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DESIGN AND PERFORMANCE EVALUATION OF A NEW SUBSURFACE EMITTER

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I- ABSTRACT

Laboratory experiments were carried out during 2011 at the Irrigation Laboratory of Agricultural Engineering Research Institute ENRI, ARC. Dokki, Giza. The aim of this study was to design and evaluation a new subsurface emitter which can be used as either a normal emitter or a bubbler. This can be achieved by two steps; first: the laterals were placed directly on the soil surface and a second: has make two exit holes in the emitter body to decrease the clogging and increase the discharge rate. The new tested emitter was evaluated by comparing its performance with both of the JR sub-surface emitter and drip bubbler made in Jordan.

The results showed that, in case of emitter, the new emitter discharge was 4.26 l/h, the coefficient of variation was 1.78%, while the sub-surface emitter JR discharge was 4.20, the coefficient of variation was 1.90% at 100 kPa.

In case of bubbler the discharge for the new sub-surface bubbler was 99.9 l/h, the coefficient of variation was 1.1%. While the discharge of the surface drip bubbler was 100 l/h and the coefficient of variation was 5.1% at 100 kPa.

II- INTRODUCTION

Irrigation simply as one of field operations in which the human supplies plants with its needs of water to grow. The sub-surface drip irrigation system is one of the most efficient irrigation methods. Which is characterized by many advantages such as include high water use efficiency, high crop productivity, and high fertilization use efficiency.

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When needed for sub-surface irrigation the farm to bury the tube interior in the soil. Which expose us to many problems such as emitter clogging, the difficulty of installation, maintenance, the spacing of emitters are constant (30, 50 cm) and the discharge values from this system are 2 and 4 L/h.(**Salman, 2009**).

Habib (1992) mentioned that the disadvantages of drip irrigation system by comparing with some other irrigation systems are emitter clogging, rats can spoil laterals, unsuitable for dense crops, salinity hazards, salts with rain to the root zone, non uniform distribution of moisture in addition to limited root growth, no protection from frost and high operating costs.

Abdelrahman (1996) found that using drip irrigation systems in North Sinai led farmers to plant their lands for few years (one to three years) then leave it for several seasons for the possibility of planting because of high salinity of lands which increases with increasing drip irrigation using time.

Shalaby (2000) concluded that in an experiment carried out in Egyptian desert lands built-in lateral lines gave the maximum water uniformity compared with on line type. Also, he indicated that drip irrigation system gave the higher values of corn crop yield and water use efficiency compared with sprinkler irrigation.

Shock *et al.* (2000) and Souline (2002) showed some disadvantages of drip irrigation system. Part of the cost is a capital investment useful for several years, and part is annual. Systems are often more elaborate than they need to be. New growers of drip irrigation might want to start with a relatively simple system on a small acreage. Drip tape must be managed to avoid leaking or plugging. Drip emitters are easily plugged by silt or other particles not filtered out of the irrigation water. Also, emitter plugging also can be caused by algae growing in tape or by chemical deposits at the emitter.

Wang *et al.* (2006) tested 16 different design combinations drip tapes in a hydraulic laboratory using ISO standard testing protocols. They concluded that, dentition spacing of emitters with labyrinth pathways showed a significant effect on the emitter discharge exponent (x). Also, they found that dentition spacing, angle, and dentition height had significant effects on the anti-clogging ability of emitters.

The aim of this study was to design and evaluate a new sub-surface emitter on the line which can be used as either a normal emitter or a bubbler. This can be achieved by two steps. First the laterals were placed directly on the soil surface and the emitters are buried in the soil. Second, make two exit holes in the emitter body to decrease the clogging

III- MATERIALS AND METHODS

III-1 Theoretical approach

A wide range of screwed joints may be adopted to various operating conditions. The American National Standard Thread has flat crests and roots (head = 0.866 pitch , θ = 60°). These threads are used for general purposes, so selected this thread in the new emitter. The screw thread were American National Standard Thread as shown in Fig. 3-1:

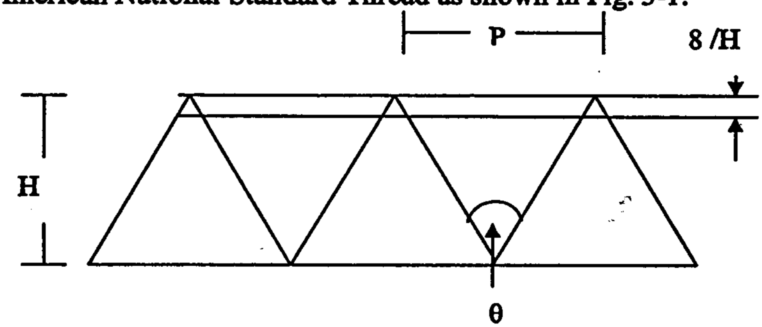


Fig. 3-1: The form of screw thread
H head P pitch

III-2 General description for new emitter

The new emitter has three parts are the head, the body and the pressure lower chamber. The head was connected to the tube on the soil surface, the length of the body of emitter is 15 cm (**Zin El-Abedin, 2006**) under the soil and the pressure lower chamber (zigzag path) can be using in this emitter under low discharge 2 to16 L/h. The sluice was selection on form for longitudinal slit to reduce stress concentration.

The specifications of emitter are: as shown in Figs. 3-2, 3-3.

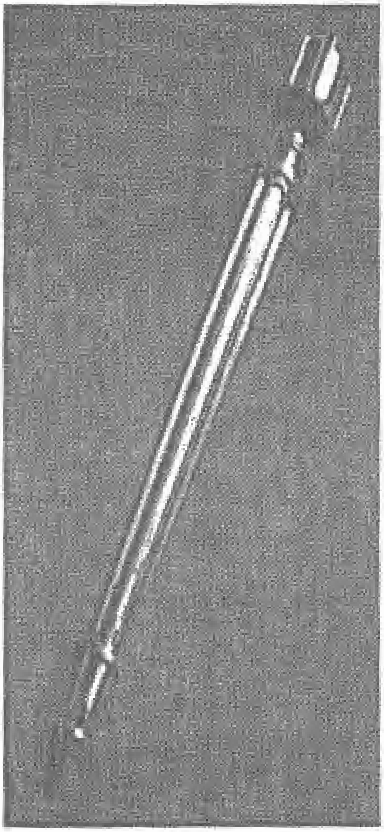
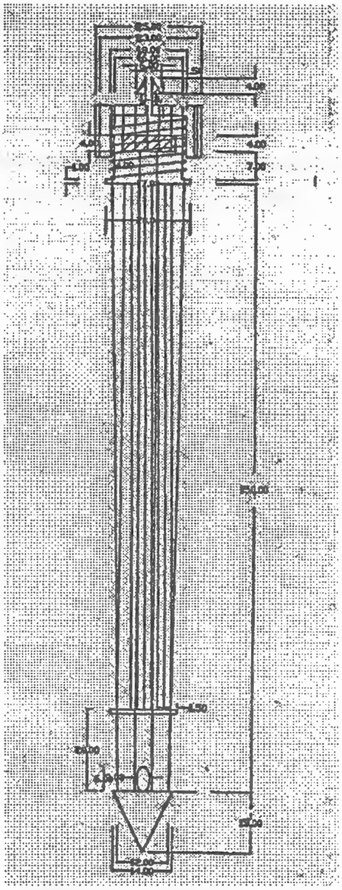


Fig. 3-1: The photo of new emitter



Scale 1:1 Diminution in mm,
Fig. 3-2: ELEV. for the new emitter

The inner volume equal 1.95 cm^3, length of emitter equal 18.5 cm, Fig. possible depth in the soil equal 15 cm, major external diameter equal 2.5 cm and head area equal 15 mm^2

III-3 Design equations:-

Energy loss, h_f:-

Hazen-Williams formula was used to calculate the pressure head loss along the lateral to calculate inlet emitter pressure head.

According to **(Wang, 2006)** as follows:

$$h_f = 1.22 * 10^{10} \frac{L}{D^{4.87}} * (Q/C)^{1.852} \text{ ....2}$$

Where: Q = discharge rate, l/s; L = length of tube, m;
D = diameter of tube, mm and
C = Hazen-Williams coefficient which was taken 130 in this study.

Discharge rate:-

The discharge rate of emitter was calculated according to **(Wang, *et al* 2006)** as follows:

$$Q = K\frac{H*d^4}{L*\eta} \text{ ....1}$$

Where: K=8.67*10^{-7};
d = diameter of the pass water in the new emitter, mm;
H = head, m; (by Hazen-Williams formula);
L = length between in let and out let for the new emitter, m and
ή = kinematics viscosity coefficient which was taken 1 * 10^{-6}m^2/s

III-4 Measurements :-

Flow rate was calculated according to **(Keller and Karmeli, 1974)** as follows:

$$Q = kH^x \text{ ....3}$$

Where: Q =discharge in L/h,
k = constant for the product and
x = the emitter exponent in MSAE and ASAE Standard was Fully turbulent.

The emitter exponent

The discharge determination was calculated per outlet. The magnitude of "k" is size or capacity for an emitter, since its value is equal to the emitter discharge when "H" equals unit. The suggested criteria for "x" values are presented of "k" and "x" are constants and can be determined by power regression performed on the logarithms "q" versus "H" . If "q_1" and "q_2" are emitter discharges at two operating pressures of "H_1" and "H_2", then the "x" value. was calculated according to **Keller and Karmeli 1974** as follows

$$X = \frac{Log(q_1/q_2)}{Log(H_1/H_2)} \quad \text{.......... 4}$$

Variation of discharge: was calculated according to (MSAE, AENRI 2002) as follows:

$$q_{var} = (\frac{q_m - q_n}{q_n})100 \quad \text{.......... 5}$$

Where: q_{var} = variation of the average discharge from the nominal flow rate (%),

q_m = average discharge in (l/h), and

q_n = nominal discharge at a pressure of 100 kPa and the same water temperature in (1/h).

Emitter manufacture's coefficient (CV) :- this parameter according to ASAE, 1996 and MSAE, 2002 as follows:

$$CV\% = \frac{1}{q_m}\sqrt{\frac{\sum q^2 - nq_m^2}{n}}(100) \quad \text{.......... 6}$$

Where:

q_m= average discharge (1/h);

n = number of emitters and

q =discharge (1/h)

Statistical uniformity:-

the statistical uniformity was calculated using the equation of (Bralts et al. 1981) as follows:

$$Us = 100(1 - CV) = 100(1 - \frac{S}{Q}) \quad \text{.......... 7}$$

Where: Us = statistical uniformity coefficient, %;

CV = emitter variation coefficient flow, %;

S = standard deviation of emitter flow l/h and

Q = the mean emitter discharge 1/h.

Emission uniformity:

The emission uniformity was calculated as (Keller and Karmeli 1974)

$$Eu = (q_n/q_a)\ 100 \quad \text{.......... 8}$$

Where: Eu = the emission uniformity, %,

q_a = the average of all emitter discharges, 1/h and

q_n = the average of the lowest quarter of the emitter discharge, 1/h.

III-5 Laboratory experiments

A total four types (Arab drip Jordan bubbler, long path emitter JR and the new tested emitter as a bubbler and as emitter). Form each group, 25 pieces were tested to study their hydraulic performance. Emitter and bubbler discharges were measured at six operating pressures, 60 ,80, 100,125,150 and 200 kPa, in two level discharges (low 2 – 8 l/h and high discharge 32 - 160 l/h).

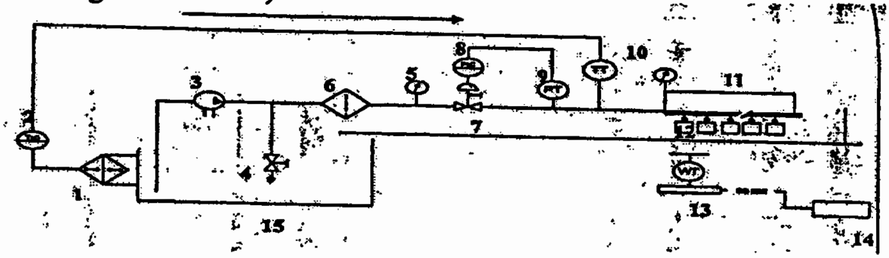


Fig. 4 Hydraulic test bench

1-Temperature conditioning unit, 2- Temperature regulator,
3- Pumping unit, 4- Manual discharge valve,
5- Pressure gauge, 6- Strainer filter,
7- Pressurized air regulating valve, 8- Pressure regulator,
9- Pressure transmitter, 10- Temperature transmitter,
11- Lines of pipes including tested emitters,
12- Water collectors for each emitter in test,
13- Weighing scale, 14- Personal computer, 15- Water tank.

The emitters and bubblers under study are tested according to (**Howell and Hiller,1974; ASAE, 1996 and AENRI-ASAE, 2002**). Twenty five new emitters from each type were tested and mounted at 0.5 m spacing on the lateral tested. Before starting the experiments, air in the lateral was flushed out by opening the downstream end of the lateral. Pressures were set at 60, 80, 100,125 ,150, and 200 kPa. During the test, water temperature was measured by a digital thermometer with a precision of ±1 °C to account for viscosity changes. Once the emitters discharges were determined, three individual runs were placed in each testing and individual volumes were averaged to obtain the emitter discharge for each one . Specific emitter flow functions, such as pressure discharge relationship and manufacture coefficient were determined using some equations as indicated in part of measurements.

VI- RESULTS AND DISCUSSION

Energy loss, h_f:-

The inlet pressure head of the emitter was 11.7 m by Hazen-Williams formula, showed that in table 1:

N.	1	2	3	4	5	6	7	8	9	10
D.	1	6	11	16	21	26	31	36	41	46
H.	14.5	14.2	13.9	12.5	**11.7**	11.2	10.6	10.1	9.5	9.2

N- No. of emitter

D- Distance of emitter from the inlet, m

H- head, m

Discharge rate:-

The inner diameter of the new emitter was 0.8 mm for the new emitter and 4 mm for the new bubbler. The length between the inlet and the outlet for the new emitter and bubbler was 0.175 m at the discharge 4 L/h.

Pressure-flow characteristics: As emitter

The effect of pressure on the emitter discharge varied for each emitter type. The influence of pressure can be presented in two ways either directly as the average of emitter discharge or as variable percentage of discharges at the actual operating pressures of 100 kPa, Equation 3. Average discharge as a function of operating pressure was determined for all emitter types. The different percentages of emitter discharge at 100 kPa, are listed in Tables (2 and 3) and Fig. 4 nominal discharge as listed by the manufacturer is 4 l/h. the discharge range tested was from 4.20 to 4.26, l/h.

Table 2: Emitter discharge, coefficient of variation and performance parameters for the two emitter types at 100 kPa.

Emitter type	discharge (l/h)		CV %	Parameter	
	Nominal	Mean		x	K
JR	4.0	4.20	1.78 Excellent	0.39	2.66
New	4.0	4.26	1.90 Excellent	0.34	2.95

x = Flow Exponent, K = emitter discharge constant

CV % = variation coefficient

Table 3: The hydraulic characteristics of both tested emitters at 100 kPa.

Emitter types	(Eu) %		(U_S) %		(q_{var}) %	
JR	99.2	Excellent	94.9	Excellent	5.0	Excellent
New	98.7	Excellent	98.1	Excellent	6.5	Excellent

Eu =emission uniformity, U_S =statistical uniformity,

q_{var} =emitter flow variation

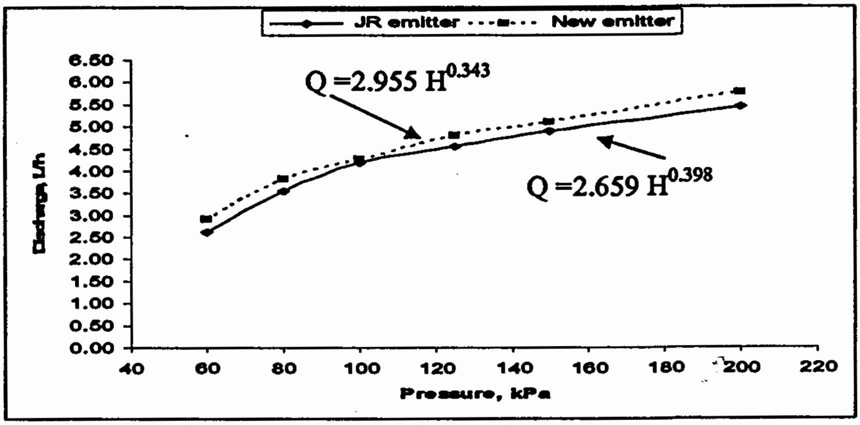


Fig. 4: The relationship between discharge rate and operating pressure for both emitters

As bubbler

The effect of pressure on the bubbler discharge varied for each bubbler type. The influence of pressure can be presented in two ways either directly as the average of emitter discharge or as variable percentage of discharges at the actual operating pressures of 100 kPa, Equation 3. The average discharge as a function of operating pressure was determined for both bubblers types. Different percentages of emitter discharge at 100 kPa, at the same water temperature is detailed in Tables 4 and 5 and Fig. 5. The high discharges 96 to 99. 9 l/h.

Table 4: The bubbler discharge, coefficient of variation and performance parameters for the two. bubbler types at 100 kPa

Bubbler type	discharge (l/h) Nominal	Mean	CV%	Parameters x	K
Arab drip Jordan	100	96	5.1	0.34	71.6
New	100	99.9	1.1	0.36	72.3

x = Flow Exponent, K = Emitter discharge constant,

CV % = Variation coefficient

Table 5: The hydraulic characteristics for bubblers at 100 kPa

Bubbler type	Eu (%)	U_S (%)	q_{var} (%)
Jordan	99.9	98.2	4.00
New	99.8	98.9	0.01

Eu =emission Uniformity, U_S =statistical uniformity and

q_{var} =emitter flow variation

Table 6: The laboratory experiment conclusions for the new emitter

Parameters	**New emitter**		**New bubbler**	
Pressure, kPa	**100**	**60**	**100**	**60**
Q l/h	4.20	2.6	100	80
q_{var}, %	6.50	2.3	0.01	1.2
CV, %	1.90	6.0	1.10	2.5
E_u, %	98.67	97.6	99.84	99.8
U_S, %	98.9	93.9	99.90	97.4

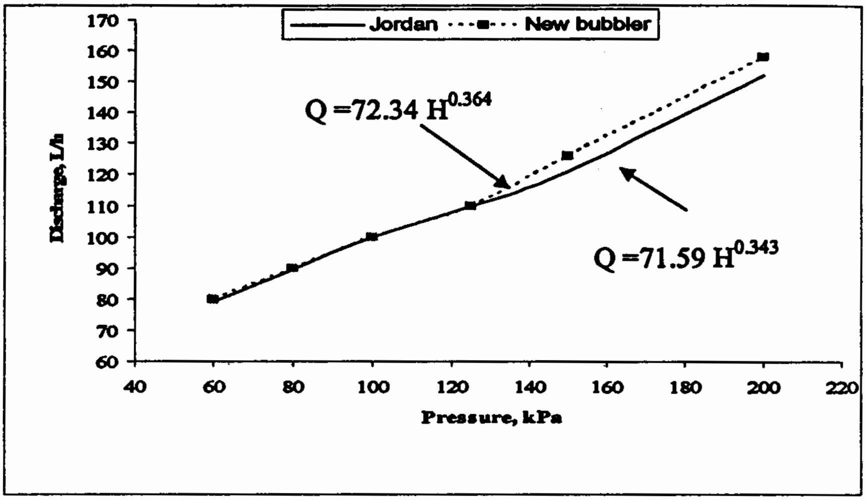


Fig. 5: The relationship between discharge rate and operating pressure for both bubbler types

CONCLUSIONS

The sub-surface drip irrigation system is one of the most efficient irrigation methods. Which is characterized by many advantages such as include high water use efficiency, high crop productivity, and high fertilization use efficiency. When needed for sub-surface irrigation the farm to bury the tube interior in the soil. which expose us to many problems such as emitter clogging, the difficulty of installation, maintenance, the spacing of emitters are constant (30, 50 cm) and the discharge values from this system are 2 and 4 L/h.

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The results showed that, in case of emitter, the new emitter discharge was 4.26 l/h, the coefficient of variation was 1.78%, while the sub-surface emitter JR discharge was 4.20, the coefficient of variation was 1.90% at 100 kPa.

In case of bubbler the discharge for the new sub-surface bubbler was 99.9 l/h, the coefficient of variation was 1.1%. While the discharge of the surface drip bubbler was 100 l/h and the coefficient of variation was 5.1% at 100 kPa. By this results the study recommended that manufacturing the new designed emitter locally by specifications in the study.

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الملخص العربى

تصميم جديد وتقييم أداء منقط تحت سطحى

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إن نظام الري بالتنقيط تحت سطحي هو أحد نظم الري الحديث والذي له العديد من المميزات ومنها عدم ابتلال سطح التربة وإمداد النبات بالماء والمخصبات فى منطقة انتشار الجذور ومع ذلك فان له بعض العيوب والتي تتطلب تطويره حيث أنه عند الاحتياج للري تحت السطحي يقوم المزارع بدفن الأنبوب الحامل للنقاطات في التربة مما يعرض النظام إلى مشاكل منها الحاجه إلى آلات وعمالة لدفن الخراطيم مما يزيد من تكاليف شبكة الري كما أنه تنحصر معدلات التصرف به بين(٢-٤) لتر/س فقط. والاحتياج الدائم لمتابعة صيانة الأنبوب لمعالجة الانسداد والتى تتطلب مجهود كبير لتحديد مكان الانسداد. وكذلك المسافة بين النقاطات والغير متحكم فيها فى النظام الحالى.

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ولذلك فان الهدف من هذا البحث هو تصميم وتقييم نقاط جديد يمكنه بدرجة كبيرة تحديد مكان الانسداد و تلافى هذه المشاكل التي تواجهنا وخاصة الحرية الكاملة فى اختيار المسافة بين النقاطات لتناسب جميع المحاصيل. ولتقييم النقاط الجديد تم دراسة بعض الخواص الهيدروليكية للنقاط الجديد ومقارنته بالنقاط (JR) وكذلك مقارنته عندما يعمل كمنقط فقاعى مع أخر اردنى الصنع .

وقد تمت الاختبارات المعملية فى المعمل القومى لاختبار نظم ومكونات الرى الحقلى الحديثه- معهد بحوث الهندسة الزراعية بالدقى وتمت الاختبارات تحت ضغوط مختلفة هى -٦٠ -٨٠ - ١٠٠-١٥٠و ٢٠٠ كيلو باسكال.

وكانت نتائج التجارب كما يلى:
معامل الاختلاف فى التصنيع للنقاط الجديد كانت قيمته المتوسطة ١.٩ ، ١.١ % فى حالة استخدامه كنقاط عادى ونقاط فقاعى على الترتيب والتى تصنف حسب (ASAE standards) بالممتازة.

معامل التغير فى معدل سريان النقاط الجديد كان ٦.٥ و ٢.٣ % فى حالة استخدامه كنقاط عادى ونقاط فقاعى على الترتيب والتى تعتبر جيدة.

انتظامية التوزيع للنقاط الجديد كانت ٩٨.٧ و ٩٩.٨ % فى حالة استخدامه كنقاط عادى ونقاط فقاعى على الترتيب عند ضغط تشغيل ١٠٠ كيلوباسكال بينما كانت هذه القيم ٩٧.٦ ، ٩٩.٨ عند ضغط تشغيل ٦٠ كيلوباسكال.

وكانت قيمة الانتظامية الإحصائية للنقاط الجديد هى ٩٨.٩% – ٩٩.٩% فى حالة استخدامه كنقاط عادى ونقاط فقاعى على الترتيب عند ضغط تشغيل ١٠٠ كيلوباسكال بينما كانت هذه القيم ٩٣.٩ ، ٩٧.٤ عند ضغط تشغيل ٦٠ كيلوباسكال.

من خلال هذه النتائج فان الدراسة تنصح بتصنيع النقاط الجديد محليا وبالمواصفات الواردة بالبحث.