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Evaluation of Hydraulic Characteristics of Some Locally Available Emitters

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Abstract. An investigation was made on seven emitter types commonly used in farms and greenhouses in the Kingdom of Saudi Arabia. Tests were performed to determine their hydraulic characteristics and to check their adequacy for trickle system design requirements. The general trend of actual flow rates, was higher as compared to manufacturer's published values in all emitters tested. Water application profiles along lateral were variable which indicate a higher coefficient of manufacturing variation Cv (low emission uniformity) in some of the emitters (B, E, F & G). The increase in operating pressures of some emitters (A & E), seems to improve the uniformity of water distribution. Comparison of the actual emission uniformities with recommended standard values suggested by ASAE, showed that only one emitter, D, is considered acceptable for field use.

Introduction

Drip or Trickle irrigation system is widely used nowadays, in many parts of the world. The drip irrigaiton system becomes so popular in arid areas due to the many advantages that the system offers, compared to other irrigation methods, its potential for conserving water, energy and labor in addition to the reported results of higher yield and better qualities of irrigated crops [1-3].

Proper system design, management and maintenance are essentials for higher irrigation efficiency [4]. Although nonuniformity of water distribution by a trickle system (low efficiency), may be attributed to many factors, the hydraulic characteristics of emitters are considered the most important of these factors [5]. The variaiton in water distribution by emitters may occur due to pressure changes, manufacturing variations, emitter sensitivity to clogging, temperature effect and others.

Trickle irrigation evaluation is very important to ensure that the desired emitter discharge uniformity required for the system design is met, and to see whether the system could be operated efficiently. Also the results of an evaluation could be used by the maintenance personnel to detrmine the proper operation of the system and to suggest any maintenance action if required [4].

The flow characteristics of most emitters are described by the following equation [6 & 7]:

$$Q = C\,H^{\beta}$$

where, Q = Emitter discharge rate (liter/hr)

C = Emitter discharge coefficient

H = Pressure head at the emitter (kPa)

β = Emitter discharge exponent

The numerical presentation for the amount of variations in emitter flow rate due to manufacturing processes could be evaluated by the coefficient of manufacturing variation [8], using the following equation:

$$C_v = S_d / Q_a$$

where, C_v = Coefficient of manufacturing variation

S_d = Standard deviation of the flow rate (liter/hr)

Q_a = Mean of the flow rates (liter/hr)

The uniformity of water distribution from emitters (emission uniformity) is dependant on the pressure variation at emitters and the coefficient of manufacturing variaiton, C_v, and could be calculated by the following equation [9]:

$$EU = 100\,(1.0 - 1.27C_v / \sqrt{N\,p})\,Q_m / Q_a$$

where, EU = The Emission uniformity (%)

N_p = Number of emitters per plant

Q_m = Minimum emitter discharge rate for the minimum pressure at the system (liter/hr)

The objective of this investigation is to test some of the commonly used emitters to determine their hydraulic characteristics and to evaluate their performances, that includes the coefficient of manufacturing variation and the sensitivity to variable pressures.

Materials and Methods

Seven commonly used emitter types were selected and tested in this study. The names and specifications of the emitters are listed in Table 1. Twenty new emitters

Table 1. Specifications of tested emitters*

Code No.	Manufacturer	Figure	Brand name	Type	Rated discharge (1/hr)	Rated pressure (KPa)
A	Irridelco		Flapper-STF	PC	4	50-350
B	Unknown		T2	NPC Long Path	4	–
C	Reed Irrigation – Systems (RIS) - Cameron		The Greentu	NPC Long Path	2	100
D	Reed Irrigation – Systems (RIS) – Cameron		Turbo Key	NPC Long Path	8	100
E	PIC Dripper		Rain Drip	PC	8	100-350
F	Rain Bird		Rain Bug EM-MOS	PC	2	100-350
G	Reed Irrigation – System (RIS)- Cameron		Key Klip	NPC Long Path	2	100

* Classification is based on manufacturer's information

PC: Pressure compensating emitter

NPC: Non-pressure compensating emitter

from each type were taken at random and fitted on a polyethylene lateral of 13 mm diameter at 0.3 m spacings. Lateral was laid on a level ground to eliminate the slope effect. The experimental setup consisted of the following components; water tank, 2 HP centrifugal pump, pressure gauges, screen filter of 200 mesh size, valve and pressure regulators, as shown in Fig. 1. Clean tap water was used to avoid emitter clogging. Flow rates were determined at five different operating pressures, namely; 100, 150, 200, 250 and 300 kPa. The flow rates were measured by collecting the volume of water in graduated cylinders at a fixed period of time. An additional mean of determining the average flow rate was made by recording the amount of water passed through a water meter during the test period. Each test run was repeated three times and the average was recorded. The water temperature was monitored throughout each run to ensure stability of collected data. Pressure gauges and a manometer were installed at the beginning and the end of lateral to detect any change during the experiment and to ensure that the regulated pressure is at the desired value along the lateral line.

Data were processed to determine the coefficients of manufacturing variation (C_v), emission uniformities (EU), emitter exponent (β), flow regimes and the characteristic equations (Q vs H), for each type of emitters. Their values at the recommended operating pressures are presented in Table 2. The number of emitters per plant Np in the emission uniformity equation was considered one for experimental purposes. Emitter exponents were calculated using the following equation:

$$\beta = \frac{\log\ (q1/q2)}{\log\ (H1/H2)}$$

As the emitter exponent, β, represents the index of the flow regime of an emitter, the flow regimes of each emitter type tested were identified following the table suggested by Karmeli *et al.* [10].

Results and Discussion

The obtained hydraulic characteristic curves of the flow rates vs pressures are shown in Fig. 2.

The individual performances of each emitter on the lateral line are shown in Fig. 3. Almost all tested emitters have shown a systematic increase in flow rate as pressure increases except emitters A and F. The manufacturer's information data (Table 1), and the experimental results shown in Table 2, have indicated that emitters A and F are pressure compensating emitters, however, emitter A seems to exhibit better pressure compensating performance than emitter F. It has been reported [11], that for pressure compensating emitters, the relation between pressure and flow rate is sometimes variable due to the displacement of the mobile pieces inside the emitter which may not take exactly the same position from one test to another.

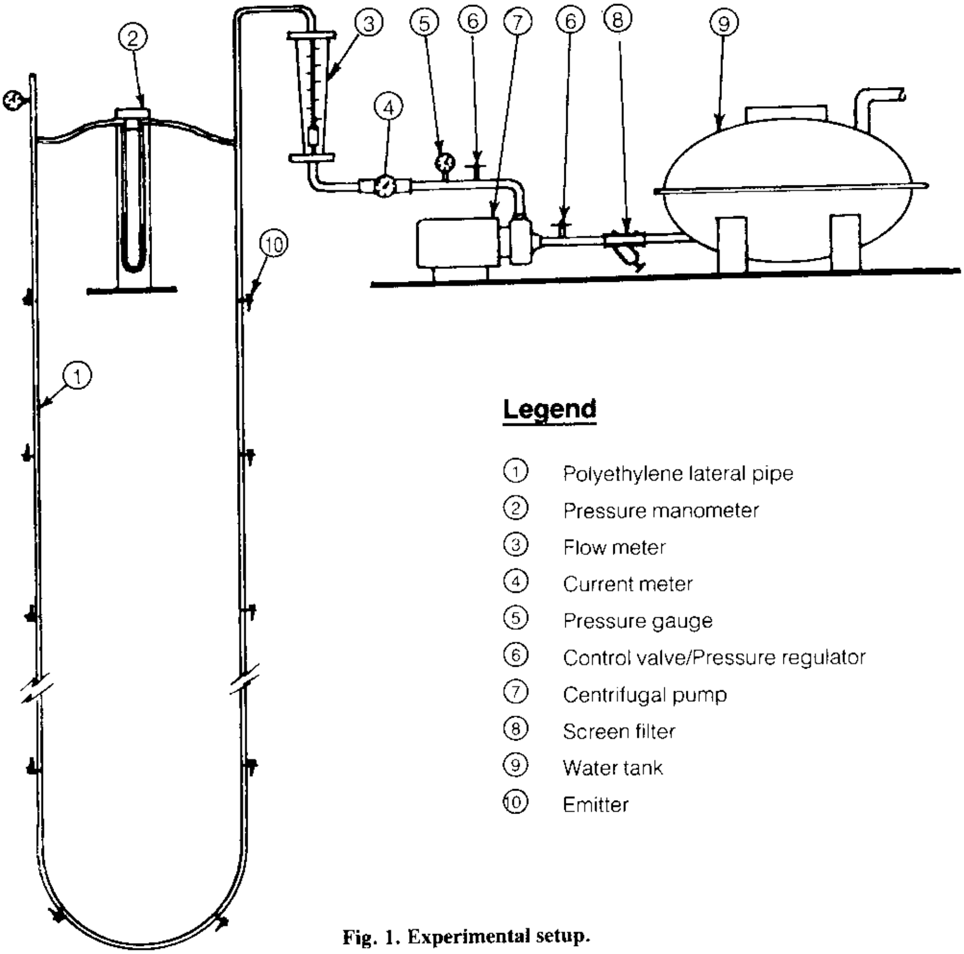

Fig. 1. Experimental setup.

The flow rate distributions along the lateral line were noticed to be variable for each emitter type. Change of operating pressure has also an influence on the uniformity of water distribution from each set of emitters. The emission uniformity of emitter A seems to be slightly higher at pressures 200 kPa or more (83%) as compared to uniformity at a pressure of 100 kPa (76.9%). The best emission uniformity obtained was that of the emitter D where emission uniformity values at all ranges of pressures varied between 86.1% and 91.2%. Emitter C has shown a consistent 75% EU at all operating pressures tested. Although emitter F is classified as a pressure compensating one, its emission uniformity was very low and range from 43.8% to 25.6% for 100 kPa and 300 kPa operating pressures respectively. Referring to the table of design emission uniformities recommended by the American Society of Agricultural Engineers [9], only emitter type D is considered acceptable.

Table 2. Emitter characteristics results at 100 kPa operatng pressure*

Emitter code	Brand name	C_v	EU %	β	Emitter type	Flow regime	Characteristic equation
A	Irridelco, Flapper	0.097	76.9	0.018	PC	Turbulent	$Q=7.594\,H^{0.018}$
B	Unknown	0.340	39.1	0.680	NPC	Turbulent	$Q=0.160\,H^{0.680}$
C	The Greentu, RIS	0.109	74.3	0.650	NPC	Turbulent	$Q=0.107\,H^{0.650}$
D	Turbo Key, RIS	0.050	91.2	0.530	NPC	Turbulent	$Q=0.725\,H^{0.530}$
E	Rain Drip, PIC Dripper	0.170	44.2	0.590	NPC	Turbulent	$Q=0.363\,H^{0.590}$
F	Rain Bug, Rain Bird	0.440	43.8	0.190	PC	Turbulent	$Q=0.846\,H^{0.190}$
G	Key Klip, RIS	0.320	48.3	0.680	NPC	Turbulent	$Q=0.093\,H^{0.680}$

*Classification is based on test performance

PC : Pressure compensating emitter

NPC : Non-pressure compensating emitter

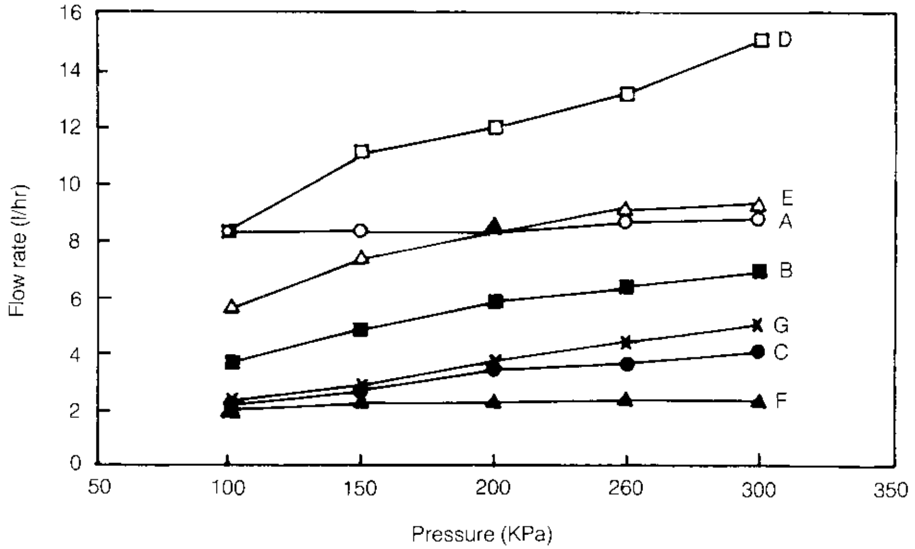

Fig. 2. Hydraulic characteristic curves of the tested emitters.

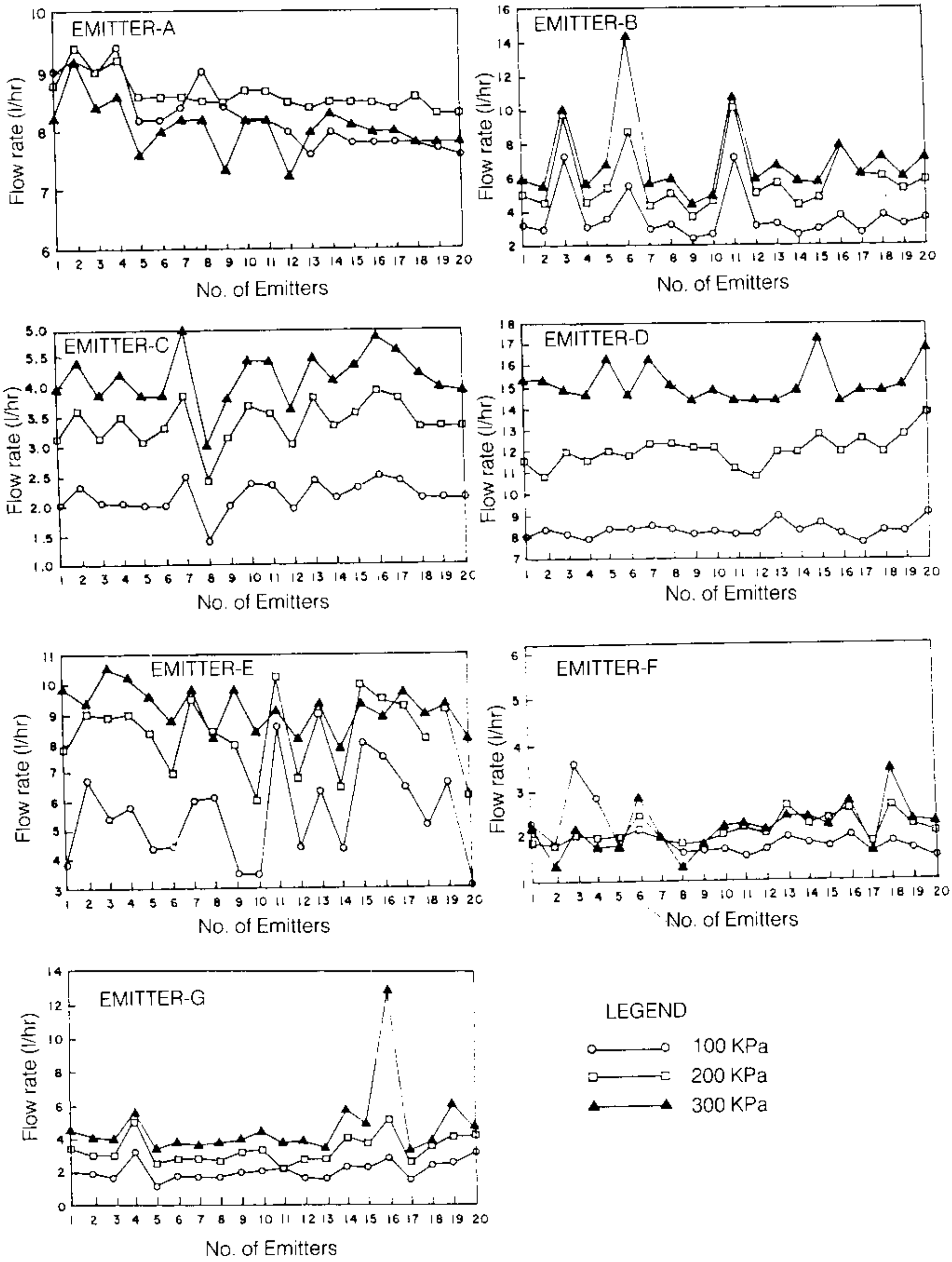

Fig. 3. Individual performances of emitters along the lateral line at various operating pressures.

The emission uniformity EU of tested emitters were noticed to be dependant on the size of emitter. Large size emitters (i.e. high flow rates; 8 liters/hr), produced higher EU, except for emitter E, consequently, lower rated emitters (i.e. 2 liters/hr), have shown a lower EU values. Emitters A and D, which are rated as 4 and 8 liters/hr, respectively, have produced 76.9% and 91.2% uniformities at 100 kP while emitters F and G with 2 liters/hr rated flow produced only 43.8% and 48.3% uniformities, at the same operating pressure.

Manufacturer's rated flow rates for most emitters were achieved at operating pressures less than 150 kPa. However average flow rates for the various emitters were found to be higher than the manufacturer's rated flow rates. At 100 kPa, the increase in flow rates of emitters A, B, C, D, E, F & G were 3.0%, 8.3%, 7%, 4%, 37.5%, 1.5% and 6% respectively. Although some of the emitters were claimed by manufacturers as pressure compensating (Emitter E) their actual behavior was actually non-pressure compensating.

Performances of some of the emitters (A, D, F & G) were compared with available characteristics curves provided by some of the manufacturers, and the results are shown in Fig. 4.

Generally, there are some similarity in trends between characteristic curves of tested emitters as compared with curves published by manufacturers. However, actual flow rates for each emitter type seem to vary from published values at different operating pressures. As illustrated in Fig. 4, flow rates of emitter A are similar at 300 kPa and higher by; 5.8%, 1.8%, 7.5% and 3.9% at 100 kPa, 150 kPa, 200 kPa and 250 kPa respectively. For emitter D, the increase in flow rates are: 4%, 14% and 7.2% at 100 kPa, 150 kPa and 200 kPa, respectively. Emitter F, is also higher in actual flow rates as compared with manufacturer's published values, the increase is: 16%, 23% and 22% at 100 kPa, 200 kPa and 300 kPa respectively. Only emitter G seems to produce same values as those of the manufacturer's.

Effect of operating pressures on the coefficient of manufacturing variation C_v is evident, as shown in Fig. 5. The effect, however, is not consistent, while C_v is higher at 100 kPa for emitters A, B, C and E, the increase of pressure to 200 kPa or more seem to reduce C_v values for all emitters except emitters F and G.

From the above observations, it is obvious that some emitters could perform pressure compensating ability, but due to lack of manufacturing precision (high C_v value), the emission uniformity of the trickle system could be low, in other words, the emitter exponent β that characterizes the flow is independent of the emission uniformity EU.

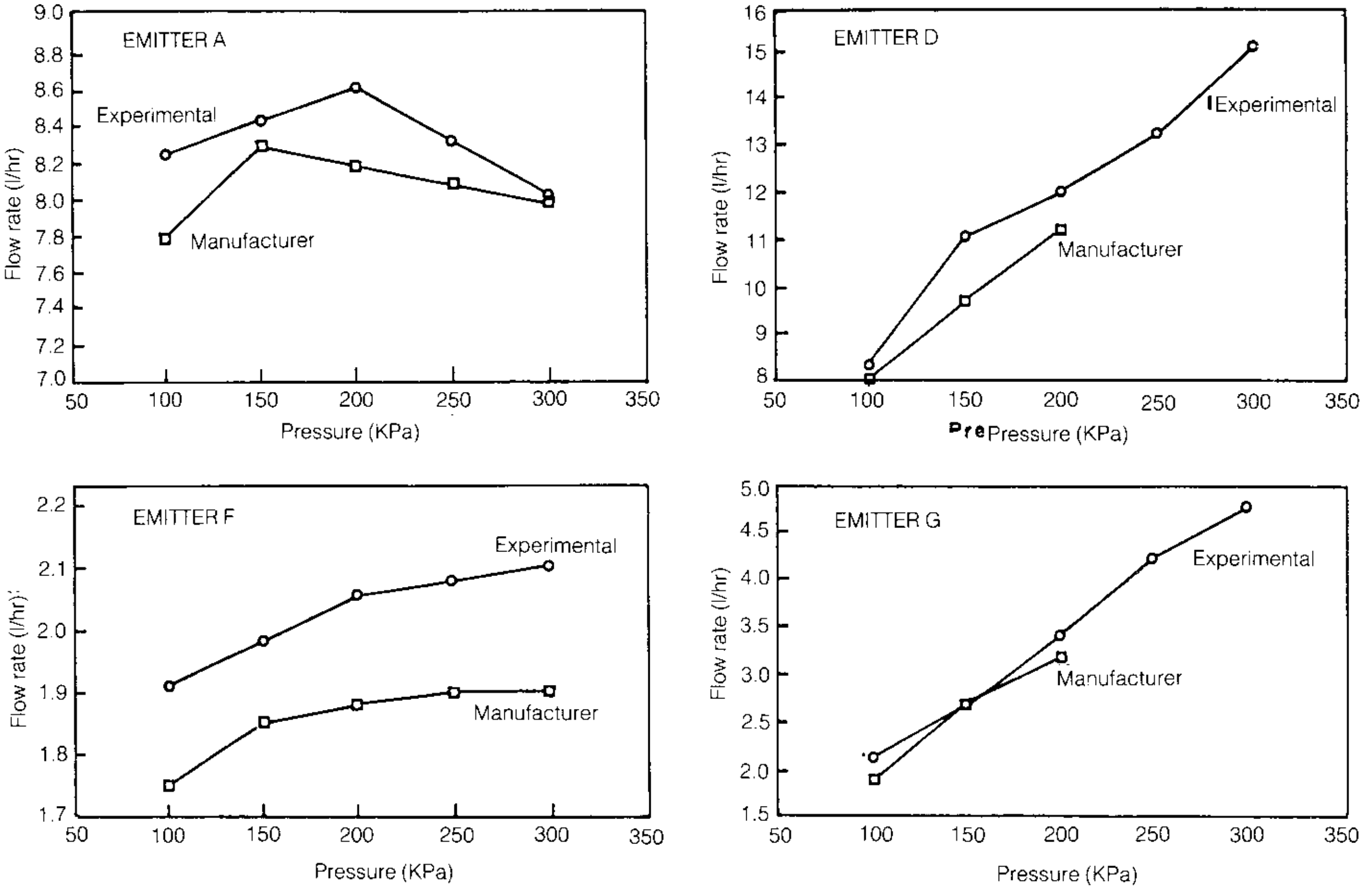

Fig. 4. Actual emitter flow rates as compared to published manufacturer's values.

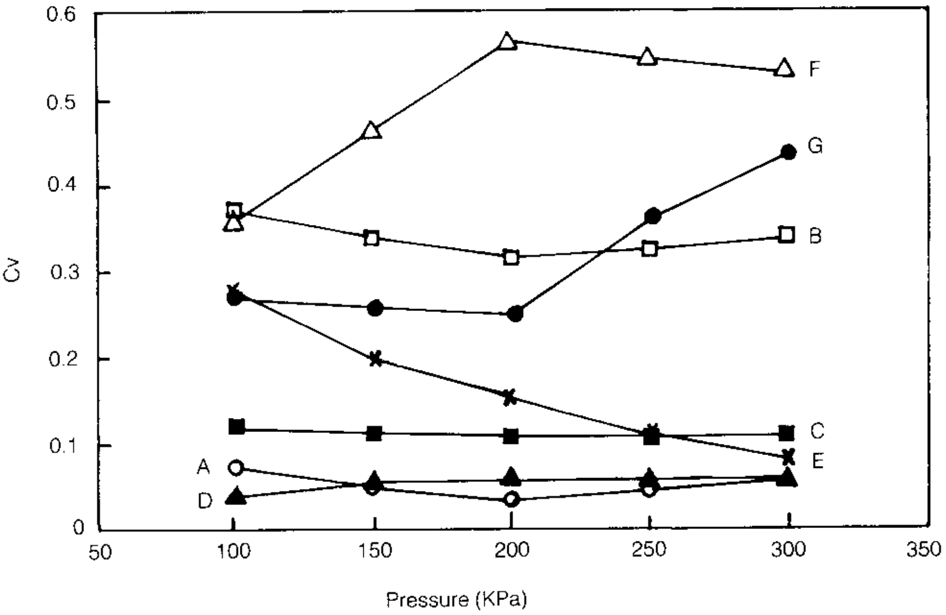

Fig. 5. Effect of pressure on the coefficient of manufacturing variation.

It was also noticed that while some of the emitters carry an international brand name, their performance was unsatisfactory which led to the question of the possible use of some of the famous names by an unknown emitter manufacturer which resulted in low precision quality.

It is evident from the results that some of the emitter types exhibit variable performance due to manufacturing as indicated by the coefficient of manufacturing variation C_v. Comparing the results of C_v with the table of recommended classification suggested by American Society of Agricultural Engineers (ASAE Standard, 1987), emitters A, C & D are considered acceptable for field operation, while the rest of the emitter types are unacceptable.

Conclusions

The investigation of the hydraulic characteristics of some of the locally available emitters have led to the following conclusions:

1. It is very important to evaluate a sample of emitters before field use to ensure satisfactory water distribution uniformity, referred to as emission uniformity.

2. New emitter products of the various brand names may behave differently from published values provided by the manufacturers due to high sensitivity of emitters and precision of manufacturing.

3. It is important to follow the operating pressures recommended by the manufacturer to have a uniform water distribution.

4. For compensating emitters it is recommended that an operating pressure higher than 100 kPa is to be used to ensure uniform water application.

5. Emission uniformity is dependent on the size of the flow emitter (rated flow rate) which means that smaller size emitters (low flow rate) are more sensitive to changes in operating pressure which results in lower emission uniformity. Therefore, the use of large size emitters may improve the water distribution uniformity.

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تقويم الخصائص الهيدروليكية لبعض المنقطات المتوافرة حاليًّا

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ملخص البحث . تم اختيار عينات جديدة لسبعة أنواع من المنقطات الشائع استخدامها محليًّا في المزارع والبيوت المحمية في المملكة العربية السعودية . وأجريت اختبارات على الخصائص الهيدروليكية لهذه المنقطات للتأكد من مطابقتها لمتطلبات تصميم نظام الري بالتنقيط .

وعند مقارنة نتائج التجارب التي أجريت مع المعلومات المتوافرة من الشركات المصنعة لوحظت بعض الفروق منها أن معدل التصرف الفعلي هو أعلى من معدل التصرف المصنعي في جميع المنقطات . كما لوحظ أيضًا أن هناك اختلافًا في معدلات توزيع المياه على طول خط المنقطات مما يشير إلى ارتفاع في معامل المتغير المصنعي (C_v) لبعض المنقطات والذي يشير بدوره إلى انخفاض كفاءة توزيع المياه (E_u) كما شمل البحث دراسة تأثير ضغط التشغيل على أداء المنقطات حيث لوحظ تحسن الأداء عند ارتفاع الضغط . في ختام البحث تم استعراض بعض الاقتراحات لتحقيق أفضل كفاءة لاستخدام مياه الري من هذه المنقطات .