HYDRAULIC PERFORMANCE EVALUATION OF DRIP IRRIGATION SYSTEM WITH DIFFERENT EMISSION DEVICES

By

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Date: December, 2005

Place: Hisar **Sandeep Kumar**

<u>CERTIFICATE - I</u>

This is to certify that this thesis entitled "**Hydraulic Performance Evaluation of Drip Irrigation System with Different Emission Devices**" submitted for the degree of **Master of Technology** in the subject of **Soil & Water Engineering** to Chaudhary Charan Singh Haryana Agricultural University, Hisar, is a bonafide research work carried out by **Mr. Sandeep Kumar** under my supervision and guidance and that no part of this thesis has been submitted for any other degree.

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CERTIFICATE - II

This is to certify that this thesis entitled "**Hydraulic Performance Evaluation of Drip Irrigation System with Different Emission Devices"** submitted by **Mr. Sandeep Kumar** to Chaudhary Charan Singh Haryana Agricultural University, Hisar, in the partial fulfilment of the requirements for the degree of **Master of Technology** in the subject of **Soil & Water Engineering**, has been approved by the student's Advisory Committee after an oral examination on the same.

MAJOR ADVISOR

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LIST OF ABBREVIATIONS AND SYMBOL

	:	Average discharge rate
%	:	per cent
Agril.	:	Agricultural
ASAE	:	American Society of Agricultural Engineers
BIS	:	Bureau of Indian Standard
BM	:	Bench mark
BS	:	Back sight
CCS	:	Choudhary Charan Singh
CD	:	Critical difference
CMV	:	Coefficient of manufacturing variation
CV	:	Coefficient of variation
Dept.	:	Department
Div.	:	Division
Drain	:	Drainage
Engg.	:	Engineering
et al.	:	*et al*ia (and others)
etc.	:	et cetera (and so forth)
EU	:	Emission uniformity
Fig.	:	Figure
FS	:	Fore slight
IS	:	Intermediate sight
J.	:	Journal
Kg/Cm^2	:	Killo gram per centimeter square
KPa	:	Kilo Pascal
KW	:	Killo walt
l/h	:	Litre per hour
LDPE	:	Low density polyethylene
lps	:	Litre per second
m	:	meter
m/100m	:	meter per hundred meter
No.	:	Number
PVC	:	Polyvinyl chloride
RL	:	Reduced level
rpm	:	Revolution per minute
Sq	:	Standard deviation
UC	:	Uniformity coefficient

CHAPTER – I

Introduction

The demand of water resources is increasing due to the increase in the water requirement of growing population, agriculture production and industrialization. The rainfall is the main source of all the waters, either on the earth surface or below the earth surface. The rains are quite variable in time and space. In arid and semi arid region, sustainable agriculture production is not possible without supplemental irrigation. Different irrigation projects were developed to stabilize the agriculture production. But the overall efficiency of water utilization in conventional methods of surface irrigation varies from 30-35% (Singh, 1999) due to poor on farm water management. This leads to the wastage of huge quantity of precious water and causes problems of waterlodgging and/or salinization in canal command areas especially where ground water is brakish. Different innovations have been made in the irrigation methods for better water application to the crops.

Drip irrigation is one of the innovation in the irrigation methods, which is becoming popular for wide spaced crops grown in light sandy soils with water scarcity. In this method, irrigation is accomplished by small diameter plastic lateral lines with different types of emission devices, at selected spacing to deliver water to the soil surface near the plants. It is a method of watering plants frequently and with a volume of water approaching the consumptive use of plants, thereby minimizing deep percolation and runoff losses. The frequent water application in drip irrigation results better moisture conditions in the crop root zone. It is found that drip irrigation results in 40-70% water saving and as high as 100% increase in crop yield for most of the horticultural and vegetable crops (Singh, 1999). The main limitation in the use of the drip irrigation system is its initial cost.

The hydraulic performance of drip irrigation system is indicated by water distribution uniformity which is measured by uniformity coefficient, emission uniformity, coefficient of variation and coefficient of manufacturing variation. The different measures for hydraulic performance of drip irrigation system are very useful for effective design and operation of the system. The water distribution uniformity in drip irrigation system varies due to variations in operating pressure, variation in manufacturing process, field topography, water quality and temperature variations. For a given drip irrigation system, operating pressure is one of the most important parameter, which influences the system performance. The pressure variation in a drip irrigation system for a given set of field and climatic conditions is mainly due to variations in head loss in different components of the system, such as header, main and sub-main line and lateral lines with different emission devices. The most common emission devices for drip irrigation system are on-line dripper, micro-tube, drip-in and drip tape. Therefore, it was decided to study the hydraulic performance of the drip irrigation system with different emission devices with the following objectives:

1. To identify the appropriate hydraulic performance evaluation measures.

2. To study the effect of operating pressure on water distribution uniformity and head loss in main line and lateral lines for following emission devices.

    a. On-line dripper

    b. Micro-tube

    c. Drip-in

    d. Drip tape

3. To develop computer software for hydraulic performance evaluation and calculation of head loss in drip irrigation system.

CHAPTER – II

Review of Literature

Attempts have been made by many scientists in India and abroad to study the hydraulic performance of drip irrigation system based on different measures. The most commonly used measures for evaluation of hydraulic performance of drip irrigation are uniformity coefficient, emission uniformity, coefficient of variation and coefficient of manufacturing variation. In the present study the work done by different workers to study the effect of different operating conditions on water distribution uniformity has been reviewed under these hydraulic performance evaluation measures. Similarly, the work done by different workers for the head loss under different operating conditions has been reviewed under head loss and the work done for software developed by different workers has been reviewed under software for drip irrigation. Some of important work done related to the present study is as under.

2.1 Uniformity Coefficient

Jonas *et al.* (1975) performed hydraulic test to calculate the uniformity coefficient for choosing the best dripper out of given types of dripper and to design the drip irrigation system by developing empirical equations.

Singh *et al.* (1990) compared the performance of various plastic drip irrigation system (TABE, Turbotape and Bi-wall). Underground tubing with TABE, TABE on ground, Bi-wall and microtube emitter were studied. It was found that the uniformity coefficient improved with increase in operating pressure up to 2.11 Kg/cm^2. Maximum uniformity was achieved by Bi-wall and minimum by TABE. Even at 60% plugging level, the variation in discharge was less than 22% at the operating pressure of 1.55 Kg/cm^2 for Bi-wall.

Oguzer and Yilmaz (1991) tested three types of emitters for measuring uniformity coefficient and coefficient of variation. The results indicated that coefficients of variation ranged from 0.10 to 0.20, thus, 33% of emitters were classified as well designed, 9% as acceptable and 55% as poor. The uniformity coefficient of 97.5% was required for an emitter to be classified as acceptable, 33% of emitter satisfied this condition.

Mastafazadeh *et al.* (2000) found that emitter clogging increased with increase in pH and mineral concentration of irrigation water. Emitter clogging reduced the discharge rate and uniformity coefficient of emitters.

Buendia *et al.* (2004) conducted a field experiment in Guaaguato, Maxico to evaluate the irrigation systems and to determine their performance and the effect on crop yield. Three types of irrigation system were evaluated:- portable sprinkler, side roll and drip irrigation. The Christiansen uniformity coefficient for portable and side role were found 75.70% and 74.57% respectively. The uniformity coefficient for drip irrigation system was found 80.77%. Water and land productivity was low in sprinkler irrigation system and high in drip irrigation system. The crop yields increased as uniformity coefficients increased.

Qui-Yang Feng *et al.* (2004) developed a model for designing a drip irrigation system by assuming uniformity coefficient equal or more than 70 percent. With the help of this model, the total yield affected by total water application for different uniformity of irrigation application could be determined.

2.2 Emission Uniformity

Al-Karaghouli and Minasian (1992) determined the crop yield on the basis of emission uniformity of a drip irrigation system. Six common types of drip irrigation system were investigated to select the most efficient drip irrigation system on the basis of their emission uniformity. Emission uniformity of the systems decreased with time due to clogging but emitters manufactured by injection moulding possessed higher emission uniformity values with relatively low reduction rate as compared with extruded emitter. Consequently, injected type emitters gave a higher crop yield than extruded type emitters.

Capra *et al.* (1995) developed an emission uniformity index to describe distribution uniformity in local drip irrigation system. Emission uniformity in such a system varied with time, mainly due to emitter clogging. The results showed that the minimum number of emitter needed for testing was 16 and there was no relationship between clogging and the position of microjets. Although dripper clogging increased along lateral.

Halsambre (1996) conducted emission uniformity tests to study the status of drip irrigation systems in Maharashtra, India. Farmers were questioned about planning and design of pipe network, suitability of pump set, sand and screen media filters and maintenance of system components. Properly planned, designed and maintained system had 88-95 percent emission uniformity but only 25 percent of responding farmers had such system.

Gogen and Hakgoren (2000) conducted a drip irrigation experiment in green house to examine the water distribution uniformity, irrigation application efficiency and soil-plant-water relationship in Kumluca region, Antalya and Turkey. The irrigation system was re-planned according to emission uniformity. Emitter flow variation and Christiansen uniformity coefficient in greenhouse conditions were compared with the system used by local formers. Problems related to system and any necessary precautions were pointed out. Suggestions were made to the farmers in order to make the drip irrigation system in their greenhouses work more efficiently.

Kale *et al.* (2000) studied that the flow rate and emission uniformity of microjet irrigation system increased with an increase in operating pressure but decreased with increase in stake height. Wetting diameter, uniformity coefficient and distribution uniformity increased with an increase in operating pressure and the decrease in stake height.

Hassanli and Sepaskash (2001) conducted experiments in seven citrus gardens in different parts of Darab, Iran to evaluate the drip irrigation system. The evaluation procedure was based on Merrian and Keller Model (1978). The field experiments indicated that emission uniformity varied from 31% to 82% i.e. poor to good.

Bhatnagar and Shrivastava (2003) designed a drip irrigation system for hill terraces. They found that the system worked efficiently with field emission uniformity above 90 percent.

Jadhav and Firake (2003) carried out a field experiment with groundnut in Maharashtra to investigate the suitability of drip irrigation scheduling approaches, in comparison to surface irrigation method. They found that the emission uniformity of drip irrigation system was more than 90% indicating the excellent performance of the system.

Senzanje *et al.* (2004) conducted an experiment to assess the technical performance and determine the operational limits of low cost drip irrigation system with three types of low cost emitter (sponge, string, steeve). The system had 16 mm diameter drip lines. The operational head tested were 1, 1.5 and 2m, whereas the drip line length varied from 5 to 45m in the steps of 5m. The results indicated that for all emitter types discharge varied from 2 to 10 liter/hour for drip line length of 10 to 35 m respectively. The emission uniformity of the system was found 79%. The most appropriate drip line length was 25m and operating head of 1.5 m for the system with string and sleeve type emitter, and 2 m for the system with sponge type emitter.

2.3 Coefficient of Variation

Keller *et al.* (1974) introduced the coefficient of variations as a statistical measure for dripper manufacturing variation. The coefficient of manufacturing variation was then included in design equations for emission uniformity.

Nakayama *et al.* (1979) developed a method for showing the uniformity of water application by trickle drippers based on coefficient of variation. The inter-relationship between computed design uniformity coefficient and coefficient of variation for drippers was used as a guide for selecting number of drippers per plant.

Braltz *et al.* (1981) developed a nomograph in which coefficient of variation was used to measure the effect of emitter plugging on uniformity of emitter flow along single and dual chamber drip irrigation lateral lines. The number of emitters per plant was shown to be important when calculating uniformity considering emitter plugging.

Braltz and Kesner (1983) proposed a method of estimating field uniformity based on statistical uniformity coefficient using coefficient of variation which was determined from a randomly sampled dripper flow rates.

Shrivastava *et al.* (1990) calculated the coefficient of variation to determine emitter flow variation along a lateral line for 15 commercially available drippers. The maximum possible length of a lateral for a particular diameter tube was worked out, considering 18 percent variation in average discharge.

2.4 Coefficient of Manufacturing Variation

Solomon (1979) observed that coefficient of manufacturing variation in emission devices was an important factor influencing emission uniformity in drip irrigation system. He proposed that coefficient of manufacturing variation must be considered when selecting drippers for a system.

Madaramootoo and Khatri (1988) observed that the coefficients of manufacturing variation were higher for pressure compensating drippers than non-pressure compensating drippers.

Correia (1990) evaluated the pressure discharge relationship and other parameters for 6 Indian companies marketing drip irrigation systems. The exponents of emitter flow equation varied from 0.14 to 0.70 at rated discharge of 4 liter/hour with an exception of 0.078 at 2 liter/hour. The deviation of discharge from mean varied from +51% to -80%. The values of coefficient of manufacturing variation ranged from 0.016 to 0.375.

Ozekiei and Sneed (1990) computed the coefficient of manufacturing variation, emitter, exponent and discharge coefficient to determine flow regime for non-pressure compensating emitters and pressure compensating emitters. The values of coefficient of manufacturing variation were found to be higher for pressure compensating emitters than non-pressure compensating emitters.

Mostatazadeh *et al.* (2002) found that emitter discharge was affected by parameters such as pressure, irrigation water temperature, coefficient of manufacturing variation and emitter clogging. They evaluated that coefficients of manufacturing variation at water temperature of about 20°C for double chamber tube, in-line dripper and pressure compensating emitter were equal to 5, 7 and 22 percent respectively.

Karnak *et al.* (2004) compared the manufacturer's reported discharge rates and the coefficients of manufacturing variation with test results for various types of in-line emitters manufactured by 4 different companies in Turkey. Seven non-pressure compensating and 2 pressure compensating emitters were tested at 50, 100, 200 and 250 KPa pressures. Pressure compensating emitters exponents ranged from 0.02 to 0.05 while non-pressure compensating emitters exponents varied from 0.60 to 0.85. The results showed that only 1 of the 7 non-pressure compensating emitter and both pressure compensating emitters had flow rate with in -10% to +10% of manufacturer's reported values.

2.5 Head Loss

Wu and Giltin (1974) estimated the head loss at any point along drip line by knowing total friction drop and total length. They proposed the use of curve for calculating head loss pattern along a drip line.

Keller and Karmeli (1975) suggested that the head losses across dripper connections should also be considered in lateral design procedure besides lateral length, pipe size, drippers spacing, ground slop and dripper flow rate.

1980 Howell *et al.* (1980) calculated the head loss across on-line dripper. The head losses were expressed in term of equivalent length of pipe. They proposed that these losses also be taken into account in lateral design procedures.

Ahmed (1995) conducted an experiment to measure the effect of on-line emitters on pressure losses in trickle irrigation laterals. He used 8 types of emitter with various barb areas installed into five commonly used polyethylene pipes of different diameters. The result showed a significant pressure losses due to emitter connections. These losses were a function of area of emitter barb protrusion and lateral pipe diameter. A simple procedure was suggested to incorporate the emitter barb losses in the design of trickle irrigation losses.

Bagarello *et al.* (1997) conducted an experiment to deduce an evaluating procedure of local losses due to protrusion of emitter barbs into flow in drip irrigation lines. Local losses were measured for different Reynolds number value. Each pipe emitter system was characterized by an obstruction index. A relationship between local losses and corresponding obstruction index was deduced. Two evaluating procedures of obstruction index were also compared.

Reddy *et al.* (2000) evaluated the pressure variation in pipelines using a modified form of Bernoulli's equation. Head loss due to friction was evaluated using Darcy's Weisbash equation. Newton Raphson technique was used to solve equations and to determine pressure head at various nodes of pipe network.

Yuredem and Demir (2003) conducted an experiment to determine the effect of design faults of the domestic screen type filters used in drip irrigation system on head losses and to provide solutions for their deduction. Screen filters with 2.5 inches and 3 inches were used. They found that some changes on outlet and inlet area, the head losses for 2.5 inches filters were reduced to approximately 60% while some changes for 3 inches filter resulted in 40% reduction in head losses. The change made on 3 inches filter body reduced the head losses for approximately 81 percent.

2.6 Software for Drip Irrigation

Camp *et al.* (1997) developed a software for irrigation scheduling of table grapes under drip irrigation. The main objectives of the software were to control daily irrigation procedures implemented by grower last week and to provide daily irrigation recommendations for next week.

Charles *et al.* (2000) developed a software to estimate distribution uniformity, causes and relative importance of various factors influencing the non-unformity of drip irrigation system. This software provided suggestions to improve the distribution uniformity. The software provided only an approximate value of irrigation efficiency.

Krishan and Ravi Kumar (2002) developed a software named as Drip System Simulation Programme. The software was developed for design drip irrigation sub unit. An equation to determine pressure distribution in pipelines with equally spaced multiple outlets and with outflow at downstream end was derived.

Rajput and Patel (2003) developed a software named as “DRIPD”. This software was designed for drip irrigation system under all agro climatic conditions of fruits, vegetables as well as for close spaced field crops. An overview of the development of drip irrigation components and the design of drip irrigation system was presented.

CHAPTER – III

Material and Methods

The present study on, "Hydraulic performance evaluation of drip irrigation system with different emission devices" was conducted in Soil and Water Engineering field Laboratory, College of Agricultural Engineering and Technology, CCS Haryana Agricultural University, Hisar. Material and Methods include location and climate, drip irrigation system, emission devices, pressure head measurement equipment, discharge measurement equipment and measurement of water distribution uniformity. Brief description of the material and methods is as under:

3.1 Location and Climate

Hisar is located at 29°10'N Latitude and 75°46'E Longitudes, with an evaluation of 215 meter above mean sea level. The area is characterized by semi-arid type of climate with an average annual rainfall of 450 mm which is scanty and erratic. The average annual evaporative demand is 2323 mm. The average minimum temperature during month of January is about 5°C and average maximum temperature during months of May and June is about 45°C.

3.2 Drip Irrigation System

Drip irrigation system used in the present study included water source, pump set, filter, main line, lateral lines, different emission devices and accessories. The layout of the drip irrigation system used in the present study is shown in Figure 3.1. The different components of the drip irrigation system used are described as under:

3.2.1 Water Source

A groundwater storage tank of size 8.4m x 8.4m x 2m was used as water source. The storage tank was filled by a tube-well with a electric operated monoblock centrifugal pump of 10cm x 10cm size, 5.5 KW, 2900 rpm, head of 12/24m with discharge of 28/14 lps. A constant water level of 1.5m was kept in the tank.

3.2.2 Pumping Set

An electric operated centrifugal monoblock pump of 1.5 KW, 5cm x 5cm size, 11.4cm impeller diameter, 7.0 to 18.0m head range, 45% overall efficiency, 9.0 lps maximum capacity was used to pump the water from underground reservoir to drip irrigation system.

3.2.3 Filter

A screen filter was installed between drip irrigation system main line and delivery pipe of the pumping set. Nominal size and pressure of the filter was 50mm and 2 Kg/cm^2. The aperture size of the filter was 103 microns.

3.2.4 Main Line

Polyvinyl chloride (PVC) plastic pipe of 5cm, diameter was used for the main line. The length of the main line was 50m. The ground profile along main line was measured with the help of dumpy level at 2m interval. The measured values of Reduce Level (RL) are given in Table 3.1 and shown in Figure 3.2.

3.2.5 Lateral Line

Low density polyethylene (LDPE) plastic pipes of 16mm diameter were used for lateral lines. There were three lateral lines

Table 3.1: Reduce level of main line

Distance (meter)	BS (meter)	IS (meter)	F.S. (meter)	R.L. (meter)
BM	1.10			100
0		1.16		99.94
2		1.26		99.84
4		1.24		99.86
6		1.21		99.89
8		1.43		99.67
10		1.38		99.72
12		1.39		99.71
14		1.36		99.74
16		1.38		99.72
18		1.35		99.75
20		1.23		99.87
22		1.26		99.84
24		1.30		99.80
26		1.31		99.79
28		1.33		99.77
30		1.31		99.79
32		1.29		99.81
34		1.28		99.82
36		1.28		99.82
38		1.27		99.83
40		1.27		99.83
42		1.34		99.76
44		1.34		99.76
46		1.35		99.75
48		1.38		99.72
50		1.32		99.78
52			1.37	99.73

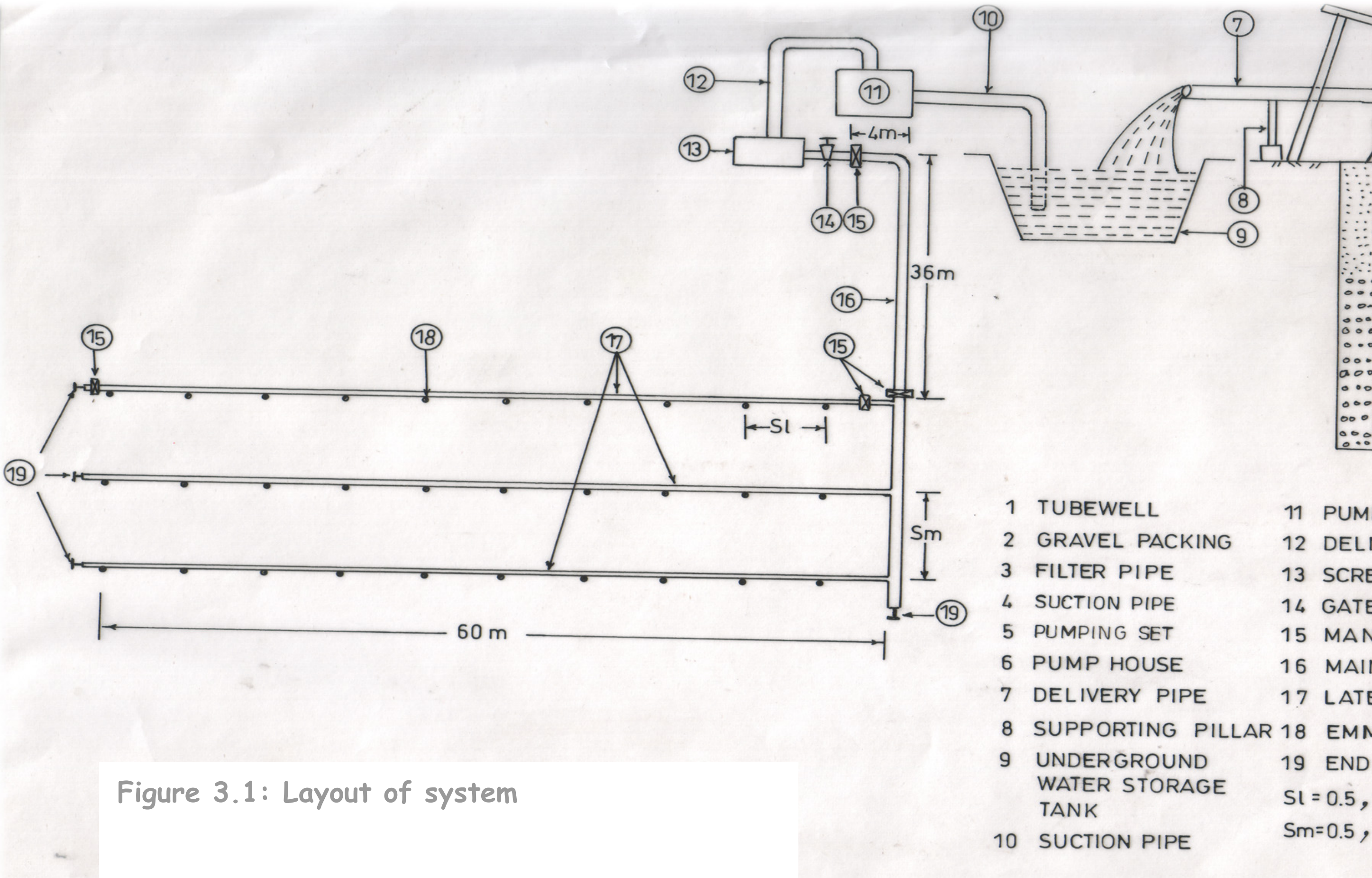

Figure 3.1: Layout of system

mounted on the main line. The spacing between lateral lines were 6m, 1m and 0.5m. The selected length of the lateral line was 60m for all emission devices except micro-tubes at 1m x 1m and 0.5m x 0.5m spacing. The selected length of lateral line for micro-tubes at 1m x 1m and 0.5m x 0.5m spacing was 24 m and 18 m respectively. The ground profile along the lateral lines was measured with the help of dumpy level at 3m interval. The measured values of Reduce Level (RL) are given in Table 3.2 and is show in Figure 3.3.

3.2.6 Accessories

Different accessories were used to pump water to control the water flow rate, to connect the main line and lateral line etc. One PVC valve of 5cm diameter was used to control the water flow from delivery pipe to the main line. The end plugs were used to close the downstream end of main line and laterals. The laterals were connected to main line with grommets. The drip tape laterals were connected to the main lines with drip tape connector. Specially fabricated punch was used to make holes in laterals to mount emitters and/or micro-tubes. The main line was connected with PVC sockets and elbows. The micro-tubes were connected to laterals by connectors.

3.3 Emission Devices

The emission devices used in the present study were drippers, micro-tubes, drip-in and drip tape (Figure 3.4). The emission devices were mounted on lateral lines at 6m, 1m and 0.5m spacing for drippers and micro-tubes. However, the spacing of the emission devices on the lateral lines for drip-in and drip tape was fixed at 60cm and 30cm respectively.

Figure 3.4: Different Emission Devices

3.3.1 Drippers

On-line non-pressure compensating orifice type drippers of 4 liter/hour capacity at the recommended operating pressure of 10m head were used.

Table 3.2: Reduced level of lateral lines

Distance (meter)	B.S. (meter)	I.S. of first later (meter)	FS for first lateral (meter)	R.L. for first lateral	I.S. for second laterl (meter)	F.S. for second lateral (meter)	R.L. for second lateral (meter)	I.S. for third lateral (meter)	F.S. for third lateral (meter)	R.L. for third lateral (meter)
BM	1.10			100			100			100
0		1.44		99.66	1.32		99.78	1.28		99.82
3		1.42		99.68	1.36		99.74	1.30		99.80
6		1.39		99.71	1.35		99.75	1.35		99.75
9		1.40		99.70	1.40		99.70	1.32		99.78
12		1.38		99.72	1.37		99.73	1.47		99.63
15		1.43		99.67	1.41		99.69	1.41		99.69
18		1.43		99.67	1.39		99.71	1.33		99.77
21		1.39		99.71	1.35		99.75	1.34		99.76
24		1.24		99.86	1.38		99.72	1.25		99.85
27		1.33		99.77	1.27		99.83	1.13		99.97
30		1.39		99.71	1.12		99.98	1.42		99.68
33		1.42		99.68	1.25		99.85	1.36		99.74
36		1.38		99.72	1.39		99.71	1.32		99.78
39		1.33		99.77	1.47		99.63	1.33		99.77
42		1.30		99.80	1.46		99.64	1.16		99.94
45		1.30		99.80	1.39		99.71	1.17		99.93
48		1.27		99.83	1.30		99.80	1.12		99.98
51		1.25		99.85	1.22		99.88	1.18		99.92
54		1.19		99.91	1.18		99.92	1.15		99.95
57		1.31		99.79	1.13		99.97	1.17		99.93
60			1.25	99.85		1.21	99.89		1.13	99.97

3.3.2 Micro-tubes

2mm diameter and 40cm long micro-tubes of 80 liter/hour capacity at the recommended operating pressure of 15m head were used.

3.3.3 Drip-in

Drip-in having outlets at 60m spacing and capacity of 1.5 liter/hour at the recommended operating pressure head of 5m were used.

3.3.4 Drip tape

Drip tape having outlets at 30cm spacing and capacity of 1 liter/hour at the recommended operating pressure head of 5m were used.

3.4 Pressure Head Measurement Equipment

The higher values of pressure head were measured with the mercury manometer and the lower values of the pressure head were measured with the water manometer (Figure 3.5). The pressure head measurement were made at four locations in the system as given below:

i) Upstream end of main line

ii) Downstream end of main line

iii) Upstream end of first lateral

iv) Downstream end of first lateral

The measured values of the pressure head at different locations of the system for different emission devices are given in Appendix-I.

Figure 3.5: Measurement of pressure head

3.5 Discharge Measurement Equipment

The discharge of different emission devices was measured at 6m interval along the lateral line with the help of 1 liter plastic containers and measuring flask (Fig. 3.6). The containers were put under the emission devices in the dugout pits. The system was operated for 15 minutes each time and the discharge of emission devices was collected in the containers and measured with the help of measuring flaks. The measurements were replicated thrice. The measured values were converted to liter/hour and are given in Appendix-II.

Figure 3.6: Measurement of Discharge

The statistical analysis of discharge measurement was done to study the interaction of spacing and pressure head on the discharge. The results are given in Appendix-III.

3.6 Measurement of Water Distribution Uniformity

The following measures for hydraulic performance evaluation as per BIS (1991)were selected.

i) Uniformity coefficient

ii) Emission uniformity

iii) Coefficient of variation

iv) Coefficient of manufacturing variation

Mathematically, the measures are expressed as under.

3.6.1 Uniformity Coefficient (UC)

Uniformity coefficient is a statistical representation of the uniformity of drip irrigation. It is expressed as

UC =

................................(3.1)

3.6.2 Emission Uniformity (EU)

It is the uniformity of emission from drip irrigation emission devices through a field and is expressed as.

$$EU = \frac{\text{Minimum rate of discharge}}{\text{Average rate of discharge}} \times 100 \quad \text{........ (3.2)}$$

3.6.3 Coefficient of Variation (CV)

The coefficient of variation is expressed as

CV = ……… (3.3)

Where,

Sq = Standard deviation of the discharge rate for the sample

= average discharge rate

3.6.4 Coefficient of Manufacturing Variation (CMV)

Coefficient of manufacturing variation is expressed as:

CMV = ……… (3.4)

Where,

Sq = Standard deviation of the discharge rate for the sample

= average discharge rate

The discharge from different emission devices for the estimate of coefficient of manufacturing variation was measured at one point and under the same operating conditions. The measured values are given in Appendix-II.

3.7 Development of Computer Software

The computer programme for software for hydraulic performance evaluation and calculation of head loss in drip irrigation system was written in C++ language. The detailed programme is given in Appendix-IV.

CHAPTER – IV

Results and Discussion

The results present in this chapter are based on the experimental findings of the study "Performance evaluation of drip irrigation system with different emission devices". The results and discussion included hydraulic performance evaluation measures, the effect of spacing and operating pressure head on different measures, head loss in different parts of system, computer programme for software and interaction of the lateral spacing and operating pressure head on discharge for different emission devices.

4.1 Hydraulic Performance Evaluation Measures

Uniformity coefficient, emission uniformity, coefficient of variation and coefficient of manufacturing variation were identified to be the important measures for hydraulic performance evaluation of drip irrigation system.

4.2 Uniformity Coefficient

The values of uniformity coefficient were calculated from Equation 3.1 using the measured values of water collected in containers as explained in article 3.5 for different emission devices at different operating pressure heads and for different spacings. The variation of the hydraulic performance evaluation measures was studied for dripper, micro-tube, drip-in, drip tape at three operating pressure heads equal to 5m, 10m and 13m at three spacing:

i) 6m x 6m, 1 x 1m and 0.5m x 0.5m for drippers and micro-tubes;

ii) 6m x 0.6m, 1 x 0.6m, 0.5m x 0.6m for drip-in;

iii) 6m x 0.3m, 1m x 0.3m and 0.5 x 0.3m for drip tape respectively.

4.2.1 Uniformity Coefficient for Dripper

The values of uniformity coefficient for drippers at different spacing and operating pressure heads are given in Table 4.1 and shown in Figure 4.1.

Table 4.1: Uniformity coefficient of drippers with different spacing and operating pressure heads

Emission Device	Spacing (meter)	Operating pressure head (meter)	Uniformity coefficient (percent)
Dripper	6 x 6	5	98.02
Dripper	6 x 6	10	98.46
Dripper	6 x 6	13	98.78
Dripper	1 x 1	5	96.19
Dripper	1 x 1	10	97.47
Dripper	1 x 1	13	97.87
Dripper	0.5 x 0.5	5	95.57
Dripper	0.5 x 0.5	10	96.19
Dripper	0.5 x 0.5	13	96.70

The values of uniformity coefficient for drippers at 6m x 6m, 1m x 1m and 0.5m x 0.5m spacing for operating pressure head from 5 m to 13m varied from 98.02% to 98.78%, 96.19% to 97.87% and 95.57% to 96.70% respectively.

The maximum value of uniformity coefficient was for 6m x 6m spacing at 13m operating pressure head and the minimum value was at 0.5m x 0.5 spacing at 5m operating pressure head.

The average measured discharge decreased from 3.975 to 1.719 (l/h) as the spacing decreased from 6m x 6m to 0.5m x 0.5m (due to increase in number of emission devices). Thus the ratio of average deviation from average measured discharge to average measured discharge increased, hence uniformity coefficient decreased as the spacing decreased.

The average measured discharge increased from 2.498 to 3.975 (l/h) as the operating pressure head increased from 5m to 13m for a particular spacing (6m x 6m). Thus the ratio of average deviation from average measured discharge to average measured discharge decreased, hence uniformity coefficient increased as the operating pressure head increased.

4.2.2 Uniformity Coefficient for Micro-tubes

The values of uniformity coefficient for micro-tubes at different spacing and operating pressure heads are given in Table 4.2 and shown in Figure 4.2.

Table 4.2: Uniformity coefficient of micro-tubes with different spacing and operating pressure heads

Emission Device	Spacing (meter)	Operating pressure head (meter)	Uniformity coefficient (percent)
Micro tube	6 x 6	5	78.40
Micro tube	6 x 6	10	80.64
Micro tube	6 x 6	13	82.43
Micro tube	1 x 1	5	77.71
Micro tube	1 x 1	10	78.27
Micro tube	1 x 1	13	79.58
Micro tube	0.5 x 0.5	5	73.91
Micro tube	0.5 x 0.5	10	75.11
Micro tube	0.5 x 0.5	13	76.56

The values of uniformity coefficient for micro-tubes at 6m x 6m, 1m x 1m and 0.5m x 0.5m spacing for operating pressure head from 5m to 13m varied from 78.40% to 82.43%, 77.71% to 79.58% and 73.91% to 76.56% respectively.

The maximum value of uniformity coefficient was at 6m x 6m spacing at 13m operating pressure head and the minimum value was at 0.5m x 0.5 spacing and 5m operating pressure head.

The average measured discharge decreased from 54.478 to 15.734 (l/h) as the spacing decreased from 6m x 6m to 0.5m x 0.5m (due to increase in number of emission devices). Thus the ratio of average deviation from average measured discharge to average measured discharge increased, hence uniformity coefficient decreased as the spacing decreased.

The average measured discharge increased from 45.236 to 54.478 (l/h) as the operating pressure head increased from 5m to 13m for a particular spacing (6m x 6m). Thus the ratio of average deviation from average measured discharge to average measured discharge decreased, hence uniformity coefficient increased as the operating pressure head increased.

4.2.3 Uniformity Coefficient for Drip-in

The values uniformity coefficient for drip-in at different spacing and operating pressure heads are given in Table 4.3 and shown in Figure 4.3.

The values of uniformity coefficient for drip-in at 6m x 0.6m, 1m x 0.6m and 0.5m x 0.6m spacing for operating pressure head from 5m to 13m varied from 95.73% to 97.43%, 96.52% to 97.66% and 97.12% to 97.75% respectively.

Table 4.3: Uniformity coefficient of drip-in with different spacing and operating pressure heads

Emission Device	Spacing (meter)	Operating pressure head (meter)	Uniformity coefficient (percent)
Drip-in	6 x 0.6	5	95.73
Drip-in	6 x 0.6	10	96.78
Drip-in	6 x 0.6	13	97.43

Drip-in	1 x 0.6	5	96.52
Drip-in	1 x 0.6	10	97.05
Drip-in	1 x 0.6	13	97.66
Drip-in	0.5 x 0.6	5	97.12
Drip-in	0.5 x 0.6	10	97.48
Drip-in	0.5 x 0.6	13	97.75

The maximum value of uniformity coefficient was at 0.5m x 0.6m spacing at 13m operating pressure head and the minimum value was at 6m x 0.6m spacing at 5m operating pressure head.

The average measured discharge increased from 1.140 to 2.646 (l/h) as the spacing decrease from 6m x 0.6m to 0.5m x 0.6m (due to close lateral lines with constant emission points). Thus the ratio of average deviation from average measured discharge to average measured discharge decreased, hence uniformity coefficient increased as the spacing decreased.

The average measured discharge increased from 1.140 to 2.437 (l/h) as the operating pressure head increased from 5m to 13m for a particular spacing (6m x 0.6m). Thus, the ratio of average deviation from average measured discharge decreased, hence, uniformity coefficient increased as the operating pressure head increased.

4.2.4 Uniformity Coefficient for Drip tape

The values of uniformity coefficient for drip tape at different spacing and operating pressure heads are given in Table 4.4 and shown in Figure 4.4.

Table 4.4: Uniformity coefficient of drip tape with different spacing and operating pressure heads

Emission Device	Spacing (meter)	Operating pressure head (meter)	Uniformity coefficient (percent)
Drip tape	6 x 0.3	5	94.28
Drip tape	6 x 0.3	10	95.18
Drip tape	6 x 0.3	13	95.37
Drip tape	1 x 0.3	5	94.93
Drip tape	1 x 0.3	10	95.37

Drip tape	1 x 0.3	13	96.01
Drip tape	0.5 x 0.3	5	95.22
Drip tape	0.5 x 0.3	10	95.89
Drip tape	0.5 x 0.3	13	96.93

The values of uniformity coefficient for drip tape at 6m x 0.3m, 1m x 0.3m and 0.5 x 0.3m spacing for operating pressure head from 5m to 13m varied from 94.28% to 95.37%, 94.93% to 96.01% and 95.22% to 96.93% respectively.

The maximum value of uniformity co-efficient was at 0.5m x 0.3m spacing at 13m operating pressure head and the minimum value was at 6m x 0.3m spacing at 5m operating pressure head.

The average measured discharge increased from 0.839 to 1.354 (l/h) as the spacing decrease from 6m x 0.3m to 0.5m x 0.3m (due to close lateral lines with constant emission points). Thus the ratio of average deviation from average measured discharge to average measured discharge decreased, hence uniformity coefficient increased as the spacing decreased.

The average measured discharge increased from 0.839 to 1.086 (l/h) as the operating pressure head increased from 5m to 13m for a particular spacing (6m x 0.3m). Thus, the ratio of average deviation from average measured discharge decreased, hence, uniformity coefficient increased as the operating pressure head increased.

4.3 Emission Uniformity

The values for emission uniformity were calculated from Equation 3.2 using the measured values of water collected in containers as explained in article 3.5 for different emission devices at different operating pressure heads and for different spacings.

4.3.1 Emission Uniformity for Drippers

The values of emission uniformity for drippers at different spacing and operating pressure heads are given in Table 4.5 and shown in Figure 4.5.

Table 4.5: Emission uniformity of drippers with different spacing and operating pressure heads

Emission Device	Spacing (meter)	Operating pressure head (meter)	Emission uniformity (percent)
Dripper	6 x 6	5	95.45
Dripper	6 x 6	10	97.12
Dripper	6 x 6	13	97.51
Dripper	1 x 1	5	92.33
Dripper	1 x 1	10	94.15
Dripper	1 x 1	13	95.09
Dripper	0.5 x 0.5	5	91.91
Dripper	0.5 x 0.5	10	92.55
Dripper	0.5 x 0.5	13	92.79

The values of emission uniformity for drippers at 6m x 6m, 1m x 1m and 0.5m x 0.5m spacing for operating pressure head from 5m to 13m varied from 94.45% to 97.51%, 92.33% to 95.09% and 91.91% to 92.79% respectively.

The maximum value of emission uniformity was at 6m x 6m spacing at 13m operating pressure head and minimum value was at 0.5m x 0.5m spacing at 5m operating pressure head.

The average measured discharge and minimum measured discharge decreased from 3.975 to 1.719 (l/h) and from 3.875 to 1.580

(l/h) respectively as spacing decreased from 6m x 6m to 0.5m x 0.5m (due to increase in number of emission devices). Thus the ratio of minimum discharge to average discharge decreased, hence emission uniformity decreased as the spacing decreased.

The average discharge and minimum discharge increased from 2.498 to 3.975 (l/h) and from 2.385 to 3.876 (l/h) respectively as the operating pressure head increased from 5m to 13m for a particular spacing (6m x 6m). Thus ratio of minimum discharge to average discharge increased, hence emission uniformity increased as the operating pressure head increased.

4.3.2 Emission Uniformity for Micro-tubes

The values of emission uniformity for micro-tubes at different spacing and operating pressure heads are given in Table 4.6 and shown in Figure 4.6.

Table 4.6: Emission uniformity of micro-tubes with different spacing and operating pressure heads

Emission Device	Spacing (meter)	Operating pressure head (meter)	Emission uniformity (percent)
Micro tube	6 x 6	5	60.55
Micro tube	6 x 6	10	62.94
Micro tube	6 x 6	13	64.84
Micro tube	1 x 1	5	60.34
Micro tube	1 x 1	10	61.11
Micro tube	1 x 1	13	62.24
Micro tube	0.5 x 0.5	5	59.07

Micro tube	0.5 x 0.5	10	60.05
Micro tube	0.5 x 0.5	13	60.84

The values of emission uniformity for micro-tubes at 6m x 6m, 1m x 1m and 0.5m x 0.5m spacing for operating pressure head from 5m to 13m varied from 60.55% to 64.84%, 60.34% to 62.24% and 59.07% to 60.84%, respectively.

The maximum value of emission uniformity was at 6m x 6m spacing at 13m operating pressure head and minimum value was at 0.5m x 0.5m spacing at 5m operating pressure head.

The average measured discharge and minimum measured discharge decreased from 54.478 to 15.734 (l/h) and 35.328 to 9.295 (l/h) respectively as spacing decreased from 6m x 6m to 0.5m x 0.5m (due to increase in number of emission devices). Thus the ratio of minimum discharge to average discharge is decreased, hence emission uniformity decreased as the spacing decreased.

The average discharge and minimum discharge increased from 45.236 to 54.478 (l/h) and 27.393 to 35.328 (l/h) respectively as the operating pressure head increased from 5m to 13m for a particular spacing (6m x 6m). Thus ratio of minimum discharge to average discharge increased, hence emission uniformity increased as the operating pressure head increased.

4.3.3 Emission Uniformity for Drip-in

The values of emission uniformity for drip-in at different spacing and operating pressure heads are given in Table 4.7 and shown in Figure 4.7.

Table 4.7: Emission uniformity of drip-in with different spacing and operating pressure heads

Emission Device	Spacing (meter)	Operating pressure head (meter)	Emission uniformity (percent)
Drip-in	6 x 0.6	5	90.51
Drip-in	6 x 0.6	10	92.25
Drip-in	6 x 0.6	13	93.53
Drip-in	1 x 0.6	5	91.77
Drip-in	1 x 0.6	10	93.78
Drip-in	1 x 0.6	13	94.25
Drip-in	0.5 x 0.6	5	93.46

Drip-in	0.5 x 0.6	10	94.40
Drip-in	0.5 x 0.6	13	94.74

The values of emission uniformity for drip-in 6m x 0.6m, 1m x 0.6m, and 0.5m x 0.6m spacing for operating pressure head from 5m to 13m varied from 90.51% to 93.53%, 91.77% to 94.25% and 93.46% to 94.74% respectively.

The maximum value of emission uniformity was at 0.5m x 0.6m spacing at 13m operating pressure head and the minimum value was at 6m x 0.6m at 5m operating pressure head.

The average measured discharge and minimum measured discharge increased from 1.140 to 2.646 (l/h) and 1.032 to 2.507 (l/h) respectively as spacing decreased from 6m x 0.6m to 0.5m x 0.6m (due to close lateral lines with constant emission points). Thus ratio of minimum discharge to average increased, hence, emission uniformity increased as the spacing decreased.

The average discharge and minimum discharge increased from 1.140 to 2.437 (l/h) and 1.032 to 2.279 (l/h) respectively as the operating pressure head increased from 5m to 13m for a particular spacing (6m x 0.6m). Thus the ratio of minimum discharge to average discharge increased, hence, emission uniformity increased as the operating pressure head increased.

4.3.4 Emission Uniformity for Drip tape

The values of emission uniformity for drip tape at different spacing and operating pressure heads are given operating pressure heads are given in Table 4.8 and shown in Figure 4.8.

Table 4.8: Emission uniformity of drip tape with different spacing and operating pressure heads

Emission Device	Spacing (meter)	Operating pressure head (meter)	Emission uniformity (percent)
Drip tape	6 x 0.3	5	84.77
Drip tape	6 x 0.3	10	86.08
Drip tape	6 x 0.3	13	87.11
Drip tape	1 x 0.3	5	86.85
Drip tape	1 x 0.3	10	87.81
Drip tape	1 x 0.3	13	89.31
Drip tape	0.5 x 0.3	5	89.13

Drip tape	0.5 x 0.3	10	90.87
Drip tape	0.5 x 0.3	13	91.82

The values of emission uniformity for drip tape at 6m x 0.3m, 1m x 0.3m, 0.5m x 0.3m spacing for operating pressure head from 5m to 13m varied from 84.77% to 87.11%, 86.85% to 89.31% and 89.13% to 91.82% respectively.

The maximum value of emission uniformity was at 0.5m x 0.3m spacing at 13m operating pressure head and the minimum value was at 6m x 0.3m spacing at 5m operating pressure head.

The average measured discharge and minimum measured discharge increased from 0.839 to 1.354 (l/h) and 0.711 to 1.108 (l/h) respectively as spacing decreased from 6m x 0.3m to 0.5m x 0.3m (due to close lateral lines with constant emission points). Thus ratio of minimum discharge to average increased, hence, emission uniformity increased as the spacing decreased.

The average discharge and minimum discharge increased from 0.839 to 1.240 (l/h) and 0.711 to 1.080 (l/h) respectively as the operating pressure head increased from 5m to 13m for a particular spacing (6m x 0.3m). Thus the ratio of minimum discharge to average discharge increased, hence, emission uniformity increased as the operating pressure head increased.

4.4 Coefficient of Variation

The values of coefficients of variation were calculated from Equation 3.3 using the measured values of water collected in containers as explained in article 3.5 for different emission devices at different operating pressure heads and for different spacings.

4.4.1 Coefficient of Variation for Drippers

The values of coefficient of variation for drippers at different spacing and operating pressure heads are given in Table 4.9 and shown in Figure 4.9.

Table 4.9: Coefficient of variation of dripper with different spacing and operating pressure heads

Emission Device	Spacing (meter)	Operating pressure head (meter)	Coefficient of variation (per cent)
Dripper	6 x 6	5	2.57
Dripper	6 x 6	10	1.93
Dripper	6 x 6	13	1.53
Dripper	1 x 1	5	4.48

Dripper	1 x 1	10	3.08
Dripper	1 x 1	13	2.64
Dripper	0.5 x 0.5	5	5.19
Dripper	0.5 x 0.5	10	4.37
Dripper	0.5 x 0.5	13	3.89

The values of coefficient of variation for drippers at 6m x 6m, 1m x 1m and 0.5m x 0.5m spacing for operating pressure head from 5m to 13m varied from 2.50% to 1.53%, 4.48% to 2.64% and 5.19% to 3.89%, respectively.

The maximum value of coefficient of variation was at 5m x 0.5m spacing at 5m operating pressure head and the minimum value was at 6m x 6m spacing at 13m operating pressure head.

The average measured discharge decreased from 3.975 to 1.719 (l/h) as spacing decreased from 6m x 6m to 0.5m x 0.5m (due to increase in number of emission devices). Thus the ratio of standard deviation to average discharge increased from 0.0153 to 0.0519 as the spacing decreased from 6m x 6m to 0.5m x 0.5m. Hence, coefficient of variation increased as the spacing decreased.

The, average discharge increased from 2.498 to 3.975 (l/h) as the operating pressure head increased from 5m to 13m for a particular spacing (6m x 6m). Thus, the ratio of standard deviation to average discharge decreased from 0.0257 to 0.0153 as the operating pressure head increased from 5m to 13m. Hence, coefficient of variation decreased as the operating pressure head increased.

4.4.2 Coefficient of Variation for Micro-tubes

The values of coefficient of variation for micro-tubes at different spacing and operating pressure heads are given in Table 4.10 and shown in Figure 4.10.

Table 4.10: Coefficient of variation of micro-tube with different spacing and operating pressure heads

Emission Device	Spacing (meter)	Operating pressure head (meter)	Coefficient of variation (percent)
Micro tube	6 x 6	5	24.41
Micro tube	6 x 6	10	22.36
Micro tube	6 x 6	13	20.36
Micro tube	1 x 1	5	25.89
Micro tube	1 x 1	10	24.98
Micro tube	1 x 1	13	24.57

Micro tube	0.5 x 0.5	5	30.48
Micro tube	0.5 x 0.5	10	29.89
Micro tube	0.5 x 0.5	13	27.05

The values of coefficient of variation for micro-tubes at 6m x 6m, 1m x 1m and 0.5m x 0.5m spacing for operating pressure head from 5m to 13m varied from 24.41% to 20.36%, 25.89% to 24.57% and 30.48% to 27.05% respectively.

The maximum value of coefficient of variation was for 5m x 0.5m spacing at 5m operating pressure head and the minimum value was for 6m x 6m spacing at 13m operating pressure head.

The average measured discharge decreased from 54.478 to 15.734 (l/h) as spacing decreased from 6m x 6m to 0.5m x 0.5m (due to increase in number of emission devices). Thus the ratio of standard deviation to average discharge increased from 0.2036 to 0.3048 as he spacing decreased from 6m x 6m to 0.5m x 0.5m. Hence, coefficient of variation increased as the spacing decreased.

The, average discharge increased from 45.236 to 54.478 (l/h) as the operating pressure head increased from 5m to 13m for a particular spacing (6m x 6m). Thus, the ratio of standard deviation to average discharge decreased from 0.2441 to 0.2036 as the operating pressure head increased from 5m to 13m. Hence, coefficient of variation decreased as the operating pressure head increased.

4.4.3 Coefficient of Variation for Drip-in

The values of coefficient of variation for drip-in of different spacing and operating pressure heads are given in Table 4.11 and shown in Figure 4.11.

Table 4.11: Coefficient of variation of drip-in with different spacing and operating pressure heads

Emission Device	Spacing (meter)	Operating pressure head (meter)	Coefficient of variation (percent)
Drip-in	6 x 0.6	5	5.21
Drip-in	6 x 0.6	10	3.81
Drip-in	6 x 0.6	13	3.09
Drip-in	1 x 0.6	5	4.29
Drip-in	1 x 0.6	10	3.39
Drip-in	1 x 0.6	13	2.95
Drip-in	0.5 x 0.6	5	3.47
Drip-in	0.5 x 0.6	10	2.97

Drip-in	0.5 x 0.6	13	2.71

The values of coefficient of variation for drip-in at 6m x 0.6m, 1m x 0.6m and 0.5m x 0.6m spacing for operating pressure head from 5m to 13m varied from 5.21% to 3.09%, 4.29% to 2.95% and 3.47% to 2.71% respectively.

The maximum value of coefficient of variation was at 6m x 0.6m spacing at 5m operating pressure head and the minimum value was at 0.5m x 0.6m spacing and at 13m operating pressure head.

The average measured discharge increased from 1.140 to 2.646 (l/h) as the spacing decreased from 6m x 0.6m to 0.5m x 0.6m (due to close spacing with constant emission points). Thus the ratio of standard deviation to average discharge decreased from 0.0699 to 0.0374 as the spacing decreased from 6m x 0.6m to 0.5m x 0.6m. Hence, coefficient of variation decreased as the spacing decreased.

The average discharge increased from 1.140 to 2.437 (l/h) as the operating pressure head increased from 5m to 13m for a particular spacing (6m x 0.6m). Thus, the ratio of standard deviation to average discharge decreased from 0.0521 to 0.0309 as the operating pressure head increased from 5m to 13m. Hence, coefficient of variation decreased as the operating pressure head increased.

4.4.4 Coefficient of Variation for Drip tape

The values of coefficient of variation for drip tape at different spacing and operating pressure heads are given in Table 4.12 and shown in Figure 4.12.

Table 4.12: Coefficient of variation of drip tape with different spacing and operating pressure heads

Emission Device	Spacing (meter)	Operating pressure head (meter)	Coefficient of variation (percent)
Drip tape	6 x 0.3	5	6.99
Drip tape	6 x 0.3	10	5.90
Drip tape	6 x 0.3	13	5.76
Drip tape	1 x 0.3	5	6.13
Drip tape	1 x 0.3	10	5.56
Drip tape	1 x 0.3	13	4.81
Drip tape	0.5 x 0.3	5	5.71

Drip tape	0.5 x 0.3	10	4.84
Drip tape	0.5 x 0.3	13	3.74

The values of coefficient of variation for drip tape at 6m x 0.3m, 1m x 0.3m and 0.5m x 0.3m spacing for operating pressured head from 5m to 13m varied from 6.99% to 5.76%, 6.13% to 4.81% and 5.71% to 3.74% respectively.

The maximum value of coefficient of variation was at 6m x 0.3m spacing at 5m operating pressure head and the minimum value was at 0.5m x 0.3m spacing at 13m operating pressure head.

The average measured discharge increased from 0.839 to 1.354 (l/h) as the spacing decreased from 6m x 0.3m to 0.5m x 0.3m (due to close spacing with constant emission points). Thus the ratio of standard deviation to average discharge decreased from 0.0699 to 0.0374 as the spacing decreased from 6m x 0.3m to 0.5m x 0.3m. Hence, coefficient of variation decreased as the spacing decreased.

The average discharge increased from 0.839 to 1.086 (l/h) as the operating pressure head increased from 5m to 13m for particular spacing (6m x 0.3m). Thus, the ratio of standard deviation to average discharge decreased from 0.0699 to 0.0576 as the operating pressure head increased from 5m to 13m. Hence, coefficient of variation decreased as the operating pressure head increased.

4.5 Coefficient of Manufacturing Variation

The values of coefficient of manufacturing variation were calculated from Equation 3.4 using the measured value of water collected in containers as explained in article 3.5 for different emission devices at different operating pressure heads (Appendix-II). The discharge was measured at one point under the same operating conditions. Thus for all spacing, the coefficient of manufacturing variation remained constant at a particular operating pressure head.

The values of coefficient of manufacturing variation for different emission devices at different operating pressure heads are given in Table 4.13 and shown in Figure 4.13.

Table 4.13: Coefficient of manufacturing variation of different emission devices at different operating pressure heads

Emission Device	Operating pressure head (meter)	Coefficient of manufacturing variation (percent)
Dripper	5	0.72
Dripper	10	0.60
Dripper	13	0.85
Micro-tube	5	0.14

Micro-tube	10	0.10
Micro-tube	13	0.09
Drip-in	5	1.56
Drip-in	10	1.18
Drip-in	13	1.07
Drip tape	5	1.75
Drip tape	10	1.89
Drip tape	13	1.95

The values of coefficient of manufacturing variation for drippers, micro-tubes, drip-in and drip tape for operating pressure head from 5m to 13m varied from 0.72% to 0.85%, 0.14% to 0.09%, 1.56% to 1.07% and 1.75% to 1.95% respectively.

The maximum value of coefficient of manufacturing variation was for drip tape at 13m operating pressure head and the minimum value was for micro-tubes at 5m operating pressure head.

The coefficient of manufacturing variation decreased with operating pressure head for micro-tube and drip-in, where as increased for dripper and drip tape. The variation was largest for drip-in and smallest for micro-tube.

4.6 Head Loss

The pressure head at different points in the system for different emission devices was measured with the help of mercury manometer and water manometer. The measured values of the pressure head in main line and lateral line for different emission devices at different operating pressure heads are given in Appendix-I. The head loss was calculated by loss in the pressure head in actual length of main line and lateral line for different emission devices considering Reduce Level (RL) of different point along the main line and the lateral line. The head loss was converted to m/100m by using following formula.

$$\text{Head loss (m/100m)} = \frac{\text{Head loss (m) in actual length x 100}}{\text{Actual length (m)}}$$

4.6.1 Head Loss in Main Line and Lateral Line for Dripper

The values of head loss in main line and lateral line at different spacings and operating pressure heads for dripper are given in Table 4.14. The variation of the head loss with operating pressure head in the main line is shown in Figure 4.14 and for lateral line in Figure 4.15.

Table 4.14: Head loss in different part of system for dripper at different operating pressure heads and spacing

Spacing (meter)	Operating pressure head (meter)	Head loss (m/100m)	
		Part of system	
		Main line	Lateral line
6 x 6	5	0.696	1.632
	10	0.809	1.803
	13	0.941	1.987

1 x 1	5	1.393	2.845
	10	1.807	3.309
	13	2.294	3.616
0.5 x 0.5	5	2.308	3.631
	10	2.829	3.983
	13	3.196	4.249

The values of head loss (m/100m) in main line for dripper at 6m x 6m, 1m x 1m and 0.5m x 0.5m spacing for operating pressure head from 5m to 13m varied from 0.696 to .941, 1.393 to 2.294 and 2.308 to 3.196 respectively.

The values of head loss (m/100m) in lateral line for dripper at 6m x 6m, 1m x 1m and 0.5m x 0.5m spacing for operating pressure head from 5m to 13m varied from 1.632 to 1.987, 2.845 to 3.616 and 3.631 to 4.249 respectively.

The head loss in main line and lateral line was maximum at 0.5m x 0.5m spacing at 13m operating pressure head and minimum at 6m x 6m spacing at 5m operating pressure head.

4.6.2 Head Loss in Main Line and Lateral Line for Micro-tubes

The values of head loss in main line and lateral line at different spacings and operating pressure heads for micro-tubes are given in Table 4.15. The variation of head loss with operating pressure head in main line is shown in Figure 4.16 and for lateral line is shown in Figure 4.17.

The values of head loss (m/100m) in main line for micro-tubes at 6m x 6m, 1m x 1m and 0.5m x 0.5m spacing for operating pressure head 5m to 13m varied from 3.405 to 4.148, 4.632 to 6.116 and 4.174 to 5.621 respectively.

Table 4.15: Head loss in different part of system for micro-tubes at different operating pressure heads and spacing

Spacing (meter)	Operating pressure head (meter)	Head loss (m/100m)	
		Part of system	
		Main line	Lateral line
6 x 6	5	3.405	4.402
	10	3.864	11.578
	13	4.148	15.822
1 x 1	5	4.632	9.104
	10	5.589	26.925
	13	6.119	37.750
0.5 x 0.5	5	4.174	13.244
	10	4.967	37.061
	13	5.621	51.456

The values of head loss (m/100m) in lateral line for micro-tubes 6m x 6m, 1m x 1m and 0.5m x 0.5m spacing for operating pressure head from 5m to 13m varied from 4.402 to 15.822, 9.104 to 37.750 and 13.244 to 51.456 respectively.

The head loss in main line was maximum at 1m x 1m spacing at 13m operating pressure head and minimum at 6m x 6m at 5m operating pressure head.

The head loss in lateral line was maximum at 0.5m x 0.5m spacing at 13m operating pressure head and minimum at 6m x 6m spacing at 5m operating pressure head.

The head loss increased both for main line and lateral line as the operating pressure head increased.

4.6.3 Head Loss in Main Line and Lateral Line for Drip-in

The values of head loss in main line and lateral line at different spacings and operating pressure heads for drip-in are given in Table 4.16. The variation of head loss with operating pressure head in main line was shown in Figure 4.18 and for lateral line in Figure 4.19.

Table 4.16: Head loss in different part of system for drip-in at different operating pressure heads and spacing

Spacing (meter)	Operating pressure head (meter)	Head loss (m/100m)	
		Part of system	
		Main line	Lateral line
6 x 0.6	5	1.402	2.891
	10	2.317	3.665
	13	2.671	3.816
1 x 0.6	5	1.485	2.928
	10	2.329	3.681
	13	2.704	3.934
0.5 x 0.6	5	1.538	3.096
	10	2.405	3.713
	13	2.765	3.968

The values of head loss (m/100m) in main line for drip-in at 6m x 0.6m, 1m x 0.6m and 0.5m x 0.6m spacing for operating pressure head from 5m to 13m varied from 1.402 to 2.671, 1.485 to 2.704 and 1.538 to 2.765 respectively.

The values of head loss (m/100m) in lateral line for drip-in at 6m x 0.6m, 1m x 0.6m and 0.5m x 0.6m spacing for operating pressure head from 5m to 13m varied from 2.891 to 3.816, 2.928 to 3.934 and 3.096 to 3.968 respectively.

The head loss in main line and lateral line was maximum at 0.5m x 0.6m spacing at 13m operating pressure head and minimum at 6m x 0.6m spacing at 5m operating pressure head.

The head loss increased in main line and lateral line as the spacing decreased and as the operating pressure head increased.

4.6.4 Head Loss in Main Line and Lateral Line for Drip tape

The values of head loss in main line and lateral line at different spacing and operating pressure heads for drip tape are given in Table 4.17. The variation of head loss with operating pressure head in main line is shown in Figure 4.20 and for lateral line in Figure 4.21.

Table 4.17: Head loss in different part of system for drip tape at different operating pressure heads and spacing

Spacing (meter)	Operating pressure head (meter)	Head loss (m/100m)	
		Part of system	
		Main line	Lateral line
6 x 0.3	5	1.871	3.405
	10	2.366	3.749
	13	2.638	3.921
1 x 0.3	5	2.002	3.486
	10	2.511	3.787
	13	2.784	3.952
0.5 x 0.3	5	2.058	3.498
	10	2.599	3.855
	13	2.848	4.061

The values of head loss (m/100m) in main line for drip tape at 6m x 0.3m, 1m x 0.3m, and 0.5m x 0.3m spacing for operating pressure head from 5m to 13m varied from 1.871 to 2.638, 2.02 to 2.784 and 2.058 to 2.848 respectively.

The values of head loss (m/100m) in lateral line for drip tape at 6m x 0.3m, 1m x 0.3m and 0.5m x 0.3m spacing for operating pressure head from 5m to 13m varied from 3.405 to 3.921, 3.486 to 3.952 and 3.498 to 4.61 respectively.

The head loss in main line and lateral line was maximum at 0.5m x 0.3m spacing at 13m operating pressure head and the minimum was at 6m x 0.3m spacing at 5m operating pressure head.

The head loss increased in main line and lateral line as the spacing decreased and as the operating pressure head increased.

4.6.5 Variation of Head Loss with Discharge in Main Line and Lateral Line for Different Emission Devices

The change in spacing and/or the change in operating pressure head results change in discharge in different components of the system. Therefore, the head loss for a given system may be related with the discharge.

The variation of the head loss with discharge in the main line and lateral line for different emission devices is shown Figure 4.22 to 4.29. The head loss both for the main line and lateral line increased at a decreasing rate as the discharge increased for all emission devices.

The variation of the head loss with the discharge both for main line and lateral can be expressed by the following equation.

$$h = aQ^b \qquad \text{........... 4.1}$$

where,

h = head loss (m/100m)

Q = discharge (liter/hour)

a, b = coefficients

The values of the coefficients, a and b in Equation 4.1 and the value of the coefficient of correlation (R^2) were calculated for different emission devices using simple correlation. The calculated values are given in Table 4.18.

Table 4.18: Values of coefficients a and b and coefficient of correlation (R^2) of different equations for main line and lateral line for different emission devices.

Emission Devices	**Part of system**

	Main line			Lateral Line		
	a	**b**	R^2	**a**	**b**	R^2
Dripper	0.056	0.576	0.987	0.490	0.374	0.997
Micro-tube	0.018	0.733	0.993	4.31×10^{-7}	2.690	0.798
Drip-in	0.012	0.816	0.998	0.488	0.375	0.994
Drip tape	0.008	0.881	0.998	0.484	0.377	0.989
All combined	0.045	0.610	0.987	0.045	0.863	0.720

4.6.6 Variation of Head Loss with Discharge in Main Line and Lateral Line Combined for All Emission Devices

The variation of the head loss with discharge in main line and lateral line combined for all emission devices is shown in Figure 4.30 and 4.31 respectively. The head loss increased at a decreasing rate as the discharged increased.

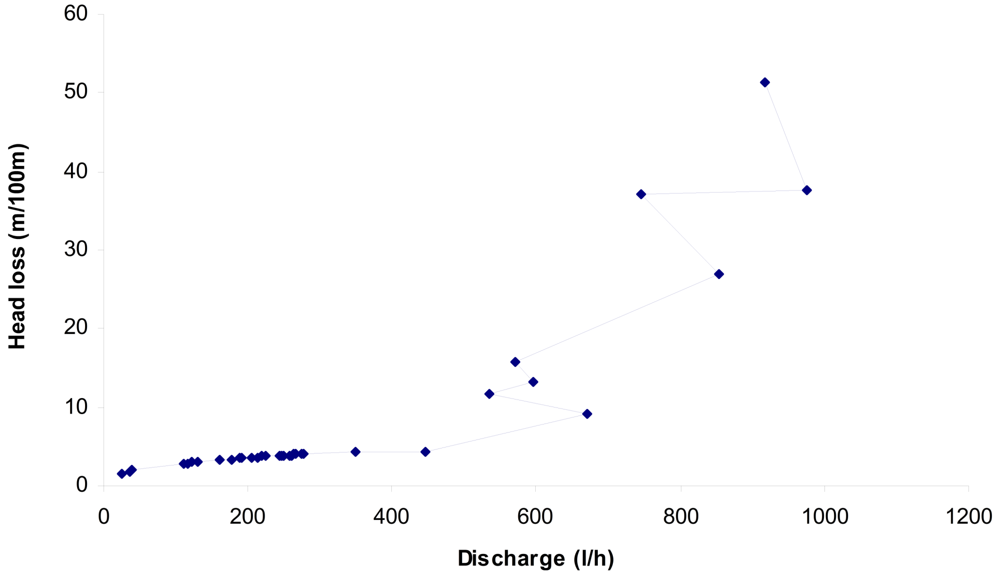

Figure 4.31: Variation of head loss with discharge in lateral line combined of all emission devices

The variation of the head loss with discharge combined for all emission devices can also be expressed by Equation 4.1. The values of the coefficients, a and b and coefficient of correlation (R^2) combined for all emission devices were calculated using simple correlation. The calculated values are given in Table 4.18.

The measured values of the head loss and the calculated values of the head loss from Equation 4.1 combined for all emission devices both for the main line and lateral line are given in Table 4.19. The calculated values from Equation 4.1 compared very well with the measured values.

4.7 Computer Programme for Software

The computer programme for software for hydraulic performance evaluation measures and for calculation of head loss in drip irrigation system was written is C++ language and is given in Appendix-III. The values of different hydraulic performance evaluation measures and head loss in main line and lateral line were calculated using computer software (Table 4.20). The calculated values are same as the measured values. Thus the developed computer software for the calculation of hydraulic performance evaluation measures and head loss is correct.

4.8 Interaction of Lateral Spacing and Operating Pressure Heads on Discharge of Different Emission Devices

The interaction of lateral spacing and operating pressure heads on discharge of different emission devices was found by analysis of data using 3 factor RBD. By the analysis, mean Tables with C.D. was found (given in Appendix-IV). The interaction of lateral spacing and operating pressure heads on discharge of different emission devices is given is Table 4.21.

Table 4.19: Measured head loss and calculated head loss combined for all emission devices at different spacing and different operating pressure head

Emission device	Spacing (m)	Operating Pressure head (m)	Discharge in main line (l/h)	Measured Head loss in main line (m/100 m)	Head loss in main line calculated by developed equation (m /100m)	Discharge in Lateral line (l/h)	Measured Head loss in Lateral line (m/100 m)	Head loss in Lateral line Calculated by developed equation (m /100m)
Drippers	6 x 6	5	74.95	0.696	0.631	25.02	1.632	0.718
Drippers	6 x 6	10	106.34	0.809	0.781	35.77	1.803	0.978
Drippers	6 x 6	13	121.08	0.941	0.845	39.87	1.987	1.074
Drippers	1 x 1	5	329.64	1.393	1.557	109.74	2.845	2.574
Drippers	1 x 1	10	481.98	1.807	1.963	160.32	3.309	3.569
Drippers	1 x 1	13	617.04	2.294	2.282	204.78	3.616	4.409
Drippers	0.5 x 0.5	5	618.84	2.308	2.286	206.28	3.631	4.437
Drippers	0.5 x 0.5	10	819.48	2.829	2.713	273.84	3.983	5.665
Drippers	0.5 x 0.5	13	1039.68	3.196	3.137	348.12	4.249	6.969
Micro-tubes	6 x 6	5	1357.09	3.405	3.691	446.4	4.402	8.636
Micro-tubes	6 x 6	10	1542.54	3.864	3.990	536.06	11.578	10.113
Micro-tubes	6 x 6	13	1634.34	4.148	4.134	570.41	15.822	10.670
Micro-tubes	1 x 1	5	1988.67	4.632	4.659	669.58	9.104	12.253
Micro-tubes	1 x 1	10	2550.98	5.589	5.423	853.01	26.925	15.099
Micro-tubes	1 x 1	13	2934.89	6.116	5.970	974.74	37.750	16.941
Micro-tubes	0.5 x 0.5	5	1699.34	4.174	4.233	594.61	13.244	11.060

Cont-d

Micro-tubes	0.5 x 0.5	10	2164.97	4.967	4.907	745.56	37.061	13.443
Micro-tubes	0.5 x 0.5	13	2589.7	5.621	5.473	916.16	51.456	16.059
drip-in	6 x 0.6	5	342	1.402	1.592	117.5	2.891	2.73
drip-in	6 x0.6	10	625.4	2.317	2.301	212.4	3.665	4.55
drip-in	6 x0.6	13	731	2.671	2.531	247	3.816	5.18
drip-in	1 x0.6	5	355.4	1.485	1.630	120.7	2.928	2.789
drip-in	1 x0.6	10	628.9	2.329	2.309	212.4	3.681	4.550
drip-in	1 x0.6	13	766.5	2.704	2.605	261.5	3.934	5.444
drip-in	0.5 x0.6	5	389.4	1.538	1.724	130.9	3.096	2.997
drip-in	0.5 x0.6	10	654.7	2.405	2.366	220	3.713	4.690
drip-in	0.5 x0.6	13	793.9	2.765	2.661	266.1	3.968	5.527
Drip tape	6 x0.3	5	503.2	1.871	2.015	177	3.405	3.888
Drip tape	6 x0.3	10	651.6	2.366	2.359	223.6	3.749	4.756
Drip tape	6 x0.3	13	744	2.638	2.558	258.6	3.921	5.392
Drip tape	1 x0.3	5	538.6	2.002	2.101	188.6	3.486	4.107
Drip tape	1 x0.3	10	698.4	2.511	2.461	243	3.787	5.110
Drip tape	1 x0.3	13	773.2	2.784	2.619	263.6	3.952	5.482
Drip tape	0.5 x0.3	5	556.8	2.058	2.144	190.2	3.498	4.137
Drip tape	0.5 x0.3	10	731.6	2.599	2.532	249.2	3.855	5.223
Drip tape	0.5 x0.3	13	812.2	2.848	2.699	276	4.061	5.704

Table 4.20: Calculated values of different measures and head loss by computer programme for different emission devices at different spacing and different operating pressure heads

Emission device	Spacing (m)	Operating pressure head (m)	Uniformity coefficient (%)	Emission uniformity (%)	Coefficient of variation (%)	Coefficient of manufacturing variation (%)	Head loss in main line calculated by developed equation (m /100m)	Head loss in Lateral line calculated by developed equation (m /100m)
Drippers	6 x 6	5	98.02	95.45	2.57	0.72	0.629	1.631
Drippers	6 x 6	10	98.46	97.12	1.93	0.60	0.779	1.865
Drippers	6 x 6	13	98.78	97.51	1.53	0.85	0.843	1.943
Drippers	1 x 1	5	96.19	92.33	4.48	0.72	1.551	2.842
Drippers	1 x 1	10	97.47	94.15	3.08	0.60	1.954	3.277
Drippers	1 x 1	13	97.87	95.09	2.64	0.85	2.272	3.592
Drippers	0.5 x 0.5	5	95.57	91.91	5.19	0.72	2.276	3.602
Drippers	0.5 x 0.5	10	96.19	92.55	4.37	0.60	2.700	4.007
Drippers	0.5 x 0.5	13	96.70	92.79	3.89	0.85	3.121	4.385
Micro-tubes	6 x 6	5	78.40	60.55	24.41	0.14	3.671	4.409
Micro-tubes	6 x 6	10	80.64	62.94	22.36	0.10	3.969	11.491
Micro-tubes	6 x 6	13	82.43	64.84	20.36	0.09	4.111	15.905
Micro-tubes	1 x 1	5	77.71	60.34	25.89	0.14	4.633	9.459
Micro-tubes	1 x 1	10	78.27	61.11	24.98	0.10	5.392	24.148
Micro-tubes	1 x 1	13	79.58	62.24	24.57	0.09	5.872	40.472
Micro-tubes	0.5 x 0.5	5	73.91	59.07	30.48	0.14	4.210	14.655

Micro-tubes	0.5 x 0.5	10	75.11	60.05	29.89	0.10	4.879	29.971
Micro-tubes	0.5 x 0.5	13	76.56	60.84	27.05	0.09	5.442	[illegible]
drip-in	6 x 0.6	5	95.73	90.51	5.21	1.56	1.586	[illegible]
drip-in	6 x0.6	10	96.78	92.25	3.81	1.18	2.290	[illegible]
drip-in	6 x0.6	13	97.43	93.53	3.09	1.07	2.519	[illegible]
drip-in	1 x0.6	5	96.52	91.77	4.29	1.56	1.623	2.945
drip-in	1 x0.6	10	97.05	93.78	3.39	1.18	2.298	3.642
drip-in	1 x0.6	13	97.66	94.25	2.95	1.07	2.593	3.938
drip-in	0.5 x0.6	5	97.12	93.46	3.47	1.56	1.716	3.037
drip-in	0.5 x0.6	10	97.48	94.40	2.97	1.18	2.355	3.690
drip-in	0.5 x0.6	13	97.75	94.74	2.71	1.07	2.649	3.964
Drip tape	6 x0.3	5	94.28	84.77	6.99	1.75	2.006	3.401
Drip tape	6 x0.3	10	95.18	86.08	5.90	1.89	2.348	3.713
Drip tape	6 x0.3	13	95.37	87.11	5.76	1.95	2.546	3.921
Drip tape	1 x0.3	5	94.93	86.85	6.13	1.75	2.091	3.483
Drip tape	1 x0.3	10	95.37	87.81	5.56	1.89	2.450	3.831
Drip tape	1 x0.3	13	96.01	89.31	4.81	1.95	2.606	3.950
Drip tape	0.5 x0.3	5	95.22	89.13	5.71	1.75	2.134	3.494
Drip tape	0.5 x0.3	10	95.89	90.87	4.84	1.89	2.520	3.867
Drip tape	0.5 x0.3	13	96.93	91.82	3.74	1.95	2.686	4.019

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Table 4.21: Results of analysis

Emission Device	Spacing (meter)	C.D. of A x B x C	C.D of A x B	C.D of A x C	C.D of B x C	C.D of A	C.D of B	C.D of C
Drippers	6 x 6	N.S	0.012	0.022	0.022	0.007	0.007	0.012
	1 x1	0.024	0.008	0.014	0.014	0.004	0.004	0.008
	0.5 x 0.5	0.021	0.007	0.012	0.012	0.004	0.004	0.007
Micro-tubes	6 x6	0.828	0.262	0.478	0.478	0.151	0.151	0.276
	1 x1	1.505	0.753	0.869	0.869	0.434	0.434	0.502
	0.5 x0.5	0.449	0.259	0.259	0.259	0.150	0.150	0.150
Drip-in	6 x0.6	0.019	0.006	0.011	0.011	0.003	0.003	N.S
	1 x0.6	0.017	0.005	0.010	0.010	0.003	0.003	0.006
	0.5 x0.6	0.021	0.007	0.012	0.012	0.004	0.004	0.007
Drip-tape	6 x0.3	0.021	0.007	0.012	0.012	0.004	0.004	0.007
	1 x0.3	0.018	0.006	0.010	0.010	0.003	0.003	0.006
	0.5 x0.3	0.020	0.006	0.012	N.S	0.004	0.004	N.S

Where,

A x B x C = Interaction of lateral spacing and operating pressure heads on discharges

A x B = Interaction between operating pressure heads and lateral spacing

A x C = Interaction between operating pressure heads and discharges

B x C = Interaction between lateral spacing and discharges

A = operating pressure heads

B = Lateral spacing

C = Discharges

The CD of interaction of lateral spacing and operating pressure heads on discharge was maximum at 1m x 1m spacing and minimum at 6m x 6m spacing for drippers. The CD of interaction between operating pressure heads and lateral spacing was maximum at 6m x 6m spacing and minimum was at 0.5m x 0.5m spacing. The CD of interaction between operating pressure heads and discharges was maximum at 6m x 6m spacing and minimum was at 0.5m x 0.5m spacing. The CD of interaction between lateral spacing and discharges was maximum at 6m x 6m spacing and minimum was at 0.5m x 0.5m spacing. The CD of operating pressure heads was maximum at 6m x 6m and minimum was at 0.5m x 0.5m spacing. The CD of lateral spacing was maximum at 6m x 6m spacing and minimum was at 0.5m x 0.5m spacing. The CD of discharges was maximum at 6m x 6m spacing and minimum was at 0.5m x 0.5m spacing.

The CD of interaction of lateral spacing and operating pressure heads on discharge was maximum at 1m x 1m spacing and minimum at 0.5m x 0.5m spacing for micro-tubes. The CD of interaction between operating pressure heads and lateral spacing was maximum at 1m x 1m spacing and minimum was at 0.5m x 0.5m spacing. The CD of interaction between operating pressure heads and discharges was maximum at 1m x 1m spacing and minimum was at 0.5m x 0.5m spacing. The CD of interaction between lateral spacing and discharges was maximum at 1m x 1m spacing and minimum was at 0.5m x 0.5m spacing. The CD of operating pressure heads was maximum at 1m x 1m and minimum was at 0.5m x 0.5m spacing. The CD of lateral spacing was maximum at 1m x 1m spacing and minimum was at 0.5m x 0.5m spacing. The CD of discharges was maximum at 1m x 1m spacing and minimum was at 0.5m x 0.5m spacing.

The CD of interaction of lateral spacing and operating pressure heads on discharge was maximum at 0.5m x 0.6m spacing and minimum at 1m x 0.6m spacing for drip-in. The CD of interaction between operating pressure heads and lateral spacing was maximum at 0.5m x 0.6m spacing and minimum was at 1m x 0.6m spacing. The CD of interaction between operating pressure heads and discharges was maximum at 0.5m x 0.6m spacing and minimum was at 1m x 0.6m spacing. The CD of interaction between lateral spacing and discharges was maximum at 0.5m x 0.6m spacing and minimum was at 1m x 0.6m spacing. The CD of operating pressure heads was maximum at 0.5m x 0.6m and minimum was at 1m x 0.6m and 6m x 0.6m spacing. The CD of lateral spacing was maximum at 0.5m x 0.6m spacing and minimum was at 1m x 0.6m and 6m x 0.6m spacing. The CD of discharges was maximum at 0.5m x 0.6m spacing and minimum was at 6m x 0.6m spacing.

The CD of interaction of lateral spacing and operating pressure heads on discharge was maximum at 6m x 0.3m spacing and minimum at 1m x 0.3m spacing for drip tape. The CD of interaction between operating pressure heads and lateral spacing was maximum at 6m x 0.3m spacing and minimum was at 1m x 0.3m and 0.5m x 0.3m spacing. The CD of interaction between operating pressure heads and discharges was maximum at 6m x 0.3m and 0.5m x 0.3m spacing and minimum was at 1m x 0.3m spacing. The CD of interaction between lateral spacing and discharges was maximum at 6m x 0.3m spacing and minimum was at 0.5m x 0.3m spacing. The CD of operating pressure heads was maximum at 6m x 0.3m and 0.5m x 0.3m spacing and minimum was at 1m x 0.3m spacing. The CD of lateral spacing was maximum at 6m x 0.3m and 0.5m x 0.3m spacing and minimum was at 1m x 0.3m spacing. The CD of discharges was maximum at 6m x 0.3m spacing and minimum was at 0.5m x 0.3m spacing.

CHAPTER – V

Summary and Conclusion

The present study was conducted for evaluation the effect of operating pressure head and spacing on different hydraulic performance evaluation measures of drip irrigation systems with different emission devices. The commonly used hydraulic performance evaluation measures were uniformity coefficient, emission uniformity, coefficient of variation and coefficient of manufacturing variation. The different emission devices were dripper, micro-tube, drip-in and drip tape. The experiment was conducted in the field laboratory of Soil and Water Engineering Department of College of Agricultural Engineering and Technology at CCS Haryana Agricultural University, Hisar. The selected spacings were i) 6m x 6m, 1m x 6m and 0.5m x 0.5m for dripper and micro-tube ii) 6m x 0.6m, 1m x 0.6m and 0.5m x 0.6m for drip-in and iii) 6m x 0.3m, 1m x 0.3m and 0.5m x 0.3m for drip tape. The operating pressure heads were 5m, 10m and 13m.

The measurements of discharge for calculation of hydraulic performance evaluation measures for each of the spacing, for each of operating pressure head and for each of emission devices were done by operating the system and putting the containers at 6m interval along the lateral line. The measurements of pressure head were done with the help of mercury manometer and water manometer at up stream and down stream end of main line and lateral line. The values of different hydraulic performance evaluation measures and head loss in main line and lateral line were calculated. The effect of the variation in the operating pressure head and in the spacing was studied. Empirical equations for calculations of the head loss with system discharge were developed. A computer software in C++ language was developed for calculation of the hydraulic performance evaluation measures and head loss in main line and lateral line of system. Some of the results of the study are as under:

(1) The lowest values of uniformity coefficient and emission uniformity were 73.91% and 59.07%, respectively for micro-tubes at 0.5 x 0.5m spacing and at 5m operating pressure head. The highest values are 98.78% and 97.5% respectively for drippers at 6m x 6m spacing and at 13m operating pressure head.

(2) The lowest value of coefficient of variation was 1.53% for dripper at 6m x 6m spacing and at 13m operating pressure head. The highest value was 30.48% for micro-tubes at 0.5m x 0.5m spacing and at 5m operating pressure head.

(3) Uniformity coefficient and emission uniformity for drippers and micro-tubes, decreased as the spacing decreased, where as, for drip-in and drip tape, the uniformity coefficient and emission uniformity increased as the spacing decreased.

(4) Coefficient of variation for drippers and micro-tubes, increased as the spacing decreased, where as for drip-in and drip tape, the coefficient of variation decreased as the spacing decreased.

(5) Coefficient of manufacturing variation was lowest equal to 0.09% for micro-tubes at 13m operating pressure head and

was highest equal to 1.95% for drip tape at 13m operating pressure head.

(6) The uniformity coefficient and emission uniformity, at a particular spacing for all emission devices, increased as the operating pressure head increased, where as the coefficient of variation, decreased as the operating pressure head increased.

(7) Head loss (m/100m) in main line was lowest equal to 0.696 for drippers at 6m x 6m spacing and at 5m operating pressure head and highest equal to 5.621 for micro-tubes at 0.5m x 0.5m spacing and at 13m operating pressure head.

(8) The Head loss (m/100m) in lateral line was lowest equal to 1.632 for drippers at 6m x 6m spacing and at 5m operating pressure head. The highest value equal to 51.456 was for micro-tubes at 0.5 x 0.5m spacing and at 13m operating pressure head.

(9) The head loss (m/100m) at a particular spacing, for all the emission devices increased as the operating pressure head increased.

(10) The head loss in the main line and lateral lines for all the emissions devices increased at a decreasing rate. The variation of head loss (h) with discharge (Q) for each of the emissions devices as well as combined for all the emission devices could be expressed by following equation

$$h = aQ^b$$

where

a, b are coefficient

The values of coefficient of correlation (R^2) for different emission devices varied from 0.9981 to 0.9868 for main line and from

0.9974 to 0.7979 for lateral line of different emission devices. The values of coefficient of correlation (R^2) combined for all emission devices were 0.9871 and 0.7201 for main line and lateral line respectively.

(11) The computer prorgramme written in C++ language match the calculated values of different measures and head loss in different part of system for different emission devices with different spacing and operating pressure heads.

APPENDIX – I

Measured values of pressure head at different locations for dripper

Spacing (meter)	Pressure head (meter)			
	Locations			
	Upstream end of main line	Downstream end of main line	Upstream end of lateral	Downstream end lateral
6 x 6	5	4.832	4.681	3.511
	10	9.786	9.603	8.332
	13	12.734	12.530	11.147
1 x 1	5	4.553	4.327	2.430
	10	9.387	9.129	6.954
	13	12.192	11.919	9.560
0.5 x 0.5	5	4.187	3.909	1.540
	10	8.978	8.669	6.090
	13	11.832	11.509	8.769

Measured values of pressure head at different locations for micro-tube

Spacing (meter)	Pressure head (meter)			
	Locations			
	Upstream end of main line	Downstream end of main line	Upstream end of lateral	Downstream end lateral
6 x 6	5	3.748	3.416	0.585
	10	8.654	8.200	1.064
	13	11.451	11.070	1.387
1 x 1	5	3.257	2.824	0.439
	10	7.874	7.392	0.730
	13	10.664	10.156	0.896
0.5 x 0.5	5	3.440	3.049	0.655
	10	8.123	7.679	0.998

	13	10.862	10.377	1.105

Measured values of pressure head at different locations for drip-in

Spacing (meter)	Pressure head (meter)			
	Locations			
	Upstream end of main line	Downstream end of main line	Upstream end of lateral	Downstream end lateral
6 x 0.6	5	4.549	4.305	2.381
	10	9.183	8.881	6.492
	13	12.042	11.719	9.239
1 x 0.6	5	4.516	4.268	2.321
	10	9.178	8.869	6.471
	13	12.028	11.697	9.147
0.5 x 0.6	5	4.495	4.242	2.194
	10	9.148	8.832	6.414
	13	12.004	11.666	9.095

Measured values of pressure head at different locations for drip tape

Spacing (meter)	Pressure head (meter)			
	Locations			
	Upstream end of main line	Downstream end of main line	Upstream end of lateral	Downstream end lateral
6 x 0.3	5	4.362	4.075	1.842
	10	9.164	8.862	6.422
	13	12.055	11.724	9.181
1 x 0.3	5	4.309	4.015	1.734
	10	9.106	8.788	6.325
	13	11.996	11.655	9.094
0.5 x 0.3	5	4.287	3.989	1.700
	10	9.070	8.747	6.244

	13	11.971	11.617	8.990

APPENDIX - II

Measured values of discharge (liter/hour) for dripper at 6m x 6m spacing at 5m operating pressure head

LATERAL LINES											
L1				L2				L3			
R1	R2	R3	Avg.	R1	R2	R3	Avg.	R1	R2	R3	Avg.
2.620	2.608	2.668	**2.632**	2.618	2.614	2.630	**2.621**	2.641	2.665	2.677	**2.661**
2.564	2.552	2.528	**2.548**	2.532	2.500	2.552	**2.528**	2.572	2.552	2.564	**2.563**
2.544	2.532	2.516	**2.531**	2.504	2.548	2.520	**2.524**	2.540	2.520	2.488	**2.516**
2.548	2.496	2.544	**2.529**	2.476	2.524	2.536	**2.512**	2.552	2.524	2.540	**2.539**
2.492	2.484	2.500	**2.492**	2.468	2.488	2.444	**2.467**	2.508	2.464	2.516	**2.496**
2.488	2.468	2.472	**2.476**	2.484	2.460	2.472	**2.472**	2.476	2.484	2.456	**2.472**
2.468	2.500	2.452	**2.473**	2.480	2.436	2.492	**2.469**	2.496	2.532	2.520	**2.516**
2.484	2.432	2.504	**2.473**	2.460	2.444	2.424	**2.443**	2.504	2.460	2.512	**2.492**
2.448	2.460	2.456	**2.455**	2.418	2.390	2.402	**2.403**	2.484	2.428	2.480	**2.464**
2.397	2.429	2.405	**2.410**	2.392	2.364	2.400	**2.385**	2.399	2.371	2.407	**2.392**

Measured values of discharge (liter/hour) for dripper at 6m x 6m spacing at 10m operating pressure head

LATERAL LINES											
L1				L2				L3			
R1	R2	R3	Avg.	R1	R2	R3	Avg.	R1	R2	R3	Avg.
3.712	3.684	3.736	**3.711**	3.668	3.688	3.652	**3.669**	3.632	3.620	3.650	**3.634**
3.692	3.640	3.632	**3.655**	3.632	3.620	3.616	**3.623**	3.600	3.532	3.584	**3.572**
3.632	3.624	3.668	**3.641**	3.604	3.576	3.548	**3.576**	3.548	3.500	3.524	**3.524**
3.616	3.596	3.540	**3.584**	3.580	3.548	3.568	**3.565**	3.572	3.528	3.560	**3.553**
3.548	3.580	3.568	**3.565**	3.528	3.520	3.512	**3.520**	3.540	3.512	3.536	**3.529**
3.556	3.544	3.536	**3.545**	3.512	3.544	3.492	**3.516**	3.504	3.480	3.512	**3.499**
3.540	3.492	3.556	**3.529**	3.516	3.524	3.544	**3.528**	3.528	3.516	3.492	**3.512**
3.528	3.552	3.572	**3.551**	3.488	3.480	3.468	**3.479**	3.492	3.492	3.480	**3.488**
3.496	3.516	3.524	**3.512**	3.460	3.408	3.460	**3.443**	3.472	3.440	3.448	**3.453**

3.480	3.452	3.500	**3.477**	3.440	3.424	3.472	**3.445**	3.448	3.428	3.460	**3.445**

Measured values of discharge (liter/hour) for dripper at 6m x 6m spacing at 13m operating pressure head

LATERAL LINES											
L1				**L2**				**L3**			
R1	**R2**	**R3**	**Avg.**	**R1**	**R2**	**R3**	**Avg.**	**R1**	**R2**	**R3**	**Avg.**
4.078	4.138	4.110	**4.109**	4.040	4.088	4.052	**4.060**	4.052	4.060	4.028	**4.047**
4.070	4.106	4.122	**4.099**	4.022	4.066	4.054	**4.047**	4.036	3.988	4.000	**4.008**
4.066	4.074	4.086	**4.075**	4.002	3.966	4.010	**3.993**	4.008	3.991	3.984	**3.994**
3.952	3.988	3.964	**3.968**	3.956	3.964	4.016	**3.979**	3.990	4.022	4.018	**4.010**
4.008	3.968	3.988	**3.988**	3.984	3.968	3.944	**3.965**	3.968	3.988	3.920	**3.959**
3.952	3.920	3.976	**3.949**	3.980	3.968	4.012	**3.987**	3.976	3.924	3.932	**3.944**
3.934	3.950	3.958	**3.947**	3.948	3.960	4.008	**3.972**	3.978	3.946	3.934	**3.953**
3.946	3.962	3.950	**3.953**	3.880	3.908	3.952	**3.913**	3.956	3.976	3.912	**3.948**
3.962	3.926	3.894	**3.927**	3.856	3.900	3.908	**3.888**	3.904	3.928	3.856	**3.896**
3.900	3.948	3.888	**3.912**	3.848	3.892	3.896	**3.879**	3.852	3.908	3.868	**3.876**

Measured values of discharge (liter/hour) for dripper at 1m x 1m spacing at 5m operating pressure head

LATERAL LINES											
L1				**L2**				**L3**			
R1	**R2**	**R3**	**Avg.**	**R1**	**R2**	**R3**	**Avg.**	**R1**	**R2**	**R3**	**Avg.**
2.008	2.020	1.988	**2.005**	1.984	1.972	1.956	**1.971**	1.948	1.960	1.968	**1.959**
1.956	1.928	1.940	**1.941**	1.936	1.920	1.912	**1.923**	1.928	1.948	1.940	**1.939**
1.892	1.900	1.912	**1.901**	1.860	1.872	1.861	**1.864**	1.896	1.860	1.868	**1.875**
1.764	1.748	1.808	**1.773**	1.892	1.888	1.880	**1.887**	1.852	1.848	1.860	**1.853**
1.808	1.792	1.784	**1.795**	1.856	1.840	1.848	**1.848**	1.820	1.832	1.812	**1.821**
1.772	1.784	1.780	**1.779**	1.740	1.752	1.788	**1.760**	1.788	1.780	1.792	**1.787**
1.760	1.748	1.768	**1.759**	1.768	1.764	1.776	**1.769**	1.872	1.888	1.880	**1.880**
1.796	1.812	1.824	**1.811**	1.712	1.700	1.728	**1.713**	1.848	1.840	1.828	**1.839**

1.780	1.792	1.800	**1.791**	1.720	1.704	1.720	**1.715**	1.816	1.824	1.804	**1.815**
1.748	1.728	1.740	**1.739**	1.700	1.688	1.684	**1.691**	1.756	1.732	1.728	**1.739**

Measured values of discharge (liter/hour) for dripper at 1m x 1m spacing at 10m operating pressure head

LATERAL LINES											
L1				L2				L3			
R1	**R2**	**R3**	**Avg.**	**R1**	**R2**	**R3**	**Avg.**	**R1**	**R2**	**R3**	**Avg.**
2.852	2.840	2.824	**2.839**	2.804	2.816	2.836	**2.819**	2.820	2.792	2.804	**2.805**
2.760	2.772	2.740	**2.757**	2.784	2.764	2.772	**2.773**	2.788	2.768	2.780	**2.779**
2.740	2.728	2.716	**2.728**	2.720	2.728	2.744	**2.731**	2.736	2.736	2.688	**2.720**
2.632	2.616	2.644	**2.631**	2.756	2.748	2.724	**2.743**	2.712	2.712	2.692	**2.705**
2.684	2.660	2.672	**2.672**	2.696	2.680	2.700	**2.692**	2.648	2.648	2.620	**2.639**
2.576	2.568	2.592	**2.579**	2.668	2.652	2.676	**2.665**	2.640	2.640	2.644	**2.641**
2.600	2.612	2.628	**2.613**	2.640	2.648	2.628	**2.639**	2.708	2.708	2.700	**2.705**
2.676	2.680	2.696	**2.684**	2.556	2.528	2.572	**2.552**	2.700	2.700	2.684	**2.695**
2.628	2.644	2.660	**2.644**	2.508	2.500	2.556	**2.521**	2.656	2.656	2.680	**2.664**
2.580	2.508	2.624	**2.571**	2.536	2.544	2.520	**2.533**	2.580	2.580	2.592	**2.584**

Measured values of discharge (liter/hour) for dripper at 1m x 1m spacing at 13m operating pressure head

LATERAL LINES											
L1				L2				L3			
R1	**R2**	**R3**	**Avg.**	**R1**	**R2**	**R3**	**Avg.**	**R1**	**R2**	**R3**	**Avg.**
3.604	3.620	3.600	**3.608**	3.588	3.592	3.609	**3.596**	3.544	3.556	3.572	**3.557**
3.546	3.510	3.526	**3.527**	3.532	3.524	3.500	**3.519**	3.500	3.508	3.524	**3.511**
3.484	3.460	3.492	**3.479**	3.500	3.480	3.508	**3.496**	3.488	3.484	3.504	**3.492**
3.450	3.418	3.426	**3.431**	3.518	3.490	3.506	**3.505**	3.480	3.480	3.508	**3.489**
3.414	3.370	3.402	**3.395**	3.426	3.414	3.406	**3.415**	3.448	3.424	3.440	**3.437**
3.378	3.354	3.350	**3.361**	3.434	3.418	3.446	**3.433**	3.400	3.408	3.436	**3.415**
3.322	3.306	3.294	**3.307**	3.386	3.370	3.350	**3.369**	3.428	3.452	3.436	**3.439**

3.318	3.334	3.330	**3.327**	3.310	3.286	3.318	**3.305**	3.400	3.412	3.456	**3.423**
3.366	3.390	3.398	**3.385**	3.292	3.276	3.268	**3.279**	3.418	3.430	3.438	**3.429**
3.318	3.302	3.314	**3.311**	3.276	3.264	3.240	**3.260**	3.358	3.330	3.350	**3.346**

Measured values of discharge (liter/hour) for dripper at 0.5m x 0.5m spacing at 5m operating pressure head

LATERAL LINES											
L1				L2				L3			
R1	R2	R3	Avg.	R1	R2	R3	Avg.	R1	R2	R3	Avg.
1.885	1.897	1.865	**1.882**	1.894	1.870	1.878	**1.881**	1.878	1.898	1.890	**1.889**
1.829	1.833	1.813	**1.825**	1.830	1.822	1.810	**1.821**	1.821	1.841	1.829	**1.830**
1.792	1.820	1.808	**1.807**	1.806	1.778	1.790	**1.791**	1.789	1.805	1.797	**1.797**
1.769	1.753	1.737	**1.753**	1.728	1.740	1.752	**1.740**	1.756	1.736	1.744	**1.745**
1.740	1.712	1.732	**1.728**	1.720	1.704	1.716	**1.713**	1.708	1.728	1.720	**1.719**
1.716	1.700	1.684	**1.700**	1.704	1.668	1.676	**1.683**	1.700	1.680	1.696	**1.692**
1.664	1.680	1.668	**1.671**	1.658	1.650	1.642	**1.650**	1.682	1.674	1.630	**1.662**
1.622	1.642	1.634	**1.633**	1.651	1.639	1.635	**1.642**	1.643	1.655	1.647	**1.648**
1.602	1.630	1.614	**1.615**	1.648	1.620	1.628	**1.632**	1.639	1.651	1.625	**1.638**
1.571	1.591	1.579	**1.580**	1.599	1.583	1.611	**1.598**	1.616	1.596	1.608	**1.607**

Measured values of discharge (liter/hour) for dripper at 0.5m x 0.5m spacing at 10m operating pressure head

LATERAL LINES											
L1				L2				L3			
R1	R2	R3	Avg.	R1	R2	R3	Avg.	R1	R2	R3	Avg.
2.437	2.461	2.445	**2.448**	2.426	2.454	2.442	**2.441**	2.438	2.430	2.450	**2.439**
2.389	2.413	2.397	**2.400**	2.365	2.393	2.373	**2.377**	2.397	2.377	2.389	**2.388**
2.348	2.364	2.384	**2.365**	2.338	2.362	2.350	**2.350**	2.354	2.386	2.362	**2.367**
2.324	2.340	2.328	**2.331**	2.320	2.304	2.316	**2.313**	2.334	2.350	2.342	**2.342**
2.300	2.288	2.304	**2.297**	2.268	2.256	2.252	**2.259**	2.314	2.322	2.290	**2.309**
2.234	2.250	2.242	**2.242**	2.248	2.232	2.240	**2.240**	2.240	2.252	2.248	**2.247**
2.196	2.224	2.204	**2.208**	2.230	2.210	2.222	**2.221**	2.252	2.228	2.240	**2.240**

2.222	2.202	2.210	**2.211**	2.195	2.191	2.175	**2.187**	2.204	2.236	2.188	**2.209**
2.208	2.200	2.188	**2.199**	2.146	2.142	2.118	**2.135**	2.200	2.188	2.180	**2.189**
2.120	2.128	2.112	**2.120**	2.114	2.098	2.110	**2.107**	2.123	2.095	2.111	**2.110**

Measured values of discharge (liter/hour) for dripper at 0.5m x 0.5m spacing at 13m operating pressure head

LATERAL LINES											
L1				L2				L3			
R1	R2	R3	Avg.	R1	R2	R3	Avg.	R1	R2	R3	Avg.
3.100	3.084	3.096	**3.093**	3.068	3.060	3.092	**3.073**	3.088	3.076	3.108	**3.091**
3.018	2.990	3.002	**3.003**	2.994	2.982	2.978	**2.985**	3.010	3.018	3.030	**3.019**
3.031	3.018	3.010	**3.020**	2.966	2.958	2.954	**2.959**	2.994	2.982	3.006	**2.994**
2.967	2.962	2.974	**2.968**	2.932	2.904	2.920	**2.919**	2.888	2.900	2.892	**2.893**
2.950	2.934	2.958	**2.947**	2.904	2.876	2.884	**2.888**	2.830	2.818	2.838	**2.829**
2.830	2.850	2.842	**2.841**	2.844	2.852	2.848	**2.848**	2.818	2.838	2.830	**2.829**
2.826	2.806	2.814	**2.815**	2.830	2.786	2.810	**2.809**	2.900	2.880	2.908	**2.896**
2.846	2.818	2.830	**2.831**	2.836	2.808	2.824	**2.823**	2.822	2.810	2.810	**2.814**
2.814	2.786	2.798	**2.799**	2.741	2.713	2.721	**2.725**	2.870	2.798	2.786	**2.818**
2.716	2.680	2.692	**2.696**	2.693	2.669	2.677	**2.680**	2.750	2.722	2.730	**2.734**

Measured values of discharge (liter/hour) for micro-tube at 6m x 6m spacing at 5m operating pressure head

LATERAL LINES											
L1				L2				L3			
R1	R2	R3	Avg.	R1	R2	R3	Avg.	R1	R2	R3	Avg.
64.800	**64.528**	65.432	**64.920**	63.616	63.316	63.868	**63.600**	60.300	60.456	60.924	**60.560**
54.342	54.254	53.410	**54.002**	61.120	60.704	61.288	**61.037**	57.012	57.404	57.192	**57.203**
55.492	54.980	55.652	**55.375**	51.900	50.600	51.984	**51.495**	57.920	58.428	58.096	**58.148**
58.340	58.412	59.436	**58.729**	49.296	49.856	49.084	**49.412**	50.912	51.796	50.768	**51.159**
43.600	43.348	43.336	**43.428**	40.240	40.420	40.428	**40.363**	46.368	47.092	47.436	**46.965**
37.936	38.008	38.904	**38.283**	46.580	47.352	47.844	**47.259**	36.064	36.964	36.300	**36.443**
36.100	36.668	36.368	**36.379**	43.640	43.504	43.856	**43.667**	34.680	34.900	35.452	**35.011**
37.524	37.976	34.604	**36.701**	40.640	41.168	40.424	**40.744**	34.936	35.612	34.240	**34.929**
31.212	31.044	31.328	**31.195**	38.136	38.904	37.968	**38.336**	32.904	34.008	34.292	**33.735**

27.290	27.726	27.162	**27.393**	30.900	30.572	29.952	**30.475**	30.100	29.588	30.748	**30.145**

Measured values of discharge (liter/hour) for micro-tube at 6m x 6m spacing at 10m operating pressure head

LATERAL LINES											
L1				**L2**				**L3**			
R1	**R2**	**R3**	**Avg.**	**R1**	**R2**	**R3**	**Avg.**	**R1**	**R2**	**R3**	**Avg.**
73.240	73.708	73.408	**73.452**	69.008	69.516	69.572	**69.365**	67.500	67.804	67.616	**67.640**
60.624	60.369	60.864	**60.619**	64.512	64.328	64.700	**64.513**	66.608	65.652	65.516	**65.925**
65.176	65.300	64.996	**65.157**	55.480	55.708	56.048	**55.745**	65.200	65.716	65.328	**65.415**
67.444	67.984	67.660	**67.696**	51.980	51.852	52.516	**52.116**	56.340	56.848	57.376	**56.855**
53.032	53.236	53.524	**53.264**	43.292	43.780	43.176	**43.416**	49.632	51.260	51.980	**50.957**
47.208	47.556	47.732	**47.499**	49.628	50.072	49.844	**49.848**	42.660	42.344	42.912	**42.639**
44.672	44.816	44.504	**44.664**	46.940	47.296	47.188	**47.141**	36.428	36.236	36.748	**36.471**
46.720	46.872	46.988	**46.860**	43.680	43.972	43.544	**43.732**	42.384	42.556	42.492	**42.477**
36.052	36.608	36.340	**36.333**	42.024	41.888	42.284	**42.065**	32.052	32.688	32.356	**32.365**
40.200	40.864	40.488	**40.517**	36.616	36.868	36.568	**36.684**	40.836	41.380	41.096	**41.104**

Measured values of discharge (liter/hour) for micro-tube at 6m x 6m spacing at 13m operating pressure head

LATERAL LINES											
L1				**L2**				**L3**			
R1	**R2**	**R3**	**Avg.**	**R1**	**R2**	**R3**	**Avg.**	**R1**	**R2**	**R3**	**Avg.**
76.500	75.488	77.416	**76.468**	71.656	71.192	72.488	**71.779**	70.360	69.328	69.784	**69.824**
63.368	64.388	63.172	**63.643**	67.680	67.484	67.940	**67.701**	67.700	67.060	67.408	**67.389**
67.896	69.160	67.352	**68.136**	52.520	53.008	52.676	**52.735**	68.408	68.116	68.652	**68.392**
69.828	71.804	70.916	**70.849**	55.532	55.944	54.860	**55.445**	59.900	59.624	60.312	**59.945**
58.740	56.492	58.084	**57.772**	45.780	46.240	45.584	**45.868**	53.920	54.008	53.576	**53.835**
49.648	47.768	48.972	**48.796**	53.152	53.456	53.236	**53.281**	46.912	46.732	47.120	**46.921**
47.220	49.460	47.728	**48.136**	50.680	49.988	50.408	**50.359**	39.908	39.668	40.144	**39.907**
48.572	49.344	50.024	**49.313**	48.304	48.728	48.900	**48.644**	46.216	45.912	45.748	**45.959**

42.640	41.964	43.500	**42.701**	46.112	45.884	47.316	**46.437**	34.960	35.740	35.284	**35.328**
44.388	45.312	44.084	**44.595**	39.580	39.948	39.016	**39.515**	44.392	44.728	44.900	**44.673**

Measured values of discharge (liter/hour) for micro-tube at 1m x 1m spacing at 5m operating pressure head

LATERAL LINES											
L1				**L2**				**L3**			
R1	**R2**	**R3**	**Avg.**	**R1**	**R2**	**R3**	**Avg.**	**R1**	**R2**	**R3**	**Avg.**
36.872	37.368	34.620	**36.287**	35.608	36.784	36.940	**36.444**	34.940	35.648	35.792	**35.460**
32.244	31.996	31.804	**32.015**	29.113	28.328	36.330	**31.257**	31.644	30.784	31.140	**31.189**
26.068	26.448	25.860	**26.125**	26.392	25.876	27.044	**26.437**	25.542	25.790	25.442	**25.591**
17.092	16.860	17.552	**17.168**	17.080	17.304	16.028	**16.804**	16.570	16.342	17.082	**16.665**

Measured values of discharge (liter/hour) for micro-tube at 1m x 1m spacing at 10m operating pressure head

LATERAL LINES											
L1				**L2**				**L3**			
R1	**R2**	**R3**	**Avg.**	**R1**	**R2**	**R3**	**Avg.**	**R1**	**R2**	**R3**	**Avg.**
49.696	48.564	49.540	**49.267**	46.796	46.104	45.990	**46.297**	46.638	47.418	47.214	**47.090**
38.080	39.264	38.972	**38.772**	38.420	38.764	38.184	**38.456**	38.875	38.533	39.241	**38.883**
31.724	31.200	31.552	**31.492**	29.432	29.980	30.088	**29.833**	33.713	33.217	34.005	**33.645**
24.584	24.888	24.440	**24.637**	25.048	25.628	24.736	**25.137**	21.240	21.980	21.736	**21.652**

Measured values of discharge (liter/hour) for micro-tube at 1m x 1m spacing at 13m operating pressure head

LATERAL LINES											
L1				**L2**				**L3**			
R1	**R2**	**R3**	**Avg.**	**R1**	**R2**	**R3**	**Avg.**	**R1**	**R2**	**R3**	**Avg.**
56.324	56.832	57.288	**56.815**	54.276	55.692	53.940	**54.636**	52.296	51.400	52.148	**51.948**

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41.652	43.112	41.490	**42.085**	45.148	46.224	45.396	**45.589**	43.460	43.168	43.684	**43.437**
38.312	37.780	38.460	**38.184**	39.784	38.656	39.568	**39.336**	35.756	34.900	36.216	**35.624**
25.326	25.826	24.962	**25.371**	27.648	27.188	26.296	**27.044**	28.676	29.744	28.820	**29.080**

Measured values of discharge (liter/hour) for micro-tube at 0.5m x 0.5m spacing at 5m operating pressure head

LATERAL LINES											
L1				L2				L3			
R1	R2	R3	Avg.	R1	R2	R3	Avg.	R1	R2	R3	Avg.
22.484	22.340	22.700	**22.508**	21.852	21.384	21.980	**21.739**	21.000	21.168	20.744	**20.971**
16.224	16.392	15.960	**16.192**	15.338	15.550	15.242	**15.377**	14.476	14.176	14.712	**14.455**
10.828	10.688	11.036	**10.851**	10.210	10.362	10.098	**10.223**	9.268	9.460	9.156	**9.295**

Measured values of discharge (liter/hour) for micro-tube at 0.5m x 0.5m spacing at 10m operating pressure head

LATERAL LINES											
L1				L2				L3			
R1	R2	R3	Avg.	R1	R2	R3	Avg.	R1	R2	R3	Avg.
28.328	28.060	28.508	**28.299**	27.420	27.852	27.160	**27.477**	26.356	26.088	26.520	**26.321**
20.572	20.756	20.284	**20.537**	20.272	19.924	19.576	**19.924**	19.570	19.790	19.334	**19.565**
13.316	13.540	13.028	**13.295**	13.100	13.216	12.560	**12.959**	12.038	12.266	11.814	**12.039**

Measured values of discharge (liter/hour) for micro-tube at 0.5m x 0.5m spacing at 13m operating pressure head

LATERAL LINES											
L1				L2				L3			
R1	R2	R3	Avg.	R1	R2	R3	Avg.	R1	R2	R3	Avg.
32.820	32.768	33.028	**32.872**	31.480	31.656	31.140	**31.425**	29.708	29.456	29.380	**29.515**
26.884	26.984	26.736	**26.868**	24.392	25.292	23.828	**24.504**	23.672	23.560	22.748	**23.327**
16.148	16.452	16.020	**16.207**	16.448	16.360	16.704	**16.504**	14.572	14.280	14.912	**14.588**

Measured values of discharge (liter/hour) for drip-in at 6m x 0.6m spacing at 5m operating pressure head

LATERAL LINES											
L1				L2				L3			
R1	R2	R3	Avg.	R1	R2	R3	Avg.	R1	R2	R3	Avg.
1.264	1.280	1.268	**1.271**	1.220	1.208	1.236	**1.221**	1.172	1.168	1.180	**1.173**
1.232	1.228	1.244	**1.235**	1.184	1.196	1.216	**1.199**	1.160	1.148	1.148	**1.152**
1.208	1.224	1.236	**1.223**	1.192	1.176	1.188	**1.185**	1.132	1.140	1.128	**1.133**
1.220	1.236	1.200	**1.219**	1.168	1.156	1.180	**1.168**	1.140	1.116	1.124	**1.127**
1.176	1.188	1.160	**1.175**	1.148	1.140	1.120	**1.136**	1.104	1.100	1.112	**1.105**
1.156	1.168	1.144	**1.156**	1.160	1.188	1.168	**1.172**	1.112	1.076	1.100	**1.096**
1.164	1.120	1.152	**1.145**	1.136	1.120	1.148	**1.135**	1.088	1.072	1.096	**1.085**
1.128	1.112	1.140	**1.127**	1.096	1.088	1.112	**1.099**	1.060	1.048	1.072	**1.060**
1.108	1.100	1.116	**1.108**	1.064	1.060	1.060	**1.061**	1.072	1.080	1.056	**1.069**
1.100	1.080	1.108	**1.096**	1.056	1.040	1.032	**1.043**	1.028	1.044	1.024	**1.032**

Measured values of discharge (liter/hour) for drip-in at 6m x 0.6m spacing at 10m operating pressure head

LATERAL LINES											
L1				L2				L3			
R1	R2	R3	Avg.	R1	R2	R3	Avg.	R1	R2	R3	Avg.
2.224	2.252	2.236	**2.237**	2.190	2.178	2.194	**2.187**	2.164	2.148	2.172	**2.161**
2.204	2.220	2.212	**2.212**	2.166	2.150	2.158	**2.158**	2.142	2.130	2.166	**2.146**
2.202	2.182	2.190	**2.191**	2.135	2.155	2.130	**2.140**	2.118	2.106	2.126	**2.117**
2.158	2.150	2.166	**2.158**	2.116	2.112	2.132	**2.120**	2.100	2.108	2.089	**2.099**
2.124	2.140	2.132	**2.132**	2.090	2.110	2.094	**2.098**	2.068	2.074	2.060	**2.067**
2.116	2.108	2.108	**2.111**	2.052	2.068	2.060	**2.060**	2.040	2.056	2.032	**2.043**
2.090	2.110	2.078	**2.093**	2.056	2.036	2.048	**2.047**	2.008	2.028	2.000	**2.012**
2.062	2.059	2.065	**2.062**	2.014	2.034	2.026	**2.025**	1.962	1.990	1.974	**1.975**
2.044	2.028	2.040	**2.037**	1.998	2.018	2.002	**2.006**	1.944	1.936	1.956	**1.945**

2.018	2.006	1.998	**2.007**	1.966	1.982	1.962	**1.970**	1.920	1.912	1.936	**1.923**

Measured values of discharge (liter/hour) for drip-in at 6m x 0.6m spacing at 13m operating pressure head

LATERAL LINES											
L1				**L2**				**L3**			
R1	**R2**	**R3**	**Avg.**	**R1**	**R2**	**R3**	**Avg.**	**R1**	**R2**	**R3**	**Avg.**
2.572	2.560	2.576	**2.569**	2.542	2.574	2.558	**2.558**	2.520	2.536	2.504	**2.520**
2.534	2.538	2.530	**2.534**	2.536	2.540	2.536	**2.537**	2.482	2.494	2.466	**2.481**
2.514	2.526	2.522	**2.521**	2.498	2.518	2.510	**2.509**	2.462	2.458	2.470	**2.463**
2.490	2.502	2.478	**2.490**	2.460	2.488	2.476	**2.475**	2.450	2.430	2.438	**2.439**
2.468	2.484	2.460	**2.471**	2.476	2.444	2.456	**2.459**	2.420	2.436	2.400	**2.419**
2.452	2.460	2.460	**2.457**	2.424	2.440	2.408	**2.424**	2.402	2.398	2.386	**2.395**
2.432	2.456	2.436	**2.441**	2.380	2.412	2.388	**2.393**	2.384	2.368	2.376	**2.376**
2.440	2.412	2.416	**2.423**	2.368	2.356	2.360	**2.361**	2.336	2.356	2.344	**2.345**
2.418	2.398	2.398	**2.405**	2.342	2.330	2.338	**2.337**	2.320	2.316	2.304	**2.313**
2.400	2.376	2.388	**2.388**	2.322	2.310	2.314	**2.315**	2.288	2.280	2.268	**2.279**

Measured values of discharge (liter/hour) for drip-in at 1m x 0.6m spacing at 5m operating pressure head

LATERAL LINES											
L1				**L2**				**L3**			
R1	**R2**	**R3**	**Avg.**	**R1**	**R2**	**R3**	**Avg.**	**R1**	**R2**	**R3**	**Avg.**
1.288	1.300	1.272	**1.287**	1.268	1.276	1.256	**1.267**	1.236	1.248	1.220	**1.235**
1.260	1.268	1.248	**1.259**	1.248	1.264	1.240	**1.251**	1.212	1.220	1.204	**1.212**
1.252	1.240	1.260	**1.251**	1.216	1.224	1.220	**1.220**	1.184	1.180	1.192	**1.185**
1.228	1.208	1.236	**1.224**	1.220	1.204	1.208	**1.211**	1.200	1.208	1.184	**1.197**
1.216	1.232	1.204	**1.217**	1.176	1.180	1.188	**1.181**	1.180	1.192	1.176	**1.183**
1.184	1.200	1.168	**1.184**	1.164	1.152	1.180	**1.165**	1.148	1.140	1.156	**1.148**
1.160	1.168	1.152	**1.160**	1.156	1.160	1.140	**1.152**	1.132	1.112	1.140	**1.128**
1.168	1.180	1.156	**1.168**	1.172	1.180	1.160	**1.171**	1.104	1.100	1.092	**1.099**

1.180	1.172	1.168	**1.173**	1.152	1.164	1.144	**1.153**	1.100	1.108	1.080	**1.096**
1.148	1.144	1.136	**1.143**	1.124	1.120	1.136	**1.127**	1.088	1.100	1.072	**1.087**

Measured values of discharge (liter/hour) for drip-in at 1m x 0.6m spacing at 10m operating pressure head

LATERAL LINES											
L1				L2				L3			
R1	R2	R3	Avg.	R1	R2	R3	Avg.	R1	R2	R3	Avg.
2.228	2.212	2.236	**2.225**	2.196	2.188	2.204	**2.196**	2.190	2.170	2.198	**2.186**
2.210	2.202	2.198	**2.203**	2.163	2.155	2.175	**2.164**	2.164	2.148	2.176	**2.163**
2.194	2.190	2.178	**2.187**	2.140	2.140	2.144	**2.141**	2.136	2.140	2.132	**2.136**
2.172	2.168	2.160	**2.167**	2.124	2.128	2.116	**2.123**	2.122	2.098	2.110	**2.110**
2.150	2.154	2.134	**2.146**	2.108	2.092	2.116	**2.105**	2.082	2.070	2.094	**2.082**
2.118	2.110	2.130	**2.119**	2.076	2.080	2.088	**2.081**	2.054	2.060	2.058	**2.057**
2.084	2.092	2.068	**2.081**	2.056	2.068	2.052	**2.059**	2.030	2.054	2.014	**2.033**
2.058	2.050	2.070	**2.059**	2.040	2.052	2.032	**2.041**	2.017	2.029	2.001	**2.016**
2.040	2.052	2.028	**2.040**	2.028	2.020	2.008	**2.019**	1.984	1.976	1.988	**1.983**
2.012	2.000	2.020	**2.011**	1.998	1.986	1.990	**1.991**	1.970	1.954	1.974	**1.966**

Measured values of discharge (liter/hour) for drip-in at 1m x 0.6m spacing at 13m operating pressure head

LATERAL LINES											
L1				L2				L3			
R1	R2	R3	Avg.	R1	R2	R3	Avg.	R1	R2	R3	Avg.
2.700	2.712	2.684	**2.699**	2.628	2.648	2.616	**2.631**	2.580	2.576	2.588	**2.581**
2.675	2.680	2.660	**2.672**	2.612	2.632	2.600	**2.615**	2.552	2.540	2.564	**2.552**
2.680	2.684	2.672	**2.679**	2.596	2.600	2.592	**2.596**	2.544	2.552	2.536	**2.544**
2.648	2.660	2.636	**2.648**	2.564	2.548	2.576	**2.563**	2.560	2.560	2.556	**2.559**
2.664	2.652	2.672	**2.663**	2.580	2.576	2.588	**2.581**	2.528	2.512	2.540	**2.527**
2.564	2.556	2.584	**2.568**	2.548	2.556	2.540	**2.548**	2.496	2.500	2.512	**2.503**
2.612	2.600	2.628	**2.613**	2.520	2.512	2.524	**2.519**	2.468	2.456	2.480	**2.468**

2.548	2.544	2.560	**2.551**	2.496	2.500	2.504	**2.500**	2.452	2.460	2.448	**2.453**
2.556	2.560	2.552	**2.556**	2.472	2.480	2.460	**2.471**	2.424	2.436	2.416	**2.425**
2.504	2.512	2.500	**2.505**	2.460	2.456	2.444	**2.453**	2.408	2.416	2.400	**2.408**

Measured values of discharge (liter/hour) for drip-in at 0.5m x 0.6m spacing at 5m operating pressure head

LATERAL LINES											
L1				**L2**				**L3**			
R1	**R2**	**R3**	**Avg.**	**R1**	**R2**	**R3**	**Avg.**	**R1**	**R2**	**R3**	**Avg.**
1.388	1.404	1.380	**1.391**	1.372	1.360	1.388	**1.373**	1.352	1.336	1.360	**1.349**
1.368	1.380	1.360	**1.369**	1.352	1.344	1.356	**1.351**	1.340	1.312	1.344	**1.332**
1.380	1.368	1.348	**1.365**	1.332	1.340	1.320	**1.331**	1.308	1.300	1.320	**1.309**
1.312	1.320	1.316	**1.316**	1.300	1.312	1.292	**1.301**	1.324	1.320	1.296	**1.313**
1.292	1.284	1.280	**1.285**	1.316	1.324	1.300	**1.313**	1.312	1.300	1.288	**1.300**
1.272	1.260	1.288	**1.273**	1.332	1.300	1.280	**1.304**	1.276	1.292	1.264	**1.277**
1.304	1.308	1.312	**1.308**	1.248	1.244	1.264	**1.252**	1.260	1.280	1.244	**1.261**
1.288	1.288	1.280	**1.285**	1.264	1.280	1.248	**1.264**	1.280	1.280	1.268	**1.276**
1.268	1.260	1.248	**1.259**	1.228	1.244	1.236	**1.236**	1.248	1.260	1.252	**1.253**
1.248	1.240	1.236	**1.241**	1.220	1.212	1.208	**1.213**	1.236	1.228	1.240	**1.235**

Measured values of discharge (liter/hour) for drip-in at 0.5m x 0.6m spacing at 10m operating pressure head

LATERAL LINES											
L1				**L2**				**L3**			
R1	**R2**	**R3**	**Avg.**	**R1**	**R2**	**R3**	**Avg.**	**R1**	**R2**	**R3**	**Avg.**
2.288	2.309	2.272	**2.290**	2.312	2.288	2.256	**2.285**	2.254	2.270	2.230	**2.251**
2.268	2.280	2.260	**2.269**	2.298	2.274	2.238	**2.270**	2.240	2.248	2.212	**2.233**
2.244	2.252	2.236	**2.244**	2.256	2.248	2.228	**2.244**	2.218	2.230	2.202	**2.217**
2.230	2.218	2.226	**2.225**	2.228	2.240	2.220	**2.229**	2.200	2.176	2.188	**2.188**
2.226	2.222	2.194	**2.214**	2.215	2.207	2.199	**2.207**	2.174	2.154	2.170	**2.166**
2.192	2.200	2.180	**2.191**	2.198	2.170	2.174	**2.181**	2.158	2.138	2.134	**2.143**

2.190	2.178	2.182	**2.183**	2.166	2.158	2.178	**2.167**	2.150	2.130	2.122	**2.134**
2.160	2.164	2.148	**2.157**	2.145	2.113	2.133	**2.130**	2.099	2.095	2.087	**2.094**
2.128	2.120	2.136	**2.128**	2.104	2.096	2.100	**2.100**	2.078	2.090	2.070	**2.079**
2.102	2.090	2.110	**2.101**	2.096	2.076	2.088	**2.087**	2.057	2.069	2.053	**2.060**

Measured values of discharge (liter/hour) for drip-in at 0.5m x 0.6m spacing at 13m operating pressure head

LATERAL LINES											
L1				**L2**				**L3**			
R1	**R2**	**R3**	**Avg.**	**R1**	**R2**	**R3**	**Avg.**	**R1**	**R2**	**R3**	**Avg.**
2.784	2.768	2.792	**2.781**	2.764	2.776	2.744	**2.761**	2.736	2.716	2.752	**2.735**
2.680	2.668	2.688	**2.679**	2.728	2.740	2.720	**2.729**	2.712	2.700	2.724	**2.712**
2.740	2.720	2.756	**2.739**	2.696	2.700	2.688	**2.695**	2.660	2.668	2.680	**2.669**
2.652	2.660	2.640	**2.651**	2.672	2.656	2.684	**2.671**	2.680	2.684	2.668	**2.677**
2.716	2.696	2.732	**2.715**	2.688	2.680	2.660	**2.676**	2.672	2.600	2.660	**2.644**
2.540	2.564	2.588	**2.564**	2.668	2.676	2.672	**2.672**	2.644	2.664	2.624	**2.644**
2.672	2.680	2.660	**2.671**	2.572	2.560	2.588	**2.573**	2.624	2.648	2.640	**2.637**
2.604	2.620	2.596	**2.607**	2.556	2.540	2.560	**2.552**	2.592	2.600	2.604	**2.599**
2.628	2.640	2.612	**2.627**	2.520	2.528	2.540	**2.529**	2.556	2.568	2.548	**2.557**
2.568	2.576	2.580	**2.575**	2.504	2.500	2.516	**2.507**	2.532	2.540	2.544	**2.539**

Measured values of discharge (liter/hour) for drip tape at 6m x 0.3m spacing at 5m operating pressure head

LATERAL LINES											
L1				**L2**				**L3**			
R1	**R2**	**R3**	**Avg.**	**R1**	**R2**	**R3**	**Avg.**	**R1**	**R2**	**R3**	**Avg.**
0.948	0.928	0.960	**0.945**	0.920	0.908	0.936	**0.921**	0.876	0.856	0.892	**0.875**
0.940	0.908	0.944	**0.931**	0.904	0.888	0.920	**0.904**	0.856	0.840	0.860	**0.852**
0.916	0.912	0.920	**0.916**	0.872	0.860	0.880	**0.871**	0.812	0.800	0.832	**0.815**
0.892	0.880	0.888	**0.887**	0.844	0.832	0.848	**0.841**	0.828	0.824	0.801	**0.818**
0.856	0.848	0.860	**0.855**	0.820	0.800	0.828	**0.816**	0.800	0.780	0.840	**0.807**

0.884	0.900	0.880	**0.888**	0.832	0.840	0.820	**0.831**	0.776	0.764	0.792	**0.777**
0.900	0.888	0.916	**0.901**	0.840	0.860	0.833	**0.844**	0.748	0.728	0.768	**0.748**
0.868	0.860	0.848	**0.859**	0.816	0.828	0.808	**0.817**	0.764	0.744	0.780	**0.763**
0.852	0.836	0.860	**0.849**	0.796	0.768	0.788	**0.784**	0.744	0.724	0.760	**0.743**
0.824	0.808	0.836	**0.823**	0.772	0.760	0.776	**0.769**	0.712	0.696	0.724	**0.711**

Measured values of discharge (liter/hour) for drip tape at 6m x 0.3m spacing at 10m operating pressure head

LATERAL LINES											
L1				L2				L3			
R1	**R2**	**R3**	**Avg.**	**R1**	**R2**	**R3**	**Avg.**	**R1**	**R2**	**R3**	**Avg.**
1.124	1.230	1.202	**1.185**	1.173	1.165	1.197	**1.178**	1.162	1.142	1.174	**1.159**
1.192	1.184	1.176	**1.184**	1.150	1.138	1.170	**1.153**	1.138	1.130	1.142	**1.137**
1.158	1.142	1.178	**1.159**	1.126	1.094	1.162	**1.127**	1.112	1.120	1.120	**1.117**
1.138	1.130	1.150	**1.139**	1.103	1.095	1.115	**1.104**	1.110	1.086	1.130	**1.109**
1.116	1.108	1.132	**1.119**	1.083	1.075	1.095	**1.084**	1.078	1.098	1.102	**1.093**
1.100	1.112	1.108	**1.107**	1.062	1.046	1.074	**1.061**	1.071	1.083	1.075	**1.076**
1.094	1.090	1.098	**1.094**	1.046	1.054	1.030	**1.043**	1.044	1.020	1.032	**1.032**
1.084	1.092	1.072	**1.083**	1.028	1.040	1.020	**1.029**	0.995	1.015	0.995	**1.002**
1.062	1.074	1.050	**1.062**	1.006	1.010	0.990	**1.002**	0.973	0.981	0.965	**0.973**
1.048	1.056	1.040	**1.048**	0.992	1.000	0.980	**0.991**	0.940	0.936	0.928	**0.935**

Measured values of discharge (liter/hour) for drip tape at 6m x 0.3m spacing at 13m operating pressure head

LATERAL LINES											
L1				L2				L3			
R1	**R2**	**R3**	**Avg.**	**R1**	**R2**	**R3**	**Avg.**	**R1**	**R2**	**R3**	**Avg.**
1.378	1.370	1.394	**1.381**	1.330	1.306	1.350	**1.329**	1.278	1.258	1.298	**1.278**
1.356	1.352	1.372	**1.360**	1.306	1.290	1.326	**1.307**	1.248	1.240	1.260	**1.249**
1.342	1.322	1.350	**1.338**	1.284	1.260	1.300	**1.281**	1.225	1.213	1.245	**1.228**
1.322	1.310	1.330	**1.321**	1.264	1.260	1.265	**1.263**	1.221	1.205	1.233	**1.220**
1.300	1.316	1.284	**1.300**	1.256	1.244	1.272	**1.257**	1.198	1.194	1.214	**1.202**
1.280	1.292	1.272	**1.281**	1.238	1.230	1.250	**1.239**	1.186	1.170	1.190	**1.182**
1.268	1.260	1.280	**1.269**	1.220	1.200	1.236	**1.219**	1.172	1.152	1.160	**1.161**
1.244	1.228	1.260	**1.244**	1.182	1.206	1.190	**1.193**	1.138	1.146	1.142	**1.142**
1.224	1.212	1.240	**1.225**	1.162	1.186	1.170	**1.173**	1.110	1.098	1.118	**1.109**

1.206	1.182	1.230	**1.206**	1.146	1.158	1.162	**1.155**	1.079	1.067	1.095	**1.080**

Measured values of discharge (liter/hour) for drip tape at 1m x 0.3m spacing at 5m operating pressure head

LATERAL LINES											
L1				L2				L3			
R1	R2	R3	Avg.	R1	R2	R3	Avg.	R1	R2	R3	Avg.
1.004	1.024	1.000	**1.009**	0.972	0.960	0.984	**0.972**	0.940	0.928	0.952	**0.940**
0.984	1.000	0.972	**0.985**	0.948	0.940	0.960	**0.949**	0.904	0.892	0.920	**0.905**
0.952	0.964	0.960	**0.959**	0.916	0.908	0.932	**0.919**	0.868	0.860	0.884	**0.871**
0.932	0.952	0.940	**0.941**	0.900	0.896	0.904	**0.900**	0.840	0.824	0.848	**0.837**
0.960	0.928	0.960	**0.949**	0.928	0.940	0.920	**0.929**	0.832	0.844	0.820	**0.832**
0.928	0.920	0.936	**0.928**	0.896	0.888	0.904	**0.896**	0.860	0.876	0.864	**0.867**
0.908	0.916	0.900	**0.908**	0.872	0.872	0.880	**0.875**	0.824	0.832	0.836	**0.831**
0.940	0.948	0.928	**0.939**	0.880	0.896	0.860	**0.879**	0.812	0.800	0.820	**0.811**
0.916	0.920	0.920	**0.919**	0.864	0.876	0.848	**0.863**	0.828	0.824	0.808	**0.820**
0.888	0.900	0.900	**0.896**	0.832	0.840	0.824	**0.832**	0.784	0.768	0.788	**0.780**

Measured values of discharge (liter/hour) for drip tape at 1m x 0.3m spacing at 10m operating pressure head

LATERAL LINES											
L1				L2				L3			
R1	R2	R3	Avg.	R1	R2	R3	Avg.	R1	R2	R3	Avg.
1.280	1.304	1.268	**1.284**	1.248	1.240	1.260	**1.249**	1.200	1.184	1.220	**1.201**
1.264	1.272	1.260	**1.265**	1.216	1.228	1.236	**1.227**	1.188	1.172	1.200	**1.187**
1.236	1.228	1.248	**1.237**	1.196	1.208	1.200	**1.201**	1.136	1.128	1.144	**1.136**
1.212	1.220	1.236	**1.223**	1.200	1.220	1.184	**1.201**	1.164	1.148	1.168	**1.160**
1.248	1.236	1.256	**1.247**	1.164	1.160	1.148	**1.157**	1.100	1.088	1.116	**1.101**
1.220	1.204	1.236	**1.220**	1.144	1.176	1.132	**1.151**	1.112	1.100	1.128	**1.113**
1.188	1.184	1.200	**1.191**	1.116	1.096	1.120	**1.111**	1.088	1.080	1.100	**1.089**
1.168	1.148	1.180	**1.165**	1.132	1.120	1.140	**1.131**	1.064	1.076	1.076	**1.072**
1.176	1.180	1.164	**1.173**	1.124	1.112	1.120	**1.119**	1.052	1.036	1.060	**1.049**

1.148	1.156	1.136	**1.147**	1.100	1.096	1.088	**1.095**	1.032	1.024	1.012	**1.023**

Measured values of discharge (liter/hour) for drip tape at 1m x 0.3m spacing at 13m operating pressure head

LATERAL LINES											
L1				**L2**				**L3**			
R1	**R2**	**R3**	**Avg.**	**R1**	**R2**	**R3**	**Avg.**	**R1**	**R2**	**R3**	**Avg.**
1.414	1.398	1.422	**1.411**	1.380	1.396	1.368	**1.381**	1.354	1.370	1.346	**1.357**
1.378	1.382	1.390	**1.383**	1.366	1.376	1.358	**1.367**	1.326	1.322	1.330	**1.326**
1.350	1.374	1.368	**1.364**	1.328	1.316	1.340	**1.328**	1.300	1.316	1.320	**1.312**
1.342	1.350	1.330	**1.341**	1.310	1.314	1.298	**1.307**	1.288	1.280	1.300	**1.289**
1.336	1.328	1.320	**1.328**	1.284	1.280	1.292	**1.285**	1.252	1.268	1.264	**1.261**
1.314	1.302	1.330	**1.315**	1.271	1.287	1.275	**1.278**	1.250	1.262	1.238	**1.250**
1.294	1.290	1.294	**1.293**	1.259	1.251	1.275	**1.262**	1.244	1.240	1.232	**1.239**
1.280	1.272	1.264	**1.272**	1.254	1.238	1.250	**1.247**	1.212	1.212	1.220	**1.215**
1.248	1.236	1.260	**1.248**	1.224	1.212	1.248	**1.228**	1.200	1.188	1.192	**1.193**
1.232	1.216	1.240	**1.229**	1.198	1.190	1.218	**1.202**	1.144	1.160	1.148	**1.151**

Measured values of discharge (liter/hour) for drip tape at 0.5m x 0.3m spacing at 5m operating pressure head

LATERAL LINES											
L1				**L2**				**L3**			
R1	**R2**	**R3**	**Avg.**	**R1**	**R2**	**R3**	**Avg.**	**R1**	**R2**	**R3**	**Avg.**
1.042	1.030	1.034	**1.035**	0.990	1.002	1.014	**1.002**	0.972	0.996	0.980	**0.983**
1.030	1.014	1.006	**1.017**	0.970	0.978	0.990	**0.979**	0.960	0.968	0.952	**0.960**
1.010	0.994	0.990	**0.998**	0.967	0.963	0.971	**0.967**	0.934	0.950	0.942	**0.942**
0.986	0.966	0.970	**0.974**	0.972	0.952	0.968	**0.964**	0.912	0.940	0.920	**0.924**
0.971	0.947	0.955	**0.958**	0.936	0.960	0.856	**0.917**	0.906	0.918	0.910	**0.911**
0.956	0.928	0.944	**0.943**	0.944	0.920	0.928	**0.931**	0.897	0.905	0.893	**0.898**
0.924	0.936	0.928	**0.929**	0.918	0.906	0.910	**0.911**	0.880	0.896	0.884	**0.887**
0.920	0.900	0.908	**0.909**	0.898	0.882	0.890	**0.890**	0.860	0.872	0.868	**0.867**

0.884	0.872	0.900	**0.885**	0.880	0.860	0.868	**0.869**	0.831	0.867	0.855	**0.851**
0.870	0.850	0.862	**0.861**	0.834	0.854	0.850	**0.846**	0.816	0.840	0.824	**0.827**

Measured values of discharge (liter/hour) for drip tape at 0.5m x 0.3m spacing at 10m operating pressure head

LATERAL LINES											
L1				L2				L3			
R1	R2	R3	Avg.	R1	R2	R3	Avg.	R1	R2	R3	Avg.
1.336	1.356	1.328	**1.340**	1.306	1.312	1.282	**1.300**	1.282	1.258	1.290	**1.277**
1.308	1.320	1.304	**1.311**	1.280	1.304	1.268	**1.284**	1.262	1.250	1.274	**1.262**
1.304	1.292	1.292	**1.296**	1.272	1.264	1.260	**1.265**	1.238	1.234	1.250	**1.241**
1.276	1.300	1.260	**1.279**	1.244	1.260	1.240	**1.248**	1.218	1.210	1.230	**1.219**
1.254	1.266	1.250	**1.257**	1.226	1.206	1.242	**1.225**	1.208	1.188	1.204	**1.200**
1.238	1.230	1.246	**1.238**	1.194	1.210	1.218	**1.207**	1.180	1.192	1.172	**1.181**
1.226	1.206	1.218	**1.217**	1.180	1.196	1.196	**1.191**	1.158	1.174	1.154	**1.162**
1.200	1.186	1.190	**1.192**	1.182	1.174	1.170	**1.175**	1.156	1.128	1.140	**1.141**
1.176	1.190	1.168	**1.178**	1.164	1.144	1.176	**1.161**	1.128	1.112	1.136	**1.125**
1.154	1.166	1.146	**1.155**	1.154	1.130	1.150	**1.145**	1.112	1.096	1.116	**1.108**

Measured values of discharge (liter/hour) for drip tape at 0.5m x 0.3m spacing at 13m operating pressure head

LATERAL LINES											
L1				L2				L3			
R1	R2	R3	Avg.	R1	R2	R3	Avg.	R1	R2	R3	Avg.
1.444	1.464	1.460	**1.456**	1.420	1.448	1.440	**1.436**	1.400	1.416	1.420	**1.412**
1.428	1.440	1.436	**1.435**	1.404	1.400	1.412	**1.405**	1.384	1.392	1.396	**1.391**
1.396	1.368	1.408	**1.391**	1.380	1.388	1.368	**1.379**	1.380	1.372	1.360	**1.371**
1.412	1.400	1.384	**1.399**	1.396	1.372	1.380	**1.383**	1.356	1.360	1.344	**1.353**
1.380	1.384	1.388	**1.384**	1.360	1.340	1.352	**1.351**	1.328	1.344	1.300	**1.324**
1.348	1.332	1.340	**1.340**	1.344	1.356	1.344	**1.348**	1.340	1.324	1.316	**1.327**
1.356	1.380	1.360	**1.365**	1.316	1.344	1.328	**1.329**	1.304	1.288	1.292	**1.295**
1.336	1.328	1.348	**1.337**	1.324	1.300	1.308	**1.311**	1.312	1.320	1.304	**1.312**
1.360	1.376	1.368	**1.368**	1.300	1.284	1.288	**1.291**	1.280	1.268	1.276	**1.275**
1.340	1.316	1.324	**1.327**	1.280	1.268	1.276	**1.275**	1.252	1.244	1.232	**1.243**

Measured values of discharge (liter/hour) at one point for different emission devices at different operating pressure head

EMISSION DEVICE											
Dripper			Micro-tube			Dripin			Driptape		
Operating pressure head (meter)			Operating pressure head (meter)			Operating pressure head (meter)			Operating pressure head (meter)		
5	10	13	5	10	13	5	10	13	5	10	13
2.720	3.872	4.408	65.060	74.972	78.716	1.524	2.400	2.852	1.036	1.288	1.460
2.704	3.844	4.392	65.088	75.024	78.776	1.488	2.368	2.816	0.992	1.236	1.388
2.736	3.888	4.460	65.072	75.000	78.744	1.480	2.360	2.808	1.000	1.244	1.408
2.728	3.868	4.432	65.048	74.984	78.720	1.504	2.384	2.836	1.032	1.280	1.440
2.740	3.892	4.476	64.944	74.848	78.552	1.516	2.400	2.848	0.980	1.220	1.380
2.712	3.860	4.400	65.060	75.000	78.732	1.500	2.380	2.820	1.020	1.272	1.436
2.688	3.832	4.372	65.028	74.976	78.700	1.468	2.340	2.780	1.008	1.248	1.404
2.760	3.920	4.500	64.904	74.784	78.440	1.504	2.392	2.840	1.040	1.296	1.460
2.720	3.860	4.408	65.100	75.040	78.784	1.488	2.360	2.808	1.024	1.288	1.440
2.740	3.888	4.468	64.920	74.820	78.488	1.448	2.320	2.760	0.988	1.228	1.380
2.756	3.908	4.488	64.976	74.904	78.612	1.536	2.420	2.876	1.000	1.240	1.396
2.720	3.872	4.424	65.000	74.936	78.660	1.500	2.376	2.824	1.024	1.280	1.448
2.732	3.880	4.456	65.080	75.020	78.768	1.476	2.348	2.800	1.012	1.264	1.428
2.696	3.844	4.392	64.956	74.860	78.552	1.460	2.324	2.776	0.996	1.236	1.392
2.720	3.864	4.440	65.012	74.956	78.700	1.508	2.392	2.836	1.004	1.248	1.400

APPENDIX - III

Drippers at 6m x 6m spacing

Mean table for Ax B x C

	C_1	C_2	C_3	C_4	C_5	C_6	C_7	C_8	C_9	C_{10}
A_1B_1	2.632	2.548	2.531	2.529	2.492	2.476	2.473	2.473	2.455	2.410
A_1B_2	2.621	2.528	2.524	2.512	2.467	2.472	2.469	2.443	2.403	2.385
A_1B_3	2.661	2.563	2.516	2.539	2.496	2.472	2.516	2.492	2.464	2.392
A_2B_1	3.711	3.655	3.641	3.584	3.565	3.545	3.529	3.551	3.512	3.477
A_2B_2	3.669	3.623	3.576	3.565	3.520	3.516	3.528	3.479	3.443	3.445
A_2B_3	3.634	3.572	3.524	3.553	3.529	3.499	3.512	3.488	3.453	3.445
A_3B_1	4.109	4.099	4.075	3.968	3.988	3.949	3.947	3.953	3.927	3.912
A_3B_2	4.060	4.047	3.993	3.979	3.965	3.987	3.972	3.913	3.888	3.876
A_3B_3	4.047	4.008	3.994	4.010	3.959	3.944	3.953	3.948	3.896	3.876

CD for A x B x C = N.S.

Mean table for A x B

	B_1	B_2	B_3	Mean
A_1	2.502	2.482	2.511	2.498
A_2	3.577	3.536	3.521	3.545
A_3	3.993	3.968	3.963	3.975
Mean	3.357	3.329	3.332	

CD for A = 0.007

CD for B = 0.007

CD for A x B = 0.012

Mean Table for A x C

	C_1	C_2	C_3	C_4	C_5	C_6	C_7	C_8	C_9	C_{10}	Mean
A_1	2.638	2.546	2.524	2.527	2.485	2.473	2.486	2.469	2.441	2.396	2.498
A_2	3.671	3.616	3.580	3.568	3.538	3.520	3.523	3.506	3.469	3.456	3.545
A_3	4.072	4.052	4.021	3.986	3.971	3.960	3.957	3.938	3.904	3.889	3.975
Mean	3.460	3.405	3.375	3.360	3.331	3.318	3.322	3.304	3.271	3.247	

CD for A = 0.007

CD for C = 0.012

CD for A x C = 0.022

Mean Table for B x C

	C_1	C_2	C_3	C_4	C_5	C_6	C_7	C_8	C_9	C_{10}	Mean
B_1	3.484	3.434	3.416	3.360	3.348	3.324	3.317	3.326	3.298	3.267	3.357

B_2	3.450	3.399	3.364	3.352	3.317	3.325	3.323	3.278	3.245	3.236	3.329
B_3	3.447	3.381	3.345	3.367	3.328	3.305	3.327	3.309	3.271	3.238	3.332
Mean	3.460	3.405	3.375	3.360	3.331	3.318	3.322	3.304	3.271	3.247	

CD for B = 0.007

CD for C = 0.012

CD for B x C = 0.022

Drippers of 1m x 1m spacing

Mean table for Ax B x C

	C_1	C_2	C_3	C_4	C_5	C_6	C_7	C_8	C_9	C_{10}
A_1B_1	2.005	1.941	1.901	1.773	1.795	1.779	1.759	1.811	1.791	1.739
A_1B_2	1.971	1.923	1.864	1.887	1.848	1.760	1.769	1.713	1.715	1.691
A_1B_3	1.959	1.939	1.875	1.853	1.821	1.787	1.880	1.839	1.815	1.739
A_2B_1	2.839	2.757	2.728	2.631	2.672	2.579	2.613	2.684	2.644	2.571
A_2B_2	2.819	2.773	2.731	2.743	2.692	2.665	2.639	2.552	2.521	2.533
A_2B_3	2.805	2.779	2.720	2.705	2.639	2.641	2.705	2.695	2.664	2.584
A_3B_1	3.608	3.527	3.479	3.431	3.395	3.361	3.307	3.327	3.385	3.311
A_3B_2	3.596	3.519	3.496	3.505	3.415	3.433	3.369	3.305	3.279	3.260
A_3B_3	3.557	3.511	3.492	3.489	3.437	3.415	3.439	3.423	3.429	3.346

CD for A x B x C = 0.024

Mean table for A x B

	B_1	B_2	B_3	Mean
A_1	1.829	1.814	1.851	1.831
A_2	2.672	2.667	2.694	2.677
A_3	3.413	3.418	3.454	3.428
Mean	2.638	2.633	2.666	

CD for A = 0.004

CD for B = 0.004

CD for A x B = 0.008

Mean Table for A x C

	C_1	C_2	C_3	C_4	C_5	C_6	C_7	C_8	C_9	C_{10}	Mean
A_1	1.978	1.934	1.880	1.838	1.821	1.775	1.803	1.788	1.773	1.723	1.831
A_2	2.821	2.770	2.726	2.693	2.668	2.628	2.652	2.644	2.610	2.563	2.677
A_3	3.587	3.519	3.489	3.475	3.416	3.403	3.372	3.352	3.364	3.306	3.428
Mean	2.795	2.741	2.698	2.669	2.635	2.602	2.609	2.594	2.582	2.530	

CD for A = 0.004

CD for C = 0.008

CD for A x C = 0.014

Mean Table for B x C

	C_1	C_2	C_3	C_4	C_5	C_6	C_7	C_8	C_9	C_{10}	Mean
B_1	2.817	2.742	2.703	2.612	2.621	2.573	2.560	2.607	2.606	2.540	2.638
B_2	2.795	2.738	2.697	2.711	2.652	2.619	2.592	2.523	2.505	2.495	2.633
B_3	2.774	2.743	2.696	2.683	2.632	2.614	2.675	2.652	2.652	2.636	2.666
Mean	2.795	2.741	2.698	2.669	2.635	2.602	2.609	2.594	2.582	2.530	

CD for B = 0.004

CD for C = 0.008

CD for B x C = 0.014

Drippers of 0.5m x 0.5m spacing
Mean table for Ax B x C

	C_1	C_2	C_3	C_4	C_5	C_6	C_7	C_8	C_9	C_{10}
A_1B_1	1.882	1.825	1.807	1.753	1.728	1.700	1.671	1.633	1.615	1.580
A_1B_2	1.881	1.821	1.791	1.740	1.713	1.683	1.650	1.642	1.632	1.598
A_1B_3	1.889	1.830	1.797	1.745	1.719	1.692	1.662	1.648	1.638	1.607
A_2B_1	2.448	2.400	2.365	2.331	2.297	2.242	2.208	2.211	2.199	2.120
A_2B_2	2.441	2.377	2.350	2.313	2.259	2.240	2.221	2.187	2.135	2.107
A_2B_3	2.439	2.388	2.367	2.342	2.309	2.247	2.240	2.209	2.189	2.110
A_3B_1	3.039	3.003	3.020	2.968	2.947	2.841	2.815	2.831	2.799	2.696
A_3B_2	3.073	2.985	2.959	2.919	2.888	2.848	2.809	2.823	2.725	2.680
A_3B_3	3.091	3.019	2.994	2.893	2.829	2.829	2.896	2.814	2.818	2.734

CD for A x B x C = 0.021

Mean table for A x B

	B_1	B_2	B_3	Mean
A_1	1.719	1.715	1.723	1.719
A_2	2.282	2.263	2.284	2.276
A_3	2.901	2.871	2.892	2.888
Mean	2.301	2.283	2.299	

CD for A = 0.004

CD for B = 0.004

CD for A x B = 0.007

Mean Table for A x C

	C_1	C_2	C_3	C_4	C_5	C_6	C_7	C_8	C_9	C_{10}	Mean
A_1	1.884	1.825	1.798	1.746	1.720	1.692	1.661	1.641	1.629	1.595	1.719
A_2	2.443	2.388	2.361	2.329	2.288	2.243	2.223	2.203	2.174	2.112	2.276
A_3	3.086	3.002	2.991	2.927	2.888	2.839	2.840	2.823	2.781	2.703	2.888
Mean	2.471	2.405	2.383	2.334	2.299	2.258	2.241	2.222	2.195	2.137	

CD for A = 0.004

CD for C = 0.007

CD for A x C = 0.012

Mean Table for B x C

	C_1	C_2	C_3	C_4	C_5	C_6	C_7	C_8	C_9	C_{10}	Mean
B_1	2.474	2.409	2.397	2.350	2.324	2.261	2.231	2.225	2.204	2.132	2.301
B_2	2.465	2.394	2.367	2.324	2.287	2.257	2.226	2.217	2.164	2.128	2.283
B_3	2.473	2.412	2.386	2.327	2.285	2.256	2.266	2.224	2.215	2.150	2.299
Mean	2.471	2.405	2.383	2.334	2.299	2.258	2.241	2.222	2.195	2.137	

CD for B = 0.004

CD for C = 0.007

CD for B x C = 0.012

Micro-tubes of 6m x 6m spacing

Mean table for Ax B x C

	C_1	C_2	C_3	C_4	C_5	C_6	C_7	C_8	C_9	C_{10}
A_1B_1	64.920	54.002	55.375	58.729	43.428	38.283	36.379	36.701	31.195	27.393
A_1B_2	63.600	61.037	51.495	49.415	40.363	47.259	43.667	40.744	38.336	30.475
A_1B_3	60.560	57.203	58.148	51.159	46.965	36.443	35.011	34.929	33.735	30.145
A_2B_1	73.452	60.619	65.157	67.696	53.264	47.499	44.664	46.860	36.333	40.517
A_2B_2	69.365	64.513	55.745	52.116	43.416	49.848	47.141	43.732	42.065	36.684
A_2B_3	67.640	65.925	65.415	56.855	50.957	42.639	36.471	42.477	32.365	41.104
A_3B_1	76.468	63.643	68.136	70.849	57.772	48.796	48.136	49.313	42.701	44.595
A_3B_2	71.779	67.701	52.735	55.445	45.868	53.281	50.359	48.644	46.437	39.515
A_3B_3	69.824	67.389	68.392	59.945	53.835	46.921	39.907	45.959	35.328	44.673

CD for A x B x C = 0.828

Mean table for A x B

	B_1	B_2	B_3	Mean
A_1	44.640	46.639	44.430	45.236
A_2	53.606	50.463	50.185	51.418

A_3	57.041	53.176	53.217	54.478
Mean	51.763	50.093	49.277	

CD for A = 0.151

CD for B = 0.151

CD for A x B = 0.262

Mean Table for A x C

	C_1	C_2	C_3	C_4	C_5	C_6	C_7	C_8	C_9	C_{10}	Mean
A_1	63.027	57.414	55.006	53.100	43.585	40.661	38.352	37.458	34.422	29.338	45.236
A_2	70.152	63.686	62.106	58.889	49.212	46.662	42.759	44.356	36.921	39.435	51.418
A_3	72.690	66.244	63.088	62.080	52.492	49.666	46.134	47.972	41.489	42.928	54.478
Mean	68.623	62.448	60.066	58.023	48.430	45.663	42.415	43.262	37.611	37.233	

CD for A = 0.151

CD for C = 0.276

CD for A x C = 0.478

Mean Table for B x C

	C_1	C_2	C_3	C_4	C_5	C_6	C_7	C_8	C_9	C_{10}	Mean
B_1	71.613	59.421	62.889	65.758	51.488	44.859	43.060	44.292	36.743	37.502	51.763
B_2	68.248	64.417	53.325	52.324	43.216	50.129	47.056	44.373	42.280	35.558	50.091
B_3	66.008	63.506	63.985	55.986	50.586	42.001	37.129	41.122	33.809	38.641	49.277
Mean	68.623	62.448	60.066	58.023	48.430	45.663	42.415	43.262	37.611	37.233	

CD for B = 0.151

CD for C = 0.276

CD for B x C = 0.478

Microb-tubes of 1m x 1m spacing

Mean table for A x B x C

	C_1	C_2	C_3	C_4
A_1B_1	36.287	32.015	26.125	17.168
A_1B_2	36.444	31.257	26.437	16.804
A_1B_3	35.460	31.189	25.591	16.665
A_2B_1	49.267	38.772	31.492	24.637
A_2B_2	46.297	38.456	29.833	25.137
A_2B_3	47.090	38.883	33.645	21.652
A_3B_1	56.815	42.085	38.184	25.371
A_3B_2	54.636	45.589	39.336	27.044
A_3B_3	51.948	43.437	35.624	29.080

CD for A x B x C = 1.505

Mean table for A x B

	B_1	B_2	B_3	Mean
A_1	27.899	27.736	27.226	27.620
A_2	36.042	34.931	35.318	35.430
A_3	40.614	41.651	40.022	40.762
Mean	34.851	34.773	34.189	

CD for A = 0.434

CD for B = 0.434

CD for A x B = 0.753

Mean Table for A x C

	C_1	C_2	C_3	C_4	Mean
A_1	36.064	31.487	26.051	16.879	27.620
A_2	47.551	38.704	31.657	23.809	35.430
A_3	54.466	43.704	37.715	27.165	40.762
Mean	46.027	37.965	31.808	22.618	

CD for A = 0.434

CD for C = 0.502

CD for A x C = 0.0.869

Mean Table for B x C

	C_1	C_2	C_3	C_4	Mean
B_1	47.456	37.624	31.934	22.392	34.851
B_2	45.792	38.434	31.869	22.995	34.773
B_3	44.833	37.837	31.620	22.466	34.189

Mean	46.027	37.965	31.808	22.618	

CD for B = 0.434

CD for C = 0.502

CD for B x C = 0.869

Micro-tubes of 0.5m x 0.5m spacing

Mean table for Ax B x C

	C_1	C_2	C_3
A_1B_1	22.508	16.192	10.851
A_1B_2	21.739	15.377	10.223
A_1B_3	20.971	14.455	9.295
A_2B_1	28.229	20.537	13.295
A_2B_2	27.477	19.924	12.959
A_2B_3	26.321	19.565	12.039
A_3B_1	32.872	26.868	16.207
A_3B_2	31.425	24.504	16.504
A_3B_3	29.515	23.327	14.588

CD for A x B x C = 0.449

Mean table for A x B

	B_1	B_2	B_3	Mean
A_1	16.517	15.780	14.907	17.734
A_2	20.710	20.120	19.308	20.046
A_3	25.316	24.144	22.476	23.979
Mean	20.848	20.015	18.897	

CD for A = 0.150

CD for B = 0.150

CD for A x B = 0.259

Mean Table for A x C

	C_1	C_2	C_3	Mean
A_1	21.739	15.341	10.123	15.734
A_2	27.366	20.009	12.764	20.046
A_3	31.271	24.900	15.766	23.979
Mean	26.792	20.083	12.884	

CD for A = 0.150

CD for C = 0.150

CD for A x C = 0.259

Mean Table for B x C

	C_1	C_2	C_3	Mean
B_1	27.893	21.199	13.451	20.848
B_2	26.880	19.935	13.229	20.015
B_3	25.602	19.115	11.974	18.897
Mean	26.792	20.083	12.884	

CD for B = 0.150

CD for C = 0.150

CD for B x C = 0.259

Drip-in of 6m x 0.6m spacing

Mean table for Ax B x C

	C_1	C_2	C_3	C_4	C_5	C_6	C_7	C_8	C_9	C_{10}
A_1B_1	1.271	1.235	1.223	1.219	1.175	1.156	1.145	1.127	1.108	1.096
A_1B_2	1.221	1.199	1.185	1.168	1.136	1.172	1.135	1.099	1.061	1.043
A_1B_3	1.173	1.152	1.133	1.127	1.105	1.096	1.085	1.060	1.069	1.032
A_2B_1	2.237	2.212	2.191	2.158	2.132	2.111	2.093	2.062	2.037	2.007
A_2B_2	2.187	2.158	2.140	2.120	2.098	2.060	2.047	2.025	2.006	1.970
A_2B_3	2.161	2.146	2.117	2.099	2.067	2.043	2.012	1.975	1.945	1.923
A_3B_1	2.569	2.534	2.521	2.490	2.471	2.457	2.441	2.423	2.405	2.388
A_3B_2	2.558	2.537	2.509	2.475	2.459	2.424	2.393	2.361	2.337	2.315
A_3B_3	2.520	2.481	2.463	2.439	2.419	2.395	2.376	2.345	2.313	2.279

CD for A x B x C = 0.119

Mean table for A x B

	B_1	B_2	B_3	Mean
A_1	1.175	1.142	1.103	1.140
A_2	2.124	2.081	2.049	2.085
A_3	2.475	2.437	2.403	2.437
Mean	1.923	1.887	1.852	

CD for A = 0.003

CD for B = 0.003

CD for A x B = 0.006

Mean Table for A x C

	C_1	C_2	C_3	C_4	C_5	C_6	C_7	C_8	C_9	C_{10}	Mean
A_1	1.222	1.195	1.180	1.171	1.139	1.141	1.122	1.095	1.080	1.057	1.140
A_2	2.195	2.172	2.149	2.126	2.099	2.071	2.050	2.021	1.996	1.967	2.085
A_3	2.549	2.517	2.498	2.468	2.449	2.426	2.404	2.376	2.352	2.327	2.437
Mean	1.989	1.961	1.942	1.922	1.896	1.879	1.859	1.831	1.809	1.784	

CD for A = 0.003

CD for C = N.S.

CD for A x C = 0.011

Mean Table for B x C

	C_1	C_2	C_3	C_4	C_5	C_6	C_7	C_8	C_9	C_{10}	Mean
B_1	2.026	1.994	1.978	1.956	1.926	1.908	1.893	1.870	1.850	1.830	1.923
B_2	1.989	1.965	1.945	1.921	1.898	1.885	1.858	1.828	1.801	1.776	1.887
B_3	1.952	1.926	1.904	1.888	1.864	1.845	1.824	1.794	1.776	1.744	1.852
Mean	1.989	1.961	1.942	1.922	1.896	1.879	1.859	1.831	1.809	1.784	

CD for B = 0.003

CD for C = N.S.

CD for B x C = 0.011

Drip-in of 1m x 0.6m spacing

Mean table for Ax B x C

	C_1	C_2	C_3	C_4	C_5	C_6	C_7	C_8	C_9	C_{10}
A_1B_1	1.287	1.259	1.251	1.224	1.217	1.184	1.160	1.168	1.173	1.143
A_1B_2	1.267	1.251	1.220	1.211	1.181	1.165	1.152	1.171	1.153	1.127
A_1B_3	1.235	1.212	1.185	1.197	1.183	1.148	1.128	1.099	1.096	1.087
A_2B_1	2.225	2.203	2.187	2.167	2.146	2.119	2.081	2.059	2.040	2.011
A_2B_2	2.196	2.164	2.141	2.123	2.105	2.081	2.059	2.041	2.019	1.991
A_2B_3	2.186	2.163	2.136	2.110	2.082	2.057	2.033	2.016	1.983	1.966
A_3B_1	2.699	2.672	2.679	2.648	2.663	2.568	2.613	2.551	2.556	2.505

A_3B_2	2.631	2.615	2.596	2.563	2.581	2.548	2.519	2.500	2.471	2.453
A_3B_3	2.581	2.552	2.544	2.559	2.527	2.503	2.468	2.453	2.425	2.408

CD for A x B x C = 0.017

Mean table for A x B

	B_1	B_2	B_3	Mean
A_1	1.207	1.190	1.157	1.184
A_2	2.124	2.092	2.073	2.096
A_3	2.615	2.548	2.502	2.555
Mean	1.982	1.943	1.911	

CD for A = 0.003

CD for B = 0.003

CD for A x B = 0.005

Mean Table for A x C

	C_1	C_2	C_3	C_4	C_5	C_6	C_7	C_8	C_9	C_{10}	Mean
A_1	1.263	1.240	1.219	1.211	1.194	1.166	1.147	1.146	1.141	1.119	1.184
A_2	2.202	2.177	2.155	2.133	2.111	2.086	2.058	2.039	2.014	1.989	2.096
A_3	2.637	2.613	2.606	2.590	2.590	2.540	2.533	2.501	2.484	2.456	2.555
Mean	2.034	2.010	1.993	1.978	1.965	1.930	1.913	1.895	1.880	1.855	

CD for A = 0.003

CD for C = 0.006

CD for A x C = 0.010

Mean Table for B x C

	C_1	C_2	C_3	C_4	C_5	C_6	C_7	C_8	C_9	C_{10}	Mean
B_1	2.070	2.045	2.039	2.013	2.009	1.957	1.952	1.926	1.923	1.886	1.982
B_2	2.031	2.010	1.986	1.965	1.956	1.932	1.910	1.904	1.881	1.857	1.943
B_3	2.001	1.976	1.955	1.955	1.930	1.903	1.876	1.856	1.835	1.820	1.911
Mean	2.034	2.010	1.993	1.978	1.965	1.930	1.913	1.895	1.880	1.855	

CD for B = 0.003

CD for C = 0.006

CD for B x C = 0.010

Drip-in of 0.5m x 0.6m spacing

Mean table for Ax B x C

	C_1	C_2	C_3	C_4	C_5	C_6	C_7	C_8	C_9	C_{10}
A_1B_1	1.391	1.369	1.365	1.316	1.285	1.273	1.308	1.285	1.259	1.241
A_1B_2	1.373	1.351	1.331	1.301	1.313	1.304	1.252	1.264	1.236	1.213
A_1B_3	1.349	1.332	1.309	1.313	1.300	1.277	1.261	1.276	1.253	1.235
A_2B_1	2.290	2.269	2.244	2.225	2.214	2.191	2.183	2.157	2.128	2.101
A_2B_2	2.285	2.270	2.244	2.229	2.207	2.181	2.167	2.130	2.100	2.087
A_2B_3	2.251	2.233	2.217	2.188	2.166	2.143	2.134	2.094	2.079	2.060
A_3B_1	2.781	2.679	2.739	2.651	2.715	2.564	2.671	2.607	2.627	2.575
A_3B_2	2.761	2.729	2.695	2.671	2.676	2.672	2.573	2.552	2.529	2.507
A_3B_3	2.735	2.712	2.669	2.677	2.644	2.644	2.637	2.599	2.557	2.539

CD for A x B x C = 0.021

Mean table for A x B

	B_1	B_2	B_3	Mean
A_1	1.309	1.294	1.291	1.298
A_2	2.200	2.190	2.157	2.182
A_3	2.661	2.637	2.641	2.646
Mean	2.057	2.040	2.030	

CD for A = 0.004

CD for B = 0.004

CD for A x B = 0.007

Mean Table for A x C

	C_1	C_2	C_3	C_4	C_5	C_6	C_7	C_8	C_9	C_{10}	Mean
A_1	1.371	1.351	1.335	1.310	1.300	1.285	1.274	1.275	1.249	1.230	1.298
A_2	2.275	2.258	2.235	2.214	2.196	2.172	2.162	2.127	2.102	2.082	2.182
A_3	2.759	2.707	2.701	2.666	2.678	2.627	2.627	2.586	2.571	2.540	2.646
Mean	2.135	2.105	2.090	2.063	2.058	2.028	2.021	1.996	1.974	1.951	

CD for A = 0.004

CD for C = 0.007

CD for A x C = 0.012

Mean Table for B x C

	C_1	C_2	C_3	C_4	C_5	C_6	C_7	C_8	C_9	C_{10}	Mean
B_1	2.154	2.106	2.116	2.064	2.071	2.009	2.054	2.016	2.004	1.972	2.057
B_2	2.140	2.117	2.090	2.067	2.065	2.052	1.998	1.982	1.955	1.936	2.040
B_3	2.112	2.092	2.065	2.060	2.037	2.022	2.011	1.989	1.963	1.944	2.030
Mean	2.135	2.105	2.090	2.063	2.058	2.028	2.021	1.996	1.974	1.951	

CD for B = 0.004

CD for C = 0.007

CD for B x C = 0.012

Drip tape of 6m x 0.3m spacing

Mean table for Ax B x C

	C_1	C_2	C_3	C_4	C_5	C_6	C_7	C_8	C_9	C_{10}
A_1B_1	0.945	0.931	0.916	0.887	0.855	0.888	0.901	0.859	0.849	0.823
A_1B_2	0.921	0.904	0.871	0.841	0.816	0.831	0.844	0.817	0.784	0.769
A_1B_3	0.875	0.852	0.815	0.818	0.807	0.777	0.748	0.763	0.743	0.711
A_2B_1	1.185	1.184	1.159	1.139	1.119	1.107	1.094	1.083	1.062	1.048
A_2B_2	1.178	1.153	1.127	1.104	1.084	1.061	1.043	1.029	1.002	0.991
A_2B_3	1.159	1.137	1.117	1.109	1.093	1.076	1.032	1.002	0.973	0.935
A_3B_1	1.381	1.360	1.338	1.321	1.300	1.281	1.269	1.244	1.225	1.206
A_3B_2	1.329	1.307	1.281	1.263	1.257	1.239	1.219	1.193	1.173	1.155
A_3B_3	1.278	1.249	1.228	1.220	1.202	1.182	1.161	1.142	1.109	1.080

CD for A x B x C = 0.021

Mean table for A x B

	B_1	B_2	B_3	Mean
A_1	0.885	0.840	0.791	0.839
A_2	1.118	1.077	1.063	1.086
A_3	1.293	1.242	1.185	1.240
Mean	1.099	1.053	1.013	

CD for A = 0.004

CD for B = 0.004

CD for A x B = 0.007

Mean Table for A x C

	C_1	C_2	C_3	C_4	C_5	C_6	C_7	C_8	C_9	C_{10}	Mean
A_1	0.914	0.896	0.867	0.849	0.826	0.832	0.831	0.813	0.792	0.768	0.839
A_2	1.174	1.158	1.135	1.117	1.099	1.081	1.056	1.038	1.012	0.991	1.086
A_3	1.329	1.306	1.282	1.268	1.253	1.234	1.216	1.193	1.169	1.147	1.240
Mean	1.139	1.120	1.095	1.078	1.059	1.049	1.035	1.015	0.991	0.969	

CD for A = 0.004

CD for C = 0.007

CD for A x C = 0.012

Mean Table for B x C

	C_1	C_2	C_3	C_4	C_5	C_6	C_7	C_8	C_9	C_{10}	Mean
B_1	1.170	1.158	1.138	1.116	1.091	1.092	1.088	1.062	1.046	1.026	1.099
B_2	1.143	1.121	1.093	1.070	1.053	1.044	1.035	1.013	0.986	0.972	1.053
B_3	1.104	1.079	1.053	1.049	1.034	1.012	0.980	0.969	0.941	0.909	1.013
Mean	1.139	1.120	1.095	1.078	1.059	1.049	1.035	1.015	0.991	0.969	

CD for B = 0.004

CD for C = 0.007

CD for B x C = 0.012

Drip tape of 1m x 0.3m spacing

Mean table for Ax B x C

	C_1	C_2	C_3	C_4	C_5	C_6	C_7	C_8	C_9	C_{10}
A_1B_1	1.009	0.985	0.959	0.941	0.949	0.928	0.908	0.939	0.919	0.896
A_1B_2	0.972	0.949	0.919	0.900	0.929	0.896	0.875	0.879	0.863	0.832
A_1B_3	0.940	0.905	0.871	0.837	0.832	0.867	0.831	0.811	0.820	0.780
A_2B_1	1.284	1.265	1.237	1.223	1.247	1.220	1.191	1.165	1.173	1.147
A_2B_2	1.249	1.227	1.201	1.201	1.157	1.151	1.111	1.131	1.119	1.095
A_2B_3	1.201	1.187	1.136	1.160	1.101	1.113	1.089	1.072	1.049	1.023
A_3B_1	1.411	1.383	1.364	1.341	1.328	1.315	1.293	1.272	1.248	1.229
A_3B_2	1.381	1.367	1.328	1.307	1.285	1.278	1.262	1.247	1.228	1.202
A_3B_3	1.357	1.326	1.312	1.289	1.261	1.250	1.239	1.215	1.193	1.151

CD for A x B x C = 0.018

Mean table for A x B

	B_1	B_2	B_3	Mean
A_1	0.943	0.901	0.849	0.898
A_2	1.215	1.164	1.113	1.164
A_3	1.318	1.289	1.259	1.289
Mean	1.159	1.118	1.074	

CD for A = 0.003

CD for B = 0.003

CD for A x B = 0.006

Mean Table for A x C

	C_1	C_2	C_3	C_4	C_5	C_6	C_7	C_8	C_9	C_{10}	Mean
A_1	0.974	0.947	0.916	0.893	0.904	0.897	0.871	0.876	0.867	0.836	0.898
A_2	1.245	1.226	1.192	1.195	1.168	1.161	1.130	1.123	1.114	1.088	1.164
A_3	1.383	1.359	1.335	1.312	1.292	1.281	1.264	1.245	1.223	1.194	1.289
Mean	1.201	1.177	1.147	1.133	1.121	1.113	1.089	1.081	1.068	1.039	

CD for A = 0.003

CD for C = 0.006

CD for A x C = 0.010

Mean Table for B x C

	C_1	C_2	C_3	C_4	C_5	C_6	C_7	C_8	C_9	C_{10}	Mean
B_1	1.235	1.211	1.187	1.168	1.175	1.154	1.130	1.125	1.113	1.091	1.159
B_2	1.201	1.181	1.149	1.136	1.124	1.108	1.082	1.086	1.070	1.043	1.118
B_3	1.166	1.139	1.106	1.096	1.065	1.077	1.053	1.032	1.021	0.984	1.074
Mean	1.201	1.177	1.147	1.133	1.121	1.113	1.089	1.081	1.068	1.039	

CD for B = 0.003

CD for C = 0.006

CD for B x C = 0.010

Drip tape of 0.5m x 0.3m spacing

Mean table for Ax B x C

	C_1	C_2	C_3	C_4	C_5	C_6	C_7	C_8	C_9	C_{10}
A_1B_1	1.035	1.017	0.998	0.974	0.958	0.943	0.929	0.909	0.885	0.861
A_1B_2	1.002	0.979	0.967	0.964	0.917	0.931	0.911	0.890	0.869	0.846
A_1B_3	0.983	0.960	0.942	0.924	0.911	0.898	0.887	0.867	0.851	0.827
A_2B_1	1.340	1.311	1.296	1.279	1.257	1.238	1.217	1.192	1.178	1.155
A_2B_2	1.300	1.284	1.265	1.248	1.225	1.207	1.191	1.175	1.161	1.145
A_2B_3	1.277	1.262	1.241	1.219	1.200	1.181	1.162	1.141	1.125	1.108
A_3B_1	1.456	1.435	1.391	1.399	1.384	1.340	1.365	1.337	1.368	1.327
A_3B_2	1.436	1.405	1.379	1.383	1.351	1.348	1.329	1.311	1.291	1.275
A_3B_3	1.412	1.391	1.371	1.353	1.324	1.327	1.295	1.312	1.275	1.243

CD for A x B x C = 0.020

Mean table for A x B

	B_1	B_2	B_3	Mean
A_1	0.951	0.928	0.905	0.928
A_2	1.246	1.220	1.192	1.219

A_3	1.380	1.351	1.330	1.354
Mean	1.192	1.166	1.142	

CD for A = 0.004
CD for B = 0.004
CD for A x B = 0.006

Mean Table for A x C

	C_1	C_2	C_3	C_4	C_5	C_6	C_7	C_8	C_9	C_{10}	Mean
A_1	1.007	0.985	0.969	0.954	0.929	0.924	0.909	0.889	0.869	0.844	0.928
A_2	1.306	1.286	1.267	1.249	1.227	1.209	1.190	1.170	1.155	1.136	1.219
A_3	1.435	1.410	1.380	1.378	1.353	1.338	1.330	1.320	1.311	1.281	1.354
Mean	1.249	1.227	1.205	1.194	1.170	1.157	1.143	1.126	1.112	1.087	

CD for A = 0.004
CD for C = NS
CD for A x C = 0.012

Mean Table for B x C

	C_1	C_2	C_3	C_4	C_5	C_6	C_7	C_8	C_9	C_{10}	Mean
B_1	1.277	1.254	1.228	1.217	1.199	1.174	1.170	1.146	1.144	1.114	1.192
B_2	1.246	1.223	1.204	1.198	1.164	1.162	1.144	1.125	1.107	1.088	1.166
B_3	1.224	1.204	1.184	1.166	1.145	1.135	1.114	1.107	1.084	1.059	1.142
Mean	1.249	1.227	1.205	1.194	1.170	1.157	1.143	1.126	1.112	1.087	

CD for B = 0.004
CD for C = N.S.
CD for B x C = NS

APPENDIX - IV

COMPUTER PROGRAMME FOR SOFTWARE FOR HYDRAULIC PERFORMANCE EVALUATION AND CALCULATION OF HEAD LOSS IN DRIP IRRIGATION SYSTEM

```
#include<stdio.h>
#include<conio.h>
#include<math.h>
#include<fstream.h>
#include<stdlib.h>
void main()
{
front:
float a[100],i,j,k;
int n;
float std[100];
float uc,mean,avgdiv,avg,y=0;
char nm;
const MAX = 10;
char line[MAX];
clrscr();
cout<<"Choices"<<endl;
cout<<endl;
cout<<"1.To Calculate U.C., E.U.,C.V. Of Equation\n";
cout<<"2.To Calculate C.M.V Of Equation\n";
cout<<"3.To Calculate Head Loss For Main Line combined for all
Emission Devices\n";
cout<<"4.To Calculate Head Loss for Lateral Line combined for all
Emission Devices \n";
cout<<endl;
cout<<"Enter Your Choice As Given Above:-> ";
scanf("%d",&n);
clrscr();
float small = 0.00;
i = 0;
switch(n)
{
case 1:
      i=0;
      ifstream infile("data1.txt");
      while (infile)
      {
            infile.getline(line,MAX);
            a[i] = atof(line);
            avg+= a[i];
            if (i==0)
            {
            small = a[i];
            }
            if (small>a[i] && a[i]>0)
            {
            small = a[i];
            }

      if (a[i]==0)
      {
            k=0;
            mean=0;
```

```
        y=0;
        k=i;
        mean=avg/k;

        for(i=0;i<k;i++)
        {
        std[i]=fabs(mean-a[i]);
        y+=std[i];
        }
        avgdiv=0;
        avgdiv=y/k;
//////////
        clrscr();
        printf("Entered Data Is:-\n");
        for(i=0;i<k;i+=2)
        {
              printf("%7.3f, %7.3f \n",a[i],a[i+1]);
        }
        uc=0;
        uc=(1-(avgdiv/mean))*100;
        printf("\n U.C.:- %f",uc);
        for (i=0;i<k;i++)
        {
              for(int j=0;j<k-1;j++)
              {
                    if(a[j]>a[j+1])
                    {
                    float m=a[j];
                    a[j]=a[j+1];
                    a[j+1]=m;
                    }
               }
        }
        float vc=0;
        //vc=(a[1]/mean)*100;
        //cout<<endl<<small;
        //getch();
        vc = (small/mean)*100;

        printf("\n E.U.:- %f",vc);
        float stdev[100],st=0;
        for(i=0;i<k;i++)
        {
        stdev[i]=(a[i]-mean)*(a[i]-mean);
        st=st+stdev[i];
        }
        float sd=0;
        sd=sqrt(st/k);
        float cv=0;
        cv=(sd/mean)*100;
        printf("\n C.V.:- %f",cv);
        getch();
  avg = 0;
  i=-1;
  }
  ++i;
  }
  break;
```

```
case 2:
      avg = 0;
      ifstream infile2("data2.txt");
      i=0;
      while (infile2)
      {
            infile2.getline(line,MAX);
            a[i] = atof(line);
            avg+= a[i];
            if (i==0)
            {
            small = a[i];
            }
            if (small>a[i] && a[i]>0)
            {
            small = a[i];
            }

      if (a[i]==0)
      {
            k=0;
            mean=0;
            y=0;
            k=i;
            mean=avg/k;
            for(i=0;i<k;i++)
            {
            std[i]=fabs(mean-a[i]);
            y+=std[i];
            }
            avgdiv=0;
            avgdiv=y/k;
///////

            clrscr();
            printf("Entered Data Is:-\n");
            for(i=0;i<k;i+=2)
            {
                  printf("%7.3f, %7.3f \n",a[i],a[i+1]);
            }

            float cmv[100],cdv=0;
            for(i=0;i<k;i++)
            {
            cmv[i]=(a[i]-mean)*(a[i]-mean);
            cdv+=cmv[i];
            }
            float cd=0;
            cd=sqrt(cdv/k);
            float cvv=0;
            cvv=(cd/mean)*100;
            printf("\n C.M.V.:- %f",cvv);
            getch();
      avg = 0;
      i=-1;
      }
      ++i;
      }
```

```
      break;
case 3:
            clrscr();
            printf("Head loss in Main Line combined for all emission
devices \n");
            float dismain;
            printf("Enter The Value Of Discharge: ");
            scanf("%f",&dismain);
            float headloss=0.045141*pow(dismain,0.609704);
            printf("HeadLoss :- %f",headloss);
            break;
case 4:
            clrscr();
            printf("Head loss in Lateral Line combined for all
emission devices: \n");
            float drip;
            printf("Enter The Value Of Discharge: ");
            scanf("%f",&drip);
            float headloss2=0.044706*pow(drip,0.862723);
            printf("HeadLoss :- %f",headloss2);
            break;
}
getch();
clrscr();

printf("DO YOU WANT TO CONTINUE AGAIN THEN ENTER y OTHER WISE ENETR n
\n");
scanf("%s",&nm);

if(nm=='y')
goto front;
else
{
clrscr();
printf("THANK YOU");
getch();
}
}
```

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ABSTRACT

Title of thesis	:	**Hydraulic Performance Evaluation of Drip Irrigation System with Different Emission Devices**
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Title of degree	:	Master of Technology, Agricultural Engineering (Soil and Water Engineering)
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Keywords: Uniformity coefficient, emission uniformity, coefficient of variation, coefficient of manufacturing variation, dripper, micro-tube, drip-in, drip tape, pressure head

Studies were conducted to evaluate the effect of operating pressure head and spacing on different hydraulic performance evaluation measures of drip irrigation systems with different emission devices. The commonly used hydraulic performance evaluation measures considered were uniformity coefficient, emission uniformity, coefficient of variation and coefficient of manufacturing variation. The different emission devices were dripper, micro-tube, drip-in and drip tape. The experiments were conducted in the field laboratory of Soil and Water Engineering Department, College of Agricultural Engineering and Technology, CCS Haryana Agricultural University, Hisar. The selected spacings were i) 6m x 6m, 1m x 6m and 0.5m x 0.5m for dripper and micro-tube, ii) 6m x 0.6m, 1m x 0.6m and 0.5m x 0.6m for drip-in and iii) 6m x 0.3m, 1m x 0.3m and 0.5m x 0.3m for drip tape. The operating pressure heads were 5m, 10m and 13m.

The measurement of discharge for calculation of hydraulic performance evaluation measures was done by operating the system and putting the containers at

6m interval along the lateral lines. The measurement of pressure head was done with the help of mercury manometer and water manometer at up stream and down stream end of main line and lateral line. The values of different hydraulic performance evaluation measures and head loss in main line and lateral line were calculated. The values of uniformity coefficient and emission uniformity decreased for dripper and micro-tube and increased for drip-in and rip tape, as the spacing decreased. The values of uniformity coefficient and emission uniformity for all emission devices increased as the operating pressure head increased at a particular spacing. The values of coefficient of variation increased for dripper and micro-tube and decreased for drip-in and drip tape, as the spacing decreased. The values of coefficient of variation for all emission devices decreased as the operating pressure head increased at a particular spacing. The values of coefficient of manufacturing variation was maximum for drip tape and minimum for micro-tube. The values of head loss in main line and lateral line for different emission devices increased as the spacing decreased and increased as the operating pressure head increased. The head loss in the main line and lateral line also increased at a decreasing rate with discharge and the variation can be expressed with a power equation. The values of the coefficients in the power relationship between head loss and discharge were calculated for each emission device and also combined for all emission devices. The coefficient of correlation for the combined equation was 0.9871 for main line and 0.7201 for lateral line. A computer software in C++ language was developed for calculation of the hydraulic performance evaluation measures and head loss in main line and lateral line of system. The values obtained from the computer software were equal to the measured values.

MAJOR ADVISOR **SIGNATURE OF STUDENT**

HEAD OF THE DEPARTMENT