The Pharma Innovation Journal 2023; 12(8): 1854-1857

www.ThePharmaJournal.com

The Pharma Innovation

ISSN (E): 2277-7695
ISSN (P): 2349-8242
NAAS Rating: 5.23
TPI 2023; 12(8): 1854-1857

www.thepharmajournal.com
Received: 02-06-2023
Accepted: 07-07-2023

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Evaluation of hydraulic performance of drip irrigation system under different operating pressure

Shakti Prakash Kaushik, Dr. BL Sinha and Dr. Rajesh Agrawal

Abstract
The use of traditional irrigation systems not only causes environmental damage but also puts pressure on limited water resources. Therefore, drip irrigation technology is becoming more popular, particularly for high-value cash crops, as it ensures efficient use of water and energy. It is important to ensure a proper design and operation of drip irrigation systems to avoid uneven watering of some plants, while leaving others without sufficient water. Effective water application into drip irrigation depends on various hydraulic parameters, such as the impact of pressure on the uniformity coefficient, application efficiency, distribution efficiency, and other factors affecting emitter flow variation and emission uniformity. The present study on evaluation of hydraulic performance of the drip irrigation system was conducted during the year of 2023 at the Centre of Excellence, IGKV, Raipur, Chhattisgarh. In the field, the discharge of a 2 lph inline emitter during drip irrigation was tested at three different operating pressures (0.8, 1.0 and 1.2 kg cm^{-2}) to ascertain the hydraulic performance. The highest average values for the hydraulic performance indicators, such as emitter discharge (1.92 lph), emission uniformity (95.54 percent), and distribution efficiency (97.6 percent), were achieved when using a 2 lph inline dripper at an operating pressure of 1.2 kg cm^{-2}. These values were within the acceptable range.

Keywords: Drip irrigation, hydraulic performance, application efficiency, distribution efficiency, uniformity coefficient

Introduction

Agriculture faces a difficult challenge in preserving water, reducing usage, and enhancing water efficiency, particularly with the impact of climate change. Crop yield targets cannot be achieved without sufficient irrigation procedures that prevent water, nutrient leaching, and groundwater contamination. In areas with low rainfall and expensive irrigation water, the drip-irrigation technique has proved to be useful in preserving water and increasing efficiency by supplying water directly to the plant roots. The drip irrigation system consists of several components such as a filter, pressure gauge, regulator, tube, and an emitter. By appropriately applying water directly to individual plant roots, the emitter is responsible for increasing the crop yield while maintaining a specific volume of water within the root zone of the crop. Instead of broadcasting water over the whole field area, it solely applies the precise amount needed to each plant, preventing the need to store excess water in the soil profile.

Improving irrigation water management has become a critical need in order to enhance efficiency of water usage and decrease water loss. Drip-irrigation is considered as an effective solution for promoting water conservation and achieving increased water use efficiency. This irrigation method distributes equivalent water supply directly to the root zone of each plant, which proves specific advantageous in regions where there is irrigation water and low rainfall carries a high cost.

It is crucial to assess trickle irrigation in the field with a specific group of conditions to ensure that all crops receive the desired discharge. One of the most significant advantages of drip irrigation is the even distribution of water, which relies on adequate planning, management, and implementation of the system. The ideal system should administer nearly the same amount of water to every plant to fulfill their water requirements while also considering design and economics. These discrepancies in discharge can stem from manufacturing differences, emitter blockage, pressure variances, aging, fractional loss of head, disparities in, slight variations in emitter sensitivity and irrigation water temperature, leading to variations in flow rates even between two matching emitter, as noted by Ashoka and Kumar in 2020 [7].

Ensuring accurate operating pressure is crucial for the design of a trickle irrigation system. If the operating pressure is not precise, it can result in poor system performance and ultimately cause the system to fail. (Valipour, 2012) [14]. In addition, the presence of pressure that is not static can lead to various issues including faulty pressure controllers, damaged pipelines, and blocked emitters. (Tyson and Curtis, 2009) [16]. However, because there is insufficient understanding of the uniformity variables at different operating pressures, the drip irrigation system is still encountering difficulties in providing uniform water distribution across the entirety of the area. As a result, this investigation seeks to assess the hydraulic functioning of the trickle irrigation system in the region under varying operating conditions.

Materials and Methods

Experimental Site

The experiment were carried out during the year 2023 at Centre of Excellence, Indira Gandhi Krishi Vishwavidyalaya, Raipur (C.G.). The experiment site, Raipur, is situated at 21°16' N latitude, 81°36' E longitude, and 289.56 meter above mean sea level in the state of Chhattisgarh. The investigation site is in a sub-humid area. It belongs to the country's seventh agroclimatic zone, which is the eastern plateau and hills. The typical yearly precipitation falls within the 1200-1400 mm range, with approximately 85% of it received during the period between the mid-September and third week of June, and sporadically minimal amounts in the winter and summer seasons. There is significant variation in the rainfall pattern between the months of June to September each year. May registers the highest temperature at 46°C, while December is the coolest month at 6 °C.

Emitter Discharge

Emitters with a 2 lph discharge capacity were tested at operating pressures of 1.2, 1.0 and 0.8 kg cm^{-2}. These pressures are kept constant by the control valves located at the head control unit and the end of the lateral. The operating pressure was set using a pressure gauge. Water was collected using drippers and directed into the plastic and glass container. Depending on the drippers used and pressure, the tests were conducted for varying amounts of time, & the findings was converted into discharge per hour. The volume of water collected in containers was measured using a measuring cylinder.

Emission Uniformity

The emission uniformity during the field test is the ratio, stated as a percentage, of the drip system's lowest 1/4th of emitters' average discharge to the drip system's whole average discharge. The United States Soil Conservation Services recommends using the average of the lowest 1/4th of emitters as a feasible figure for minimal discharge, and this value is represented by the equation:

$$EU = \frac{q_m}{q_a} \quad (1)$$

Where,
EU = the field test emission uniformity, percentage
q_m = average of the lowest $1/4^{th}$ of the field data emitter discharge, l/h
q_a = average of all the field data emitter discharge, l/h

Table 1- Lists the ASAE-recommended emission uniformity classifications

Table 1: Suggested classification of emission uniformity

S.N.	Emission uniformity	Classification
1.	Less than 70%	Poor
2.	70 to 80%	Fair
3.	80 to 90	Good
4.	90% or greater	Excellent

Distribution efficiency (Ed)

The distribution efficiency test results exhibit the evenness of irrigation water application in a field with the help of a trickle irrigation system. The uniformity of water distribution in the field may be calculated and expressed by looking at the fluctuation of emitter flow along a lateral line using an equation

$$Ed = 100 * [1 - \frac{q_a}{q_m}] \quad (2)$$

Where,
Ed = distribution efficiency, %
q_m= mean emitter flow rate, liter per hour
Δq_a = average absolute deviation of each emitter flow from the mean emitter flow

$$\Delta q_a = [\frac{q_{r-} q_{ave}}{q_{ave}}] \quad (3)$$

q_r= rated flow, liter per hour
q_{ave} = Average emitter flow rate, liter per hour

Application Efficiency (Ea)

Application Efficiency is a performance criterion that measures how well an irrigation system operates when set up to provide a particular volume of water. It gives an indication of how well irrigation water is used, especially how much of the applied water remains in the plants root zone and is available to the plants. For the duration of the irrigation period, apply the least amount of water feasible at the lowest flow rate to the root zone. Therefore, application efficiency can be expressed as,

$$E_a = 100 (\frac{q_{min}}{q_{avg}}) \quad (4)$$

Where,
E_a = application efficiency, %
q_{min} = minimum emitter flow rate, liter per hour
q_{avg} = average emitter flow rate, liter per hour
Average emitter flow rate can be expressed by an equation

$$q_{avg} = \frac{V_W}{N\,T} \quad (5)$$

Where,
V_W = total volume of water applied
N = total number of emitters
T = total irrigation time

Results and Discussion

The current hydraulic performance of operational systems was evaluated using various indicators by analyzing the data collected during experimental trials conducted on drip irrigation systems. The parameters that had been used for evaluation:

Emission Uniformity
The maximum emission uniformity was 95.4% under 1.2 kg/cm^2 operating pressure in 2 lph discharge emitters. Similarly, the emission uniformity was 92.31% and 89.25% at 1.0 and 0.8 kg/cm^2 operating pressure in 2 lph emitters respectively. What this means is that the emission increases as the operating pressure increases. It is clear from the result (Table 2 with fig.1) that emission uniformity at 1.2 kg/cm^2 operating pressure is best with 95.4%.

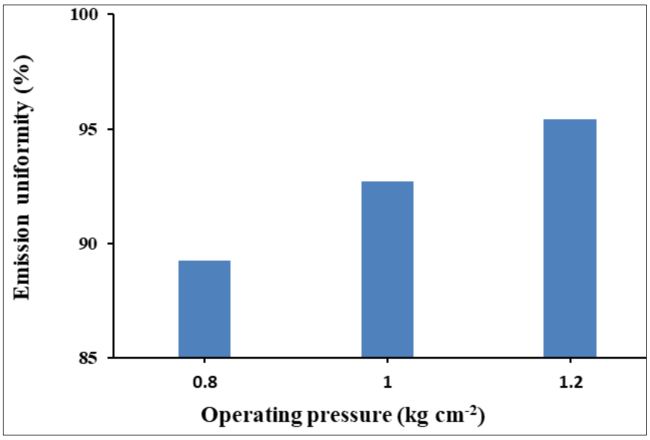

Fig 1: Emission uniformity for 2 lph dripper in different operating pressure

Table 2: Emission uniformity at different operating pressure

S.N.	Emission uniformity (%)			
1.	Operating pressure	0.8 kg cm^{-2}	1 kg cm^{-2}	1.2 kg cm^{-2}
2.	2 lph emitters	89.25	92.31	95.4
3.	Classification	Good	Excellent	Excellent

Average emitter discharge
The average discharge rate increased as the pressure increases from 0.8 to 1.0 kg cm^{-2}. The dripper's highest discharge was recorded to be 1.92 lph under 1.2 kg cm^{-2} pressure, while its minimum discharge were measured at 1.28 lph at 0.8 kg cm^{-2} pressure. It is also found that maximum average discharge rate in 2 lph dripper at 1.2 kg cm^{-2} operating pressure was best.

Distribution efficiency
The distribution efficiency (Ed) of a trickle irrigation system is calculated for 2 lph emitters at various pressures are given table 3 and Fig. 3. The higher distribution efficiency was determined to be 97.6% under 1.2 kg per cm^2 operating pressure and minimum was 91.15 % under 0.8 kg cm^{-2} pressure. As a result, at a specific spacing of dripper, distribution efficiency rises along with the operating system's increasing pressure for all irrigation systems.

Application efficiency
A maximum application efficiency of 94.85 percent and a minimum application efficiency of 87.35 percent are shown in Table 3 and Figure 4 for 1.2 kg per cm^2 and 0.8 kg per cm^2, respectively. The system's poor performance may be caused by clogging issues, careless handling, or a lack of competent personnel with system understanding.

Table 3: Performance parameter of drip irrigation system at Centre of Excellence, IGKV, Raipur (C.G.)

Operating Pressure kg/cm^2	Emitter Discharge (lph)	Distribution Efficiency (E_d, %)	Application Efficiency (E_a, %)
0.8	1.28	91.15	87.35
1.0	1.79	94.3	92.75
1.2	1.88	97.6	94.85
Average	1.65	94.35	91.65

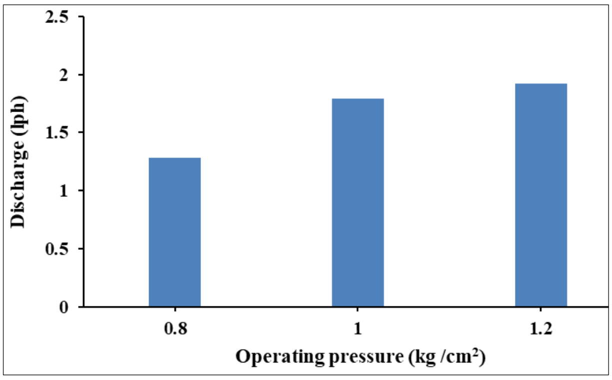

Fig 2: Discharge variation for 2lph dripper at different operating pressure

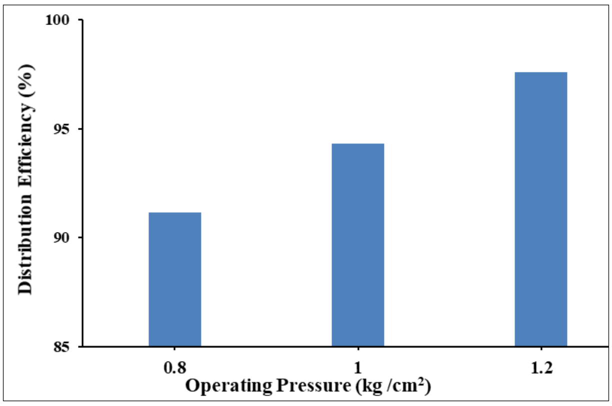

Fig 3: Distribution efficiency for 2 lph dripper under different operating pressure

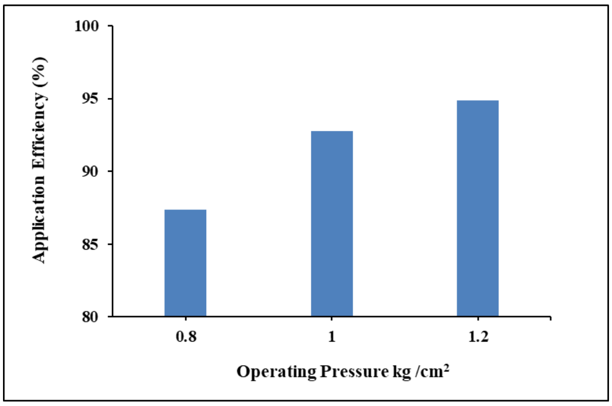

Fig 4: Application efficiency for 2 lph dripper at different operating pressure

Conclusions
The hydraulic performance of the drip irrigation system were evaluated at Centre of Excellence on Protected Cultivation, Indira Gandhi Krishi Vishwavidyalaya, Raipur (C.G.). The maximum average value of the hydraulic performance

indicators emitter discharge (1.92 lph), emission uniformity (95.54 percent) and distribution efficiency (97.6 percent) were obtained at 1.2 kg cm^{-2} operating pressure in 2 lph inline dripper and those were in acceptable limit. The drip irrigation system's overall performance was satisfactory and met recommended standards. Therefore, there is an opportunity to implement drip irrigation technology, which can enhance crop productivity and the farmers' income by expanding the area of cultivation with the existing irrigation resources.

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