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RESEARCH ARTICLE

Performance evaluation of different types of emitters

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ABSTRACT : Drip irrigation system has gained considerable importance in the recent years in view of the need for efficient utilization of water resources. Efficiency of drip system depends directly on the uniformity with which water is discharged by the emission devices throughout the system. Emitter is one of the important components used in drip irrigation system as compared to all other components. The performances of the emission devices have major impact on the success of drip irrigation system. Eight different types of emitter's *viz.,* O-Tif02, O-Tif04, O-Tif08, O-Tif16, JSCPC02, JSCP04, JTKP08, J-Loc16 were selected for the performance tests. The study has been conducted to evaluate the parameter such as manufacturing coefficient of deviation, mean flow rate, coefficient of discharge, emitter discharge exponent, emission uniformity, absolute emission uniformity and flow rate. The study indicated that operating pressure affects flow rates of non-pressure compensating (NPC) type emitters. The relationship between pressure and discharge was linear. The manufacturing quality of all the emitter found excellent. The Otiff-16 having 16 lit/hr nominal discharge was found to be having best manufacturing quality of C_v as 0.018 among all the tested emitters.

KEY WORDS : Drip irrigation, Emitters, Emission uniformity, Flow rate index

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INTRODUCTION

Drip irrigation system has gained considerable importance in the recent years in view of the need for efficient utilization of water resources. In this system small quantities of water are applied at frequent intervals directly to the plant root zone drop by drop. Efficiency of drip system depends directly on the uniformity with which water is discharged by the emission devices throughout the system. Ideally all emitters in the system should discharge equal amount of water. Emitter is one of the most important components used in the drip irrigation system and its performance will have major impact on the success of the system as compared to all other components. Nowadays various types of emitters are available in the market and have different specific characteristics. Singh *et al.* (1997) conducted an experiment on performance evaluation of micro irrigation emitters.

The experiment was carried out at M/S Jain Irrigation System Limited, Jalgaon. Seven types of emitters *viz.,* Turbo key (TK), Turbo sc (SC), J-npc (JNPC), J-loc (JL), Drip co (DRP), K_2 (K) and J-mini in line (JML) were selected for performance test. Solomon (1979) tested the manufacturing variation (C_v) of several commercially available emitters. The C_v was a suitable measure of unit-to-unit consistency in emitters. C_v values of several types of emitter's ranges from 0.02-0.04. Dahiwalkar *et al.* (1994) developed a mathematical model for the pressure discharge sensitivity, $Q = 2.54\ H^{0.759}$ and presented the results in tabular form for turbo-key type of emitters.

It is, therefore, necessary to test the emitters, so that the drip designer can select the best emitter suitable for specific requirement. Keeping this in view, the present study of performance evaluation like manufacturing, hydraulic and operational characteristics of drip irrigation emitters, which can be used for design, operation and selection of drip irrigation

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system was conducted.

Theoratical considerations :

The different characteristics used for performance evaluation of emitters are described below.

Manufacturing characteristics :

Keller and Karmeli (1974) introduced concept of manufacturing coefficient of variation, as statistical measure. The manufacturing coefficient of variation describes the quality of processes used to manufacture those devices :

$$c_v = \frac{s}{q_a} \quad ....(1)$$

where,

C_v = Coefficient of manufacturers variation

S = Standard deviation of emitter discharge, $l.h^{-1}$

q_a = Average discharge of emitter , $l.h^{-1}$

S is calculated by :

$$s = \frac{(q_1^2 + q_2^2 + q_3^2 + ... + q_n^2 - n \times q_a^2)^{1/2}}{(n-1)^{1/2}} \quad ....(2)$$

where,

q_1, q_2, q_3 = Discharges of emitter 1, emitter 2, emitter 3etc., $l.h^{-1}$

q_n = Discharge of n^{th} emitter , $l.h^{-1}$

q_a = Average emitter discharge, $l.h^{-1}$

n = Total number of emitters

Besides this individual flow rate varies from nominal flow rate. The percentage difference between actual flow rate and nominal flow rate is characterized by equation :

$$Q_d = \frac{(q_r - q_a)}{q_r} \times 100 \quad ....(3)$$

where,

Q_d = Mean flow rate deviation, per cent

q_r = Rated emitter discharge, $l.h^{-1}$

q_a = Average emitter discharge, $l.h^{-1}$

The ASAE interpreted the quality of emitters based on the values of coefficient manufacturing variation and are presented in Table A.

Table A : ASAE (1985) interpretation of manufacturing coefficient of variation

	Cv	Interpretation
Point source emitter	<0.05	Excellent
	0.05 – 0.07	Average
	0.07 – 0.11	Marginal
	0.11 – 0.15	Poor
	>0.15	Unacceptable
Line source emitter	<0.10	Good
	0.10 – 0.20	Average
	>0.20	Marginal to unacceptable

The manufacturing coefficient of variation (C_v) and mean flow rate deviation (Q_d) at a nominal pressure head of 1.0 kg/cm^2 at atmospheric temperature for all tested emitters were calculated.

Hydraulic characteristics :

Over the range of discharges, the flow characteristics of emitters can be characterized by :

$$Q = K_d H^x \quad ....(4)$$

where,

Q = Emitter discharge, l/hr

K_d = Constant of proportionality that characterizes each emitter

H = Working pressure head at the emitter, m

x = Emitter discharge exponent that is characterized by the flow regime

To determine K_d and x, the discharges at two different operating pressure heads must be known. The exponent x may be determined by measuring the slope of log-log plot of H Vs q or analytically by :

$$x = \frac{\log\left(\frac{q_1}{q_2}\right)}{\log\left(\frac{H_1}{H_2}\right)} \quad ....(5)$$

where,

x = Emitter discharge exponent

q_1 = Emitter discharge at H_1, $l.h^{-1}$

q_2 = Emitter discharge at H_2, $l.h^{-1}$

H_1, H_2 = Pressure heads.

The value of x can be used in equation 5 to solve for K_d . The value of x characterizes the flow regime and discharge versus pressure relationship of the emitter. The lower the value of x, the less discharge will be affected by pressure variations. In fully turbulent flow x = 0.5 and in laminar flow x = 1.0. Non-compensating orifice and nozzle emitters are always fully turbulent with x = 0.5. However, the exponent of long-path emitters may range anywhere between 0.5 and 1. For different flow regime expected values of x are given in Table B.

Table B : ASAE (1985) emission device classification

	X - value	Emitter type
Variable flow path	0.0	Pressure compensating
	0.1	
	0.2	
	0.3	
Vortex flow	0.4	Vortex
Fully turbulent flow	0.5	Orifice, tortuous
Mostly turbulent flow	0.6	Longer spiral path
	0.7	
	0.8	
Mostly laminar flow	0.9	Micro tube
Fully laminar flow	1.0	Capillary

Operational characteristics :

Emission uniformity :

To define uniformity of water application of a micro irrigation system, Keller and Karmeli (1974) suggested two parameters namely emission uniformity and absolute emission uniformity characterised by :

$$EU = \frac{q_n}{q_a} \times 100 \qquad ....(6)$$

$$EU_a = \frac{1}{2} \times \left(\frac{q_n}{q_a} + \frac{q_a}{q_x} \right) \times 100 \qquad ....(7)$$

where,

EU = Emission uniformity, per cent

EU_a = Absolute emission uniformity, per cent

q_n = Average emitter flow rate, $l.h^{-1}$

q_a = Average of lowest 1/4 of emitter flow rate, $l.h^{-1}$

q_x = Average of highest 1/8 of emitter flow rate, $l.h^{-1}$

EXPERIMENTAL PROCEDURE

The present study was carried out on the Research farm of the Department of Irrigation and Drainage Engineering, College of Agricultural Engineering and Technology, Dapoli. Different types of emitters *viz.,* O-Tif02, O-Tif04, O-Tif08, O-Tif16, JSCPC02, JSCP04, JTKP08, J-Loc16 were selected for the performance tests. Twenty samples of each type of emitter were chosen randomly. Experimental set up was installed in the field. Water source was well where horizontal axis monoblock pump was installed. Filter was placed between pump set and the ball valve. The emitter field consisted of four laterals of 20 m length, each equipped with 20 emitters, each emitter at 1m distances. Laterals were placed at the distance of 1m on the submain. Flow rates of emitters were measured at different pressures beginning at 0.4-kg/ cm^2 to 1.4 kg/cm^2 with an increment of 0.2 kg/cm^2. The pressure was maintained in the laterals by adjusting ball valves (By pass valve) located at main line. The valve was set to adjust the discharge at a predetermined pressure. The pressure gauge (0-6 kg /cm^2 range and least count 0.1 kg/cm^2) located at the start of sub main was used to monitor pressure in the laterals throughout the test. Lateral valves were used to control the flow from each lateral and one lateral was tested at a time by keeping other three lateral valves closed. With catch can arrangement; ten alternate emitters were tested at one time on each lateral. Catch cans were placed underneath each emitter to measure the discharge. Discharge of O-Tif02 and JSCPC02 emitter was collected for the period of 15 min., O-Tif04 and JSCPC04 for 10 min., O-Tif08 and JTKP08 for 7.5 min, O-Tif16 and J-Loc-16 for 5 min.

EXPERIMENTAL FINDINGS AND ANALYSIS

The results of the present study as well as relevant discussions had been presented under following sub heads:

Manufacturing characteristics :

The manufacturing coefficient of variation (C_v) and mean flow rate deviation (Q_d) at nominal pressure (1 kg/cm^2) for all the tested emitters are given in Table 1. It can be seen that the manufacturing coefficient of variation for nominal operating pressure (1 kg/cm^2) decreases with increase in nominal discharge for same type emitter.

Table 1: Manufacturing characteristics of emitters

Emitter type	q_a (lit/hr)	C_v	Q_d (%)	Class
O-Tif02	2.156	0.041	7.80	Excellent
O-Tif04	4.317	0.033	7.92	Excellent
O-Tif08	8.616	0.028	7.70	Excellent
O-Tif16	17.124	0.018	7.025	Excellent
JSCPC02	2.01	0.039	1.90	Excellent
JSCPC04	4.074	0.036	1.925	Excellent
JTKP08	8.364	0.032	4.6	Excellent
J-Loc16	16.356	0.030	2.225	Excellent

As per ASAE (1985) recommendation it is obvious that the manufacturing quality is excellent for all the tested emitters *i.e.* O-Tif02, O-Tif04, OTif08, OTif16, JSCPC02, JSCPC04, JTKP08, J-Loc16 for the pressure 1 kg/cm^2.

The mean flow rate deviation for tested emitters of Plastro make is minimum for O-Tif16 and maximum for O-Tif04. Similarly for Jain make emitters the mean flow rate deviation is minimum for JSCPC02 and maximum for JTKP08.

Hydraulic characteristics :

It can be seen from Fig.1, that emitter's discharge increased with increase in pressure. On the above graphs trend lines were drawn and equations of the line were found in the form of (y = mx + c) and from this equation slope of the trend line (m), constant (c) and regression constant (R^2) were determined and presented in Table 2.

Table 2 : Regression constant for emitter discharge and operating pressure

Emitter type	Slope (m)	Constant (c)	R^2
O-Tif02	0.2049	1.3215	0.9902
O-Tif04	0.4341	2.534	0.9956
O-Tif08	0.3083	6.3071	0.9127
O-Tif16	0.4858	12.736	0.9836
JSCPC02	0.0797	1.6165	0.9752
JSCPC04	0.1397	3.3543	0.9897
JTKP08	0.3717	6.0915	0.9662
J-Loc16	0.3497	13.55	0.9989

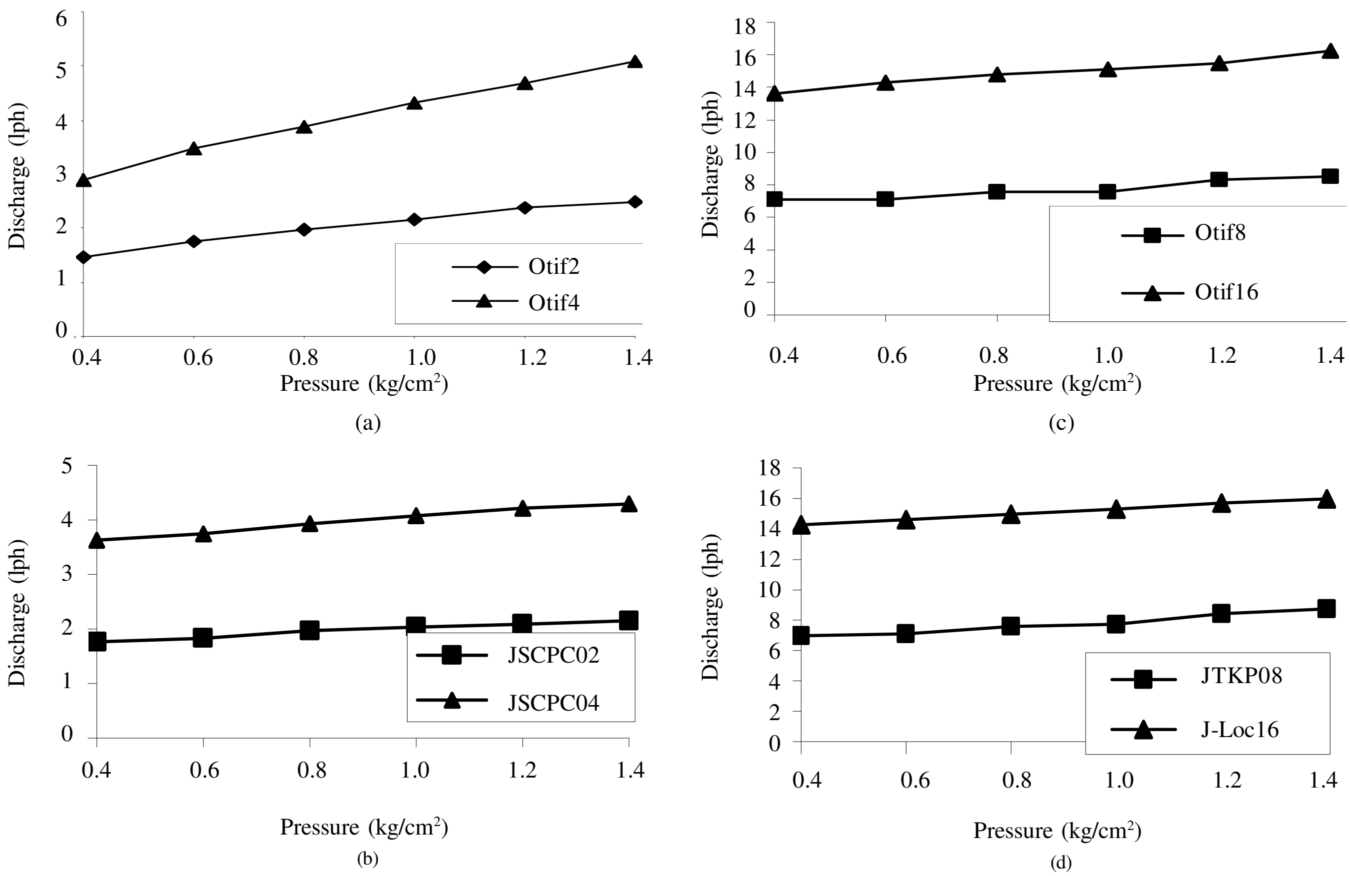

Fig. 1 : Variation of discharge with pressure for different emitters

From the graphs it is found that the pressure discharges relationship for the tested emitter was linear. According to the equation ($y = mx + c$), it is clear that the more the value of slope (m), the more is variation in discharge with respect to pressure. The maximum variation in discharge was found in case of O-Tif 16 emitter (0.4858), followed by O-Tif 04 (0.4341), JTKP 08 (0.3717), J-Loc 16 (0.3497), O-Tif 08 (0.3083) and O-Tif 02 (0.2049). The pressure compensating emitters like JSCPC 04 (0.1397) and JSCPC 02 (0.0797) were found with least slope (m) values indicating least variation in discharge with respect to pressure among the tested emitters.

Coefficient of discharge :

The coefficient of discharge of the emitters under study for different pressure ranges are presented in Table 3. Theoretically the coefficient of discharge is constant for an emitter, however, there exists a slight variation with pressure. It is also obvious that for some emitters, K_d is always less than

Table 3 : Coefficient of discharge of the emitter at different pressure range

Emitter type	Pressure range (kg cm^{-2})				
	0.4-0.6	0.6-0.8	0.8-1.0	1.0-1.2	1.2-1.4
O-Tif02	2.17	2.14	2.16	2.16	2.25
O-Tif04	4.35	4.20	4.32	4.31	4.26
O-Tif08	9.66	8.86	8.62	8.62	8.90
O-Tif16	15.97	16.26	17.12	17.12	16.27
JSCPC02	1.93	2.07	2.01	2.01	2.02
JSCPC04	3.9	4.08	4.07	4.07	4.13
JTKP08	7.79	8.22	8.37	8.37	8.44
J-Loc16	16.54	16.31	16.36	16.36	15.

its nominal discharge but for some emitters it is greater than its nominal discharge.

Emitter discharge exponent :

The data in Table 4 shows the emitter discharge exponent of the emitters for different pressure range. Ideally x value should be constant for an emitter, however, for some emitters changes are very similar to K_d value. Emitter having minimum x value may be most suitable for use in that pressure range. It can be seen that for most of the emitters x value lies from fully turbulent (0.5) to mostly turbulent (0.6 to 0.8) flow range. For emitter JSCPC 02 and JSCPC 04 exponent x lies between 0.08 to 0.24, so according to the emission device classification flow regime is variable flow path and emitters are pressure compensating. Remaining tested emitters lie in fully turbulent flow to mostly turbulent flow regime according to exponent x.

Emission uniformity :

The value of the emission uniformity of all the emitters under study is presented in Table 5. It can be seen that the value of emission uniformity of all the emitters under study remained nearly constant. In general emitters have high emission uniformity for narrow range of pressure and low value for both lower and upper sides of that pressure range. Value of emission uniformity was above 95 per cent in pressure range of 0.8 to 1.2 kg/cm^2. It can also be seen from the data in Table 6 that variation in absolute

Table 4: Emitter discharge exponent of the tested emitter for different pressure range

Emitter type	Pressure range (kg cm^{-2})				
	0.4-0.6	0.6-0.8	0.8-1.0	1.0-1.2	1.2-1.4
O-Tif02	0.42	0.39	0.42	0.54	0.32
O-Tif04	0.45	0.38	0.50	0.46	0.53
O-Tif08	0.57	0.40	0.27	0.77	0.60
O-Tif16	0.39	0.43	0.66	0.24	0.52
JSCPC02	0.1	0.24	0.10	0.21	0.18
JSCPC04	0.08	0.17	0.16	0.19	0.12
JTKP08	0.34	0.44	0.52	0.53	0.48
J-Loc16	0.41	0.39	0.40	0.55	0.47

Table 5: Emission uniformity of various emitters

Emitter type	Pressure range (kgcm^{-2})					
	0.4	0.6	0.8	1	1.2	1.4
O-Tif02	92.34	92.54	96.50	95.24	94.96	94.93
O-Tif04	93.11	97.63	97.13	94.51	96.91	96.92
O-Tif08	93.71	96.61	95.38	96.87	96.25	94.15
O-Tif16	95.65	93.27	97.40	98.11	97.32	94.65
JSCPC02	90.15	88.06	93.69	95.52	95.05	94.35
JSCPC04	98.62	97.95	98.22	98.67	98.15	94.30
JTKP08	97.37	93.61	95.65	96.24	96.85	95.64
J-Loc16	92.51	94.09	93.56	96.30	96.26	97.16

Table 6: Absolute emission uniformity for various emitters

Emitter type	Pressure range (kg/cm^2)					
	0.4	0.6	0.8	1	1.2	1.4
O-Tif02	93.00	96.19	95.87	95.74	93.96	93.76
O-Tif04	93.30	97.71	96.76	95.38	96.76	97.00
O-Tif08	94.60	96.52	96.18	96.73	96.24	94.12
O-Tif16	95.54	94.23	97.59	97.76	96.41	94.48
JSCPC02	90.4	88.93	94.05	95.62	96.82	93.47
JSCPC04	97.43	96.02	97.12	98.26	96.99	95.72
JTKP08	96.66	96.34	96.04	96.32	96.47	96.55
J-Loc16	92.13	94.73	94.37	94.03	94.78	96.97

emission uniformity with pressure was similar to emission uniformity.

Conclusion :

– The manufacturing quality of all the emitters tested was found excellent. O-Tif-16 having least value of C_v as 0.018

– The operating pressure affects flow rate of NPC type emitters. Also pressure and discharge were related linearly. It can also be attributed that 1.00 kg/cm^2 pressure head is optimum for excellent emitter performance.

– The average discharge of all the emitters varies from nominal discharge. The percentage variation was minimum for JSCPC02 (1.9 %), while it was maximum for O-Tif04 (7.92 %).

– The flow regime was fully turbulent to mostly turbulent for NPC emitters and flow regime was variable flow path for pressure compensating emitters.

– The emission uniformity was found to be above 90 per cent for all the tested emitters and goes mostly above 95 per cent for pressure range 0.8 to 1.2 kg/cm^2.

– The absolute emission uniformity was found above 90 per cent for all emitters. The overall quality of emitter was better for high nominal discharge.

– The JSCPC02 and JSCPC04 were found with least slope (m) values so they have least variation in discharge with respect to pressure among the tested emitters.

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