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Flow and Manufacturing Variation of Drippers

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ABSTRACT

Uniformity includes two key elements describing how well the emission device is designed and how well it is manufactured. These two elements are known as the flow exponent "x" and the coefficient of manufacturing variation, "CV". Both these "x" and the "CV" are integral parts of the Emission Uniformity equation, which describes uniformity due to manufacturing design and variation. The flow exponent x describes how "pressure compensating" the emission device is, and normally measures between 0 to 1, the lower (closer to 0) the value of x, the better (pressure compensating), values of 0.5 represent turbulent flow and values of 1.0 represent laminar flow. While CV is a statistical description of how uniformly each device is manufactured in relation to one another in terms of its flow rate. The paper presents the values of x and CV estimated through laboratory test of emitters used commercially in India belonging to some of the leading manufacturers. It was observed that none of the emitters could be termed as pressure compensating while values of CV for most of the emitters ranges between 0.1-0.25.

Drip irrigation system is characterized by high application uniformity and application efficiency along with advantage in saving of water is considered one of the most efficient irrigation systems. The system combines of many sub-components; their individual performance directly affects the overall performance of the system. Drippers are one of the most important components in drip irrigation system, which delivers water either on the surface, next to plant or subsurface or near the root-zone, carrying overall major responsibility for system performance. Type of drippers varies from simple orifice to complex pressure compensating. Although all drippers of same characteristics in an irrigation system should deliver equal quantity of water but in real conditions, there is variation in discharges of drippers unit by unit. The main reasons behind this can be the manufacturing variation. As drip irrigation emission devices are designed to discharge water at low rate, hence small variation in the design of drippers causes a relatively large variation in discharge. Some drippers also utilize elastomer material to achieve pressure compensating action. Such materials are difficult to prepare with consistent dimensions, which causes variation in discharge. Apart from manufacturing variation, friction losses and the variation in topography along the lateral also affect emitter discharge due to change in pressure. Coefficient of manufacturing variation (CV) reveals the amount of variation in uniformity from one emitter to the next emitter. A CV of 0.05 or less is considered excellent while CV between 0.05 and 0.1 is acceptable.

Hence the amount of variation in discharge at a particular pressure can be sufficient to determine the uniformity characteristics of drippers to term pressure compensating or non pressure compensating. Estimation of flow rates of emitters under the real field condition can provide information about variation in emitter flow rate and helps in determining the ability in pressure compensation of emitters. This information can be critical for calculating the friction losses while designing the system, which ultimately will improve the overall application efficiency as well as application uniformity of the system. Application uniformity of drip irrigation system can be expressed by several uniformity parameters; however most require the measurement of emitter discharge for a representative sample. Nakayama and Bucks (1986) reviewed several widely used parameters including uniformity coefficient, emitter flow variation and coefficient of variation. Solomon (1979) related expected yield to several uniformity measures, including Christiansen's uniformity coefficient, statistical uniformity (Bralts et al., 1981) and distribution uniformity (Kruse, 1978).

This study was undertaken to assess the hydraulic performances of different emitters under laboratory conditions with following specific objectives:

1. Measurement of emitter flow rate at different operating pressures to compare these results with manufactures rated discharges.
2. Determination of emitter discharge exponents (x)

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to identify pressure-compensating characteristics of emitters.

3. Estimation of coefficients of manufacturing variation (CV) at different operating pressures, in order to establish the emitters flow rate sensitivity to pressure.

METHODOLOGY

The manufacturing variations exhibited by several commercially available drip irrigation emission devices were determined by laboratory flow rate tests. Flow rates of number of samples of each different category were measured at the normal operating pressure. Clean water was used so that clogging would not be a factor. Nine emitters were tested of different makes. Fig.1 Emitters chosen were the product of some of the leading manufacturers available in India commercially (a coding has been done for each manufacturer to discuss the performances) and their products are widely used by growers. Forty emitters of each make type were selected randomly. The discharges of all emitters were measured at five different operating pressures: 1.0, 1.5, 2.0, 2.5 and 3.0 kg/cm², which were placed on lateral of 6m lengths. Nine emitters were placed at 0.60 m interval on the lateral at one time, as it was observed that by putting nine emitters at one time on the lateral there was not much significant difference in operating pressure at each emitting points of the lateral.

The operating pressure of 2.5 and 3.0 kg/cm² exceeds the manufacturer's recommendations but higher limit were considered keeping in view the large irrigation

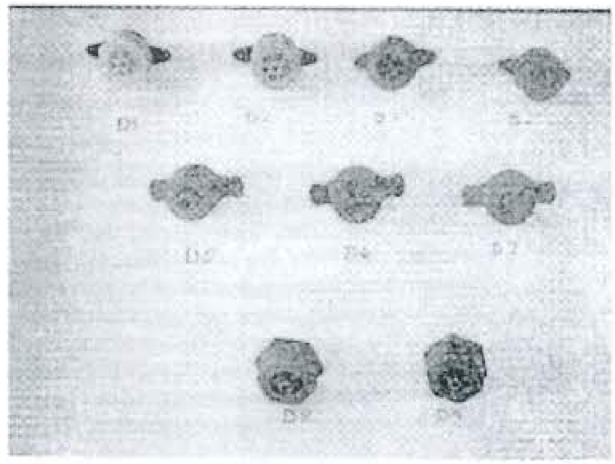

Fig. 1: Drippers tested

farms. The pressure was regulated by pressure control valve. A cylindrical shape collector was placed below the dripper to collect water in a stipulated testing time. The system was operated for one hour for each set of testing and the amount of water collected in the cylinder was measured volumetrically.

Emitter flow rate was expressed aas a function of pressure head in the following manner (Keller and Karmeli 1975)

$$q = kH^x \qquad \text{............................1}$$

Where,

q = emitter discharge rate (L/h)

k = emitter constnt,

H = pressure head (kPa),

x = emitter discharge expon (dimensionless)

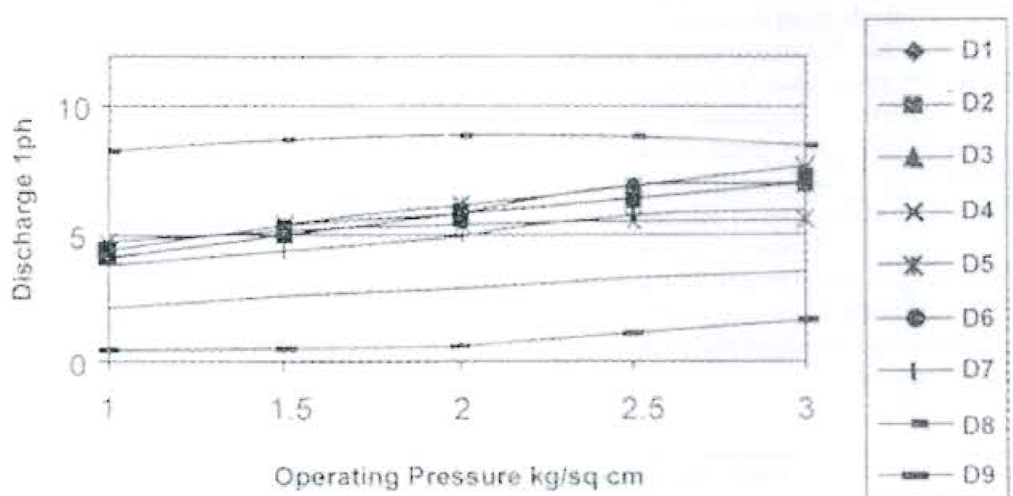

Fig. 2: Pressure Discharge Relationship

Table 1. Values of x and k for different drippers based on test results and specifications claimed by manufacturers

Emitter	Based on Test results		Claimed by Manufacturer			
	*x	*k	x (at 1.0 Kg/cm² operating pressure)	k (flow coefficient at 1.0 kg/cm² operating pressure)	Discharge (lph)	Type
D1	0.71	8.81	0.48	8.0	8.0	Turbo Non Pressure Compensating
D2	0.49	8.33	0.48	4.0	4.0	Turbo Non Pressure Compensating
D3	0.56	7.61	0.04	2.4	2.0	Pressure compensating
D4	0.23	8.98	0.03	4.2	4.0	Pressure compensating
D5	0.48	8.32	NA	NA	10.0	Turbo Non Pressure Compensating
D6	0.41	8.52	NA	NA	8.0	Turbo Non Pressure Compensating
D7	0.46	8.24	NA	NA	4.0	Turbo Non Pressure Compensating
D8	0.16	9.23	NA	NA	8.0	Turbo Pressure compensating
D9	0.50	8.57	NA	NA	2.0	Turbo Non Pressure Compensating

*x and *k values are based on the experiment conducted and computed by developing graph between ln Pressure vs ln Discharge when drippers were operated in the pressure range of 1.0 – 3.0 kg/cm² as discussed in equations 1
x and k values of D5, D6, D7, D8 and D9 type of dripper is not available.

RESULTS AND DISCUSSION

Discharge

The mean discharges observed for emitter at different operating pressure are shown in Fig. 2. In most of the cases the observed discharge was found to be reasonably close to those provided by the manufacturer. It was observed that discharge of the emitter's increases with increase in operating pressure. However there was no significant increase in discharge in case of D4 and D8 emitters. It is due to the fact that both the emitters are pressure compensating. It is also observed from the graph that there is significant increase in the discharge of D1 emitter with pressure, which indicates the emitter under consideration to be non-pressure compensating type.

Table 2. Coefficients of manufacturing variation for different emitters

Emitter	Operating pressure (kg/cm²)				
	1	1.5	2	2.5	3
D1	0.05	0.03	0.01	0.12	0.04
D2	0.07	0.08	0.09	0.09	0.12
D3	0.01	0.08	0.08	0.07	0.08
D4	0.04	0.04	0.04	0.03	0.17
D5	0.06	0.05	0.05	0.05	0.05
D6	0.10	0.11	0.10	0.11	0.12
D7	0.24	0.25	0.17	0.18	0.33
D8	0.13	0.14	0.15	0.12	0.25
D9	0.12	0.13	0.13	0.15	0.16

The greatest deviation between experimental and manufacturers' rated discharges occurred with the D9 emitter where measured flow rates were consistently 2 L/h below the rated. The D1, D2, D3, D4 emitters were most accurate with identical measured and rated discharge curves, followed by the D5, D6, D7, D8.

Emitter Discharge Exponent

Emitter discharge exponents x and the values of emitter constant k were determined using Eq. 1. Based on these values; hydraulic performance of each emitter was characterized and calculated and is shown in Table 1.

Comparing the values of x and k it was found that most of the values claimed by manufacturers holds true for D1, D2 and D3. The x and k values for other emitters claimed by all manufacturers were not available. The x values of emitters D1, D3 and D9 were found to be greater than 0.5 thus were classified as non-pressure compensating type. The x values of drippers D2, D5.D6 and D7 were found less than 0.5. Hence, these may also be classified as non-pressure compensating. Two emitters D4 and D8 with exponents close to 0.2 can be considered as pressure compensating when operated in the pressure range of 1.0 – 3.0 kg/cm². However, besides these none of the emitters' show x values closer to zero, signifies that none of the emitter is pressure compensating.

Coefficient of Manufacturing Variation

The percentage of emitters in the sample falling within a given deviation from the mean discharge was calculated. Solomon (1979) classified emitter performance on the basis of CV. The calculated C.V. values are given in Table 2.

CVs of D5 and D6emitters remained relatively constant over the range of pressure tested. D6 emitter with CV more than 0.10 can be classified as poor while D5 and D1 with values of CV as low as 0.05 is rated as excellent. Emitters D2 and D3 behave excellent at low operating pressure of 1.0 and 1.5 kg/cm². D4 can be categorized as excellent for all operating pressure; however, its performance decreases as operating pressure increases to 3.0 kg/cm². D7, D8 and D9 emitters showed CV more than 0.15, hence can be classified as poor, hence these are unsuitable for installation in the field condition as there would be lot of variation in discharge of these emitters. Other emitters should be operated for working pressure, which gives low CV.

CONCLUSIONS

1. The study indicates that none of the drippers are fully pressure compensating.
2. It was also observed that manufacturing variation affects the performance of individual drippers in a system with respect to the operating pressures.
3. It shows that while selecting drippers for a system its flow rate sensitivity for a wide range of operating pressure should be given due consideration.

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