HYDRAULIC PROPERTIES OF SOME POLY-ETHELENE LATERALS WITH BUILT-IN DRIPPERS

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Abstract

A field study was conducted in Bustan area to determine the suitable length of PE pipes built-in drippers) with outer diameters of 15.6 mm, 16mm and 20 mm at 50 cm spacing between drippers. The average emitter discharges ranged from 2.0 to 2.5 l/h at operating pressure 1.0 bar. Three random samples were tested according to the described methods in ISO 9260 (1991) and AEnRI Standard Coding: IR/DR/EM/TEST/ (2002). The tested samples were:

1- PE built-in dripper 15.6 mm/ 50 cm and nominal discharge 2.2 l/h.

2- PE built-in dripper with 16.0 mm /50cm and nominal discharge 2.2 l/h.

3- PE emitter built-in dripper 20/ 50cm and nominal discharge 2.5 l/h.

The results showed that:

1- In case of pipe 15.6/13.8 mm (O.D/ I.D.), the maximum length under test conditions was 140 m of pressure drop from 1.5 bar to 1.0 bar. The emitter showed a turbulent characteristic according to observed equation $q = 2.5073\ h^{0.5001}$. However, at conventional design condition of allowable pressure drop 10 % from inlet pressure of 1.0 bar , the suitable design length was 75 m with discharge drop 2.5 to 2.38 l/h.

2- In case of drip line emitters with O.D/ I.D 16/13.8 mm of fully self compensating, , the suitable design length reached to 140 m according to field data which showed an almost constant discharge of about 2.2 l/h at inlet pressure 1.0 bar according to observed equation $q = 2.2\ h^{0.0523}$.

3- In case of pipe 20.0 mm O.D. and 17.6 mm I.D the suitable length 160 m, at inlet operating pressure 1.5 bar decreased to 1.0 bar resulted with turbulent flow, $q = 2.69457h^{0.4938}$ at the allowable variation of the pressure 10.0% from inlet pressure (1.0 bar) and discharge 5.0%. The discharge ranged between 2.70 l/h and 2.56 l/h for length 120 m.

Keywords: PE pipes, Built- indrippers, Allowable length, Distribution uniformity of driplines, Hydraulics.

INTRODUCTION

The use of built-in dripprs for row crops production is increasing as competition for water resources increases and as the benefits of drip irrigation is demonstrated. Built-in drippers hydraulic characteristics must be known to design drip irrigation systems. The hydraulic variation is the one which can be controlled through hydraulic design by engineers.

As water resources are limited in Egypt, it is extremely important to introduce modern irrigation systems and management techniques to save water for expanded agriculture. Considerable research and field trials have demonstrated, to the producer, the suitable lateral length of PE inline emitters smaller than 20 mm. to decrease the costs, especially of lateral lines, and generally of the irrigation systems. Awady *et al.*(1975) reported early trickle irrigation system designed, constructed, and tested, and used unified testing criteria regarding an allowable pressure drop 10% for the first time in Egypt. Since then standard procedure for design and testing of driplines was demanded. Wu and Gitlin (1983) said that the uniformity of emitter (or orifice) flow depends on the emitter flow variation along lateral lines which is mainly affected by the hydraulic design of the drip irrigation system, manufacturing variation, temperature and emitter plugging including partial plugging of emitters. ISO 9260 (1991) cites the emission rates of the emitters in the test samples when the water pressure at the emitter inlets equals the nominal test pressure. The measured emission rate is recorded at each emitter outlet. AENRI-MSAE (2002) explained that the number of drippers in the test samples should not be less than 20, in addition to the number used in preliminary tests. El-Berry *et al.* (2004) presented a theory and procedure for drip line testing. Their work was on the same testing setup of this work although its objective was different and aimed at standardizing the test procedure, rather than obtaining experimental results.

Bralts *et al.* (1985) pointed out that the field evaluating of trickle irrigation systems is important for several reasons: field evaluation is important to the design engineer in order to determine whether or not the desired emitter discharge uniformity specifications are being met for the system capacity and its subunits. It is important to an irrigator in deciding if the system can be operated efficiently and whether or not it can be improved. It is important as a diagnostic tool for determining what equipment or hardware items may need to be repaired. Warrick and Yitayew (1988) indicated that an important objective of any trickle system is a uniform distribution of water delivered through the emitters. Computation of flow distribution requires knowledge of the variables such as pressure, flow rate, length of lateral, characteristics of the orifices and frictional loss in the system. They said that several studies established these relationships. In each study, the primary solution is based on discharge that is uniform, although ramifications of the manufacture variability have been modeled based on the derived hydraulic profile. ASAE (1989) defined the manufacturer's variation as follows: it is a measure of the variability of discharge of a random sample of a given make, module and size of emitter, as produced by the manufacturer and before any field operation of aging has taken place. Wu (1992) said that there are several parameters, which can serve uniformity definition. Emitter flow variation was defined as:

$$q_{var.} = \{ q_{max} - q_{min} / q_{max} \}.$$

Where: (q_{var}) is the emitter flow variation, (q_{max}) maximum emitter flow rate, L/h. and (q_{min}) emitter minimum flow rate, L/h along a lateral or in a submain unit.

Wu and Gitlin (1974) demonstrated that the hydraulic design of drip irrigation system can be made by designing lateral lines and sub main separately.. Parchomchuk (1976) recommended that temperature caused variations can drastically reduce irrigation uniformity. To achieve precise control of water application which is possible with trickle irrigation, design must account for temperature effects. Solomon (1985) has indicated that the major factors affecting a micro irrigation subunit uniformity in order of importance are as follows: clogging, number of emitters per plant , emitter coefficient , emitter exponent, emitter response to water temperature , and subunit pressure variation Irudayaraj(1987) reported that the emitter flow variation is caused by a single lateral and the submain

The present work aims to:

1- Study the suitable length of lateral line under inlet pressure at inlet pressure 1.5 bar decreased to 1.0 bar and inlet [pressure around 1.0 bar with drop of about 10%.

2- Calculate the lateral length at flow rate variation of 5.0 % and pressure variation of 10.0% for turbulent type emitters.

3- Identify the flow type (laminar, turbulent, or self compensating) with relevant indices.

MATERIALS AND METHODS

2a – Experimental site.

Field experiment was conducted in July 2004 at El-Bustan Research Station, Nobaria District. The site belongs to the Ministry of Agriculture and Land Reclamation. The water temperature during the testing duration was about 32 °C with density of 995 kg/m^3 and kinematics viscosity 0.761 Pa.s. The some values of chemical analysis of the irrigation water are presented in Table (1).

Table 1. Some chemical analysis of irrigation water (Nile Water from Bustan Canal) at Bustan site.

p^H	EC	Soluble Cations, meq/l				Soluble Anions, meq/l			SAR
	Mmhos/cm	Ca^{++}	Mg^{++}	Na^+	K^+	Hco_3^-	SO_4^{--}	Cl^-	
7.74	1.02	1.03	0.74	8.01	0.42	1.95	4.52	3.73	8.51

2b - Laterals tested.

Three laterals of PE with same samples of emitters (GR drip irrigation). The tested samples that used in this study were 200 m long, built- in drippers with 50 cm spacing, and have some fine specifications as shown in the Table (2).

Table 2. Specifications of the tested samples.

Specifications	Sample (1)	Sample (2)	Sample (3)
Outer diameter (mm)#	15.6	16.0	20.0
Wall thickness (mm)	0.9	1.1	1.2
Inlet diameter (mm)	13.8	13.8	17.6
Nominal working pressure (bar)	1.0	1.0	1.0
Nominal discharge (l/h)#	2.2	2.2	2.5

According to the manufacturer catalog.

2c - Components of the layout of the field test

The control head is located at the source of water supply. It consisted of a centrifugal pump, back flow prevention device, pressure regulator, pressure gauges, flow meter, sand media filter, and screen filter. Main and sub-main lines: 110 mm diameters (OD), P.V.C. pipe were used for the main and 63 mm P.V.C. for sub-main.

Manifold: 32 mm PE., pipes were used to supply water to the constructed three laterals at once: 16 mm and 15.6 mm PE outer diameter tube, built-in drip lines with nominal flow rate of 2.2 l/h 0.5 m. spacing, and 20 mm PE outer diameter tube, built-in drip line with nominal flow rate of 2.2 lPh/0.5 m for total length 200 m. The inlet pressure was taken 1.5 bar and the mean flow rate and operating pressure were measured each 20 m for each sample. The suitable length at 10.0% pressure losses and the mean flow rate were determined and emitter equation was established to identify the flow type. ISO 9260: 1991(E) reported that, the determination of emitter exponent applies only to regulated emitters. The relation between the emission rate, in liter per hour q, and the inlet pressure in an emitter, P_i (kilopascals) is given by the formula.

$$q = kh^m \quad ....(1)$$

where:

k = is a constant

m = is the emitter exponent.

The value of the emitter exponent m shall not exceed 0.2.

Ratio of pressure drop ratio ($\Delta P/P_o$) is calculated as follows:

$$(\Delta P/P_o) = (Pi - P_o/ Pi) ....(2)$$

where:

Pi = inlet operating pressure (bar).

P_o = outlet pressure (bar) after the specified line - length.

Length ratio (L/S) calculated as given by Berry *et al.* (2004) as an example in case of PE built -in dripper 1506 mml 50 cm and nominal discharge 2.2 l/h which can be estimated through the following equation. $(\Delta p/po) = 4.92\ E.6\ (LIS)^{1.98}$

Where : L= Measured length (meter).

S= Spacing between emitters in same pipe line (0.5 m).

This equation is dimensionless and based on (L/S) parameter for any spacing between emitters on the lateral line.

Measure the emission rates of the emitting units in the emitting- pipe when the water pressure at the inlets of the emitting units equals the nominal test pressure. Record separately the measured emission rate of each emitting outlet.

Coefficient of variation, C_v may be calculated from the following formula (According to ISO 9261, 1991).

$$C_v = S_q / q_m \times 100 \quad (3)$$

Where:

S_q = is the standard deviation of the emission rates for the sample.

q_m = is the mean emission rate of the sample.

The following requirement shall be met :

a) The mean emission rate of the sample shall not deviate from the nominal emission rate by more than 5.0% for category A , nor more than 10% for category B.

b) The coefficient of variation, C_v, of the emission rate of the test sample shall not exceed 5% for category A nor 10% for category B.

RESULTS AND DISCUSSION

3a – The relationship between lateral length ratio and pressure drop ratio.

The following relationships were obtained from curve fitting of the relevant graphs. However the driplines were obtained as one piece from long coils without joints. (as shown in Fig. 1).

3a1- PE built-in dripper 15.6 mm/ 50 cm and nominal discharge 2.2 l/h.

The maximum experimental length obtained causing pressure drop from 1.5 bar to 1.0 bar was 140 m. However the suitable length at inlet operating pressure 1.0 bar with pressure drop 10.0% was 75 m with C_v of drippers 8.2%, which can be estimated through the following equation :

$$(\Delta P/P_o) = 4.92\text{ E-}6\ (L/S)^{1.98} \quad (4)$$

3a2- PE built-in dripper self compensating 16.0 mm/ 50 cm and nominal discharge 2.2 l/h.

The length at pressure drop from 1.5 bar to 1.0 bar was 100 m and the suitable length for self compensation was 140 m with C_v of drippers 5.5%, which can be estimated through the following equation:

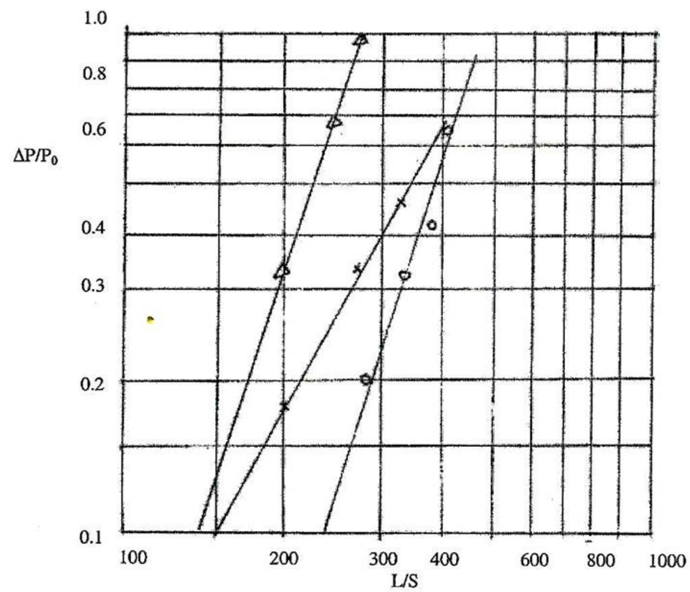
$$(\Delta P/P_0) = 5.6\text{ E-}9\ (L/S)^{3.37} \quad (5)$$

3a3- PE built in dripper 20.0 mm/ 50 cm and nominal discharge 2.5 l/h.

The suitable length at pressure reducing from 1.5 bar to 1.0 bar was 160 m and the suitable length at inlet operating pressure 1.0 bar with reducing operating pressure 10.0% was 120 m with C_v of drippers 7.5% , which can be estimated through the following equation :

$$(\Delta P/P_0) = 1.44\ E\text{-}9\ (L/S)^{3.32} \quad \ldots\ldots (6)$$

The economical cost is effective parameter in the irrigation system design in general. The lateral length is usually around 50.0 – 100 m in most designs of drip irrigation systems. Meanwhile, tested lengths ranged from 75m to 200 m. The cost of the drip irrigation system decreases, in longer laterals according to the test results, within 10.0% pressure drop.



$(\Delta = (\Delta P/P_o) = 4.92\ E-6\ (L/S)^{1.98})$. for 15.6 mm O. D..

$x = ((\Delta P/P_o) = 5.60\ E-9\ (L/S)^{3.37})$. for 16.0 mm O. D..

$o = ((\Delta P/P_o) = 1.44\ E-9\ (L/S)^{3.32})$. for 20.0 mm O. D..

Fig. 1. The relationship between pressure reducing ratio and Length ratio.

3b – The relationship between operating pressure and dripper flow rate.

3b1- PE built-in emitters 15.6 mm/ 50 cm and nominal discharge 2.2 l/h.

The data in Fig.2 show that the dripper flow rates at inlet operating pressure 1.0 bar ranged from 2.5 to 2.38 l/h with variation ratio 5.0% through lateral length up to 75 m which conform closely to nominal flow rate . Generally, the dripper flow rate through distributors varied from 2 .0 l/h to 2.5 l/h at operating pressure 1.0 bar. So the equation of the PE built-in dripper 15.6 mm/ 50 cm spacing was as follows:

$$q = 2.5073\ h^{0.5001} \qquad (7)$$

The type of flow in this case is turbulent, as defined by the exponent of 0.5 and the mean flow rate was 2.5 l/h at 1.0 bar working pressure for length of 75 m which is about 13.6% above the nominal discharge.

3b2- PE built-in self compensating dripper 16.0 mm/ 50 cm and nominal discharge 2.2 l/h.

The data in Fig.3 show that in the case of drip line emitters of self compensating flow, with pipe O.D/ I.D 16/13.8 mm, the suitable design length reached 140 m according to field data showing an almost constant discharge of about 2.2 l/h at 1.0 bar working pressure. The type of flow in this case is fully self compensating, found from the exponent 0.05 and the mean flow rate equal 2.2 l/h was as follows.

$$q = 2.2\ h^{0.0523} \qquad (8)$$

3b3- PE built-in dripper 20.0 mm/ 50 cm and nominal discharge 2.5 l/h.

The data in Fig.4 show that the dripper flow rates ranged from 2.7 to 2.57 l/h with variation ratio 5.0% through lateral length up to 120 m at inlet operating pressure 1.0 bar. Generally the dripper flow rate through distributors varied from 2 .5 l/h to 2.8 l/h at operating pressure 1.0 bar with mean flow rate 2.7 l/h. So the equation of the PE built-in dripper 20.0 mm/ 50 cm spacing was as follows:

$$q = 2.6945\ h^{0.4938} \qquad (9)$$

The type of flow in this case is essentially turbulent as defined by the exponent of 0.4938 and the mean flow rate was equal 2.7 l/h at operating pressure 1.0 bar for length of 120 m which is about 8.0% above the nominal discharge.

Finally, from the data in Figs. 4, 5, and 6,it is clear that the use of emitters flow function is an appropriate model to fit into PE properties. Also the coefficient of manufacturing variation and relationship between flow rate and operating pressure should be measured and reported for use into in line source drip irrigation design.

COMMENTS AND CONCLUSION

The results at inlet operating pressure between 1.0 and 1.5 bar on two sizes of PE lines 15.6 mm O.D./ 50 cm spacing, and 20 mm O.D./50 cm spacing, showing that the suitable length reached 140 m at inlet operating pressure 1.5 bar and the discharge ranged between 2.5 l/h and 3.0 l/h with turbulent flow , $q = 2.5073\ h^{0.5001}$ and the suitable length reached 75 m at inlet operating pressure 1.0 bar and the discharge ranged between 2.5 l/h and 2.38 l/h with variation of the pressure 10.0% from inlet pressure and discharge variation 5.0%. On the other hand larger line O.D. of 20 mm had emitters of the equation, $q = 2.6945\ h^{0.4938}$ giving allowable length of 160 m at inlet operating pressure 1.5 bar and the discharge ranged between 2.7 l/h and 3.3 l/h and the suitable length reached 120 m at inlet operating pressure 1.0 bar and the discharge ranged between 2.7 l/h and 2.56 l/h with variation of the pressure 10.0% from inlet pressure and discharge variation 5.0 %respectively.

In the case of pipe 16 mm O.D. and 13.8 mm inlet diameter the suitable length was 140 m resulting with self compensating emitters , $q = 2.2\ H^{0.0523}$

Tested types reached lengths from 75 m to 140 m. within 10.0% pressure drop. These longer reaches make economical design simpler.

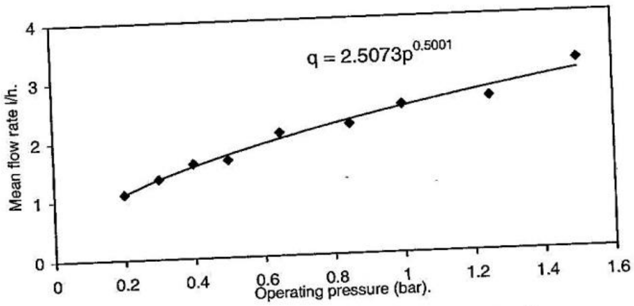


Fig.(2):The relationship between operating pressure and mean flow rate for P.E.O.D. 15.6 mm.

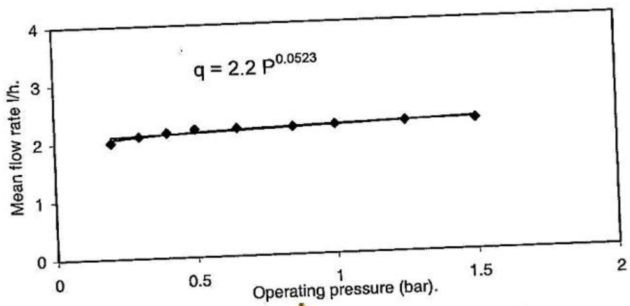


Fig.(3):The relationship between operating pressure and mean flow rate for P.E.O.D. 16 mm.

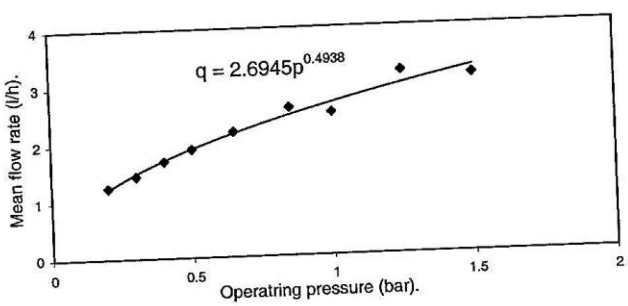


Fig. (4) The relationship between operating pressure and mean flow rate for P.E. O.D. 20 mm.

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الخصائص الهيدرولية لبعض خطوط البولي ايثلين الفرعيه ذات النقاطات الداخلية

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أجريت هذه الدراسة بمنطقة البستان، بوحدة بحوث وتطوير الري الحقلي التابعة لمعهد بحوث الهندسة الزراعية لتحديد أنسب طول لخراطيم البولي الأيثلين ذات النقاطات الداخليه، بقطر خارجي ١٦,٠، ١٥,٦، ٢٠ مم بمسافات بينيه ٥٠ سم على الخط تراوح .متوسط التصرف للنقاطات من ٢,٢ الى ٢,٧ لتر / ساعة عند ضغط تشغيل ١,٠ جوي، وتم أختبار تلك العينات تبعا للمواصفات القياسيه العالمية ٩٢٦٠ لعام ١٩٩١م.

وقد أوضحت النتائج مايلي:

١– بلغ أقصى طول للخرطوم البولي ايثلين ذو قطر خارجي ١٥,٦ مم وقطر داخلي ١٣,٨ مم عند أنحفاض ضغط التشغيل من ١,٥ جوي الي ١,٠ جوي حتى١٤٠ متر وكان نوع السريان في المخارج مضطربا. وعند حدوث انخفاض في ضغط التشغيل (١,٠ ض. ج.) في حدود ١٠,٠% ومتوسط معدل سريان ٥,٠ % أنخفض معدل التصرف من ٢,٥ الي ٢,٣٨ لتر / ساعة حتي طول ٧٥,٠ متر

وكانت معادلة السريان للمخارج كما يلي **معدل السريان = ٢,٥٠٧٣ ضغط التشغيل**^{٠,٠٥٠٠١}.

٢– – بلغ أقصى طول للخرطوم البولي ايثلين ذو قطر خارجي ١٦,٠ مم وقطر داخلي ١٣,٨ مم حتي ١٤٠متر ومتوسط معدل تصرف ٢,٢ لتر/ ساعة وكان نوع السريان ذاتي التنظيم.

وكانت معادلة السريان للمخارج كما يلي **معدل السريان = ٢,٢ ضغط التشغيل**^{٠,٠٥٢٣} .

٣– ١– بلغ أقصى طول للخرطوم البولي ايثلين ذو قطر خارجي ٢٠,٠ مم وقطر داخلي ١٧,٦ مم عند أنحفاض ضغط التشغيل من ١,٥ جوي الي ١,٠ جوي أعطي حتي ١٦٠ متر وكان نوع السريان مضطربا . وعند حدوث انخفاض في ضغط التشغيل (١,٠ ض. ج.) في حدود ١٠,٠% ومتوسط معدل سريان ٥,٠ % فأنخفض معدل التصرف من ٢,٧ الي ٢,٥٦ لتر / ساعة حتي طول ١٢٠,٠ متر

وكانت معادلة السريان للمخارج كما يلي **معدل السريان = ٢,٦٩٤٥ضغط التشغيل**^{٠,٤٩٣٨} .