Available online at www.ijpab.com
DOI: http://dx.doi.org/10.18782/2320-7051.4071
ISSN: 2320 – 7051
Int. J. Pure App. Biosci. **5 (4):** 758-765 (2017)
Research Article
International Journal of Pure & Applied Bioscience
OPEN ACCESS

Hydraulic Performance Evaluation of Drip System by Developing Relationship between Discharge and Pressure

G. Pragna*, G. Manoj Kumar and M. Shiva Shankar
Department of Agricutural Engineering, CAE, Sangareddy, PJTSAU
*Corresponding Author E-mail: guglothpragna@gmail.com
Received: 16.06.2017 | Revised: 25.06.2017 | Accepted: 27.06.2017

ABSTRACT

The system was tested for its uniformity co-efficient, emission uniformity, and manufacturing co-efficient of variation. The head discharge relationships at different operating pressure i.e. 0.5, 0.7, 0.9, 1.25 and 1.5 kg/cm^2 for emitters were expressed and the best fitted model with highest R^2 was determined. Results indicated from developed models for the pressure discharge relationship that the exponent of the pressure was less than and equal to 0.5 which indicated that the nature of flow from the dripper was not an orifice flow. Co-efficient of variation values of all considered drippers at different operating pressure falls under 0.04 to 0.1 concluded that drippers are of good quality. The Emitter flow variation is also less than 25% which is in an acceptable range. Emission uniformity ranged from 81.78 % to 83.38 % at 0.5 kg/cm^2 to 89.36 % to 89.94 % at 1.5 kg/cm^2 for different drippers. Co-efficient of uniformity ranged from 92.15 % to 94.36 % at 0.5 kg/cm^2 to 95.25% and 96.21% at 1.5 kg/cm^2 for different drippers. The uniformity co-efficient and emission uniformity increased while co-efficient of variation decreased as operating pressure increased for drippers.

Key words: *Coefficient of variation, Coefficient of uniformity, Emission uniformity, Discharge rate*

INTRODUCTION

Water scarcity and lack of water resource management technologies are common challenges faced by majority of small and marginal farmers in fast developing countries like India. In order to solve the problem of water shortage in agriculture, it is necessary to develop water-saving management technologies. Irrigation water is supplied to the plants/crops to replenish soil moisture at root-zone when natural rainfall is inadequate or poorly distributed. The efficient utilization of irrigation water is possible by the adoption of high efficient irrigation system, such as, micro irrigation system. Drip irrigation method is one of the best water application methods that has been used in the world among the other irrigation methods because of its good and high uniformity and high water use efficiency.

Cite this article: Pragna, G., Kumar, G.M. and Shankar, M.S., Hydraulic Performance Evaluation of Drip System by Developing Relationship between Discharge and Pressure, *Int. J. Pure App. Biosci.* **5(4):** 758-765 (2017). doi: http://dx.doi.org/10.18782/2320-7051.4071

A successful performance of drip irrigation system depends on the physical and hydraulic characteristics of the drip tubing[1]. A best and desirable feature of trickle irrigation is that the uniform distribution of water is possible, which is one of the most important parameters in design, management, and adoption of this system. Ideally, a well-designed system applies nearly equal amount of water to each plant maintaining uniformity, meets its water requirements, and is economically feasible. Efficiency of drip irrigation system depends on application uniformity which can be evaluated by direct measurement of emitter flow rates. The main factors affecting drip irrigation uniformity are manufacturing variations in emitters, pressure regulators, and pressure variations caused by elevation changes, friction head losses throughout the pipe network, emitter sensitivity to pressure, irrigation water temperature changes and emitter clogging[7]. Therefore, evaluation of hydraulics of drip irrigation system helps in improving the design of drip irrigation system and better distribution of irrigation water. Keeping in view the importance of water management, the present study was undertaken to “Evaluate the hydraulic performance of drip irrigation system by developing relationship between discharge and pressure” a field experiment was conducted at College Farm, College of Agriculture, Professor Jaya Shankar Telangana State Agricultural University, Rajendranagar.

MATERIALS AND METHODS

The field experiment was conducted in field number 1 of ‘A’ block during *Rabi* season at the college farm, College of Agriculture, Professor Jayashankar Telangana State Agricultural Universities, Rajendranagar, Hyderabad. The Farm is geographically situated in the southern part of Telangana at 17° 50' N latitude and 80°00' E longitude at an altitude of 542.6 m above mean sea level. The geographical area of Hyderabad comes under dry tropical and semi-arid region.

The dripper lines of 10 m length were laid at 1.2 m apart. Emitters with different discharge rates of 1.6 lph, 2.2 lph, 3.0 lph and 4.0 lph were fixed to the lateral as per the treatments. The end plugs (caps) were fixed to all main, submain, and laterals to facilitate maintenance of the system. Control valves were provided at each treatment (with 3 lateral lines) which facilitates the operation of the system according to irrigation time. Non return valve fixed regulated the flow in one direction and prevented the reversal of water flow. The field layout plan of experiment is presented in Fig.1.

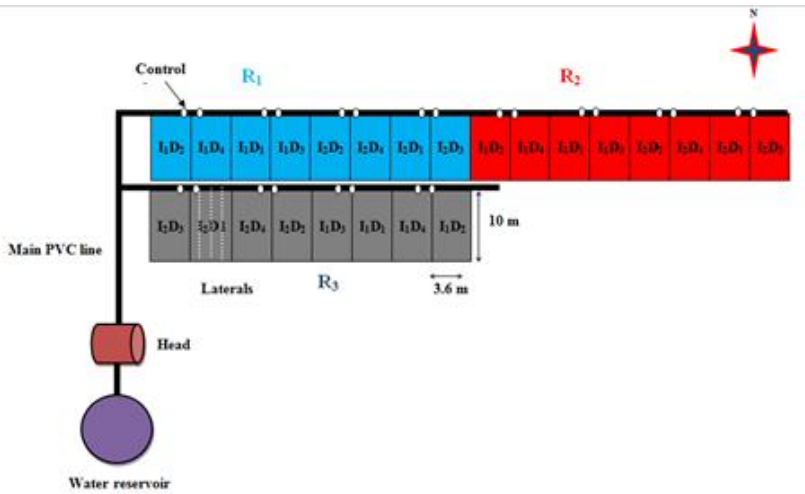

Fig. 1: Layout of Plan of experiment

Hydraulic evaluation of trickle system was done based on a method defined by the ASAE[2]. The system was tested for its uniformity co-efficient, emission uniformity, and manufacturing co-efficient of variation. Drippers having discharge capacity i.e. 1.6 lph, 2.2 lph, 3.0 lph and 4.0 lph respectively were tested at different operating pressure i.e. 0.5, 0.7, 0.9 1.25 and 1.5 kg/cm^2 and these pressures are maintained by using control valve at the inlet of each lateral. The pressure was adjusted by using the bypass valve. The operating pressure head was measured by pressure gauge. Two drippers on a lateral were selected randomly and discharges were measured on them. For each measurement, a small area in the bed was excavated, and a catch-can placed under the trickling emitter. Water was collected from drippers to confine the discharge into the plastic container directly. Water collected in containers was measured with the help of measuring cylinder. The irrigation system was then pressurized and the volume from each of the emitters was measured over a period of one hour.

Co-efficient of variation (CV)

Co-efficient of variation defines as the ratio of the standard deviation of flow to the mean flow for a sample number of emitters. Co-efficient of Variation (CV) is a statistical parameter expressed as

$$CV = \frac{S_q}{Q_{avg}} \text{ x } 100$$

Where,

CV = Co-efficient of variation

Sq = Standard deviation of the discharge rate for the sample

$$= \sqrt{\frac{\Sigma(Q_q - Q_{avg})^2}{N}}$$

Q_i = Emitter discharge, lph

Q_{avg} = Mean emitter discharge, lph

N = No. of emitters

Table 1: Classification of manufacturer’s co-efficient of variations[3]

Manufactures Co-efficient Cv	Interpretation
<0.05	Excellent
0.05- 0.07	Average
0.07-0.11	Marginal
0.11- 0.15	Poor
>0.15	unacceptable

Emitter flow variation (Q_{var}):

Emitter flow variation (Qvar) was calculated by

$$Q_{var} = 100\left[1 - \frac{Q_{min}}{Q_{max}}\right]$$

Where,

Q_{var} = emitter flow variation in percentage

Q_{min} = minimum emitter discharge rate in the system, l/h

Q_{max} = average or design emitter discharge rate, l/h

General criteria for Qvar values are 10% or less (desirable) and 10 to 20% acceptable and greater than 25%, not acceptable.

Emission uniformity (EU)

Emission uniformity is the measure of the uniformity of emitters discharge from all the emitters of drip irrigation system and is the single most important parameter for evaluating system performance.

EU = 100 [1-1.27C_v/ ($n^{0.5}$)] (q_{min}/q_{avg})

Where

EU = Emission uniformity

C_V = Manufacturer’s co-efficient of variation

n = Number of emitters per plant for trees and shrubs

q_{min} = Minimum emitter discharge rate for the minimum pressure in the section

The emission uniformity of the water application varies with pressure, emitter variation, and number of emitters discharging.

For a point source of drip irrigation system installed in uniform topography recommended value of EU ranges from 85-90%[3] (ASAE, 1989). General criteria for EU values are 90% or greater (excellent), 80 to 90% (good), 70 to 80% (fair) and less than 70% (poor).

Uniformity Co-efficient (CU):

Uniformity co-efficients of emitters were tested using the Christiansen's formula[4]. It gives the information that how efficiently water is distributed in the field.

Cu = 100(1- ΣX / mn)

Where CU = Co-efficient of uniformity

m= Average value of all observations

n= Total number of observation points

X = Numerical deviation of all observation points from the average application rate.

General criteria for CU values are 90% or greater (excellent), 80 to 90% (very good), 70 to 80% (fair), 60 to 70% (poor) and less than 60% (unacceptable).

Head – Discharge relationship:

The head discharge relationships for emitters were expressed by the formula[5,11]

$$Q = K.\ H^X$$

Where

Q = Discharge rate of drippers (lph)

K = Discharge co-efficient

H= Pressure Head

X= Dripper flow exponent

The observed data of Q and H was plotted through Excel and the best fitted model with highest R^2 was determined. If the value of X lies in between 0 to 0.5, the drippers are called pressure compensating and if X greater than 0.5, the drippers are classified as non-pressure compensating[10].

RESULTS AND DISCUSSIONS

The discharge rate increased as the pressure increases from 0.50 kg/cm^{2}to 1.5 kg/ cm^2. At maximum pressure of 1.5 kg/ cm^2, the discharge from 4 lph drippers were found to be 3.94 lph. When pressure decreased from 1.5 kg/cm^2 to1.2 kg/cm^2 ,0.9 kg/cm^2, 0.7 kg/cm^2 and 0.5 kg/cm^2, the discharge from 4 lph drippers were found to be 3.43 lph, 2.98 lph, 2.37 lph and 1.79 lph respectively. Similarly for remaining drippers of 3 lph, 2.2 lph and 1.6 lph also the discharge decreased with decrease in pressure. The observed data of discharge of different drippers at various operating pressure are presented in Table 2. From the table it is evident the discharge and pressure are directly proportionate.

Table 2: Average discharge rate of emitters at different operating pressures

Pressure kg/cm^2	Average discharge of emitters (lph)			
	1.6	**2.2**	**3.0**	**4.0**
0.5	0.73	1.01	1.40	1.79
0.7	0.95	1.31	1.82	2.37
0.9	1.23	1.80	2.41	2.98
1.2	1.38	1.93	2.61	3.43
1.5	1.56	2.11	2.99	3.94

Pressure discharge relationship:

From Table 2 it could be seen that the discharge from the different drippers were increased with increase in operating pressure. Logarithmic relationships were developed between pressure and discharge for each of the dripper. The relationship of pressure and discharge of each dripper were shown in Fig 2. The power form of the mathematical relationships were presented in Table 2 was found for the pressure-discharge relationships. R^2 value of each dripper discharge was above

0.95 and can be said that the model fits good. It could be seen from Table 2 that in case of all the dripper discharge rates, the exponent of the pressure was less than 0.5. This indicated that the nature of flow from the dripper was not an orifice flow. The exponent of power function was decreased with capacity of dripper which indicated that the sensitivity of the dripper to pressure for the discharge was decreased with increase in dripper capacity.

Table 2: Developed models for the pressure discharge relationship

Dripper discharge (lph)	Developed Model	R^2
1.6	$Q = 1.7485P^{0.4895}$	$R^2 = 0.9935$
2.2	$Q = 1.3723P^{0.4769}$	$R^2 = 0.9868$
3.0	$Q = 0.9954P^{0.4797}$	$R^2 = 0.9782$
4.0	$Q = 0.717P^{0.4761}$	$R^2 = 0.991$
Where, Q= Dripper discharge (lph), P= Pressure input (kg/cm^2) and R^2= Goodness of fit.		

Co-efficient of Variation:

To decide whether the system was excellent, good and marginal, it was necessary to determine the manufactures co-efficient of variation. The co-efficient of variation of 0.101 and emitter flow variation of 23.59% of for 1.6 lph emitter was found maximum at 0.5 kg/cm^2 operating pressure and minimum 0.049 and 12.61% at 1.5 kg/cm^2 operating pressure (Table 4). While for 2.2 lph emitter, the co-efficient of variation (0.095) and emitter flow variation (22.40%) was found maximum at 0.5 kg/cm^2 operating pressure respectively and minimum 0.060 and 14.29% at 1.5 kg/cm^2 operating pressure (Table 5). Similar trend was followed by other drippers also.

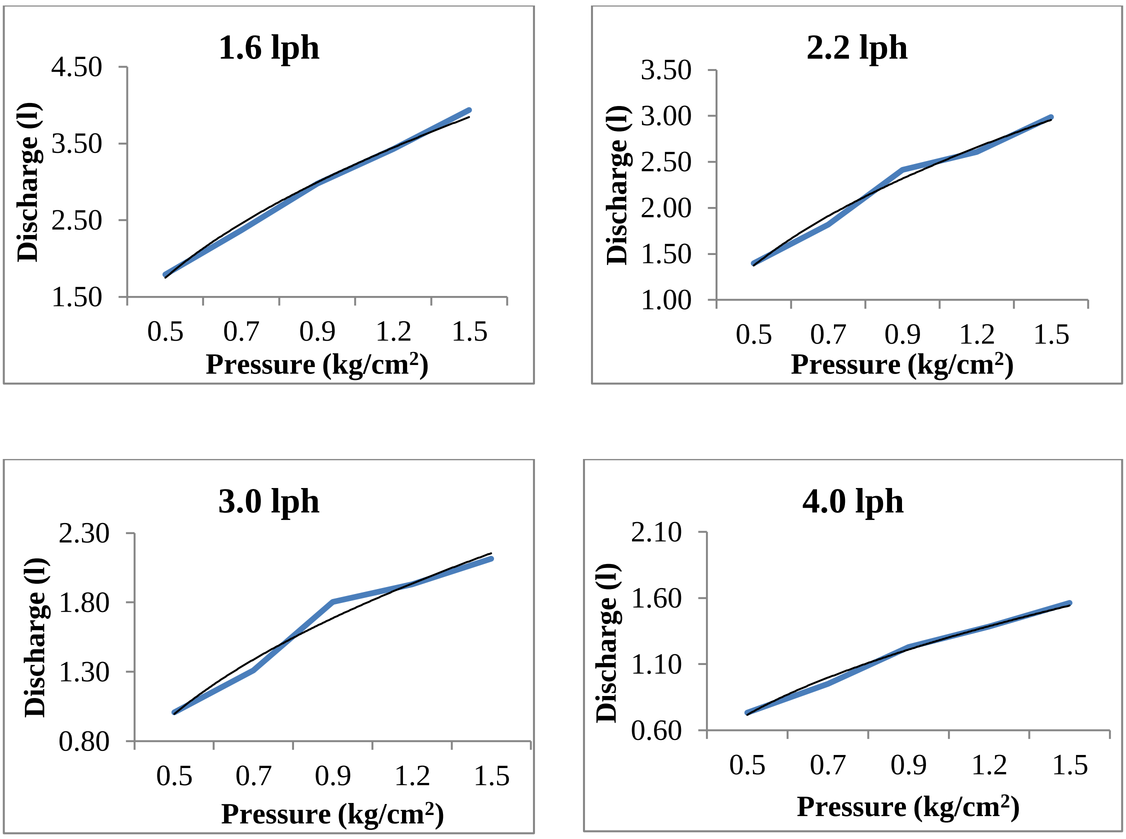

Fig. 2: Relation between pressure and discharge of different emitters

Table 4: Co-efficient of Variation of different drippers at different operating pressures

Pressure kg/cm^2	Co-efficient of Variation			
	1.6 lph	2.2 lph	3.0 lph	4.0 lph
0.5	0.101	0.095	0.081	0.086
0.7	0.079	0.075	0.069	0.078
0.9	0.076	0.066	0.065	0.070
1.2	0.064	0.066	0.056	0.063
1.5	0.049	0.060	0.060	0.054

For a particular spacing, co-efficient of variation and emitter flow variation decreased as the operating pressure increased for all emission devices. Co-efficient of variation values of all considered drippers at different operating pressure falls under 0.04 to 0.1. Hence it can be concluded that drippers are of good type. The Emitter flow variation is also less than 25% which is in acceptable range.

Table 5: Emitter Flow Variation (%) of different drippers at different operating pressures

Pressure kg/cm^2	Emitter Flow Variation (%)			
	1.6 lph	2.2 lph	3.0 lph	4.0 lph
0.5	23.59	22.40	21.21	20.80
0.7	18.59	18.33	18.10	19.79
0.9	18.00	17.52	16.60	17.63
1.2	15.61	16.04	14.45	13.80
1.5	12.61	14.29	14.58	14.38

Emission Uniformity (EU):

Emission uniformity is the measure of the uniformity of emitters discharge from all the emitters of drip irrigation system and is the most important parameter for evaluating system performance. Emission uniformity of the system decides the uniformity distribution of discharge by each emitter or uniformity distribution of water to each crop. EU shows relationship between minimum and average emitter discharge. The calculated emission uniformity data at different pressure of 1.5 kg/cm^2, 1.2 kg/cm^2, 0.9 kg/cm^2, 0.7 kg/cm^2 and 0.5 kg/cm^2 and are presented in Table 6. The average emission uniformity co-efficient observed at 1.5 kg/cm^2, 1.2 kg/cm^2, 0.9 kg/cm^2, 0.7 kg/cm^2 and 0.5 kg/cm^2 operating pressure were 89.94%, 89.19%, 86.51%, 85.37% and 83.38% respectively for 4lph dripper. Thus, for a particular spacing, emission uniformity increases as the operating pressure increases for all emission devices. The increase in emission uniformity is mainly due to increase in the ratio of minimum rate of discharge to the average rate of discharge. At a particular spacing, the ratio of minimum rate of discharge to average rate of discharge increases as the operating pressure is increased due to constant emission point per unit length of lateral, and thus the emission uniformity increased as the operating pressure increased for all emission devices. The results are in conformity with the findings of Popale *et al*[8]., Safi *et al*[9]., and Kumar and Singh[6].

Co-efficient of Uniformity:

Drip irrigation system was designed to apply precise amount of water near the plant with a certain degree of uniformity. The uniformity describes how evenly an irrigation system distributes water over a field. It is regarded as one of the important features for selection, design, and management of the irrigation system. The calculated co-efficient of uniformity data at different pressure of 1.5 kg/cm^2, 1.2 kg/cm^2, 0.9 kg/cm^2, 0.7 kg/cm^2 and 0.5 kg/cm^2 and are presented in table 3. The average co-efficient of uniformity observed at 1.5 kg/cm^2, 1.2 kg/cm^2, 0.9 kg/cm^2, 0.7 kg/cm^2 and 0.5 kg/cm^2 operating pressure were 96.02%, 94.69%, 94.49%, 94.12% and 93.27% respectively for 4lph (Table 7). Thus, for a particular spacing, emission uniformity increases as the operating pressure increases for all emission devices. The results are in conformity with the findings of Popale *et al*[8]., Safi *et al*[9]., and Kumar and Singh[6].

Table 6: Emission uniformity of different drippers at different operating pressures

Pressure kg/cm^2	Emission uniformity (%)			
	1.6 lph	2.2 lph	3.0 lph	4.0 lph
0.5	81.78	83.47	83.52	83.38
0.7	85.34	85.28	85.70	85.37
0.9	86.36	86.79	87.61	86.51
1.2	88.69	88.60	88.18	89.19
1.5	89.51	89.36	89.86	89.94
Classification	Good	Good	Good	Good

Table 7: Co-efficient of Uniformity (%) of different drippers at different operating pressures

Pressure kg/cm^2	Co-efficient of Uniformity (%)			
	1.6 lph	2.2 lph	3.0 lph	4.0 lph
0.5	92.15	92.70	94.36	93.27
0.7	93.89	94.15	94.95	94.12
0.9	94.00	95.26	94.95	94.49
1.2	94.76	94.87	95.97	94.69
1.5	96.21	95.29	95.25	96.02
Classification	Excellent	Excellent	Excellent	Excellent

CONCLUSION

Better discharges of emitters can be obtained when the operating pressure is at 1.5 kg/ cm^2, followed by 0.9, 1.25 and 1.5 kg/cm^2. Operating pressure of 0.9, 1.25 and 1.5 kg/cm^2 is required, respectively to achieve high uniformity co-efficient of more than 85 % and high emission uniformity. The uniformity co-efficient and emission uniformity increased while co-efficient of variation decreased as operating pressure increased for drippers. Co-efficient of variation values of all considered drippers at different operating pressure falls under 0.04 (1.5 kg/cm^2) to 0.1 (0.5 kg/cm^2), according to ASAE[3] drippers are of good quality. The Emitter flow variation is also less than 25% which is in an acceptable range.

REFERENCES

1. AL Amound, A.I., Significance of energy losses due to emitter connections in trickle irrigation lines. *Journal of Agricultural Engineering Research*, **60:** 1-5 (1995).
2. ASAE. Field evaluation of mirco-irrigation systems. *American Society of Agricultural Engineers*. 792-797 (1999).
3. ASAE. Joseph, M.I., Design, installation and performance of trickle systems. *American Society of Agricultural Engineers.* EP405.1 (1989).

4. Christiansen, J.E., The uniformity of application of water by sprinkler systems. *Agricultural Engineering*. **22:** 89-92 (1942).
5. Karmeli, D., Classification and flow regime analysis of drippers. *Journal of Agricultural Engineering Research.* **22:** 165-173 (1977).
6. Kumar, S. and Singh, P., Evaluation of hydraulic performance of drip irrigation system. *Journal of Agricultural Engineering*. 44 (2007).
7. Mizyed, N. and Kruse, E.G., Emitter discharge evaluation of subsurface trickle irrigation systems. *Transactions of the ASAE*. **32:** 1223-1228 (1989).
8. Popale, P.G., Bombale, V.T. and Magar, A.P., Hydraulic performance of drip irrigation system. *Engineering and Technology in India*. **2:** 24-28 (2011).
9. Safi, B., Neyshabouri, M.R., Nuzemi, A.H., Massina, S. and Mirlatifi, S.M., Water application uniformity of a sub-surface drip irrigation system at various operating pressure and tape lengths. *Turkey Journal of Agriculture*. **31:** 275-285 (2007).
10. Schwab, G.O., Fangmeier, D.D., Elliot and Fervert, R.K., John Wiley Sons. *Soil and Water Conservation Engineering*. **4:** 433 (1993).
11. Wu, I.P. and Giltin, H.M., Drip irrigation efficiency and schedules. *Tranactions of the American Society of Agricultural Engineers*. **26(1):** 92-97 (1977).