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ASSESSMENT THE UNIFORMITY OF LOW HEAD BUBBLER IRRIGATION SYSTEMS

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ABSTRACT

*This study aims to evaluate the effect of low pressure and bubbler tube diameter on discharge uniformity (Cu) when using a simple and complex design of low head bubbler irrigation. Three available tube diameters ϕ 3.8, 5.2 and 13.6 mm in the local market at three initial pressure of 15, 30 and 45 kPa were considered. In the simple design, the bubbler tube height levels were 0.0, 0.2, 0.4, 0.6, 0.8 and 1.0 m. Excellent **Cu** values were recorded with small tubes ϕ 3.8 and 5.2 mm with all heights at all initial pressure (P_I). While **Cu** values were not reaching a good classification with ϕ 13.6 mm in all treatments.*

In the complex design, it was considered a full uniformity with ϕ 3.8 and 5.2 mm with all operating pressures P_o at all initial pressures. While, the ϕ 13.6 mm diameter discharge uniformity was achieved excellent and good classification with all operating pressures at initial pressures 15 and 30 kPa, respectively.

***Key words:** bubbler tube, Pressure, design, Uniformity.*

INTRODUCTION

The main goal of irrigation is to achieve optimal agricultural production and maximum economic return. A well-designed microirrigation system can help achieve this goal through its highly uniform water application. A microirrigation system is defined as a localized irrigation system that can deliver water directly into the crop root zone. Water and energy saving are the most important advantage which is smaller than other irrigation systems. The high cost of installation, operation, and maintenance of microirrigation systems remains a major constraint to microirrigation expansion. The low pressure (about *10* to *50 kPa*) tube irrigation is one of the microirrigation systems. Water is applied to the soil surface as a little stream, typically from a small tube diameter (*1* to *13 mm*).

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Water distributed to the tubes by adjusting the elevations of the tube outlets along the lateral so that water flows out from all hoses at approximately equal rates. This type are prefeared than other microirrigation systems by its low requirements of the installation, operation and maintenance **(Hull, 1981; Lamm *et al.* 2007).**

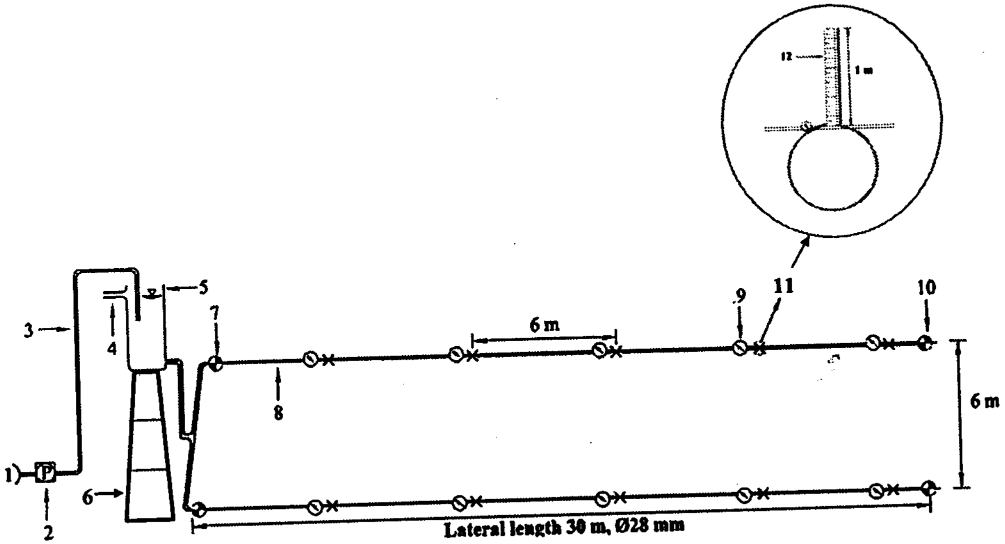
The assessment of irrigation uniformity is the key to efficient irrigation. **Nakayama and Bucks (1986)** studied the relationship between emitter flow variation and uniformity coefficient and reported that a uniformity coefficient of about *(98%)* equal an emitter flow variation of *(10%)* and a uniformity coefficient of about *(95%)* equals an emitter flow variation of *(20%)*. **Habib and Awady (1992)** stated that the discharge uniformity from tube irrigation system is controlled by varying the tube diameter and/or length and/or using valve for each tube along lateral line.

Rashad (2013) developed a model which optimize the design of low head bubbler irrigation by identifying tube height at each outlet point, maximum of outlet numbers, lateral length and flow. These results are identified using the data obtained from water temperatures, tubes and lateral diameters, allowable pressure and the soil slope. One of the main reasons for the lack of the current designs dissemination is the complex criteria of the models which need more simplification.

At the present, there is a few research associated with the difficulties of change of bubbler tube outlet heights along lateral lines from the practical point of view. So, the aim of this study was to evaluate the effect of different pressures and tube diameters on bubbler discharge uniformity when using a simple design (outlet heights at the same level) and complex design (outlet heights parallel to the hydraulic grade line).

MATERIALS AND METHODS

The experimental work for this study was conducted at the Farm of Agriculture Faculty, Suez Canal University. **Figure (1)** shows the experimental low head bubbler irrigation system which can be described in the following steps: By using centrifugal pump powered using electric motor *3* horse power, *220 volts,* the water is pumped from the water source to a cylindrical plastic tank with dimensions; height *0.9 m*, diameter *0.49 m* with $0.17\ m^3$ capacity. Using an over flow pipe with diameter *50 mm,* the water level in the tank was kept constant. The tank was located on adjustable base to three initial pressure head levels at *1.5, 3.0* and *4.5 m (15, 30 and 45 kPa)*. The main pipe branched to two submain pipes with one lateral mounted in each one. To control and flushing the air from the irrigation system, two relief valves were mounted on entrance and end of each lateral. The lateral pipe was a smooth polyethylene with *30 m* length and diameter *32 mm* (*ϕ, 28 mm* internal diameter). The lateral pipe was in the same level. Five tubes with length *5 m* were mounted on each lateral pipe with *6 m* space between them. The smooth polyethylene bubbler Tubes were available in the local irrigation kits market with internal diameter *ϕ 3.8, 5.2* and *13.6 mm.*



1- Water source
2- Centrifugal pump
3- Delivery pipe
4- Over flow pipe
5-Tank
6- Adjustable base
7- Valve
8- Lateral pipe
9- Pressure gauge
10- Flushing valve
11- Tube
12- Steel tape

Figure (1). The experimental setup diagram.

Uniformity coefficient

The effect of bubbler hight on Uniformity coefficients was studied at six levels from zero to one meter. The **Christiansen's formula (1942)** was used to give the information about how efficiently water is distributed in the field.

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

Where

Cu = Coefficient of uniformity.
q_i = Tube flow rate.
$\bar{q}$ = Average of tube flow rate values.
n = Total number of observation points.
$\sum_{i=1}^{i=n}|q_i - \bar{q}|$ = Summation of absolute values deviation from the mean tube flow rate.

The coefficient of uniformities, standards/ classifications is presented by **ASAE standards EP458 (1999)**. Micro-irrigation system uniformity classifications based on uniformity coefficient are presented in **Table (1).**

Table (1). Classification/standards of uniformity coefficient

Uniformity coefficient, *CU* (%)	**classification**
Above 90%	Excellent
90-80%	Good
80-70%	Fair
70-60%	Poor
Below 60%	Unacceptable

RESULTS AND DISCUSSION

The results of the study can be presented by simple and complex designs.

a. Bubbler Outlets at the Same Elevation

Table 2 presents the influnced of operating pressures (P_o) by the bubbler tube diameter and the variation in outlet elevation at the same initial pressure. In all tube diameters, the operating pressure had inverse relationship with bubbler heights at the same initial pressure. The Bubbler discharge was increased proportionally with increasing the operating pressure for all tube diameters. Generally, the mean bubbler discharge ($\bar{q}$) was decreased and the discharge uniformity coefficients (*Cu*) increased by increasing the heights (h_b) from *0.0* to *1.0 m* at the all initial pressures for all tube diameters.

The uniformity coefficients (**Cu**) were excellent values and more than *98.0%* at all bubbler heights (**h_b**) from *0.0* to *1.0 m* with all initial pressure (**P_i**) for ϕ *3.8 mm*. Also for ϕ *5.2 mm*, **Cu** were excellent and tended to increase from *(94.4* to *95.6%) to (99.2* to *99.4%)* by increasing **P_i** from *15 to 30 kPa* and decreased to *96.8%* by increasing **P_i** from *30 to 45 kPa*. While **Cu** for *13.6 mm* were decreased at all heights (**h_b**) from *(65.8* to *72.8%), (56.0 to 62.2 %)* and *(61.8* to *54.2%)* with initial pressure *15, 30* and *45 kPa* at all heights (**h_b**), respectively.

The excellent discharge uniformity values were recorded with ϕ *3.8* and *5.2 mm*. While **Cu** values for *13.6 mm* were just fair at initial pressure of *15 kPa* with one meter height and poor with other heights from *0.0* to *0.9 m* nothing else and considered unacceptable with almost heights at **P_i** *of 30* and *45 kPa*. Based on the previous results, it is not recommended to use relatively large tube diameter as ϕ ***13.6 mm*** in case of tube outlets elevation at the same level. These results agree with **Reynolds *et al.*, (1995)** which indicated that hose diameters greater than 10 *mm* are not recommended for low-head bubblersystems due to poor water distribution uniformity.

Table (2). Tube discharge and uniformity of different diameters at different initial pressure with same height levels.

P_i (kPa)	ϕ (mm)	h_b (m)	P_o (kPa)	q (l/min)	Cu (%)	Classification
15	3.8	0.0	7.0	0.51	98.8	Excellent
		0.2	6.5	0.50	98.8	Excellent
		0.4	6.2	0.49	98.8	Excellent
		0.6	5.8	0.49	98.8	Excellent
		0.8	5.5	0.48	98.8	Excellent
		1.0	5.2	0.47	98.8	Excellent
	5.2	0.0	13.0	1.03	94.4	Excellent
		0.2	12.1	1.00	94.4	Excellent
		0.4	11.8	0.99	94.6	Excellent
		0.6	11.4	0.97	94.6	Excellent
		0.8	11.0	0.95	94.8	Excellent
		1.0	10.6	0.94	95.6	Excellent
	13.6	0.0	9.1	6.83	65.8	Poor
		0.2	8.6	6.66	66.2	Poor
		0.4	8.1	6.48	66.8	Poor
		0.6	7.8	6.35	68.4	Poor
		0.8	7.2	6.16	69.6	Poor
		1.0	6.8	6.00	72.8	Fair

Table 2 (Continued)

P_i (kPa)	*ϕ (mm)*	*h_b (m)*	*P_o (kPa)*	*$\bar{q}$ (ℓ/min)*	*Cu (%)*	*Classification*
30	3.8	0.0	24.4	0.68	98.8	Excellent
		0.2	23.4	0.68	98.8	Excellent
		0.4	22.8	0.67	98.8	Excellent
		0.6	22.1	0.67	98.8	Excellent
		0.8	21.3	0.66	98.8	Excellent
		1.0	20.7	0.66	98.8	Excellent
	5.2	0.0	24.8	1.43	99.2	Excellent
		0.2	24.2	1.42	99.2	Excellent
		0.4	23.7	1.40	99.2	Excellent
		0.6	23.0	1.38	99.2	Excellent
		0.8	22.5	1.37	99.4	Excellent
		1.0	21.8	1.34	99.4	Excellent
	13.6	0.0	15.7	8.70	56.0	Unacceptable
		0.2	15.0	8.53	56.8	Unacceptable
		0.4	14.4	8.39	57.6	Unacceptable
		0.6	14.1	8.30	58.0	Unacceptable
		0.8	13.7	8.17	58.6	Unacceptable
		1.0	13.1	8.02	62.2	Poor
45	3.8	0.0	40.5	0.76	98.2	Excellent
		0.2	38.3	0.75	98.0	Excellent
		0.4	36.3	0.74	98.2	Excellent
		0.6	34.1	0.73	98.0	Excellent
		0.8	32.5	0.73	98.4	Excellent
		1.0	30.9	0.72	98.4	Excellent
	5.2	0.0	35.6	1.72	96.8	Excellent
		0.2	34.7	1.70	96.8	Excellent
		0.4	33.9	1.68	96.8	Excellent
		0.6	33.1	1.66	96.8	Excellent
		0.8	32.2	1.64	96.8	Excellent
		1.0	31.2	1.61	97.0	Excellent
	13.6	0.0	21.0	9.93	54.2	Unacceptable
		0.2	19.9	9.69	54.4	Unacceptable
		0.4	18.8	9.45	55.4	Unacceptable
		0.6	17.6	9.17	55.4	Unacceptable
		0.8	16.3	8.85	55.8	Unacceptable
		1.0	15.4	8.61	61.8	Poor

Finally, the discharge uniformity was more sensitive to increase bubbler height with diameter *13.6 mm* than small diameters. Also, there was inverse relationship between discharge and uniformity, as a result the discharge uniformity increased with heights increasing which agrees with **Elmeseery (1993)**. From a practical point of view, this study recommended to use diameter *5.2* compared to *3.8 mm* with low pressure less than *30 kPa* due to airlock and clogging problems. However, it is possible to use *3.8* or *5.2 mm* with pressures more than *30 kPa*.

b. Bubbler Outlets Parallel to the Hydraulic Gradient Line

The bubblers discharge were measured when its outlets parallel to the hydraulic gradient line. The relationship between tube diameters ϕ, initial pressure P_i, operating pressure P_o, mean tube discharge $\bar{q}$ and The uniformity coefficients (***Cu***); were displayed in **Table (3)**. The discharge uniformities were higher in the complex design than the simple one in all diameters. The discharge uniformities were insignificant change in the two designs with small diameters ϕ (*3.8* and *5.2 mm*), but the two cases still have higher classification. However there is a high change with relatively large diameters ϕ *13.6 mm*.

Table (3). Tube hydraulic properties of different diameters and locations at same pressure.

ϕ *(mm)*	P_i *(kPa)*	P_o *(kPa)*	$\bar{q}$ (ℓ/min)	*Cu (%)*	*Classif.*
3.8	15	7	0.51	99.2	Excellent
	30	27	0.7	99.2	Excellent
	45	39	0.75	99	Excellent
5.2	15	11	0.95	98.8	Excellent
	30	28	1.52	99.3	Excellent
	45	31	1.6	98.9	Excellent
13.6	15	8	6.44	94.6	Excellent
	30	13	8	82.8	Good
	45	23	10.35	59.6	Unacceptable

On the other hand, with all operating pressures P_o at all initial pressures (*15, 30* and *45 kPa*), there is almost full discharge uniformity for small diameters *3.8* and *5.2 mm*. The discharge uniformity was more sensitive to increasing the tube height with diameter ϕ *13.6 mm* than the small diameters. ***Cu*** classification for *ϕ 13.6 mm* at initial pressure of *15, 30* and *45 kPa*, was decreased from excellent to good and unacceptable respectively, which agrees with the results of **Ngigi (2008)**.

From a practical point of view, based on the results of the complex design, it is not recommended to use diameter *ϕ 13.6 mm* with initial pressures more than *30 kPa*. However, it is possible to use *3.8* or *5.2 mm* with pressures more than *30 kPa*. For the diameter *3.8 mm,* it is not recommended to use the initial pressures less than *30 kPa* due to the reasons which mentioned in the simple design.

CONCLUSION

The discharge uniformity was studied in two designs: simple design (tube outlets at the same level) and complex design (tube outlets parallel to the hydraulic grade line). In the simple design, there was inverse relationship between discharge and uniformity. The excellent values of discharge uniformity (***Cu***) were recorded with *ϕ 5.2* and *3.8 mm* at all initial pressures with all outlet heights for all diameters, while (***Cu***) values was considered a unacceptable for *ϕ 13.6 mm.* So this study do not recommended the using of relatively large tube diameters as *ϕ 13.6.*

On the other hand, in the complex design, the discharge uniformities were higher than the simple one in all diameters. With all operating pressures P_o at all initial pressures (*15, 30* and *45 kPa*), there is almost full discharge uniformity for small diameters *3.8* and *5.2 mm.* From a practical point of view, it is not recommended to use diameter *ϕ 13.6 mm* with initial pressures more than *30 kPa.*

However in the two desgins, it is possible to use *3.8* or *5.2 mm* with pressures more than *30 kPa*. For the diameter *3.8 mm,* it is not recommended to use the initial pressures less than *30 kPa* due to airlock and clogging problems.

REFERENCES

ASAE Standards. EP 458 (1999): Field evaluation of micro irrigation systems. St. Joseph, Michigan, ASAE.918- 924.

El-Meseery A. A. (1993). A study on some factor affecting on bubbler irrigation, Unpublished M.SC. Thesis, Department of Agricultural

Engineering, Faculty of Agriculture, Al-Azhar University, Egypt 16-18 and 39-40.

Habib, I. M. and Awady, M. N. (1992). Irrigation methods of desert land, Text book, Open Ed., Cairo University: 326-393. (In Arabic).

Hull, P.J. (1981): A low pressure irrigation system for orchard tree and plantation crops. The Agricultural Engineer. 55-58.

Lamm, F. R.; Ayars, J. E. and Nakayama, F. S. (2007). Micro-irrigation for crop production: design, operation, and management. 13th ed., Italy. Elsevier Co: 533-570.

Nakayama, F. S. and Bucks, D. A. (1986). Trickle irrigation for crop production, Elsevier Co: 11-17.

Ngigi. S. N. (2008). Technical evaluation and development of low-head drip irrigation systems in Kenya. Irrig. and Drain.Vol. 57: 450-462.

Rashad, M. A. (2013). Development a program to optimize design of low head bubbler irrigation. Misr J. Ag. Eng., Irrigation and Drainage, 30 (3): 765 – 784.

Reynolds, C. A.; Yitayew, M. and Peterson, M. S. (1995). Low-head bubbler irrigation systems - Part I: Design. Agriculture and Water Management. Vol 29:1-24.

الملخص العربي

تقييم انتظامية نظم ري فوار منخفضة الضاغط

محمد أبوزيد رشاد*

المامول من اي منظومة ري هو المساهمة في انتاج زراعي عالي مع تعظيم العائد الاقتصادي. ان التصميم الجيد لمنظومات الري الدقيق يتم من خلال اضافة المياه بانتظامية عالية يمكنها المساعدة في تحقيق هذه الآمال. و يعتبر الري الفوار المنخفض الضاغط واحداً من نظم الري الدقيق التي تتميز بمتطلبات الصيانة المنخفضة و انخفاض ضغوط تشغيلها. تهدف هذه الدراسة الى تقييم تأثير ضغوط التشغيل وأقطار انابيب الفوار على انتظامية تصرفاتها. تم إنشاء وحدة اختبار تجريبية بمزرعة كلية الزراعة جامعة قناة السويس بالإسماعيلية. حيث درست انتظامية توزيع المياه لثلاثة أقطار داخلية من انابيب الري المتاحة في السوق المحلية *(٣,٨ ٥,٢١، و ١٣,٦مم)* عند ثلاثة ضغوط ابتدائية منخفضة *(١٥، ٣٠ و ٤٥ كيلو باسكال)* تم تقييمها في اثنين من التصاميم:

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أولا: عند استخدام تصميم بسيط حيث أن ارتفعات مخارج الانابيب عند نفس المستوى بارتفاع ٠,٠، ٠,٢، ٠,٤، ٠,٦، ٠,٨ و ١,٠ متر. وقد سجلت قيم انتظامية تصريف ممتازة مع الفوارات ذات الأقطار الصغيرة مثل ٣,٨ و ٥,٢ مم عند جميع الارتفاعات مع كل الضغوط الأبتدائية. في حين ان القطر ١٣,٦ مم لم يصل الى مستويات جيدة مع كل المعاملات.

ثانيا: التصميم المعقد عندما تكون ارتفعات مخارج الفوارات موازية لخط التدرج الهيدروليكي . حيث سجلت الأقطار ٣,٨ و ٥,٢ مم انتظامية كاملة مع كل ضغوط التشغيل عند كل الضغوط الابتدائية. و وجد أن انتظامية تصرف القطر ١٣,٦ مم كانت ممتازة و جيدة مع ضغوط التشغيل المختلفة عند ضغوط ابتدائية منخفضة كـ ١٥ و ٣٠ *كيلو باسكال* على التوالي في حين كانت غير مقبولة مع ٤٥ كيلو باسكال.

و يتضح من الدراسة أنه لا يوجد اختلافات معنوية في قيم انتظامية التصرف ما بين التصميم البسيط و التصميم المعقد بالنسبة للأقطار الصغيرة مثل ٣,٨ و ٥,٢ مم. لذا ينصح باستخدام التصميم البسيط عند استعمال الأقطار الصغيرة. و قد وجد من الناحية العملية أنه لا يفضل استخدام الاقطار الصغيرة كقطر ٣,٨ مم في كلا التصميمين مع الضغوط الابتدائية الأقل من ٣٠ *كيلو باسكال* نظرا لظهور مشاكل الجيوب الهوائية و الانسداد. أما في التصميم المعقد فلا ينصح باستخدام الأقطار الكبيرة مع ضغوط ابتدائية أكبر من ٣٠ *كيلو باسكال*.