **Keller and Karmeli (1974)** and many researchers can be expressed as:

$$q = k\, h^{x} \quad \dashrightarrow (1)$$

Where q : emitter discharge rate (ℓ/h), h : pressure head at the entry of the emitters (m), k : dimensionless constant of proportionality that characterizes each emitter, and x : dimensionless emitter discharge exponent which characterizes the flow regime.

The emitter manufacturer's coefficient of variation was calculated by measuring the discharge from a sample of the new emitters after **ASABE EP405.1 (2008)** as follows:

$$C_V = \frac{S}{\bar{x}} \quad \cdots\rightarrow (2)$$

Where C_V: manufacturer's coefficient of variation (Dimensionless); S : the standard deviation of the emitters discharge in the sample (ℓ/h), and $\bar{\chi}$: emitter's discharges mean (ℓ/h).

Evaluation the Subunit Hydraulic Performance:

The second experiment was conducted to evaluate the hydraulic performance of drip irrigation subunit designs (Fig. 1). Fresh water was pumped to the experiment by a 1.5HP pump. A ball valve, flow meter and a pressure gauge (0.6bar) with an increment of 2kPa were attached to the entrance of every manifold line (to control the discharge and the pressure under 20kPa). Sub main pipe PE (low density polyethylene) with inside diameter (I.D) of 54.50mm was branched to two groups of subunit designs (three subunits in each group) for each emitter. Three PE laterals (14.50mm I.D) from each length of 20, 30 and 40m were connected with each PE manifold pipe (25.25mm I.D) on a level terrain. These laterals loop were open in the first group, and closed in the second group. The distance between lateral lines was 1m with emitter spacing of 50cm.

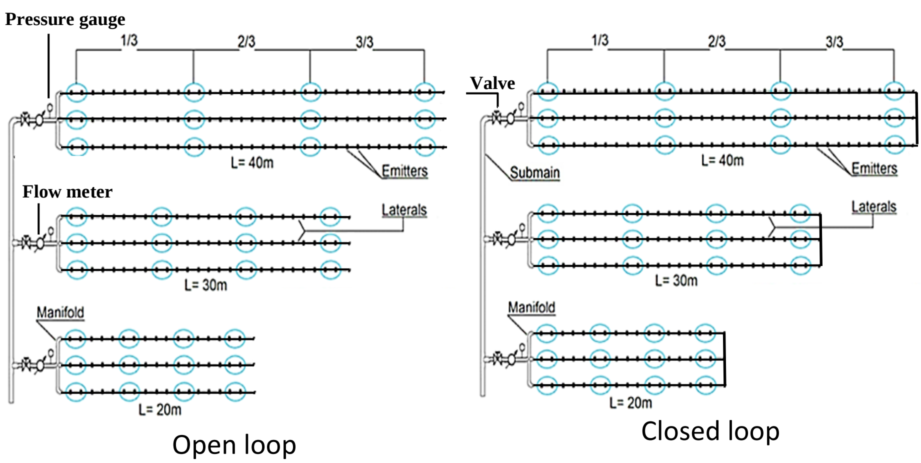

Figure (1): Schematic diagram of the subunit designs with locations of testing for each emitter type.

Pressure variation P_{var} compares maximum and minimum pressure along a single lateral as:

$$P_{var} = \frac{(P_{max} - P_{min})}{P_{max}} \times 100 \quad \dashrightarrow (3)$$

Where P_{max} and P_{min}: maximum and minimum emitter pressure (kPa), respectively.

The emitter discharge variation q_{var} calculated in the same manner of P_{var}. The desirable q_{var} according to **(Clark *et al.*, 2007)**; is less than 10% (approximately 20% for variation in pressure) for the design of lateral line. The acceptable variations ranged from 10% to 20%, (approximately fallen in 20% to 40% range variation in pressure), while, the unacceptable variation is more than 20% (approximately 40% for variation in pressure). Distribution Uniformity (*DU)* is a common index for uniformity application. The excellent *DU* values were above 90%, good between 90 to 80%, fair between 80 to 70%, poor between 70 to 60%, and unacceptable below 60% **(ASABE EP405.1, 2008)**. Two contiguous emitters were selected on each lateral at four locations (at the inlet, 1/3, 2/3 and the far end of the lateral) measured as representative sample of flow rate as shown in Fig. 1. The sample of flow rate was calculated as **(Jiang and Kang, 2010):**

$$DU = \left(\frac{q_{lq}}{q_a}\right) \times 100 \dashrightarrow (4)$$

Where q_{lq}: the mean discharge of the lowest one-fourth of emitter flow rates, ℓ/h, and q_a : the mean discharge of all the sampled emitters, ℓ/h.

RESULTS AND DISCUSSION

Emitter Hydraulic Characteristics:

Table (1) shows the main hydraulic properties of the calibrated emitter types such as nominal and measured flow rate, difference percentage between nominal and measured discharge, emitter discharge equation constants (*k*, *x*), flow regime; the manufacturer's coefficient of variation (*Cv*) and its classifications according to ASABE EP405.1 (1988).

***Tab**le (1): The main hydraulic characteristics of emitter types.

Emitter		q (ℓ/h)		Diff.	constants		Type	(*Cv*)	
Symbol	Trademark	Nom.[1]	Meas.	(%)	*K*	*X*		Value	Classify.
Em_1	Katif	3.75	4.01	6.93	7.60	-0.14	PC[2]	0.06	Average
Em_2	Turbo Key	4.00	4.22	5.50	0.54	0.45	T[3]	0.13	Marginal
Em_3	Metallic	4.00	29.6	640	2.06	0.57	T	0.28	Unacceptable

(1) = Nominal discharge at100kPa, (2) =Pressure Compensating, (3) =Turbulent Flow.

The emitter exponent (*x*) for Em_1 was a negative number close to zero (-0.14). Where, the *x* values were 0.45 and 0.57 for Em_2 and Em_3, respectively. The results of *x* were agreed with the emitter manufacturer's classification. *Cv* was on the same classification under different operating pressures with the three emitter types. *Cv* evaluation was average, marginal and unacceptable with Em_1, Em_2 and Em_3 respectively.

Subunit Hydraulics Performance:

Pressure variation (P_{var}). Figure 2-A showed P_{var} under the two Lateral loops at three lengths using *Eq. (3)*. P_{var} of Em_1 under *OL* and *CL* was 5, 25; 38.35% and 5, 20.85; 31.65 % at 20, 30; 40m lateral lengths, respectively. It was desirable classification at 20m and acceptable at 30m; 40m lateral lengths under both loops. Em_2 under *OL* and *CL* were 5, 18.35; 21.65 and 3.35, 10.85; 12.5 at 20, 30; 40m lateral lengths, respectively. P_{var} was desirable for all lateral lengths under both loops. P_{var} of Em_3 under *OL* and *CL* were 51.65, 60, 64.15 and 50, 53.35, 54.15 at lateral lengths of 20, 30 and 40m, respectively. All P_{var} values of Em_3 were classified as unacceptable. P_{var} was increased by lateral length increasing for all emitter types under the two loops. P_{var} under *CL* were lower than *OL* at the three lateral lengths for all emitter types. P_{var} was in the following descending order ($Em_3 > Em_1 > Em_2$) at the three lateral lengths under the two loops.

The average discharge (q_a). Average discharge of Em_1 under *OL* and *CL* was 4.41, 4.36; 3.80ℓ/h and 4.50, 4.44; 3.85ℓ/h at 20, 30; 40m lateral lengths, respectively.

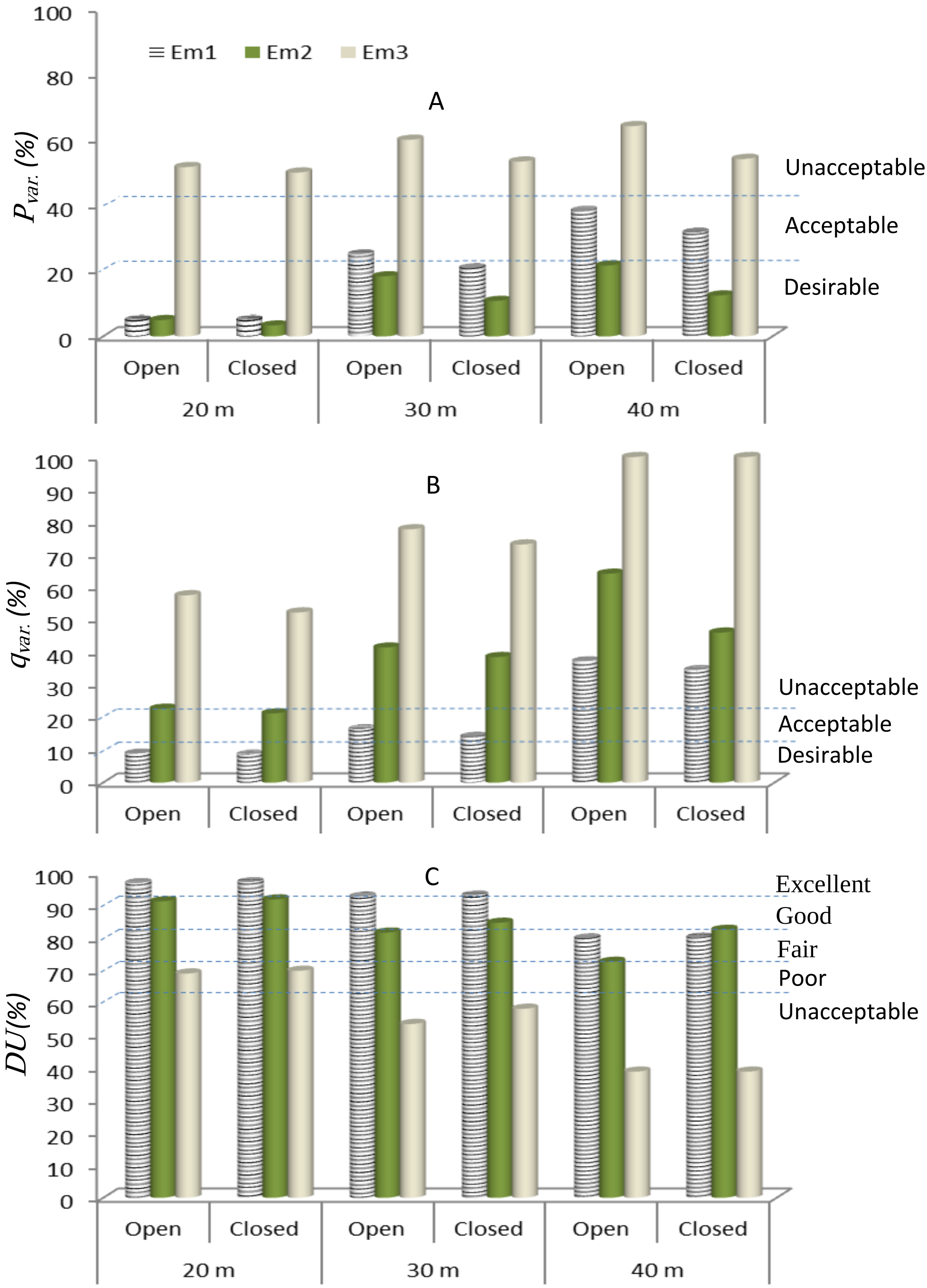

Figure (2): The effect of lateral length, emitter type and subunit loop on the pressure variation P_{var} (%), discharge variation q_{var} (%) and distribution uniformity DU (%).

Average discharge of Em_2 under *OL* and *CL* was 2.08, 2.04; 1.80ℓ/h and 2.08, 2.05; 1.88ℓ/h at 20, 30; 40mlateral lengths respectively. Average discharge of Em_3 under *OL* and *CL* were 9.11, 7.84; 7.30ℓ/h and 9.52, 7.93; 7.30*ℓ/h* at 20, 30; 40m lateral lengths, respectively. Average discharge values were slightly increased under *CL* than *OL* and proportionally decreased by lateral length increasing under the both loops for all emitter types.

Emitter discharge variation (q_{var}). Discharge variation under different treatments showed in (Fig. 2-B). Discharge variation *of* Em_1 in *OL* and *CL* was 8.95, 16.42; 37.28% and 8.62, 14.10; 34.53% at 20, 30; 40m lateral lengths, respectively. Discharge variation was classified as desirable, acceptable and unacceptable at 20, 30 and 40m lengths, respectively under the two loops. Discharge variation of Em_2 under *OL* and *CL* were 22.72, 41.51; 64.18% and 21.27, 38.59; 46.09% at 20, 30; 40m lengths, respectively. All the flow variation percentages for Em_2 were higher than 20%, which classified as unacceptable. Discharge variation for Em_3 under *OL* and *CL* were 57.55, 77.82; 100.0% and 52.29, 73.16; 100.0% at 20, 30; 40m lengths, respectively which classified as unacceptable. The *CL* has lower q_{var} than the *OL* at all lateral lengths for all emitter types. Discharge variation increased by increasing lateral length for all emitter types under the two loops. In conclusion emitters Em_3 and Em_2 were turbulent flow (*TF*) with low *Cv* classification, while Em_1 was pressure compensating and had average *Cv*. The effect of emitter types on q_{var} dissimilar the effect on P_{var} and could be stated in the following descending order: $Em_3 > Em_2 > Em_1$.

Distribution uniformity *(DU)* showed in Figure 2-C, for Em_1 under *OL* and *CL* were 96.73, 92.61; 79.79% and 97.03, 92.95; 80.01% at 20, 30; 40m lateral lengths, respectively. Em_1 has an excellent *DU* at 20; 30m and good at 40m lateral lengths under both loops. *DU* of Em_2 under OL and CL was 91.16, 81.52; 72.53% and 91.72, 84.55; 82.37% at 20, 30; 40m lateral lengths, respectively. *DU* at 20m and 30m lengths were excellent and good, respectively under the two loops, whereas *DU* was fair and good at 40m under *OL* and *CL*, respectively. The *DU* of Em_3 under *OL* and *CL* were 68.94, 53.43; 38.79% and 69.78, 58.11; 38.79% at 20, 30; 40m lateral lengths, respectively. *DU* at 20m was poor and unacceptable at 30; 40m lengths under the two loops. The *CL* had higher distribution uniformity than the OL at 20 and 30m lateral lengths. It is noted that the length of 40m showed identical *DU* percentages; due to absence of water pressure at the lateral outlet ends.

CONCLUSIONS

The results show that global emitters Em_1 *and* Em_2 were pressure compensating with average C_V and turbulent flow with marginal C_V, respectively. On the other hand local emitter Em_3 was turbulent flow with unacceptable C_V. Distribution Uniformity (*DU)* of Em_1 was excellent with all lateral lengths. *DU* of Em_2 was decreased from excellent with *20*; 30m to good with 40m lateral length. While *DU* of Em_3 was decreased from fair to unacceptable by increasing lateral length more than 20m. *DU* was increased while P_{var} and q_{var} were decreased with close loop *(CL)* and short lateral length compared with open loop *(OL)* and long lateral length for all emitters. The study concluded that the lateral length and emitter type are the main influence parameters. Although there are hydraulic limited benefits for *CL*, it may have added some advantages such as facilitating washing laterals.

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الملخص العربى

تقييم أداء الوحدة الفرعية للري بالتنقيط منخفض الضغط عند تصميمات و انواع منقطات مختلفة

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تهدف هذه الدراسة لتحسين الأداء الهيدروليكي للوحدة الفرعية للري بالتنقيط منخفضة الضغط لصغار المزارعين كما هو الحال في مصر. لتحقيق هذا الهدف، أجريت تجربتين في كلية الزراعة، جامعة قناة السويس. وكانت التجربة الأولى لمعايرة الخصائص الهيدروليكية لثلاثة منقطات المستخدمة في التجربة مختارة من المتداولة في السوق المحلية $(Em_1, Em_2; Em_3)$. حيث كانت المنقطات Em_1 و Em_2 مستوردة، معوض للضغط بمعامل اختلاف تصنيع CV متوسط و مضطرب السريان بمعامل CV هامشي ، على التوالي. في حين كان المنقط Em_3 محلي التصنيع و مضطرب السريان ذو معامل CV غير مقبول.

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ثاني تجربة كانت تهدف لتقييم الأداء الهيدروليكي لعدة تصاميم للوحدة الفرعية تحت ضغط تشغيل ٢٠ كيوباسكال. وقد تألفت الوحدات الفرعية من ثلاثة أطوال لخطوط الري الجانبية (٢٠ و ٣٠ و ٤٠ م) لكل نوع منقط في نظام مفتوح OL (نهايات الخطوط غير متصلة) و نظام مغلق CL (متصلة النهايات). و أظهرت النتائج أن تقصير طول الخطوط الجانبية و استخدام التصميم المغلق CL يزيد قيم q_a و DU و ينقص من P_{var} و q_{var} لجميع أنواع المنقطات. كذلك هناك اختلاف في التأثير على الأداء الهيدروليكي للوحدة الفرعية تبعاً لنوع المنقط. و خلصت الدراسة لأن التأثير الرئيسي يعزى إلى الطول الجانبي و نوع المنقط و ليس نظام اتصال الخطوط الجانبية. وعلى الرغم من الفوائد الهيدروليكية المحدودة للنظام المغلق CL، الا أنه قد يكون له بعض المزايا الاخرى كتسهيل غسيل الخطوط الجانبية.