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EVALUATION OF DRIP IRRIGATION SYSTEM FOR DIFFERENT OPERATING PRESSURES

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ABSTRACT-*Drip irrigation method distributes water to the field using the pipe network and transforms it from the pipe network to the plant by emitters. Hydraulic design seems to be only one of the major factors in the evaluation of overall uniformity of a micro-irrigation system. A field experiment was conducted to analyze the hydraulic performance drip irrigation system on emitter discharge, coefficient of variation and emission uniformity, statistical uniformity coefficient, variation of emitter flow, emitter flow uniformity and absolute uniformity. This The experiment were conducted to collect discharge rate at nine different pressures i.e. 0.3, 0.4, 0.5, 0.6, 0.7, 0.9, 1.0, 1.1 and 1.2 kg/cm^2 to assess the hydraulic performance of drip irrigation system. Emission uniformity (Eu) of the system decides the uniformity distribution of discharge by each emitter or uniformity distribution of water to each crop. Result shows that the discharge flow rate of emitter is increased when the increase of the pressure and the coefficient of variation is increased when the pressure is decreased means the pressure directly affected the discharge rate of emitter. The average emission uniformity coefficient (E'u) observed at 0.3, 0.4, 0.6, 0.7, 0.9, 1.0, 1.1 and 1.2 kg /cm^2 pressure were 79.913, 90.914, 94.040, 87.361, 90.373 91.120 94.546 and 94.753 percent respectively for 2 l/hr. The best results were concluded for 1.2 kg/cm^2 with Coefficient of determination (R^2) with 0.798 and different hydraulic measures such as E'u, Eu, EuA and Q_{avg} at 1.2 kg/cm^2 pressure for inline drippers was 94.75, 90.46, 94.69, 1.875 l/hr respectively which indicates that the system is excellent and efficient. The above results can be suggested for actual practise to get better yield.*

Keywords-*Drip Irrigation; Hydraulic Performance evaluation parameters, Uniformity coefficient, Emission uniformity, Coefficient of variation.*

I. INTRODUCTION

Drip irrigation or Trickle irrigation is a form of irrigation that saves water and fertilizer by allowing water to drip slowly to the roots of many different plants, either onto the soil surface or directly onto the root zone, through a network of valves, pipes, tubing, and emitters. It is done through narrow tubes that deliver water directly to the base of the plant. It is chosen instead of surface irrigation for various reasons, often including concern about minimizing evaporation.

Drip irrigation system is widely spread as it can be used safely for most soil types; beside it has high theoretical application efficiency.The use of drip irrigation has been increase in most crop commodities, especially vegetable and fruit crops, to improve water use efficiency and water supply as in [2]. Nowadays how uniform is the distribution of water on land surface is accepted as one of the key criteria for evaluating irrigation system performance. Poor irrigation-water-application uniformity can be a cause of low crop-yields. Improved yields could result from maintaining the soil moisture at an optimum level through more frequent water and nutrient application. This can result from a uniform water application and effective scheduling. The uniform application of water will cause more uniform distribution of water in the root zone as the behaviour of applied water affects the soil moisture pattern under point source trickle emitter.

Trickle irrigation system offers considerable potential for saving irrigation water while maintaining or even increasing yield in drought conditions. Now the appropriate technology, skills and services are available which will be used in future for large-scale adoption of trickle irrigation in the country as in [1]. Trickle irrigation systems are high in initial investment but at the same time these are labour, water and fertilizer efficient while no investment is involved in land levelling. Although trickle irrigation systems have reached a level that farmers are adopting them yet their performances under field condition has to be tested and standardized.

Drip Irrigation Method is the best method that has been used in the world among the other irrigation methods because of its good and high uniformity. This method distributes water to the field using the pipe network and transforms it from the pipe network to the plant by emitters. In spite of the advantages of drip Irrigation method, the traditional network in drip irrigation method has many problems. The main problem is the drop in pressures and discharges distribution in the network resulting from the amount of pressure losses between the head of the lateral as compared with that in the end of the lateralas in [3]. This drop affects the discharge distribution of emitters and uniformity. The research studies the improvement of emission uniformity of emitters by using new system layouts instead of the traditional system. The first proposed system layout concluded to improve the hydraulic performance by improving the pressure of distribution in the system by connecting the ends of the laterals together in the subunit. For further improvement, a carrier (close pipe convey the water) near the source to the lateral ends has been added to the looped network to represent the second proposed system (looped with carrier network).

II. OBJECTIVESOF THE PRESENT STUDY

The objectives of this research work is to evaluate different hydraulic performance parameters i.e., Coefficient of manufacture variation (Vm), Statistical uniformity coefficient or uniformity estimation (Us), Variation of emitter flow (Qvar), Emission Uniformity or Emitter flow uniformity (E'u), Absolute uniformity (E'_{UA}) and Design emission uniformity (Eu) for different Pressures for 10 minutes.

III. STUDY AREA AND LOCATION

The Experiments were conducted at Micro Irrigation Laboratory in Water Resources Engineering and Management Institute (WREMI), Samiala. It is located at 22.2608° N, 73.1191° E and it is 35.5m above mean sea level.

IV. METHODOLOGY

Experimental set up was installed for determination of different hydraulic performance parameters. The different hydraulic performance parameters were discussed below.

V. DETERMINATION OF HYDRAULIC PERFORMANCE PARAMETERS

The hydraulic design of drip systems is essentially centred on ensuring that water is conveyed to each emitter at a pre-determined pressure head that would cause satisfactory flow. The general design criterion is to limit the pressure and discharge variation in the system to within 30%. The hydraulic performance parameters used to evaluate drip systems therefore exposes the differences in discharge within the system. Differences in flow rates are reflected in discharge coefficients of variation. Discharge coefficients of variation are conventionally used to evaluate micro-irrigation systems. The important coefficients and uniformity terms to evaluate drip irrigation system are:

1. Coefficient of manufacture variation (Vm)
2. Statistical uniformity coefficient or uniformity estimation (Vs)
3. Variation of emitter flow (Qvar)
4. Emission uniformity or emitter flow uniformity(E'u)
5. Design emission uniformity(Eu)
6. Absolute emission uniformity(Eua)

5.1. Coefficient of Manufacture Variation (V_m):

The discharge of individual emitters at a particular pressure is calculated by dividing the volume of each of the calibrated cylinders by the time it takes for the particular cylinder to fill. A parameter which can be used as a measure of emitter flow variation caused by variation in manufacturing of the emitter is called the coefficient of manufacturing variation (C_v). The coefficient of manufacture (Vm) is calculated by following equations:

$$V_m = \left(\frac{S_q}{q}\right)(100) \tag{1}$$

$$\bar{q} = \frac{1}{n}\sum_{i=1}^{n} q_i \tag{2}$$

$$s_q = \left[\left[\frac{1}{n-1}\sum_{i=1}^{n}(q_i - \bar{q})^2\right]^{1/2}\right] \tag{3}$$

(Range for coefficient of manufacture variation (Vm) = 0.2 to 0.02)

Where,
q_i = emitter discharge rate (l/h)
n= number of emitters of the sample
q = mean of all the measured discharge rates (l/h)
S_q = standard deviation of the discharge rate of the emitter
V_m = coefficient of variation of discharge rate of the emitters (%).

5.2. Statistical Uniformity Coefficient or Uniformity Estimation (U_s):
Statistical uniformity was calculated using equation 4. By using the statistical treatment, all of the various factors such as emitter manufacturing variation, lateral line friction, elevation difference, and emitter plugging are included. Following **Table 1** shows criteria for an acceptable statistical discharge uniformity.

$$U_s=100*(1-V_m) \quad (4)$$

Table 1. Criteria for an acceptable Statistical discharge uniformity (Us).

Classification	Us – Value (%)
Excellent	>90
Very Good	80-90
Fair	70-80
Poor	60-70
Unacceptable	<60

A statistical discharge uniformity (U_s) value of 80% or higher is required, where fertilizer is applied through an irrigation system.

5.3. Variation of Emitter Flow (Q_{VAR}):
The emitter manufacturer's coefficient of variation is a measure of the variability of discharge of a random sample of a given make, model and size of emitter, as produced by the manufacturer and before any field operation or aging has taken place. The emitters' flow rate variation was calculated using the following equation.5 simple way to show emitter flow variation for drip irrigation is based on lateral line hydraulics which takes the form:

$$Q_{var} = 100\left(1-\left(\frac{q_{min}}{q_{max}}\right)\right) \quad (5)$$

Where,

Q_{max} = maximum emitter flow
Q_{min} = minimum emitter flow.

(Value of Q_{var} more than 20% is not acceptable)

5.4. Emission Uniformity or Emitter Flow Uniformity (E'u) and Absolute Emission Uniformity (EU'):
The field emission uniformity (EU´) is also used to judge the uniformity of emitter discharges within an irrigation block. Also from **Table 2** shows the Comparisons between Statistical Uniformity coefficient (Us) and Design Emission Uniformity (Eu) for design Purposes.

$$EU' = 100\frac{q'_{min}}{\bar{q}} \quad (6)$$

Where;
EU'= field emission uniformity (%)
EU'_a= absolute field emission uniformity (%)
Q_{min} = measured mean of lowest ¼ of emitter discharge (l/h)
q = measured mean emitter discharge (l/h)
q'_{max} = measured mean of highest 1/8 of emitter discharge (l/h).

$$EU'_a = 50\left[\frac{q'_{min}}{\bar{q}} + \frac{\bar{q}}{q'_{max}}\right] \quad (7)$$

Table 2. Comparisons between Statistical Uniformity coefficient (Us) and Design Emission Uniformity (Eu) for design Purposes

Classification	Us (%)	EU (%)
Excellent	95-100	94-100
Good	85-90	81-87
Acceptable	75-80	68-75
Poor	65-70	56-62
Unacceptable	<60	<50

5.5. Design Emission Uniformity (E_u):

The equation of EU' has been predefined and modified to include the emitter coefficient of manufacturing variations (Vm) and no. of emitters per plant etc. Emission uniformity expresses the uniformity of emitters under constant pressure. Thus, to estimate the emission uniformity for a proposed drip irrigation system design. The emission uniformity in percent was calculated by the following formula

$$E_u = 100\left(1-\left(\frac{1.27V_m}{e^{0.5}}\right)\right)\left(\frac{q_{min}}{q_{avg}}\right) \quad (8)$$

When the value of e is not giventhen assumee = 1.

VI. Results and Analysis

For evaluation of drip irrigation system, an isolated drip irrigation system was operated under different operating pressures to study their hydraulic performance. Below **Table 3** shows the results of different hydraulic performance parameters for different operating pressures.

Table 3. Calculated different Hydraulic performance parameters for different Pressures

	0.3 kg/cm^2	0.4 kg/cm^2	0.6 kg/cm^2	0.7 kg/cm^2	0.9 kg/cm^2	1.0 kg/cm^2	1.1 kg/cm^2	1.2 Kg/cm^2
S_Q	0.0744	0.0486	0.0570	0.0906	0.0511	0.0848	0.0548	0.0613
V_m	0.1209	0.0414	0.0449	0.0687	0.0318	0.0536	0.0300	0.0328
V_s	87.900	95.859	95.507	93.123	96.814	94.632	96.999	96.717
Q_{var}	33.333	15.238	12.719	22.580	13.571	15.789	11.384	10.606
E'u	79.913	90.919	94.040	87.361	90.373	91.120	94.546	94.753
Eu	67.707	86.927	87.890	79.650	88.969	85.195	90.383	90.464
1/8*No of Emitter	2.250	2.250	2.250	2.250	2.250	2.250	2.250	2.250
Q_x	0.729	1.254	1.362	1.458	1.674	1.707	1.929	1.974
EuA	82.181	92.287	93.630	88.903	93.134	91.847	94.649	94.692

The calculation of Emitter flow uniformity (E'u), Emission uniformity (Eu), and Absolute Emission uniformity (EuA) and Average discharge (Qavg) for different pressures is shown below **Table 4:**

Table 4. Hydraulic performance evaluation measure for different emission devices and operating pressure.

Pressure (kg/cm^2)	E'u	Eu	EuA	Qavg
0.3	79.913	67.707	82.181	0.615
0.4	90.914	86.927	92.287	1.164
0.6	94.040	87.890	93.630	1.281
0.7	87.361	79.651	88.904	1.320
0.9	90.373	88.968	93.134	1.566
1.0	91.120	85.195	91.847	1.575
1.1	94.546	90.383	94.649	1.839
1.2	94.753	90.464	94.692	1.875

From the above results it can be seen that 1.2kg/cm^2 pressure is best suitable for the present study is shown in below **Table 5:**

Table 5. Results for 1.2 Kg/cm^2

Hydraulic Performance Parameters	Results (%)	Criteria/Classification
V_s	**96.7170**	**Excellent**
Q_{var}	**10.6061**	**Acceptable**
E'u	**94.7537**	**Excellent**
Eu	**90.4641**	**Excellent**
EuA	**94.6024**	**Excellent**

To decide the system good, average, marginal and excellent, it was necessary to determine the manufactures coefficient of emitters either point source or line source. Below **Figure 1, 2 and 3** shows the graph of emitter flow uniformity v/s operating pressures, Emission Uniformity V/S Operating Pressures and Distribution Uniformity V/S Operating Pressures respectively.

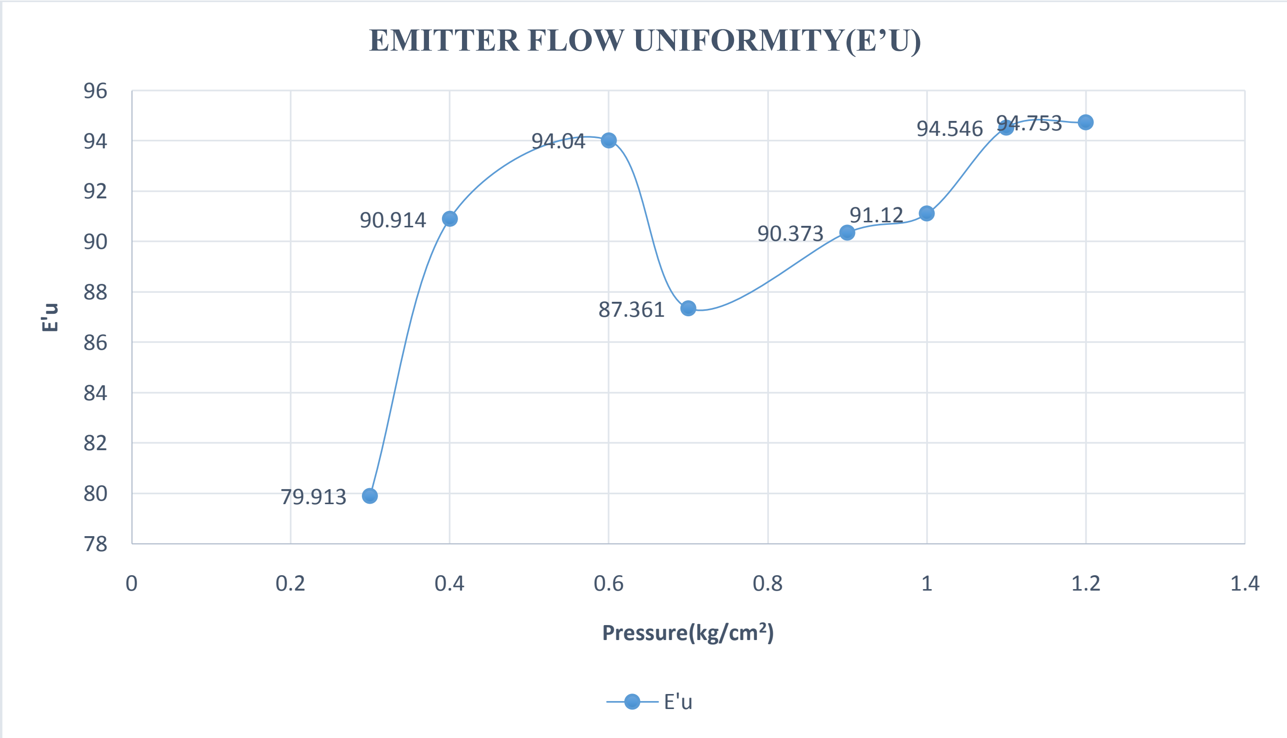

Figure 1. Emitter Flow Uniformity V/S Operating Pressures

From figure 1 it can be seen that emitter flow uniformity (E'U) varies from 79.913 to 94.753 for pressure 0.3 to 1.2 kg/cm^2.Also E'U for $1.2kg/cm^2$ is 94.753% which is excellent.

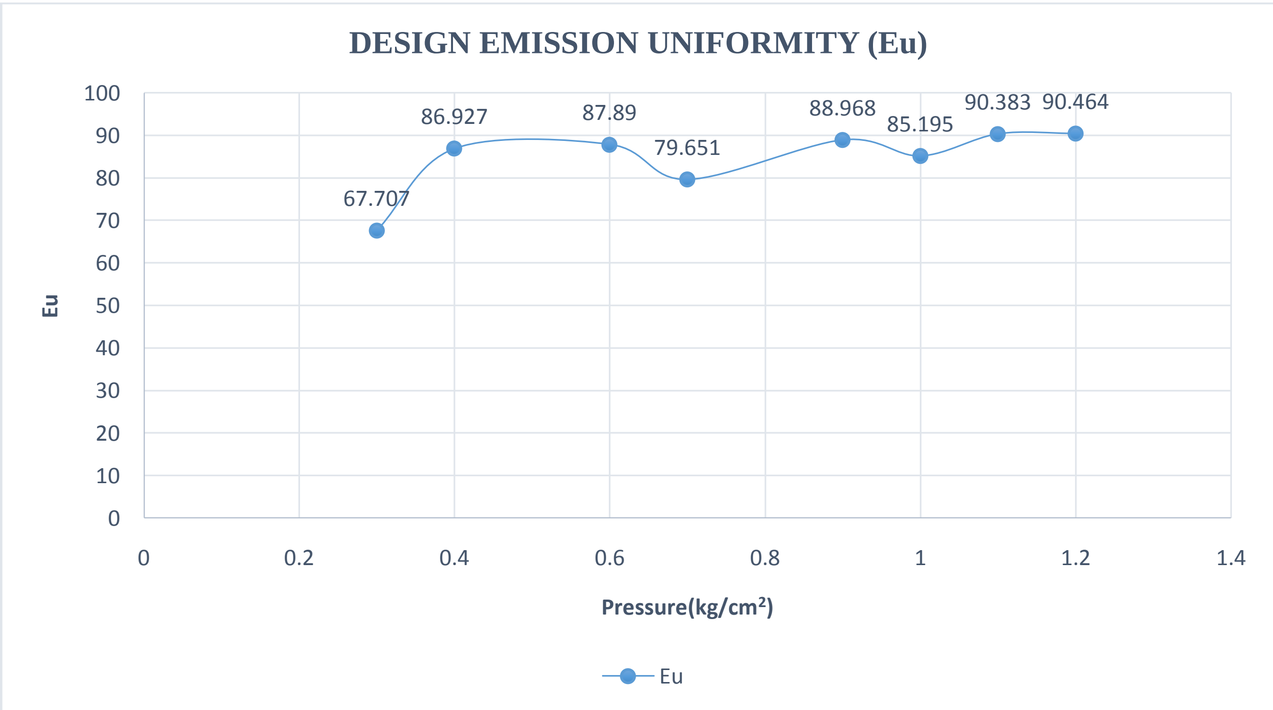

Figure 2. Emission Uniformity V/S Operating Pressures

From figure 2 it can be seen that emission uniformity (EU) varies from 67.707 to 90.464 for pressure 0.3 to 1.2 kg/cm^2. Also EU for $1.2kg/cm^2$ is 90.464% which is excellent.

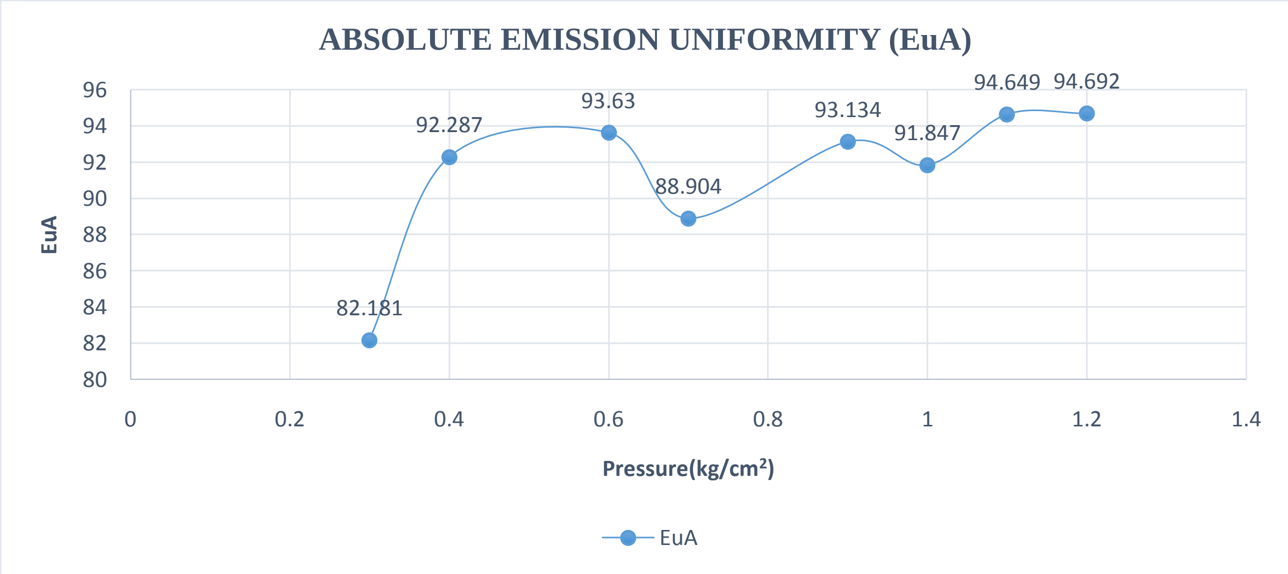

Figure 3. Distribution Uniformity V/S Operating Pressures

From figure 3 it can be seen that emitter flow uniformity (E'U) varies from 82.181 to 94.692 for pressure 0.3 to 1.2 kg/cm^2.Also EuA for 1.2kg/cm^2 is 94.692% which is excellent.

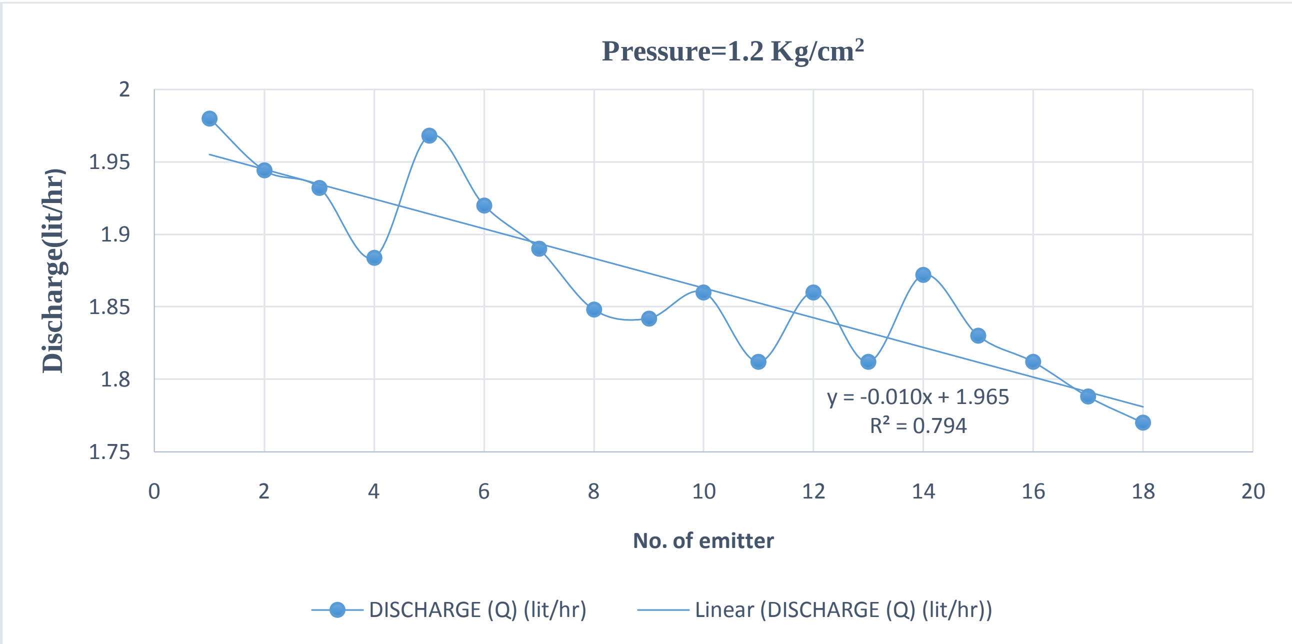

Figure 4.Scatter plot of number of emitter v/s discharge

CONCLUSIONS

In this experiment the best results were concluded for 1.2 kg/cm^2 with Coefficient of determination (R^2) is 0.798 and different hydraulic measures such as E'u, Eu, EuA and Q_{avg} at 1.2 kg/cm^2 pressure for inline drippers was 94.75, 90.46, 94.69, 1.875 l/hr respectively which indicates that the system is excellent and efficient for the present study. For the succefull operation of the drip system, water distribution across the field is important to derive the maximum benefits from irrigation scheduling. The present study encourages trickle installation companies and researchers for further studies on design, installation and evaluation of trickle irrigation system for orchards and other valuable crops.

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