HYDRAULIC PERFORMANCES OF VARIOUS DRIPPERS USED IN IRRIGATION SYSTEMS IN NORTH SINAI

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ABSTRACT

The hydraulic performances of five commonly on-line emitters (Em1, Em2, Em3, Em4; Em5) were evaluated at the hydraulic laboratory of Agricultural Engineering Department, Agriculture Faculty, Suez Canal University, Ismailia, Egypt in October 2011. The test was under five operating pressure between 20 to 130 kPa. Em1, Em2, and Em3 were imported; the first type had pressure compensating flow, and the others with turbulent flow. While Em4, and Em5 types were locally manufactured with turbulent flow regime. Em5 is the most common in Sinai region because of its cheap price, although it had unacceptable coefficient of variation values. The measured or/ actual discharges for most emitter types were excess than the nominal discharge under 100 kPa operating pressure, by these percentages: 6.93, 0.0, 5.5, 165, and 640% for Em1, Em2, Em3, Em4, and Em5, respectively.

Keywords: Drip irrigation, Hydraulic performance, Manufacturer coefficient of variation, Emitter type.

1. INTRODUCTION

Sinai is an arid area: the temperatures cover wide daily and seasonal ranges, the rainfall is low and the evaporation rates high. Sinai is a faraway from the Nile with limited underground water resources. This area is important for Egypt's economic growth (**Abou Rayan et al., 2001**). In some parts of Sinai, the local inhabitants must use salty groundwater as potable water in the face of the water crisis (**Elewa and Qaddah, 2011**).

Drip irrigation generally improving the water-use efficiency (WUE), in addition dilution of soil solution's salt concentration. (**Tagar et al., 2010**).

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The actual emitter discharge rate for typical field layouts varies considerably, and is very sensitive to pressure variation throughout the pipe distribution network, topographic variation (slope), partial or complete emitter clogging, design emitter characteristics, emitter manufacturer variation, emitter wear, water quality variation and temperature variation (**Keller and Karmeli, 1974; El Awady *et al*., 2008; Tagar, *et al*., 2010**).

Coefficient of Manufacturer's Variation in discharge describes the quality of the processes used to manufacture emission devices. This implies that it is possible to obtain variable flow rate from emitters by the same manufacturer (**Awe and Kola, 2011**). Manufacturing of an emission device must be precise because the emitter flow path is usually small, less than 2 mm in diameter (**Ghaemi, 1998**). Small differences between what appears to be identical emitters may result in significant discharge variations (**Kirnak *et al*., 2004**).

Unless care is taken in manufacturing emitter, plastic parts can be subject to considerable variation. There are a number of control variables for a molding machine, such as pressure and temperature, injection speed, mold temperature, cycle time, cooling rate, mold operation, and mold damage. Changing any of these factors causes a change in the conditions of the plastic being molded; these in turn affect the ultimate characteristics of the part produced, size, shape, weight, strength and surface finish. In addition a high Cv could occur due to a heterogeneous mixture of the materials used in the production of emitters (**Kirnak *et al*., 2004; Hassan, 2007; Tagar *et al*., 2010**).

The emitter discharge exponent (x); is a measure of the sensitivity of the emitter flow rate to changes in pressure. This exponent is dimensionless and it is independent of the units used to measure flow rate and pressure (**Smajstrla *et al*., 2011**). The value of x typically falls between 0.0 and 1.0 mainly depending on the make and design of the emitter, i.e. hydraulic characteristics.

Moshe Sne, (2006) reported that the water flows along a labyrinth in which the flow direction changes abruptly, that result in turbulent flow, high-energy losses and decreased flow-rate (emitter discharge exponent 'x' is about 0.5). Pressure-compensating emitters use excess inlet pressure

to modify the shape, length, or diameter of the flow path to control the discharge rate by a diaphragm made of silicon or other elastic material. As the pressure increases, the diaphragm restricts the passage diameter, the friction head losses increases that keep the flow rate constant ('x' is normally less than 0.1).

2. MATERIALS AND METHODS

2.1. Emitters:

Figure (1) shows the five on-line emitter types with nominal discharge of 4 ℓ/h at 100 kPa. Five emitter types were used. An emitter samples each of 40 pieces were tested using the hydraulic calibration unit, see Fig. (2).
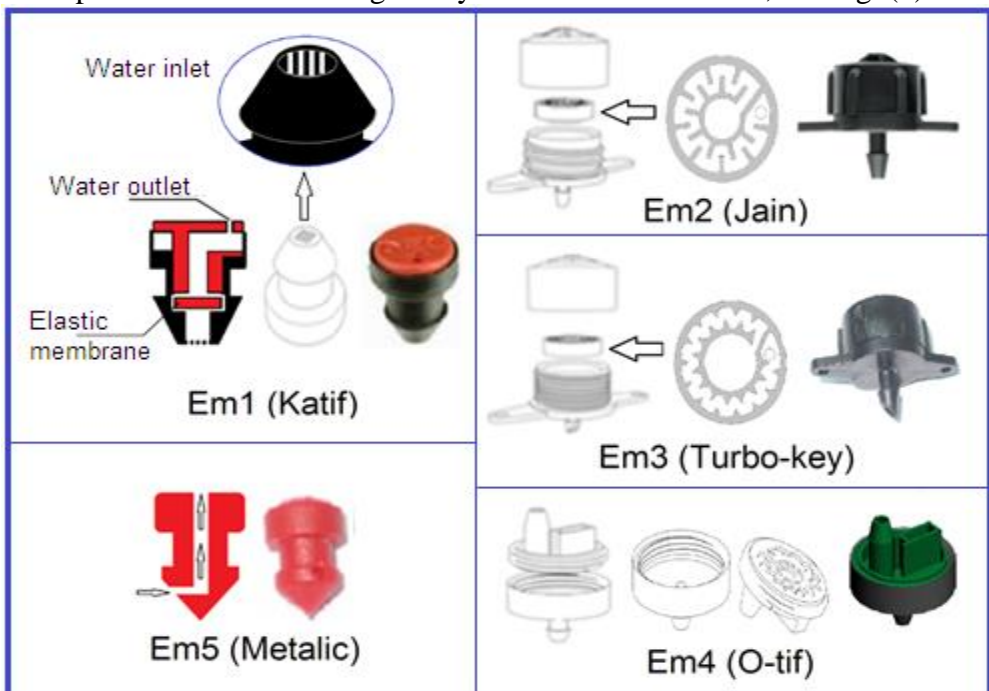

Figure (1): Photograph and schematic 3D model of the calibrated drippers.

The indicated symbols in this study and nominal discharges in the market for different emitter types are show in Tab. (1).

Table (1): The symbols, nominal discharges, and flow-path dimension of the emitter types.

Emitter				Nominal discharge[***] (ℓ/h)
Type	Symbol	Trademark	Minimum flow-path dimension (mm)	
PC[*]	Em1	Katif (Plastro)	0.14	3.75
TF[**]	Em2	Jain	0.97	4.00
	Em3	Turbo-key	0.95	4.00
	Em4	O-tif	1.04	4.00
	Em5	Metalic	1.18	4.00

[*]PC=Pressure Compensating, [**]TF =Turbulent Flow, [***] Nominal discharge at100 kPa.

1) Reservoir Tank   5) Pressure Gauge   9) Catch Cans
2) Valve   6) Water Meter   10) End Line
3) Pump   7) Pressure Regulator 11) Basin
4) Main Line   8) Lateral Lines   12) Sub-main Line   13) Drainage Line From Basin
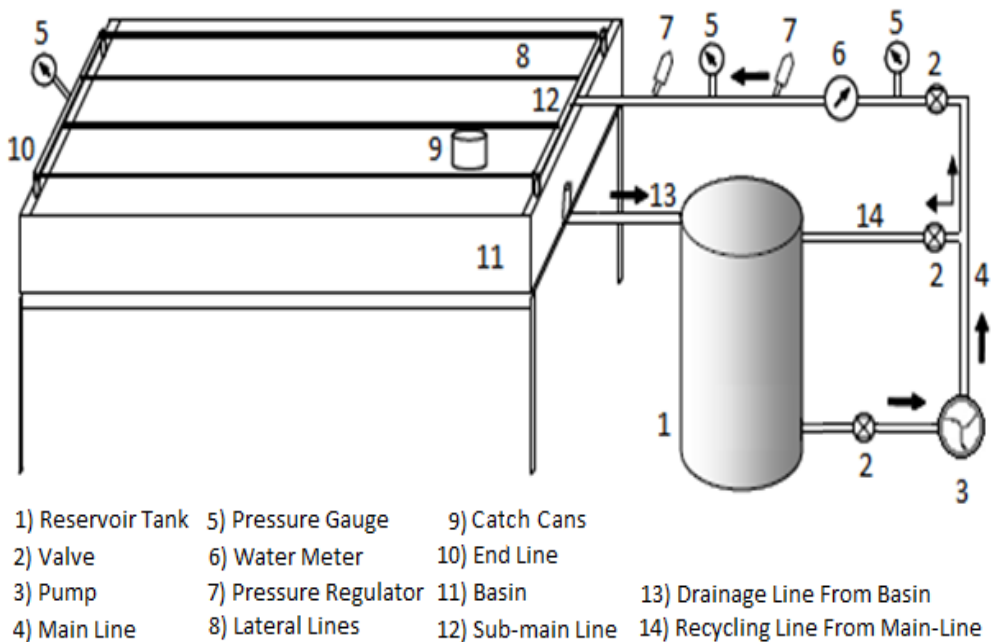   14) Recycling Line From Main-Line

Figure (2): Diagram of the laboratory experimental layout for testing the hydraulic performance of the emitter types.

2.2. The hydraulic calibration unit components:

Reservoir tank: made from plastic, cylindrical shape 127 liters volume, filled by municipal water, water outlet from the bottom and return to the top of the tank. Pump with power supply 220 V - 50/60 Hz - 1 HP (0.74 kW) - 5.2 A, and 2800 rpm, the actual flow rates 1.2 - 6.0 m^3/h. Main line (cast-iron pipe) 24.5 mm diameter which carries pressure regulators, two bourdon pressure gauges (range 0.0 - 250 kPa with 10 kPa scale accuracy) to control the pressure, water meter and valves to get the desired discharge. 40 plastic collectors (2liters volume) for catching water from emitters were used. The basin for containing collectors was fabricated from galvanized steel sheet of 1.5 mm thickness, 175 cm long, 65 cm width and 18 cm height with total volume of 205 liters. The measured water pours into the basin and drainages to reservoir tank by a polyethylene (PE) drainage pipe which connected with an orifice on the bottom of the basin. Four lateral pipes (PE) of 14.5 mm (I.D) with 1.5 m length. The distance between the lines was 15 cm, every line contains ten emitters at 15 cm spacing. The four lateral line's ends were connected together by one line (cast-iron pipe, 1.9 cm diameter) with a pressure gauge.

The emitter's characteristics were tested according to **(Keller and Karmeli, 1974; ASABE, 2008)**, using a sample of fourteen new emitters from each type.

Emitter discharges were measured at five operating pressures of 20, 50, 80, 100 and 130 kPa and the flow rates were taken and measured by using two graduated cylinders: the first 500 ml with 5 ml scale accuracy and the other 100 ml with 1ml scale accuracy, in a time of 3 minutes as indicated by a stop watch; to minimize error associated with starting and stopping of the runs and residual water in the containers.

Specific emitter flow functions, such as pressure flow relationship and manufacturer's coefficient of variation, were determined as follows:

2.3. Criteria for assessing the hydraulic performance:

Drip irrigation emitter flow rates have different responses to pressure variations. The response of a specific emitter depends on its design and

construction. Emitter flow rate can be expressed by **(Keller and Karmeli, 1974)** as:

$$q_e = k_e \, h_e{}^x \;\; \dashrightarrow (1)$$

Where q_e is emitter discharge rate (ℓ/h), h_e is working pressure at the emitter (kPa), k_e is dimensionless constant of proportionality that characterizes each emitter, and x is dimensionless emitter discharge exponent which characterizes the flow regime.

The variability of discharge can measure by taking a random sample of a given make, model and size of emitter as produced by manufacturer, and before any field operation **(ASABE, 2008)** as follows:

$$Cv = SD/q_a \;\; \dashrightarrow (2)$$

In which Cv is manufacturer's coefficient of variation (dimensionless), SD is standard deviation of discharge of emitters (ℓ/h), and q_a is mean discharge of emitters in the sample (ℓ/h).

$$SD = \left[\frac{\sum_{i=1}^{n} (q_i - q_a)^2}{n-1} \right]^{1/2} \;\; \dashrightarrow (3)$$

Where q_i is discharge of an emitter (ℓ/h), and n is number of emitters in the sample.
Flow variation q_{var} could express as:

$$q_{var} = \frac{(q_{max} - q_{min})}{q_{max}} \times 100 \;\; \dashrightarrow (4)$$

Where q_{max} and q_{min}: maximum and minimum emitter discharge rate (ℓ/h), respectively.

3. RESULTS AND DISCUSSION

3.1. Pressure-flow relationship:
The nominal and measured flow rate, difference percentage of measured from nominal discharge, emitter discharge equation constants (k_e, x), flow regime, and the manufacturer's coefficient of variation and its

classifications are presents in Tab. (2). Great differences between nominal and measured discharges were recorded with local emitters (Em4 and Em5) by 165% and 640%, respectively.

Table (2): Flow rate (ℓ/h), the difference percentages between nominal and measured flow rates, emitter discharge equation constants, flow regime and manufacturing coefficient of variation Cv for the five emitter types at 100kPa.

Emitter type	Flow rate (ℓ/h)		Difference Percentage (%)	Emitter constants		Flow regime	Coefficient of variation "Cv"	
	Nominal	Measured		"k_e"	"x"		Value	Classification*
Em1	3.75	4.01	6.93	7.60	-0.14	Pressure Compensating	0.06	Average
Em2	4.00	4.00	0.00	0.38	0.52	Turbulent	0.04	Excellent
Em3	4.00	4.22	5.50	0.54	0.45	Turbulent	0.13	Marginal
Em4	4.00	10.60	165.00	1.22	0.47	Turbulent	0.24	Unacceptable
Em5	4.00	29.60	640.00	2.06	0.57	Turbulent	0.28	Unacceptable

*ASABE standards, (2008).

In turbulent flow (TF) emitters (Tab. 2) and (Fig. 3), the emitter discharge was proportionally increased by increasing the operating pressure. By increasing pressure from 20 to 130 kPa, discharge was generally increased from (1.79 to 4.60), (2.11 to 4.80) and (5.05 to 11.90) ℓ/h for Em2, Em3 and Em4, respectively. Meanwhile in the case of Em5, the operating pressure ranged only between 20 to 100 kPa (because of its high flow-rate), and the discharge had been increased from (11.49 to 29.60) ℓ/h. But in the case of PC emitter (Em1), the discharge was proportionally decreased from (5.15 to 4.00) by increasing pressure from 20 to 130 kPa.

The statistical coefficient of determination for the pressure flow relationship was recorded higher values ($R^2 \geq 0.99$) with turbulent flow emitters, than PC emitter, see (Tab. 2) and (Fig. 3). High values of R^2 indicated that; Eq. (1) is an appropriate model to describe the relationship between the discharge and the pressure. This result was agreed with **(Bralts and Wu, 1979; Ozekici and Bozkurt, 1999; Kirnak et al., 2004)**, they reported that: theoretically the compensating drip emitter

discharges should not show any variation under different pressures. But, in the actual discharge measurements there were different discharges under variable pressures.
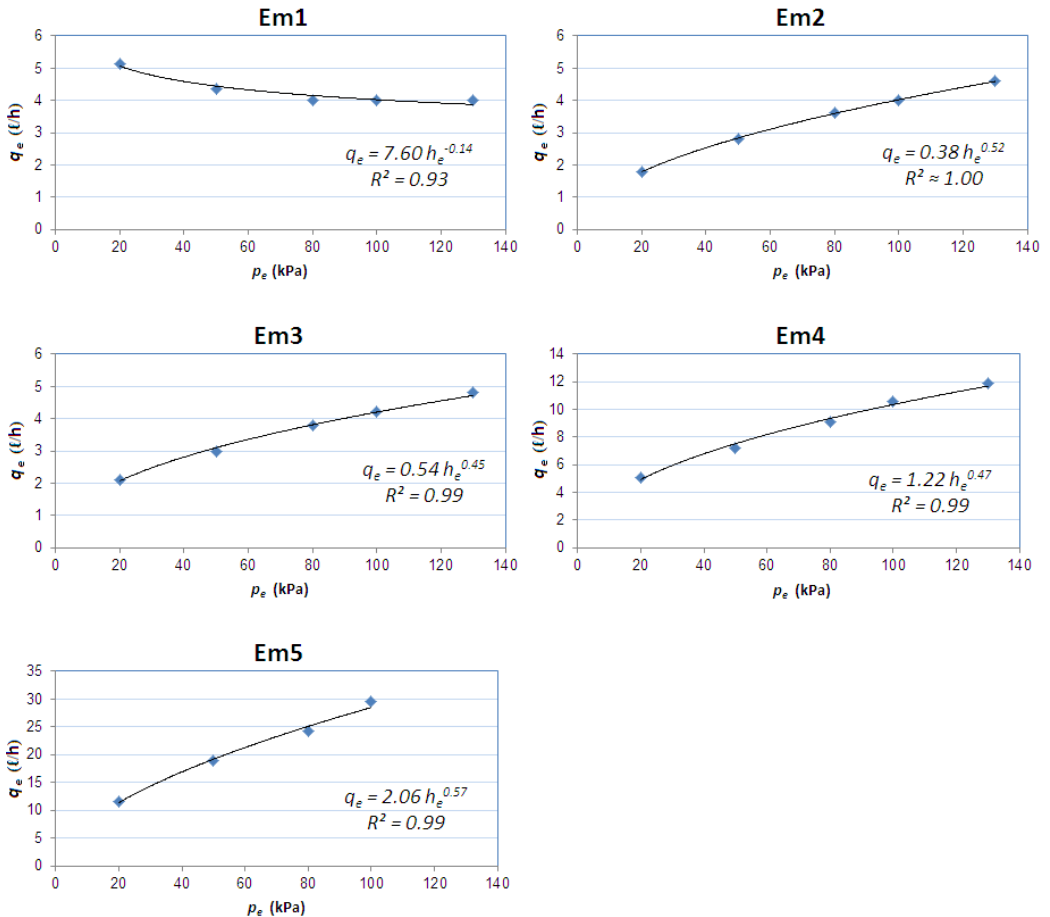

Figure (3): Relationship between operating pressures versus discharge for calibrated emitters (Em1, Em2, Em3, Em4; Em5).

A lower value of "x" for PC emitters indicates lower sensitivity of flow rate to changes in pressure; a higher value of the turbulent flow emitters indicates higher sensitivity.

Table (2) and (Fig. 3) shows the calibration of tested emitter types, the constants x and k_e were determined for all emitter types using Eq. (1). The emitter exponent (x) for PC emitter was a negative number close to zero (-0.14), which mean that emitter flow rate was slightly decreased with

pressure increase. Where, the x values were around 0.5 and ranged from 0.45 to 0.57 for turbulent flow emitters, indicating relatively increase in the emitter flow rate by increasing the operating pressure.

The emitter discharge coefficient (k_e) values ranged from 7.60 to 0.38. The results were shown a compatible x values with the classification of the manufacturers of these emitters.

3.2. Coefficient of variation (Cv):

The Cv classifications of the five emitter types are present in Tab. (2) and Fig. (4), the results showed that; Cv classification of emitter discharge under 100 kPa operating pressure was average with Em1, which has pressure compensating flow (PC). While it were varied with turbulent emitters types from excellent for Em2 to marginal with Em3, and unacceptable with Em4 and Em5.

Manufacturer's coefficient of variation (Cv) values of the PC emitters were higher than those of TF emitters, because it was difficult to manufacture the movable parts in the PC emitters **(Ozekici and Sneed, 1995; Ozekici and Bozkurt, 1999; Hassan, 2007 and Tagar** *et al.***, 2010)**. Previous results applies to Em2 type only, while the other three emitters (Em3, Em4; Em5) showed higher Cv values than imported PC emitter (Em1); due to low manufacturing level for it in the industry.
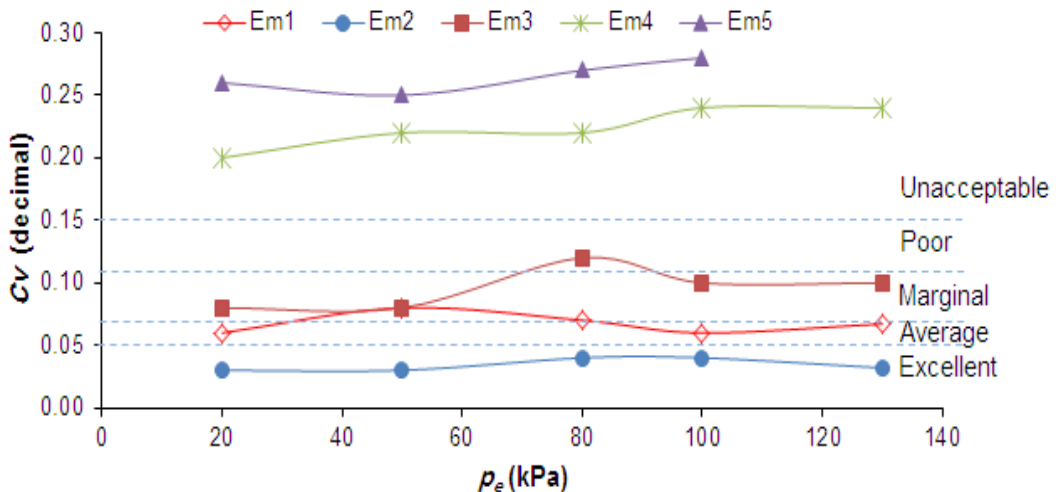

Figure (4): Relationship between operating pressures versus manufacturer's coefficient of variation (Cv) for calibrated emitters.

The Cv classification **(ASABE, 2008)** in Fig. (4), where are as follows: excellent category ($Cv<0.05$), average ($0.07>Cv>0.05$), marginal ($0.07>Cv>0.05$), poor ($0.07>Cv>0.05$), and unacceptable ($Cv>0.15$).

Figure (4) indicate that all Cv values of Em4 and Em5 befallen in the unacceptable range ($Cv>0.15$). While all the Cv values for Em3 were classified as marginal ($0.11>Cv>0.07$), except one value at 80 kPa was in the poor range ($0.15>Cv>0.11$). All Cv values for Em1 were stated in the average range ($0.07>Cv>0.05$), except one value at 50 kPa pressure where the Cv value was upraised to the marginal category. All Cv values of Em2 were in the excellent range ($Cv<0.05$).

Overall there was no systematic pattern in all emitter's Cv values, indicating no obvious regular increase or decrease with increases in pressure (Fig. 4). The Cv values were relatively insensitive to operating pressure in accordance with **(Hassan, 2007)**.

3.3. Emitter flow variation:

Calculation of q_{var} using Eq. (4) showed that; the mean value of q_{var} at operating pressures ranging from 20 to 130 kPa for (Em1, Em2, Em3; Em4) were (26.02, 15.30, 35.79; 60.93%), respectively. Meanwhile the mean value of q_{var} for Em5 was 69.11% under 20 to 100 kPa operating pressures.

Hence the effect of emitter type on the flow variation could be stated in the following descending order: Em5>Em4>Em3>Em1>Em2.

The maximum and minimum values of q_{var} for the Em1, Em2, Em3, Em4 and Em5 were (30.80; 22.29%), (19.04; 11.28%), (38.08; 33.58%), (64.28; 51.35%) and (72.81; 66.36%) respectively, created by operating pressures of (50; 130), (80; 50), (130; 50) (80; 20) and (100; 50) kPa, these results are present in Fig. (5). Desirable q_{var} values were below 10%, acceptable between 10 to 20%, and unacceptable above 20%, according to **(Camp *et al*., 1997; Clark *et al.,* 2007)**.
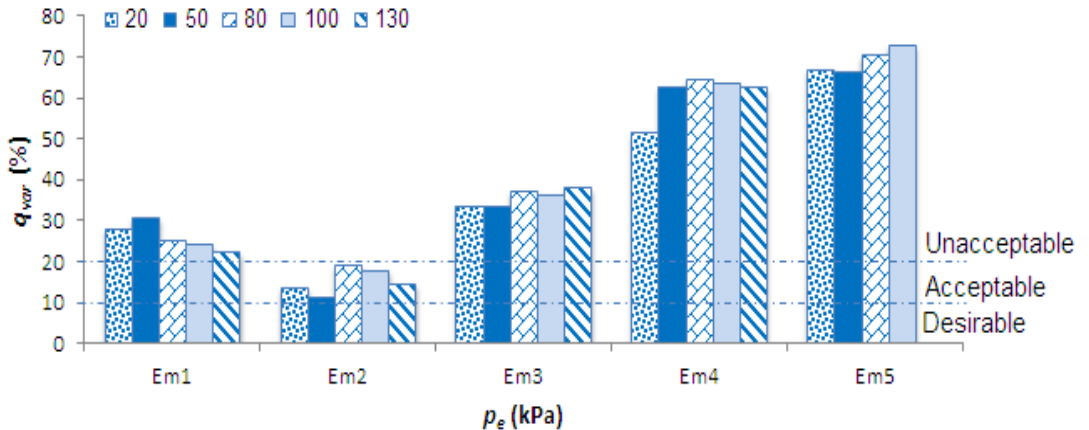
Figure (5): Relationship between operating pressures (p_e, kPa) versus emitter flow variation (%) for calibrated emitters.

Finally it can be seen that; the maximum values of q_{var} were under pressures of 80 kPa or higher for all TF emitter types, but Em1 (PC emitter) had the maximum q_{var} value with a pressure of 50 kPa. The lowest q_{var} values were by pressures 50 and 20 kPa for all tested emitters, except for the Em1 where the lowest q_{var} value was under 130 kPa operating pressure. All tested emitters hadn't desirable q_{var} values under all operating pressures, the whole q_{var} percentages of Em2 only had acceptable flow variation percentages (q_{var}<20%) under all operating pressures.

4. RECOMMENDATIONS

We can recommend from the previous study that:

1. The design of drip irrigation network should base on reliable laboratory test data, not on published data by manufacturers. Serious manufacturers only who published the actual specifications of the product.

2. Locally manufacturing of high quality emitter types with suitable selling prices.

3. Spread awareness between farmers via the agricultural extension views over the water shortages in the near future and the importance of water resources saving and improving water distribution efficiency.

4. Emitter type Em5 is widely common handled in the region; it had very high *Cv* values moreover the massive water consumption. However its smallest price it's not recommended to use. But the expensive price represents the substantial obstruction for adopting high quality drippers.

5. REFERENCES

Abou Rayan, M.; B. Djebedjian and I. Khaled, (2001). Water supply and demand and a desalination option for Sinai, Egypt. Desalination, (136): 73-81.

ASABE STANDARDS, (2008). Design and installation of micro-irrigation systems. ASAE EP405.1 APR1988: 1-5.

Awe, G. O. and O. Kola, (2011). Performance evaluation of Bamboo (Bambusa Vulgaris, Schrad)-pipe and medi-Emitter in a gravity-flow drip irrigation. International J. of Agric. and Forestry, 1(1): 9-13.

Bralts, V.F. and I.P. Wu, (1979). Emitter flow variation and uniformity for drip irrigation. ASAE, St. Joseph, Michigan, USA: 79-2099.

Camp, C.R.; E.J. Sadler and W.J. Busscher (1997). A comparison of uniformity measure for drip irrigation systems. Transaction of the ASAE, 40: 1013-1020.

Clark, G. A.; D. Haman; J. F. Prochaska and M. Yitayew, (2007). Micro Irrigation for Crop Production (General system design principles). Elsevier: 161-215.

El-Awady, M.N.; A.M. El-Berry; M. A. El-Genaidy and A. M. Zayton, (2008). Hydraulic properties effect of filter media on emitter clogging problems; Misr J. Agric. Eng., 25 (3): 824-836.

Elewa, H. and A. Qaddah, (2011). Groundwater potentiality mapping in the Sinai peninsula, Egypt, using remote sensing and GIS-watershed-based modeling. Hydrogeology J., (19): 613-628.

Ghaemi, A., (1998). Impact of different patterns of emitter clogging on hydraulic characteristics of micro-irrigation laterals laid on flat and sloped terrains, Ph.D. Th., Chemical and Bio-Resource Engineering., Fac. of Graduate Studies., British Columbia U.: 10-39.

Hassan, N. S. H., (2007). Evaluation of trickle irrigation designs based on uniformity concept. M.SC. Dept. of Agric. Eng. Fac. of Agric., Ain Shams U., Egypt: 18-33.

Keller, J. and D. Karmeli, (1974). Trickle irrigation design parameters. Transaction of the ASAE, Vol., 17(4): 678-684.

Kirnak, H.; E. Dogan; S. Demir and S. Yalcin, (2004). Determination of hydraulic performance of trickle irrigation emitters used in irrigation systems in the Harran Plain. Turk. J. Agric. Forest., (28): 223-230.

Moshe Sne, (2006). Guidelines for Planning and Design of Micro Irrigation In Arid And Semi-Arid Regions. International commission on irrigation and drainage (ICDI): 1-14.

Ozekici, B. and R. Sneed, (1995). Manufacturing variation for various trickle irrigation on-line emitters. Appl. Eng. Agric. St. Joseph. MI: ASAE, 1985-Mar. V.II (2): 235-240.

Ozekici, B. and S. Bozkurt, (1999). Determination of hydraulic performances of in-line emitters. Tr. J. of Agric. and Forestry, 23: 19-24.

Smajstrla, A.G.; B.J. Boman; D.Z. Haman; D.J. Pitts and F.S. Zazueta, (2011). Field evaluation of micro-irrigation water application uniformity. Agricultural and biological engineering department. Florida cooperative extension service. Institute of food and agricultural sciences, Florida U.

Tagar, A. A.; M. S. Mirjat; A. Soomro and A. Sarki, (2010). Hydraulic performance of different emitters under varying lateral lengths**.,** Pak. J. Agri., Agric. Eng., Vet. Sci., 26 (2): 48-59.

الملخص العربى

الأداء الهيدرولى لأنواع نقاطات مستخدمة بأنظمة الرى بشمال سيناء

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تم تقييم الخواص الهيدرولية لخمس أنواع نقاطات متاحة فى السوق المحلى: أحدهم نقاط معوض للضغط (Em1) والأخرون Em2 و Em3 وهى نقاطات ذات سريان مضطرب مستوردة, بينما Em4 و Em5 نقاطات ذات سريان مضطرب محلية الصنع. وذلك فى معمل الهيدروليكا بقسم الهندسة الزراعية – كلية الزراعة – جامعة قناة السويس. وقد ازداد التصرف الإسمى للنقاط عن التصرف الفعلى (المقاس معمليا) لمعظم أنواع النقاطات بالنسب التالية: ٠,٠و ٥,٥و ٦,٩٣و ١٦٥و ٦٤٠% لأنواع النقاطات Em2, Em1, Em3, Em4; Em5 على الترتيب - أيضا يتأثر أس تصرف النقاط (x) بنوع السريان الداخلى للنقاط فكلما قلت قيمة أس تصرف النقاط (x) يقل تأثر التصرف بإختلاف ضغوط التشغيل - وحققت جميع أنواع النقاطات المضطربة السريان أقصى قيم اختلاف التصرف (q_{var}) عند ضغط تشغيل ٨٠ ك باسكال فما فوق. بينما نوع النقاط المعوض للضغط (Em1) حقق أقصى قيمة (q_{var}) تحت ضغط تشغيل أقل يصل الى ٥٠ ك باسكال – وكان للنقاطات ذات السريان المضطرب أقل قيم (q_{var}) عند ضغطى تشغيل (٥٠و ٢٠ ك باسكال). بينما نوع النقاط المعوض للضغط (Em1) كان له أقل قيم q_{var} عند أعلى ضغط تشغيل (١٣٠ ك باسكال). وتوصى الدراسة بأن يعتمد تصميم الشبكات على نتائج المعمل الموثوقة والمختبرة وليس على النتائج المنشورة للمنتج بواسطة الشركات المصنعة - يعتبر نوع النقاط Em5 الأوسع انتشاراً وتداولاً بين التجار والمزارعين فى المنطقة وله معامل تصنيع عالية جداً ، علاوة على الإستهلاك المهدر للمياه و السماد والطاقة فعلى الرغم من أنه الأرخص سعرا فلا يوصى بتصنيعه و تداوله بين المزارعين. إلا ان إرتفاع أسعار النقاطات عالية الجودة تمثل العائق الأساسى لإستخدامها – وأخيراً توصى الدراسة بتصنيع نقاطات عالية الجودة محلياً وبأسعار مناسبة.

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