Int.J.Curr.Microbiol.App.Sci (2020) *9*(2): 626-633

EXCELLENT PUBLISHERS

International Journal of Current Microbiology and Applied Sciences
ISSN: 2319-7706 **Volume 9 Number 2 (2020)**
Journal homepage: http://www.ijcmas.com

Original Research Article https://doi.org/10.20546/ijcmas.2020.902.077

Study on Hydraulic Performance of Drip Irrigation System under Field Condition

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Keywords

Inline drip emitter, Drip irrigation, Hydraulic parameters, Emission uniformity

Article Info

Accepted:
08 January 2020
Available Online:
10 February 2020

A B S T R A C T

A field study was undertaken to evaluate the performance of 4 lph capacity inline drip emitter in farmer's field at 0.75 kg/cm^2 and 1.00 kg/cm^2 operating pressure. The efficient water application through drip irrigation is mainly depends upon the hydraulic parameters of the system, which includes the effect of pressure on coefficient of manufacturer variation, emitter flow variation, emission uniformity, uniformity coefficient, application efficiency and distribution efficiency. The results of the hydraulic parameters evaluation revealed that the coefficient of manufacturer variation, emission uniformity, uniformity coefficient, application efficiency and distribution efficiency were found to be excellent at both 0.75 and 1.00 kg/cm^2 operating pressure for all the farmers' fields. However, among the farmers field, emitter flow variation was observed to be in only for 33.33% farmers' fields at 1.00 kg/cm^2 operating pressure and it was not acceptable at 0.75 kg/cm^2 for all the farmers' fields.

Introduction

Drip irrigation system is defined as "an irrigation which maximises the application efficiency of water and fertilizer by allowing water drop by drop to the root zone of plants, either in to the soil surface or directly in to the root zone, through a network system of valves, pipes, tubing and emitters". The objective of the drip irrigation is to provide continuous supply of water to each plant to meet the requirement of water for the plant to the healthy growth and to meet the transpiration demands (Karmeli and Keller, 1974). Efficient drip irrigation system needs to be free from suspended materials, organic matter, sand and clay and it is achieved by installing the different types of filters. The control valve is installed in the pumping station to maintain the required pressure head for operating the system (Hensen *et al.*, 1980; Bralts and Wu, 1979).

The improvement of irrigation water management is becoming critical to increase the efficiency of irrigation water use and to reduce water losses. Drip irrigation evaluation in the field under a set of operating conditions is very important to ensure the desired discharge to all the growing crops.

A best and desirable feature of trickle irrigation is the uniform distribution of water and it is governed by proper design, management and adoption of the system. Ideally, a well-designed system applies nearly equal amount of water to each plant to meets its water requirements in addition to rational design and economics. The causes of the irrigation discharge variations are mainly due to manufacturing variations, pressure differences, emitter plugging, aging, frictional head losses, change in irrigation water temperature and the emitter sensitivity results in flow rate variations even between two identical emitters (Mizyed and Kruse, 2008)

Materials and Methods

Experimental site

The present study was carried out during 2017-18 in the farmer's field of different villages of Nelamangala, Devanahalli, Doddaballapura and Hosakote taluks of Bengaluru rural district. There were 15 different irrigating field involved for the study.

Hydraulic parameters for drip irrigation system

Discharge of emitters

The study was conducted in the farmers' fields having a 4 lph dripper spaced at 40 cm on laterals. The distribution of water application and discharges from emitters along the lateral are measured using ASAE Standards. The procedure was based on measurements of emitter discharge like;

The four lateral lines were selected on a sub main - one at the inlet, one at the far end and the two in the middle which was at the one-third and two-thirds positions.

The four dripper positions were tested on each lateral - one at the inlet, one at the far end and the two in the middle which was at the one-third and two-thirds positions.

Therefore, there were 16 measurement positions used for the study. The discharge was measured by collecting the water from individual drippers using measuring cylinders. The discharge was collected for ten minutes period and continued for different pressure ranges like 0.75 kg/cm^2 and1 kg/cm^2. The procedure was repeated thrice and the average of the volume of the water was considered as the discharge for a particular position (Capra and Scieotone, 1998).

Coefficient of Manufacturer's Variation (C_v)

Coefficient of manufacturer's variation is definedastheratioofthestandarddeviationofflo wtothemeanflowforasamplenumberofemitters (Keller and Karmeli, 1974). Coefficient of manufacturer's variation is a statistical parameter and expressed as:

$$C_v = \frac{S_d}{q_{ave}} * 100 \quad .....(1)$$

Where,

S_d = standard deviation of flow

$$= \sqrt{\frac{(q_1^2+q_2^2+q_3^2+q_n^2-nq_{ave}^2)}{(n-1)}}$$

q_{ave} =mean flow for a sampled number of emitters

$= \frac{q1+q2+ \ldots\ldots\ldots\ldots qn}{n} * 100$

$q1$, $q2$, $q3$, qn = are the discharges (lph)
n = number of emission devices tested

The recommended classification of manufacturer's coefficient of variation as per ASAE are;

Emitter type	Cv range (%)	Classification
Point Source	< 5	Good
	5 to 10	Average
	10 to 15	Marginal
	> 15	Unaccepted
Line Source	< 10	Good
	10 to 20	Average
	> 20	Marginal

Emission Uniformity (Eu)

TheEUduringthefieldtestistheratioexpressedas apercentageofaverageemitterdischargefromthe lower1/4thofemitter to the average discharge of all the emitters of the drip system (Burt *et al.*, 1997). The average of lowest 1/4th of emitter was selected as a practical value for minimum discharge, as recommended by the United States soil conservation services for field evaluation of irrigation systems and is expressed by the equation.

$$EU = \frac{q_m}{q_a} * 100 \quad \ldots\ldots(2)$$

Where,
EU = the field test emission uniformity, percentage

q_m = average of the lowest 1/4th of the field data emitter discharge, lph
q_a = average of all the field data emitter discharge, (lph)
The Recommended classification of emission uniformity as per ASAE are;

EU range	Ratings
90% or greater	Excellent
80 to 90%	Good
70 to 80%	Fair
Less than 70%	Poor

Emitter flow variation

The second method of field evaluation of emission uniformity relies on the design procedure based on estimating emitter flow variation (Wu and Gitlin, 1973 and 1974). It consists of finding the minimum and maximum pressure in the sub-units and the emitter flow variation (Qvar) was worked out using the following equation.

$$Q_{var} = 100 \left[1 - \frac{Qmin}{Qmax}\right] \ldots\ldots(3)$$

Where,
Q_{var} = emitter flow variation in percentage
Q_{min} = minimum emitter discharge rate in the system, lph
Q_{max} = average or design emitter discharge rate, lph

General criteria for Qvar values are 10 per cent or less (desirable) and 10 to 20 per cent Acceptable and greater than 25 per cent Not Acceptable.

Uniformity coefficient (UC)

The uniformity coefficient was worked out using Bralts and Kesner, (1982) equation.

$$UC = 100\,(1 - V_q) = 100\,(1 - \frac{s_d}{q_a}) \quad \ldots\ldots(4)$$

Where,
UC =Statistical uniformity coefficient (%)
Vq= coefficient of variation emitter flow
Sq = standard deviation of emitter flow

qa =mean emitter flow rate, lph

Recommended classification of uniformity coefficient as per ASAE are;

UC range	Ratings
90% or	Excellent
80 to 90%	Very good
70 to 80%	Fair
60 to 70%	Poor
Less than	Unacceptable

Distribution efficiency (E_d)

The distribution efficiency determine show uniformly irrigation water can be distributed through a drip irrigation system into the field. It can be determined from the emitter flow variation along a lateral line in a drip irrigation system layout in the field and can be expressed by the equation,

$$E_d = 100 * \left[1 - \frac{\Delta q_a}{q_m}\right] \quad .....(5)$$

Where,

Ed = distribution efficiency in percentage
qm = mean emitter flow rate, lph
Δqa = average absolute deviation of each emitter flow from the mean emitter flow

$$\Delta q_a = \left[\frac{q_r - q_{ave}}{q_{ave}}\right] * 100$$

q_r = rated flow, lph
q_{avg} = Average emitter flow rate, lph

Application efficiency (E_a)

The application efficiency is defined as the ratio of water required in the root zone to the total amount of water applied. It shows how well irrigation water is applied that is, what percentage of water applied is stored in the root zone as required and is available for plantuse (Mane *et al.*, 2018)

The water required in the root zone is assumed to be applied at the minimum flow rate and over the total irrigation time. Therefore, application efficiency can be expressed as,

$$E_a = \frac{N.Qmin\ T}{Vw} \times 100 \quad .....(6)$$

Where,

Ea= application efficiency, %
N = total number of emitter
Q_{min} = minimum emitter flow rate, lph
T = total irrigation time,
V_w = total volume of water applied, l

Since, the mean emitter flow (Qavg) is,

$$Qavg = \frac{Vw}{N.T}$$

The application efficiency can also be expressed as,

$$E_a = \frac{Q_{min}}{Q_{avg}} * 100$$

Where,
Qmin = minimum emitter flow rate, lph
Qavg = average emitter flow rate, lph

Results and Discussion

Drip irrigation system was operated under different operating pressures to study the different hydraulic parameters of drip irrigation system. For this purpose, drip irrigation discharges were measured at different operating pressures for 4 lph emitter discharge. The Average Emitter flow rate of 3.67 lph was found to be maximum at 1.00 kg/cm^2 operating pressure in F2 fields and a minimum of 2.15 lph at 0.75 kg/cm^2 operating pressure in F14 fields (Table 5).

The coefficient of manufacturer variation of 0.0549 and emitter flow variation of 47.75 % was found maximum at 0.75 kg/cm^2 operating pressure for F15 and F7 fields. It was minimum of 0.0123 and 17.12 % at 1.0 kg/cm^2 operating pressure for F2 and F1 fields (Table 1 and 2). Thus, for a particular spacing, coefficient of variation and emitter flow variation and operating pressure having inverse relation for all emission devices. To decide whether the system is good, average, marginal and excellent, it is necessary to determine the manufactures coefficient of variation either for point source or line source. It is observed that, C_v for 4 lph discharge of drippers comes under the range of classification as good for both the operating pressure.

The Q_{var} is acceptable at 1.00 kg/cm^2 operating pressure for F1, F2, F3, F4 and F6 fields. However, it is not acceptable at 0.75 kg/cm^2 for all the fields. From the Table 1 and 2, it is evident that when the operating pressure of drip irrigation system is higher, coefficient of manufacturer variation and emitter flow variation is lower and therefore the pressure directly affect the discharge rate of emitter.

Emission uniformity of the system decides the uniformity distribution of discharge by each emitter or uniformity distribution of water to each crop. The emission uniformity of 98.73% and the uniformity coefficient of 98.68% for 4 lph emitter were found to be maximum at 1.0 kg/cm² operating pressure for F1 and F3 fields. While it is minimum of 92.79% and 94.15% at 0.75 kg/cm² operating pressure for F15 field (Table 3 and 4). It is observed that EU and UC for 4 lph discharge of drippers comes under the range of classification as excellent for both the operating pressure. Thus, for a particular spacing, emission uniformity and uniformity coefficient increases as the operating pressure increases for all irrigation systems. The emission uniformity increases due to increase in the ratio of the minimum rate of discharge to the average rate of discharge. At a particular spacing emission uniformity (EU) increases due to constant emitter point throughout the lateral length.

Table.1 Coefficient of Manufacturer variation (C_v) under different operating pressure

Field No.	Coefficient of Manufacturer variation (C_v) (%)		Classification	
	0.75 (kg/cm^2)	1.00 (kg/cm^2)	0.75 (kg/cm^2)	1.00 (kg/cm^2)
F1	0.0268	0.0183	Good	Good
F2	0.0280	0.0123	Good	Good
F3	0.0290	0.0132	Good	Good
F4	0.0301	0.0238	Good	Good
F5	0.0523	0.0360	Good	Good
F6	0.0344	0.0274	Good	Good
F7	0.0405	0.0311	Good	Good
F8	0.0237	0.0197	Good	Good
F9	0.0226	0.0195	Good	Good
F10	0.0368	0.0300	Good	Good
F11	0.0490	0.0469	Good	Good
F12	0.0325	0.0317	Good	Good
F13	0.0343	0.0168	Good	Good
F14	0.0290	0.0238	Good	Good
F15	0.0549	0.0379	Good	Good

Table.2 Emitter flow variation (Q_{var}) under different operating pressure

Field No.	Emitter flow variation (Q_{var}) (%)		Classification	
	0.75 (kg/cm^2)	1.00 (kg/cm^2)	0.75 (kg/cm^2)	1.00 (kg/cm^2)
F1	26.87	17.12	Not Acceptable	Acceptable
F2	35.31	23.69	Not Acceptable	Acceptable
F3	34.28	25.00	Not Acceptable	Acceptable
F4	34.00	25.00	Not Acceptable	Acceptable
F5	33.48	30.43	Not Acceptable	Not Acceptable
F6	29.50	23.13	Not Acceptable	Acceptable
F7	47.75	34.37	Not Acceptable	Not Acceptable
F8	37.65	27.01	Not Acceptable	Not Acceptable
F9	34.00	27.81	Not Acceptable	Not Acceptable
F10	41.70	36.31	Not Acceptable	Not Acceptable
F11	41.00	34.56	Not Acceptable	Not Acceptable
F12	37.60	29.71	Not Acceptable	Not Acceptable
F13	43.25	27.68	Not Acceptable	Not Acceptable
F14	47.12	33.56	Not Acceptable	Not Acceptable
F15	39.43	28.50	Not Acceptable	Not Acceptable

Table.3 Emission Uniformity under different operating pressure

Field. No.	Emission uniformity (EU) (%)		Classification	
	0.75 (kg/cm^2)	1.00 (kg/cm^2)	0.75 (kg/cm^2)	1.00 (kg/cm^2)
F1	95.93	98.73	Excellent	Excellent
F2	95.54	98.24	Excellent	Excellent
F3	95.69	97.20	Excellent	Excellent
F4	94.63	98.68	Excellent	Excellent
F5	95.18	98.03	Excellent	Excellent
F6	94.79	97.55	Excellent	Excellent
F7	94.19	96.69	Excellent	Excellent
F8	94.01	97.55	Excellent	Excellent
F9	93.20	97.38	Excellent	Excellent
F10	94.22	97.33	Excellent	Excellent
F11	93.09	97.69	Excellent	Excellent
F12	93.70	97.01	Excellent	Excellent
F13	93.39	97.33	Excellent	Excellent
F14	93.38	97.79	Excellent	Excellent
F15	92.79	96.19	Excellent	Excellent

Table.4 Uniformity coefficient (UC) under different operating pressure

Field. No.	Uniformity coefficient (UC) (%)		Classification	
	0.75 (kg/cm^2)	1.00 (kg/cm^2)	0.75 (kg/cm^2)	1.00 (kg/cm^2)
F1	97.19	98.07	Excellent	Excellent
F2	97.02	98.77	Excellent	Excellent
F3	96.93	98.68	Excellent	Excellent
F4	96.99	97.63	Excellent	Excellent
F5	94.76	96.45	Excellent	Excellent
F6	96.65	97.25	Excellent	Excellent
F7	95.95	96.68	Excellent	Excellent
F8	96.93	97.62	Excellent	Excellent
F9	95.97	97.73	Excellent	Excellent
F10	95.45	96.82	Excellent	Excellent
F11	94.48	95.10	Excellent	Excellent
F12	94.45	96.82	Excellent	Excellent
F13	96.34	98.31	Excellent	Excellent
F14	96.94	97.61	Excellent	Excellent
F15	94.15	96.20	Excellent	Excellent

Table.5 Average emitter flow rate, Application efficiency and Distribution efficiency under different operating pressure

Field. No	Average emitter flow rate (lph)		Application Efficiency (E_a) (%)		Distribution Efficiency (E_d) (%)	
	0.75 (kg/cm^2	1.00 (kg/cm^2)	0.75 (kg/cm^2)	1.00 (kg/cm^2)	0.75 (kg/cm^2)	1.00 (kg/cm^2)
F1	2.97	3.38	95.71	98.73	97.93	98.45
F2	3.02	3.67	93.70	97.04	97.90	99.11
F3	2.66	3.02	94.61	97.83	97.64	98.95
F4	2.73	3.04	91.80	93.34	97.52	98.03
F5	2.66	2.96	90.31	95.84	96.85	97.60
F6	2.74	3.12	91.95	96.15	96.67	97.05
F7	2.49	2.72	92.77	93.92	96.44	97.62
F8	2.50	2.96	93.24	96.61	97.36	98.15
F9	2.64	2.98	93.02	96.83	97.38	98.05
F10	2.37	2.59	92.48	94.64	96.53	97.59
F11	2.43	2.68	92.68	94.93	94.33	95.73
F12	2.54	2.90	93.00	94.90	96.55	97.72
F13	2.33	2.92	93.96	97.06	96.12	98.64
F14	2.15	2.71	93.46	95.59	97.65	98.21
F15	2.55	3.18	93.91	95.25	92.73	96.78

The application efficiency (E_a) and distribution efficiency (E_d) of drip irrigation system is estimated for 4 lph emitters under different operating pressure. The application efficiency of 98.73% and distribution efficiency of 99.11% found to be maximum at 1.0 kg/cm² operating pressure for F1 and F2 fields and minimum of 90.31% and 92.73% at 0.75 kg/cm² operating pressure for F5 and F15 fields (Table 5). Thus, for a particular spacing, application efficiency and distribution efficiency increases with the increased pressure of the operating system for all irrigation systems. The results are in conformity with the findings of Popale *et al.*, (2011), SAFI *et al.*, (2007) and Kumar and Singh (2007).

In conclusion, a study was conducted to evaluate the performance of drip irrigation system under different operating pressure. Itwas observed that at a particular spacing, the emission uniformity, uniformity coefficient, application efficiency and distribution efficiency increased with increase in operating pressure. While coefficient of variation and emitter flow variation were decreased for all farmers field. By considering all the above calculated hydraulic parameters, only 5 (33.33%) farmers field showed a better hydraulic efficiency (Emmittor flow variation) by meeting the standards set by ASCE.

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How to cite this article:

Ajay Kumar, H. P. and Ashoka, H. G. 2020. Study on Hydraulic Performance of Drip Irrigation System under Field Condition. *Int.J.Curr.Microbiol.App.Sci.* 9(02): 626-633.
doi: https://doi.org/10.20546/ijcmas.2020.902.077