STUDIES ON DISCHARGE PERFORMANCE OF DIFFERENT TYPES OF EMITTERS USED IN TRICKLE IRRIGATION

By

Prasenjit Ghosh

A THESIS SUBMITTED TO
THE ORISSA UNIVERSITY OF AGRICULTURE AND TECHNOLOGY
BHUBANESWAR

IN PARTIAL FULFILMENT OF THE REQUIREMENTS
FOR THE DEGREE OF

MASTER OF TECHNOLOGY

(AGRICULTURAL ENGINEERING)
IN
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ORISSA UNIVERSITY OF AGRICULTURE AND TECHNOLOGY
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2003

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(External Examiner)

Dedicated to my Beloved Baba Maa & others

Prof. K. N. Sharma
Associate Professor.
Department of Soil and Water
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and Technology, Bhubaneswar.

16. 08. 2003

CERTIFICATE

This is to certify that the thesis entitled "Studies of discharge performance of different types of emitters used in trickle irrigation" submitted in partial fulfillment of degree of Master of Technology (Agricultural Engineering and Technology) in Soil and Water Conservation Engineering of the Orisisa University of Agriculture and Technology, Bhubaneswar, is a faithful record of bonafide research work carried out by Sri Prasenjit Ghosh under my guidance and supervision. No part of this thesis has been submitted for any other degree or diploma.

The help and information as have been availed of, in course of this research work, have been duly acknowledged by him.

16.8.03
(Dr. K. N. Sharma)

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Bhubaneswar

16.08.03.

(Prasenjit Ghosh)

ABSTRACT

The main objective of this study was to test the various types of emitters along with moisture front advance and effect of temperature change on emitter discharge. The system was installed at precision farming development center, OUAT, Bhubaneswar. Seven emitters were tested. These were Turbo Key, Turbo Seal, J-Lock and Self-Pressure Compensating types. The performance parameters considered for test manufacturing coefficient of variation, pressure discharge relationship and emission uniformity. Moisture front advance was studied for three discharge rates 2 lph, 4 lph and 8 lph. Variation of discharge of emitters with change of field temperature also studied.

The results of study reveal that flow in J-Lock and Turbo Seal emitters, was close to laminar in nature. While flow was in turbulent region for rest of the emitters. Self-pressure compensating emitters gave the best performance. The performance of Turbo Key, J -Lock and Turbo Seal was found upto the mark. Moisture front studies revealed that when the discharge of emitters was doubled, the wetted diameter of soil was increased to roughly 20 per cent. Studies on effect of temperature change in the field on discharge of tested emitters revealed that temperature increase of the water flowing through pipe, which was exposed to solar radiation, did not have any significant effect on discharge of tested emitters.

Key-Words:

Self-pressure compensating, Manufacturing coefficient of variation, Emission Uniformity, J-Lock, Turbo Seal, Turbo Key.

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ABBRIVATIONS

Agric.	Agriculture
ASAE	American Society of Agricultural Engineers
ASCE	American Society of Civil Engineers
Bull.	Bulletin
C.A.E.T.	College of Agriculture and Engineering Technology
Cm	Centimeter
Deptt.	Department
Dia	Diameter
Div.	Division
EU	Distribution-uniformity
Engg.	Engineering
FAO	Food and Agriculture Organization
fig.	Figure
gm	gram
hr.	hour
ha	hectares
H.P.	Horse Power
Irrig.	Irrigation
J.	Journal
1 ph	liter per hour
1 pm	liter per minute
m	meter

mfg.	Manufacturing
min	minutes
mm	millimeter
M. Tech.	Master of technology
No.	Numbers
O.U.A.T.	Orissa University of Agriculture & Technology
PFDC	Precision Farming Development Centre
Proc.	Proceeding
Prof.	Professor
Pub.	Publication
Res.	Research
RPM	Revolution per minute
Sci.	Science
Soc.	Society
Trans.	Transaction
wt	weight
%	Per cent

INTRODUCTION

CHAPTER – I

GENERAL

Water is a vital input in agricultural production. The increasing population and industrialization will have a higher share from the available water and will stress the allocation for agriculture. Water being a limited resource, Public awareness and optimum utilization by efficient water management techniques, are necessary.

Water scarcity looms large on the national horizon as of today. Water resources are becoming extremely scarce. According to the projection made by the National Commission for Integrated Water Resource Development Plan, the requirement of water for irrigation in India will grow by more than 50 per cent in the next 50 years. The water requirement for household consumption and industry would rise even faster. In view of this, even after fully exploiting the usable water resources, the balance between supply and demand for irrigation water can be achieved only by improving the level of irrigation efficiency in a big way from about 36 per cent efficiency in 1993-94 to 60 percent in the year 2050.

In a vast country like India, with a geographic area of 328 Mha, less then 45 per cent of the area is only cultivated. Out of this, gross cultivable area is 165 Mha. Of this, only 72 Mha gets irrigation. It has been estimated that, even if all the resources of the country are harnessed, it will not be possible to irrigate all available cultivable area. Hence, there is an urgent need of paradigm shift in the emphasis in the management of water resources sector. From the present emphasis on the creation and expansion of water resources for diverse uses, there is now a need to give greater emphasis on the improvement of the performance of existing water resources facilities.

Saleth 1996 reported that a 10 per cent improvement in the efficiency of water use would be equivalent to adding some 14 million hectors of gross irrigated area. Researches on Irrigation Engineering were aimed at developing the water application techniques, which satisfy the crop demand with minimum application and conveyance losses, without deteriorating the fertility and productivity of land. Consistent efforts led to the development of drip and sprinkler irrigation methods.

A model of water supply and demand for 118 countries accounting for 93 per cent of world population by developed International Water Management Institute (IWMI) shows that around 50 per cent of the increase in demand for water by the year 2025 can be met by increasing the effectiveness of irrigation. Most of this gain in irrigation effectiveness would be in countries with high percentage of irrigated rice. India & China together would account for as much as one-half of the world's total estimated water savings from increased irrigation effectiveness. According to Seckur *et al. 1998* capacity of large countries like India & China to efficiently develop & manage water resources is likely to be a key determinant for global food security in the 21st century.

In the last two decades, we have been flattering in our efforts to augment water resources. Though use of the available water resources have become increasingly unsustainable, we have not taken significant steps so far for improving water use efficiency through modernization or renovation of existing systems. Ultimately, savings in irrigation water can be achieved only by raising the productivity of water, defined broadly as the crop output per unit of water used. In this direction the adoption of technologies for efficient irrigation and development of crop through genetic improvement targeted towards saving water holds the key for survival. Here lies the importance of Drip Irrigation.

Table:1.1 Productivity of Irrigation for Food grains in Indian Agriculture:

(Growth Rates)

	1970-1980	1980-1990	1990-1997
Gross Irrigated area	2.31	1.72	1.70
Out put	2.30	2.90	2.00
Productivity of Irrigation	0.01	1.18	0.30

Drip irrigation offers best possible solution for increasing agricultural productivity with the judicious use of natural resources including saving in energy. Hence, utilization of Drip Irrigation system is increasing at faster rate.

Some advantages of micro irrigation or drip irrigation are, improved water and nutrient management, potential for improved yields and crop quality, greater control on applied water resulting in less water and nutrient loss through deep percolation, and reduce total water requirements. There is tremendous potential for the adoption of drip irrigation on field crop as well as on permanent plantings.

The uniformity parameters chosen to evaluate Drip-irrigation system are Emission Uniformity Co-efficient (EU) and co-efficient of variation of emitters flow. These uniformity parameters are mainly affected by hydraulics, manufacturing variations, plugging and temperature.

Water losses due to several factors can be minimized by improving irrigation technology. Water saving of the order of 50 per cent can be realized in drip irrigation system over other conventional systems. In India, only 1 per cent of irrigated area in the country is presently covered by drip and sprinkler methods of irrigation.

JUSTIFICATION

Although drip irrigation in India had it's beginning in Seventies, its adoption level is still poor due to high initial cost, lack of awareness. The status of Drip Irrigation in India is given below-

Table: 1.2

Area covered under drip irrigation (8th plan period)

Sl. No.	State	Hectare
1.	Maharastra	46000
2.	Karnataka	31500
3.	Tamil Nadu	19000
4.	Andhra Pradesh	13700
5.	Kerala	4700
6.	Gujarat	4500
7.	Madhya Pradesh	2300
8.	Orissa	1750
9.	Rajasthan	1700
10.	Haryana	1400
11.	Punjab	1100
12.	Uttar Pradesh	700
13.	Goa	300
14.	Nagaland	250
15.	Manipur	200
16.	Sikkim	100
17.	Others	1800

Now a days various types of drip emitters are available with each having specific hydraulic characteristics. It is therefore necessary to test the various types of drip emitters so that emitter best suitable for specific requirement can be selected and a system can be installed according to requirements.

Drip Irrigation is characterised by the application of water through low discharge emitters at a particular point where the water infiltrates into the soil. Discharge rate of the emitter should be equal to or less than the rate of infiltration, however, sometimes exceeds the infiltration capacity of the soil, consequently, a pool of water develops around the emitter from which infiltration proceeds. If the hydraulic characteristics of different types of emitters are available precisely. We will able to assist in selection of proper emitters suiting the crop and soil requirement.

When drip system is irrigating row crops, emitters are spaced in order to produce a continuous strip of wetted soil along the row. The distance between emitters and soil moisture movement characteristics would determine the degree of overlap between neighboring wetted circles. In addition, the number of emitters on it influences the unit cost of a lateral. Thus the spacing of the emitters will play an important role in the cost of the system. One of the basic needs for better drip irrigation design is more information about the moisture movement pattern under a trickle source for different soils and discharge rates. In trickle irrigation, soil serves less as a reservoir for water than the conventional irrigation because water that is withdrawn from the soil is frequently replenished. Thus the soil type is not a prime-determining factor in establishing irrigation scheduling. However, the soil type and discharge rates both are important for the moisture movement. Efficient operation and management of a drip system therefore, requires a good understanding of these factors.

Therefore a necessity was realized for study of hydraulic characteristics of different types of emitters and soil moisture movement pattern. Hence, the study was undertaken with the following objectives:

1. To study the hydraulics of the different types of the drip emitters.
2. To study the water front advance pattern in the sandy loam soil with the point source.
3. To study the effect of temperature change on emitters discharge.

REVIEW OF LITERATURE

CHAPTER - II

This chapter deals with a brief chronology of development of drip irrigation systems and selected review of research work done on design, evaluation and hydraulics of drip irrigation systems and waterfront advance pattern studies.

2.1 CHRONOLOGY OF DRIP IRRIGATION:

Drip irrigation was developed originally as sub-irrigation in West Germany in 1860. In 1913, the farmers of Colorado, in their attempt to use their drip irrigation complained of its high cost. This instigated subsequent modifications in the system to render it economical.

In 1920 perforated pipes were used in Germany, resulting reduction in cost. Also in 1930 some peach growers of Victoria reported considerable saving in micro tube length by using helical tubes. During the early 1940, Symcha Blass, an Israeli Engineer observed that a large tree near a leaking tap exhibited a more vigorous growth than the other trees in the area which were not reached by the water from tap. This incident led him to the concept of an irrigation system that would apply water in small amount. Eventually he devised and patented a low-pressure system.

Around 1948 green house operators in U.K. began to try similar method with some modifications. With the increased availability of plastic pipe and development of emitters in Israel in 1950s, drip irrigation system has since progressed from being a novelty employed by researchers to an accepted method of irrigation through out the world.

Drip irrigation is accepted mostly in the arid regions for watering high value crops, such as fruits and nut trees, grapes and other vine crops, sugarcane, pineapple, strawberries, flowers and vegetables. Although successfully used on cotton, sorghum and sweetcorn, drip irrigation is not as well adopted to field crops due to several complex factors.

2.2 HYDRAULICS OF DRIP IRRIGATION SYSTEM:

Hydraulics of drip irrigation can be divided into three major parts:

1. Emitter hydraulics.
2. Lateral and sub main hydraulics, and
3. Efficiency and irrigation uniformity.

2.2.1 Emitter Hydraulics:

Wu I-Pai *et al.,* (1973) elucidated a simple way of estimating pressure distribution along a drip line. They divided the whole length of drip line into an equal segments, each of length δL and gave the pressure distribution along the drip line as

$$\delta H = K\left(\sum_{p=1}^{n} Q_p^{4.75}\right)\delta L$$

where, $Q_p = Average\ discharge\ from\ p^{th}\ section$

$$K = \frac{2.53\,\nu^{0.25}\,A^{0.25}}{g\pi^{0.5}\,D^{5.25}}$$

$D = Diameter\ of\ the\ pipe,$

$\nu = Dynamic\ viscosity\ of\ water,$

$A = \pi\ D^2 / 4$

They showed that if the pressure distribution along the lateral is determined by using 'n' equal to three or four, this will cause an error of less than 2% only. They also suggested the use of different sizes of emitters, different length and sizes of micro tube and spacing between emitters, to achieve uniformity in irrigation.

Keller and Karmeli (1974) suggested a simple generalized equation for emitter flow

$$Q = K_d H^x$$

Where Q = Average flow rate through the emitter,

K_d = A coefficient specific to each emitter,

H = Pressure at which the emitter operates,

x = an exponent, the value of which depends on the flow regime.

If discharges are known at different pressures, K_d can be determined by

$$\log K_d = \frac{m\Sigma \log q_i (\log H_i^2) - \Sigma(\log q_i \times \log H_i) \times \Sigma \log H_i}{m\Sigma (\log H_i)^2 - (\Sigma \log H_i)^2}$$

and χ *by the equation* –

$$\chi = \frac{m\Sigma \log q_i \times \log H_i - \Sigma \log q_i \times \Sigma \log H_i}{m\Sigma (\log H_i)^2 - (\Sigma \log H_i)^2}$$

If $m = 2$, *then*

$$\chi = \frac{\log (q_1 / q_2)}{\log (H_1 / H_2)}$$

The exponent x characterises the flow regime of the emitter,

- For fully turbulent regime $x = 0.5$
- For laminar flow regime $x = 1.0$
- For an intermediate stage $0.5 < x < 1.0$

Flow equations for some of specific types of emitters are given below-

2.2.1.1 Orifice type emitter:

In orifice type of the emitters, flow is usually turbulent, ($X = 0.5$) and the relation is of the form:

$q = C_d A (2 g h)^{0.5}$

Where, C_d = orifice constant,

A = area of cross section of the orifice.

2.2.1.2 Long Flow path emitter

In case of long flow path emitters, flow is usually laminar ($x = 1.0$) and the relationship can be given as

$$q = K_d H = \frac{\pi D^4 g H}{128 v l}$$

where, $v =$ *the kinematic friction*

2.2.1.3 Bi-wall type emitter

In this case

$$q_0 = C_{do} A_0 \frac{2 g H_i}{N_r^2 C_r^2 D_r^2 + 1}$$

Where q_o = discharge from orifice of outer chamber,

C_{do} = coefficient of discharge of outer orifice,

A_o = cross sectional area of outer orifice,

H_o = pressure head at the orifice of outer chamber,

C_r = ratio of coefficient of discharge of outer orifice to That of the inner orifice, (can be assumed as 1.0)

Khatri *et al.,* (1979) studied hydraulics of micro tube emitters and gave the relation for pressure drop I the form of:

$$H_r = K (Q^a / D^b) L$$

He also separated minor losses from the total losses by using computer's simulation.

2.2.2 EFFICIENCY AND UNIFORMITY:

Ideally, the application of water throughout the field should be absolutely uniform in spite of pressure variation in the pipe network, which is very difficult to achieve in actual practice.

Christiansen defined a term 'coefficient of uniformity' (CU) to quantify the degree of flow variation, as –

$$CU = (1 - \delta q/q)$$

Where, q = mean emitter flow,

δq = mean absolute variation from the mean emitter Flow.

Hart and Reynolds gave the simple relationship for CU as

$$CU = 1 - 0.789 (\sigma/q)$$

Where σ = standard deviation of emitter flow.

Keller and Karmeli (1975) proposed the concept of emission uniformity and system efficiency. They defined emission uniformity as-

$$E_u = 100(1 - \frac{1.27C_v}{n}) q_{\min/q}$$

Where n = number of emitters per plant,

q_{mim} = minimum distributors discharge,

E_u = emission uniformity,

C_v = coefficient of variation.

And system efficiency as –

$$E_a = K_a E_u$$

Where, K_a = management practice factor.

Wu I-Pai *et al.*, (1975) developed a graphical method for determining the lateral uniformity as a function of lateral length, inlet flow rate and lateral slope. In addition they presented dimensionless curves for the pressure drop ratio versus length ratio and lateral uniformity versus maximum to minimum emitter flow rate.

2.2.3 MANUFACTURING COEFFICIENT OF VARIATION:

Soloman and Keller (1978) gave the concept of manufacturing coefficient of variation and gave the design equations for trickle irrigation lateral length by considering the effect of variation of manufacture and aging of emitters.

Bralt *et al.,* (1981) made an attempt to statistically include manufacturing variation of single chamber drip irrigation lateral lines and reported that relation between hydraulic variation and manufacture variation is orthogonal.

Singh *et al.,* (1997) pointed out that the manufacturing characteristics of different types of emitter could be represented by the coefficient of variation (C_v). The coefficient of variation (C_v) for emitters as introduced by Keller and Karmeli was

$$C_v = S/q_a$$

Where,

S = standard deviation of the sample

Q_a = average emitter flow rate, lph

The ISAE recommendations for C_v for emitters are presented below.

Coefficient of variation	Interpretation
< 0.05	Excellent
0.05-0.07	Average
0.07-0.11	Marginal
0.11-0.15	Poor
> 0.15	Unacceptable

2.2.4 BASIC HYDRAULIC CONCEPTS RELATED TO FLOW REGIME:

2.2.4.1 The Reynold's Number

It is defined as the ratio of inertial forces to gravity forces. It is considered as the basic criteria to distinguish laminar flow from turbulent flow.

It is expressed as –

R_e = V d/ Kμ

Where, V = the average velocity, (m/s)

d = the flow cross section diameter, (mm)

μ = kinematic viscosity of water

K = a constant = 1000 in metric system.

If expressed as function of the discharge

Re = 4 q/ K μ A d

Where, Q = pipe discharge in 1 ph,

K = 3600 in metric system.

Three flow regimes may be considered as a function of Re

Laminar flow regime, when Re < 1000,

Unstable flow regime, when 2000<Re < 4000,

Turbulent flow regime, when Re>4000.

2.2.4.2 Darcy-Weishbach Formula

Darcy-Weishbach formula for flow in pipe can be expressed as: -

h = f l v^2/ 2 g d

Where, h = the energy losses in a length of ℓ of the pipe.

f = the friction coefficient.

d = the internal diameter of the pipe

v = the average velocity

g = acceleration due to gravity

The frictional coefficient f depends upon Re and relative roughness of the pipe. For laminar flow the frictional coefficient is independent of the relative roughness and hence depends on Re only.

F = 64/Re

For turbulent flow, the flow may be divided into three categories-

a) flow in smooth pipes,

b) flow in relative rough pipes,

c) flow in transition zone,

For smooth pipes, (Re < 80,000)

$$f = 0.3164/Re^{0.25}$$

Or, for all values of Re –

$$1/\sqrt{f} = 2\log(\mathrm{Re}\sqrt{f}) - 0.8$$

For relatively rough pipes

$$1/\sqrt{f} = 2\log d/s + 1.14$$

Where, s = dimension of the roughness.

For the transition zone between smooth and rough boundaries-

$$1/\sqrt{f} = 1.14 - 2\log\left[s/d + 9.35/\mathrm{Re}\sqrt{f}\right]$$

2.2.4.3 Hazen-Williams Formula

$$V = 1.32\ C\ Rh^{0.69}\ Sr^{0.54}$$

Where, V = Velocity,

C = a discharge coefficient,

Rh = the hydraulic radius,

Sr = the slope energy line.

And head loss value –

$$h = \frac{3.022\, lv^{4.052}}{C^{4.052}\, d^{4.467}}$$

$$[c = 150\ for\ soft\ PVC\ pipes]$$

2.2.4.4 Scobey Formula

$$h = \frac{K_2 l v^{4.0}}{1000 d^{4.4}}$$

Where, h = the friction losses in a length *l* of the pipe d = the internal diameter of the pipe,

υ = the average velocity,

C, f, K_a are constant.

2.3 WATER FRONT ADVANCE:

Some important works on wetting front advance were reviewed for better understanding of moisture front advance and its distribution in soil.

In 1970 Goldberg and Shmueli concluded that both soil type and discharge rate controls the rate of horizontal water movement in the soil and metric potential at different distances from the trickle source. So these two functions are interrelated with each other. Thus the width of wetted zone along a trickle irrigation line is a function of the amount and rate of water application and soil type.

Goldberg *et al.,* (1971) investigated the effect of trickle irrigation interval on soil water and salt distribution in an established vineyard where the distance between row to row was 3 m. They found out that the main active soil layer supplying water to the roots is restricted to an approximate width of 2 m and depth of 1.2 m.

Goldberg *et al.,* (1971) declared that it is possible to somewhat increase the lateral spread of wetting front by increasing the emitter discharge rate or the amount of water applied while conducting an experiment on the effect of drip irrigation on distribution of roots, water and minerals in a three dimensional soil profile. They also concluded that the emitter spacing would be close if the soils' infiltration capacity is high and the lateral movement of water is low.

Brandt *et al.,* (1971) and Bresler *et al.,* (1971) compared the results of experimental data with theoretical predictions from the characteristics of the moisture pattern based on certain assumptions by studying the infiltration from a drop source and flow of water in a two dimensional profile. They also took the effect of the trickle discharge rate on the water content distribution and location of wetting front into consideration. Their works indicated that for the condition studied, the trickle discharge rate is indirectly proportional to the horizontal wetted area and is inversely proportional to the depth of wetted soils.

Lomen and Warrick (1974) and Raats (1970) presented interesting theoretical analysis for the water flow from the line sources. Basing on the solution of different flow equations, subjected to certain boundary and initial conditions, they have made their analysis. Their solutions produced theoretical metric flux potential and streamline distribution below a line source.

Keller and Karmeli (1974) presented a useful table as a guide for estimating the percentage of wetted area for various soil texture, emitter discharges and spacing. They have pointed out that, under drip irrigation, the percentage of wetted area as compared to whole irrigated area depends on emitter discharge, spacing and soil type.

Ahmed *et al.,* (1976) have studied the effect of soil type and water application rate from a drip line source on the two dimensional water movement and distribution within the soil profile. Due to the effect of gravitational force, the horizontal water movement during irrigation for loamy sand soil declines with time and tends to approach a limit at larger values of time. It is definite that after terminating the irrigation, the horizontal advance is very small when compared to vertical advance. However, the water movement in the silt loam is dominated by capillary forces resulting in a uniform or equal water advance in both directions. Water application rate and horizontal advance are directly proportional to the volume of water applied and vertical advance of the wetting front is inversely proportional to the volume of water applied. The shape of the wetting front confirms to a semi ellipse. At the time T_i, the water in the soil profile penetrates to a vertical depth V_i. However, the water continues downward.

An equation describing the additional water movement is:

$$V = V_i \exp\left(K\sqrt{In\frac{t}{T}}\right)$$

Where,

V = Vertical advance of water front;

V_i = Depth of wetting front at the end of Irrigation;

K = A proportionality factor;

t = Time equal to or greater than of irrigation;

T = Time less or equal to the time of irrigation.

For shallow rooted and widely spaced row crops, higher water application rates recommended and for deep rooted and closely spaced row crops, lower application rates are advisable.

Kumar and Sivanappan (1979), concluded that drip irrigation, the moisture condition in root zone does not fluctuate between wet and dry extremes; the yield is higher than other irrigation methods, especially when saline irrigation water used, while conducting research on drip irrigation at Tamil Nadu Agricultural University,Coimbatore, Research Farm. This was partially explained by the fact that a plant responds differently to an equal change in the total soil water potential caused either by changing the osmotic pressure or metric component.

Taghavi *et al.,* (1984) used a Galerkin finite element model to investigate two-dimensional infiltration from a drip source. The numerical results compare well with the laboratory and field experiments. The advantages of this model is its capability to simulate water movement through very dry soil environments, which causes a steep moisture front, as well as its potential applicability in irregularly shaped flow regions, which are commonly encountered in the field and are difficult to model with finite difference or other numerical methods.

Clothier *et al.,* (1985) concluded that the distribution of water from a drip emitter is dominated by the physical properties of the soil. Micro jets are an option for soil with cracks, biopores and other preferential water flow pathways, which act to subvert the uniform distribution of water.

Schwartzman and Zur (1986) described a method for determining width and depth of wetted soil volume under an emitter. Emperical expressions relating to the wetted width and wetted depth to saturated hydraulic conductivity (Ks) of the soil, emitter discharge (q) and total amount of water in soil (V) were obtained from the results of cylindrical model simulation experiments. An increase in the value of Ks results in the ratio of wetted soil depth to wetted soil width. This is most prominent in heavier soils. The wetted soil depth increases than the width for an increase in the amount of water in the soil, in a lighter soil. They also develop a procedure for determining the optimal emitter spacing based on the geometry of the wetted soil volume and the cost of the irrigation lateral.

Dash *et al.,* (1989) studied the two dimensional water movement and distribution in sandy loam soil, under drip irrigation system. They observed that at an early stage the vertical water movement was relatively lower than the horizontal water movement. But after a lapse of 100 minutes, the vertical water movement became higher than the horizontal water movement. As the water application rate was increased the horizontal and vertical movement of the wetting front also increased.

The rate of water advance decreased with increase in irrigation time. The moisture content within the wetted zone was found to be higher than the field capacity and hence sufficient moisture is available within the root zone for healthy growth of plant. The shape of wetting front movement within the soil profile irrigated from drip system of irrigation, by utilizing micro tubes confirmed to semi ellipse.

To explore the detail of infiltration phenomena some equations were discussed here,

Green and Ampt (1911) gave the following equation for infiltration process-

$$I = K\,(H_o + L - H_f)/L$$

Where, I = infiltration rate,

K = hydraulic conductivity,

H_o = pressure head at the soil surface

H_f = pressure head at the wetting front,

L = depth of the wetting front.

And the rate of advance of wetting front was given by

$dL/dt = i/f$

Where, f = fillable porosity

Kostiakov (1940) gave a simple infiltration; equation

$i = B\, t^{-N}$

This equation although is less appropriate, but it can accommodate varieties of field results.

Horton (1940) expressed the infiltration phenomena in the following form –

$i = i_c + (i_o - I_c)\ e^{-KL}$

Where, i = infiltrability,

t = time of infiltration,

i_c, i_c and and k = characterizing constants.

Philip (1954) derived a two-term infiltration equation

$I = S\, t^{0.5} + A\, t$

WhereI = accumulated infiltration,

t = infiltration time,

A & S = characteristic constants.

This equation although is physically sound, but it fails to explain field events in many cases, because the assumed conditions are rarely available in-situ condition.

Holton (1961) presented the following infiltration equation

$i = i_c + a\,(M - I)^n$

Where i_c a, M and n = constants.

This equation holds good for the range of $0 \le I \le M$

M is defined as the water storage potential of the soil above the soil stratum.

Seginer (1963) gave the two different equations for describing the horizontal and vertical infiltration. –

$$K_r = \frac{\theta d}{2t H_0} X^2$$

and vertical infiltration as –

$$K_r = \frac{\theta d}{t}(X - H_0.I_n \frac{H_0 + X}{H_0})$$

Where H_o = head at the surface,

K_r = final hydraulic conductivity,

t = wetting front advance time,

S_d = moisture content difference by volume

Brand *et al.* (1971) developed a theoretical model to investigate the multi-dimensional transient infiltration from a trickle source. Results of their developed model indicated that an increase in the trickle discharge resulted in an increase in the horizontal wetted area and a decrease in the depth of the wetted soil, with a typical bulb-shaped cross-section. The percentage of wetted area as compared to the whole-irrigated area depends on emitter discharge, spacing and soil type (Keller & Karmeli, 1974).

Goldberg and Shmueli (1970) indicated that the rate of horizontal water movement in the soil and the final width of the wetted zone along the trickle irrigation line are functions of amount, rate of water application and soil type.

Goldberg *et al.* (1971) reported that it is possible to somewhat increase the lateral spread of the wetting front by increasing the emitter discharge rate or the amount of water applied.

Hawatmeh and Battikhi (1983) studied the wetting fronts under a trickle source in two uncrusted soils of the Jordan Valley. They developed equations for the horizontal Y_h and Y_v advance of the wetting front as a function of time t since wetting starts on sandy loam soil using an application rate of $8.4 l/h^{-1}$ and initial soil moisture between 5.5% and 8%.

$$Y_h = 2.12 + 11.14t^{1/2} \qquad (1)$$

$$Y_v = 5.71\ t^{1/2} + 4.9t \qquad (2)$$

The success of localized irrigation system is possible if there is a good understanding of the infiltration phenomena and water distribution in soil. Several theoretical and experimental studies have been conducted for this purpose, Ould-Mohamad EL-Hatesh, 1996 *et al.* proposed relationship blow between volumetric water content (θ) and head (h) can be expressed by

$$\theta(h) = \theta wp + \frac{\Sigma - \theta wp}{1 + 0.541h}$$

Where, θwp = volumetric water content at wilting point (%)

h = metric head (meter of water)

Σ = Porosity (%) in soil

For the improvement of irrigation efficiency of Drip Irrigation system, the optimal irrigation amount of water (v), which can be stored in the root zone, should be calculated for determination of emitters spacing. In this direction Askri, and Goldberg et al. used a formula

$V = (\theta_{tc} - \theta_1)\ d\ \delta Z_r$

Where θ_{tc} = Volumetric water content at field capacity,

θ_I = Initial volumetric water content,

d = Dripper Spacing,

δ = Width of the root-zone,

Z_r = is the root depth.

2.4 EFFECTS OF TEMPERATURE CHANGES ON EMITTER DISCHARGE

Temperature affects water viscosity and emitter geometry. Emitters are devices which discharge through small sections open to water flows. The hydraulic performance of emitters has been characterized by an empirical potential equation that relates emitter flow q and operating pressure at the emitter p.

$q = kp^x$ (1)

Where k and x=constants that can be determined by linear regression performed on the logarithms of measured q versus p, at a constant temperature.

Temperature variations influence water properties, especially temperature affects water viscosity and emitter geometry. This may be a significant factor affecting flow through emitters. Geometry in the flow passage may also be affected. As a consequence, changes in, friction and emitter discharge are expected.

Zur and Tal (1981) observed that discharge changes of helical long-path emitters were significantly less than those predicted by the dependence of viscosity on temperature. Their flow regime was influenced by inertial as well as viscous forces (Tal and Zur 1980).

The studies of Parchomchuk (1976), Solomon (1977), and Zur and Tal (1981) indicated that, with a few exceptions, the effect of water temperature on emitter flow rate is roughly linear. It is generally described by linear regression (Zur and Tal 1981; Von Bernuth and Solomon 1986). Decorix and Malaval (1985) observed the dependence of discharge variation of non-compensating emitters on the exponent x. Discharge rates increased as temperature increased for emitters with x>0.5 but decreased for emitters with x<0.5. A linear regression of the discharge variation on the exponent x was proposed as follows:

$$\left(\frac{q_{40}-q_{20}}{q_{20}}\right)100 = 57.35x - 28.24\ (R^2 = 0.98) \qquad (2)$$

Where q_{40} = emitter discharge at 40°C; and q_{20} = emitter discharge at 20°C.

Compensating emitters behave according to different principles. They are constructed to give a nearly constant discharge over a wide range of inlet pressures. That is achieved using an elastomer consisting of a resilient membrane in the flow path. It works like a diaphragm separating two chambers. When it is acted on by a pressure differential, the flow cross-section decreases.

The temperature of water flowing in irrigation pipes exposed to solar radiation is expected to increase with distance.

Kandale and Narda (1993) found that the discharge rate through emitters tested in the laboratory was varied with variation of temperature ranging from 18°c to 30°c with a relation

$$Q = a + bT$$

Where,

Q = discharge of emitter, lph

T = temperature of water, °c

a and b are constants, whose values were found out for different types of emitters at different operating heads.

MATERIALS AND METHODS

CHAPTER – III

This chapter deals with the details of the system used, site selection, site preparation and other materials installation of drip system along with the procedure of the testing of the system and water front study.

3.1 DETAILS OF THE SYSTEM HEAD UNIT

3.1.1 Water Storage Tank

This was a underground tank of 1200 liters capacity. The main water supply from the deep tube well was connected to this tank. Water supply to the drip system was made by 0.5 H.P. pump taking water from the storage tank.

3.1.2 Pumping Set

A mono-block pump of capacity 2400 lits at head of 6m capable of delivering water at a pressure of 2.5 kg/sq.cm. was used. Details of the pump is given below:

Design No.	-	2859[Crompton Greaves]
Size	-	25mm X 25mm
RPM	-	2800 (constant rating)

3.1.3 Screen Filter

A screen filter of 120 mesh size was connected in the system to prevent the dirt and debris from entering into the system.

3.2 DETAILS OF THE SYSTEM

3.2.1 Mainline

Main line, a 30 mm diameter rigid PVC pipe was laid on the ground surface. A 'T' junction is provided so that the mainline can be laid out on either side of the pump assembly.

3.2.2 Pressure Reducing Valves

Mainline was fitted with an adjustable pressure reducing valve so that pressures can be adjusted separately and maintained at a predetermined level. Pressure gauge are fitted downstream of each regulator so that pressure can be measured.

3.2.3 Laterals and Emitters

Laterals were 30 meters long and 12 mm dia are connected to the mainline through a ball valve to open or close the flow. A snap coupling is provided to facilitate easy and quick connection and disconnection of laterals from mainline. Pressure gauge was located immediately downstream for monitoring the operating pressure at the head of the lateral. Different types of emitters used in the experiment are given in table.

Table 3.1 Types of emitters tested.

Sl. No.	Type	Discharge rating
1.	Turbo Key	2 lph
2.	Turbo Key	4 lph
3.	Self Pressure Compensating	2 lph
4.	Turbo-key	8 lph
5.	J-Lock	8 lph
6.	Turbo Seal	2 lph
7.	Turbo Seal	4 lph

3.3 EXPERIMENTAL SITE AND LAYOUT

The experimental plot (30m × 30m) was selected at Precision Farming Development Center, Orissa University of Agriculture and Technology, Bhubaneswar.

3.4 SOIL

The soil of the experimental plot was sandy loam. The details of the properties of the soil are described in the Appendix: A.

3.5 FIELD PREPARATION

The field preparation for uniform movement of moisture front was carried out in three stages –

(i) Clearing of the grasses.

(ii) Partial land smoothening.

(iii) Fine leveling.

3.6 INSTALLATION OF THE DRIP SYSTEM

The system was installed to receive water from underground tank through the pump. For installation of Drip System a main line of (30 mm) dia was laid down on ground surface. In between the pump and main line a filter was installed to screen out all the particles flowing through water. Other end of the main was plugged. From main line a laterals was connected which was laid down on the ground surface. In the lateral, emitters were fitted for study of their hydraulics.

3.7 OPERATING SYSTEM

Operating system consists of tank and pump with accessories. For starting the experiment following works followed for pumping water to the drip system.

Before start-up

i) Water storage tank was filled with water.

ii) It was checked that the screen filter is clean

iii) All the ball- valves at the head of laterals were kept in closed position.

Start-up

i) Priming was done

ii) Pump switch was started.

iii) Delivery valve are opened and pressure was adjusted within working range.

iv) The pressure of lateral was adjusted with the help of the valve at the head of that lateral.

v) The end plugs of the lateral were opened for about 5 minutes time for flushing before taking any observation.

3.8 PRESSURE DISCHARGE RELATIONSHIP

For pressure discharge relationship, pressure was set at the head of the lateral with the help of ball valve and discharge was collected in a container for a period of 60 minutes. The discharge of five same type of emitters was recorded for a particular pressure in the same operating

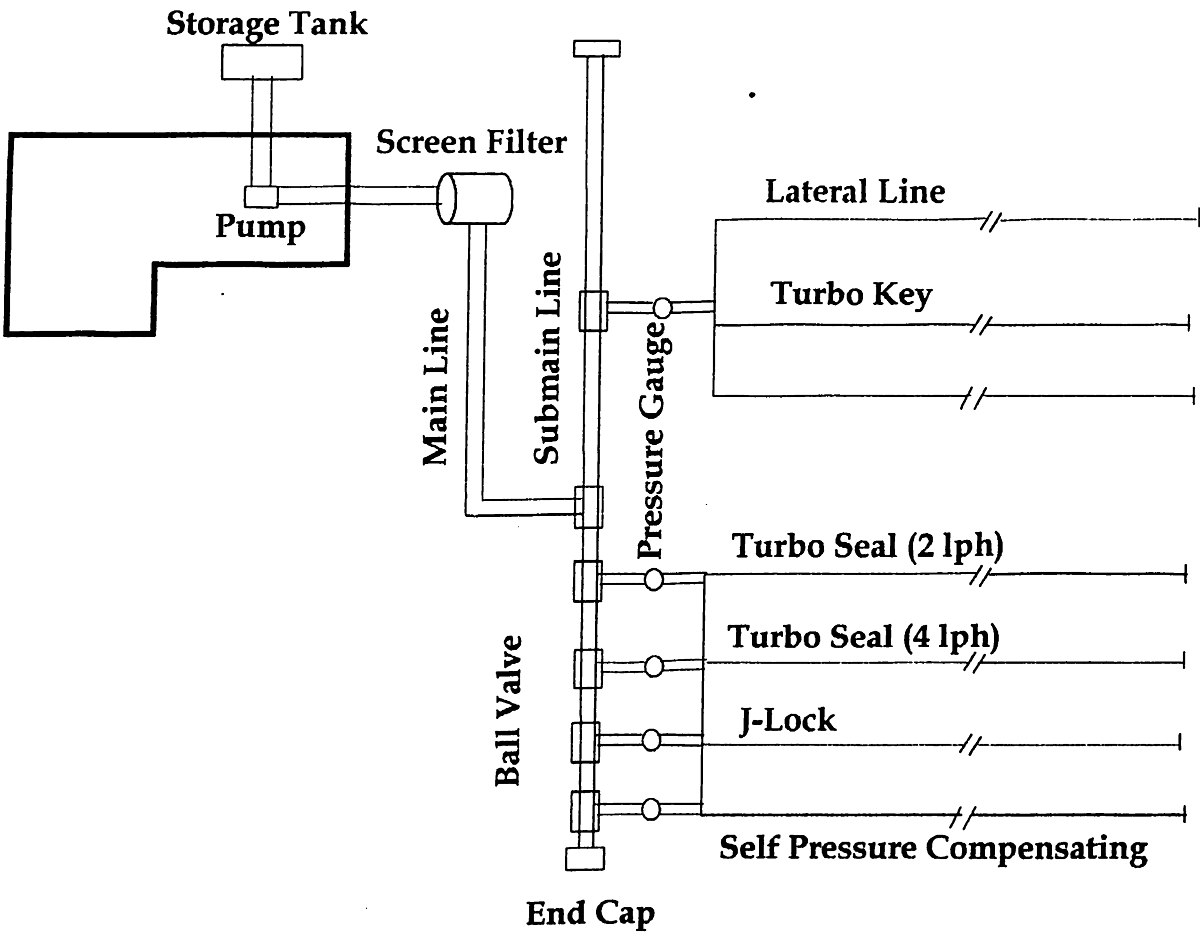


fig. 3.1 LAYOUT OF THE SYSTEM

Plate No. 1 Different types of emitters tested

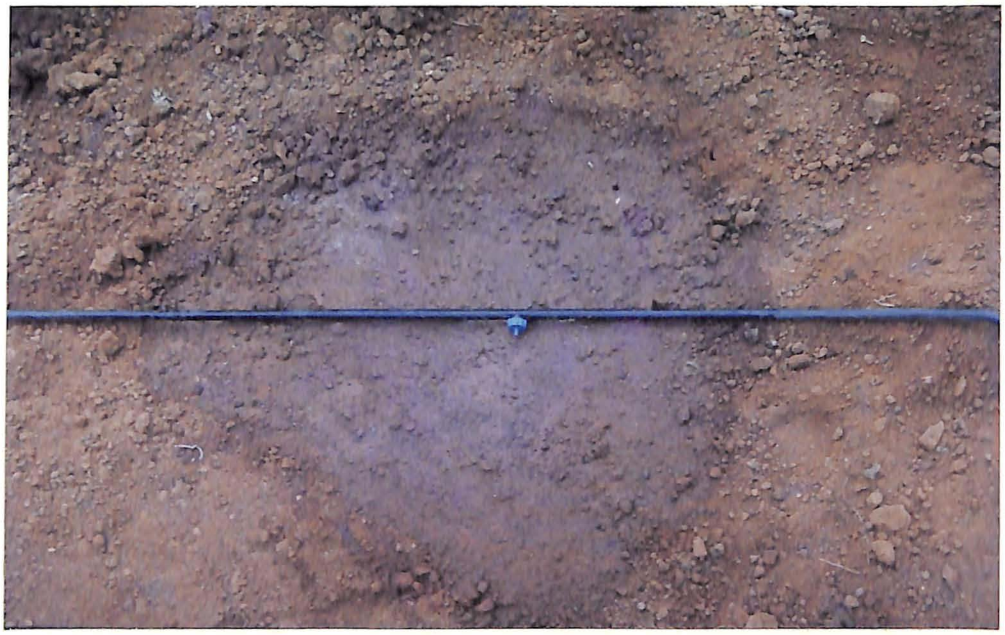


Plate No.2 Lateral line operating in field condition and then we took the average of five reading to minimize the error. This procedure was repeated for other type of emitters.

3.9 DETERMINATION OF MANUFACTURING COEFFICIENT OF VARIATION:

The water passages in emitters are usually of small diameter and accuracy is essential if large differences in emitter flow are to be avoided. To determine manufacturing co-efficient of variation for a set of emitters operating at a reference pressure was measured using equation given below:

$$CV = \frac{\sigma q}{q}$$

The procedure followed for determination of the co-efficient of variation was as follows:

(1) Irrigation system was switched on, pressure reducing valve was set so that pressure at the head of the lateral can be within operating pressure range.

(2) Discharge of the first emitter along the lateral was measured for period of 15 minutes for 3 times. Then taking the average of three readings we recorded the discharge of that emitters at that particular pressure.

(3) Valve at the head of the lateral was then closed and emitter was replaced with the emitter of same type and same discharge rating and step 2 was repeated.

(4) Procedure was replicated for 8 emitters.

(5) Manufacturing coefficient of variation was calculated using the above equation.

(6) Experiment was repeated for other types of emitters in the similar way.

3.10 EFFECT OF PRESSURE ON EMISSION UNIFORMITY

Emission uniformity can be considered as the most important parameter in deciding system performance. It can be given as-

$$EU = Q_1/Q_2$$

Where, Q_1 = average discharge of one fourth number of the total emitters giving lowest discharge.

Q_2 = average discharge of the all emitters.

Procedure followed for determination of emission uniformity step by step is discussed below.

(i) The whole lateral length was divided into four segments. From each segment four evenly spaced emitters were selected.

(ii) Below each of the emitter selected, a small pit was dug so that container can be put under the emitter without disturbing the emitter.

(iii) Only one lateral was operated at a time.

(iv) Pressure of 0.25 kg was set at the head of the lateral with the help of ball valve.

(v) Discharge from all the emitters was collected for the period of 60 minutes. Pressure was checked in the middle and at the end of the set to see the variation, if any.

(vi) Emission-uniformity was calculated using equation given above.

(vii) Procedure was replicated for the pressure range of 0.25, 0.75, 1.0, 1.5 and 2.00 kg/sq cm in the increment of 0.25kg/sq cm and above steps were repeated respective pressure.

3.11 STUDY OF THE MOISTURE FRONT ADVANCE

Study of the moisture front advance was conducted in the field at Precision Farming Development Centre at O.U.A.T.,Bhubaneswar. Experiment to determine the advance of moisture front Turbo Key emitters of discharge 2 lph, 4 lph and 8 lph were selected. Moisture front advance was measured readily for horizontal movement at different time interval. Procedure for taking observations in brief as follows:

(i) System was switched on and pressure was adjusted within operating range.

(ii) Tray was kept under the emitter from which water was to be applied and pressure was set precisely with the help of ball valve at the head of the lateral.

(iii) Discharge rate was checked by collecting water in a container for a known period of time and adjusted if required, and then tray was removed.

(iv) Lateral was operated for required time.

(v) Soil samples were taken from different place, once after 150 minutes of irrigation and again after 240 minutes of irrigation and after 360 minutes of irrigation. Moisture content was determined by gravimetric method.

3.11.1 Determination of Volumetric Moisture Content:

Gravimetric sampling is the direct and most commonly adopted method for determination of soil water content. We followed gravimetric method for soil moisture determination. In this method samples were taken from the field by auguring and dried in the oven at 105°C for 24 hours, until constant weight is attained and the difference in initial and final weight is expressed as a fraction of unit of dry soil moisture. At first we collected soil samples from different points of the experimental plot at different points of time for determination of moisture content.

We get volumetric moisture content using this relationship

$$\theta = D_b \times W$$

Where, D_b = Bulk Density (gm/cm^3)

W = Gravimetric water content (gm/gm)

$$W = \frac{W_2 - W_3}{W_3 - W_1}$$

Where, W_1 = Weight of moisture box

W_2 = Weight of moisture box + Weight of soil

W_3 = Weight of moisture box + Weight of oven dry sample

3.12 EXPERIMENT ON EFFECT OF TEMPERATURE CHANGES ON EMITTER DISCHARGE:

The total experiment was conducted in the precision farming center, O.U.A.T., Bhubaneswar. The main objective was to study the effect of temperature variation on emitter discharges. We mainly considered the temperature variation between morning and afternoon temperature of a bright summer day in actual field condition at Bhubaneswar, maximum temperature variation between morning and afternoon periods in a bright summer day was recorded 11°C during experiment.

A 12 mm dia 30 m plastic pipe was taken stretched on the field in the bright sunshine to study the effect of temperature variation on discharge. Temperature at the field was recorded at the 8.00 A.M. and then discharge of different emitters were taken at different pressure and recorded. Then same procedure was applied to record the discharge at 2.00 P.M. after recording the temperature .For accuracy same procedure was repeated for 7 bright summer days. The temperature of water flowing in irrigation pipes exposed to solar radiation was expected to increase with time.

RESULTS AND DISCUSSION

CHAPTER – IV

This chapter deals with the results of experiment conducted for evaluation of the hydraulic performance of seven different types of emitters and water front advance pattern observed in sandy loam soil from a point source.

4.1 EFFECT OF PRESSURE ON DISCHARGE

The discharge variation of emitter was recorded for the pressure range of 0.25 to 2.0 kg/sq.cm with the increment of 0.25 kg/cm^2. The pressure discharge relationship for the emitter was presented graphically.

From the plot we can see that discharge increases with increasing pressure, but at a decreasing rate. The equation of best fit can be given in the power form (Keller and Karmeli, 1973):

$$Q = K H^x$$

Where, Q = discharge of the emitter (in lph),

H = total head governing flow, (kg/cm^2),

K = constant depending on the emitter and also on the units used in the equation,

x = a constant representing emitter flow regime.

The values of constants for all the tested emitters have been presented in Table 4.1.The discharges of different tested emitters at different pressure were presented in Appendix:B.

4.1.1Turbo Key:

The discharge variation of Turbo Key emitter was recorded for the pressure range 0.25 to 2.00 kg/sq.cm with an increment of 0.25 kg/sq.cm. The pressure discharge relationship for the emitters is presented in Fig.4.1.

From the curves, we can see that pressure versus discharge graph for 2 lph rating and 4 lph rating follow almost same pattern but the steepness of curve for 8 lph rating Turbo Key emitters are found highest.

From the table 4.2 it can be seen that for Turbo Key emitters, the value of flow parameters 'x' = 0.279 and 0.3651 for 4 lph or 8 lph rating respectively which defines the flow regime is turbulent and the value of 'K' is 3.6340 and 5.9296 for 4 lph or 8 lph respectively.

4.1.2 Turbo Seal:

The Discharge variation of Turbo Seal was recorded for the pressure range 0.25 to 2.0 kg/sq.cm with the increment of 0.25 kg/sq.cm. The pressure discharge relation was represented in the fig. 4.2.

The discharge of 2 lph rating Turbo Seal emitters showed better performance in the pressure ranges 0.75 kg/sq.cm to 1.5 kg/sq.cm. Both 2 lph rating and 4 lph rating types of Turbo Seal emitter showed a little increase in discharge when pressure was increased from 1.5 kg/sq.cm to 2.0 kg/sq.cm. So from the study we found the optimum pressure range of operation of Turbo Seal emitters were found 0.75 kg/sq.cm to 1.5 kg/sq.cm. The flow parameters 'x' and 'k' value for Turbo Seal are given in Table 4.1.

4.1.3 Self Pressure Compensating:

The discharge variation of Self Pressure Compensating emitter was recorded for the Pressure range 0.25 to 2.00 kg/sq.cm with an increment of 0.25 kg/sq.cm. The discharge-pressure relationship for the emitters is presented in Fig 4.4. From the obtained curve, we can see that the curve is not that steep and the rate of discharge variation with the increment of pressure is low. It gives best result in low pressure in comparison to others type of emitters. Its flow parameter was found to be 'x'=0.15451, so flow is turbulent in nature.

4.1.4 J-Lock:

The Discharge variation of J-Lock was recorded for the pressure range 0.25 to 2.0 kg/sq.cm with the increment of 0.25 kg/sq.cm. The pressure discharge relation was represented in the fig 4.3.

Among the all type of emitters tested, the variation of discharge with the increment of pressure, was found highest in J-Lock type

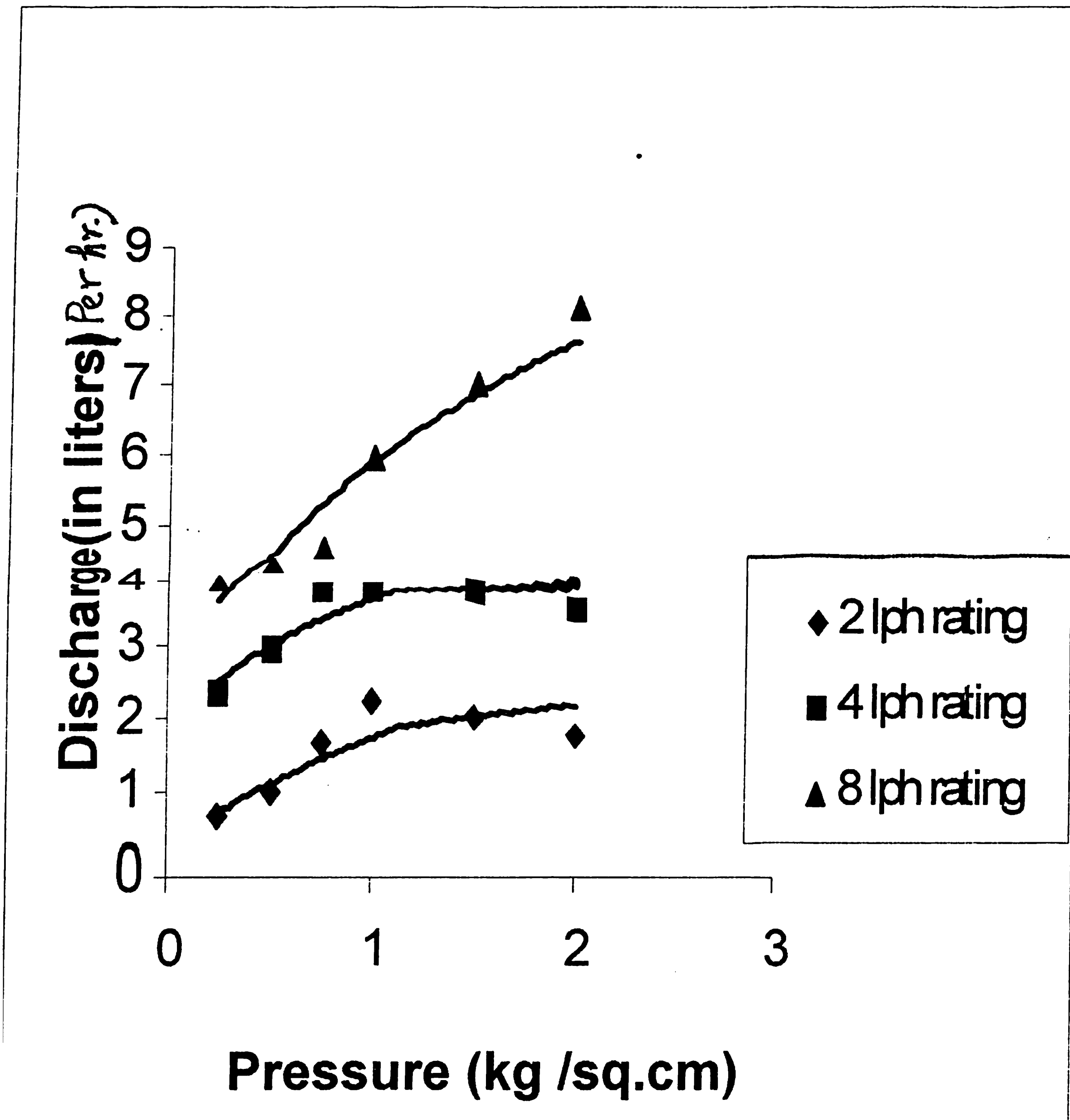


fig. 4.1

Pressure Discharge relationship for Turbo Key

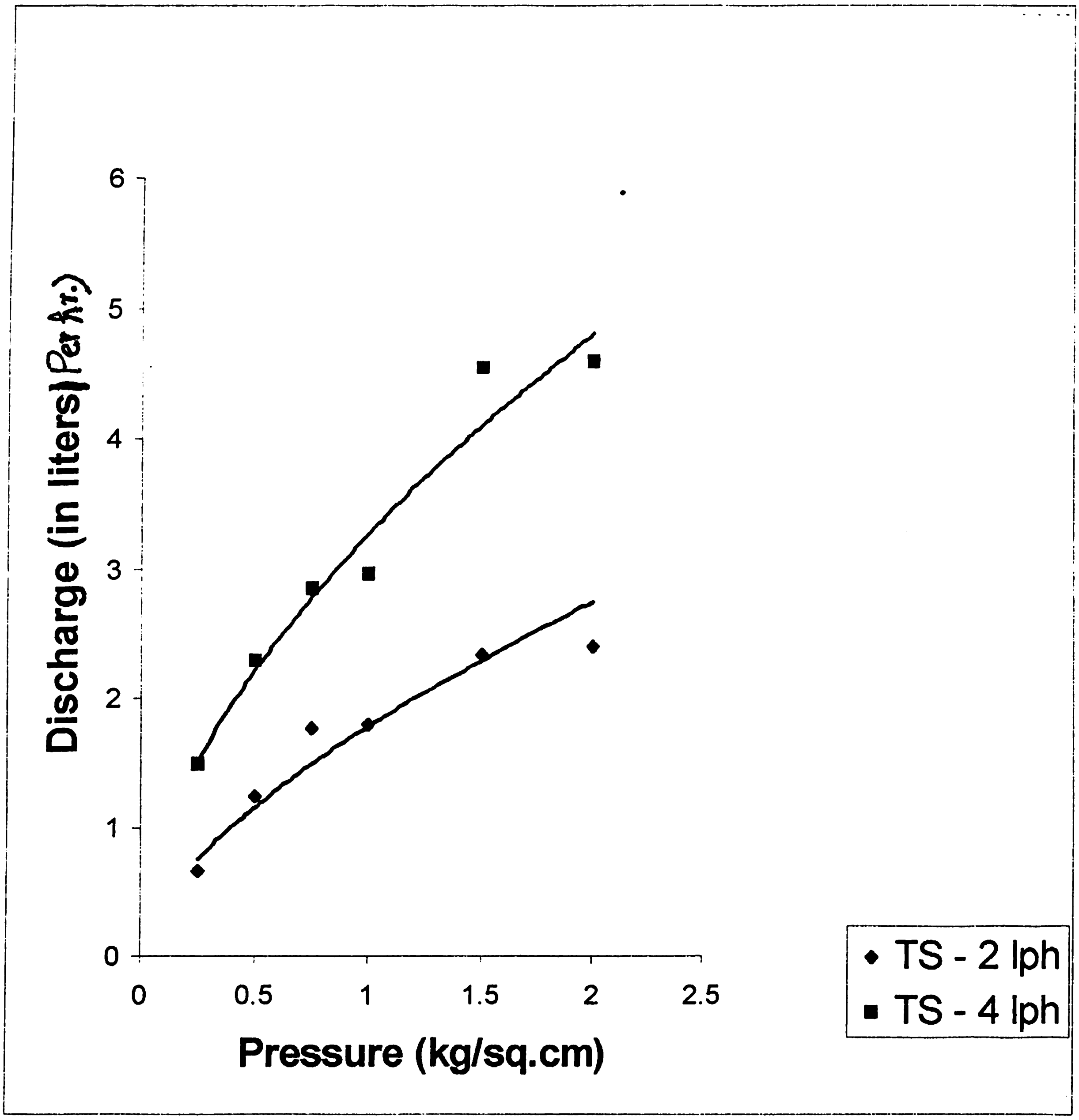


fig. 4.2

Pressure Discharge relationship for Turbo Seal

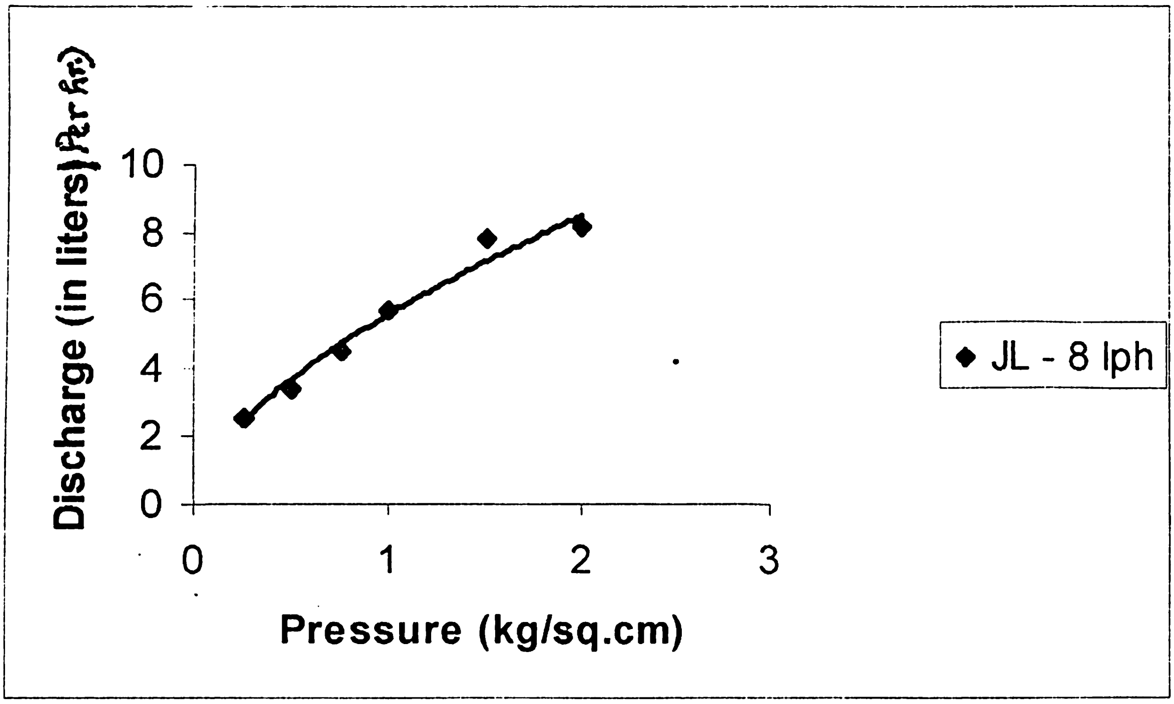


fig. 4.3

Pressure Discharge relationship for J-Lock

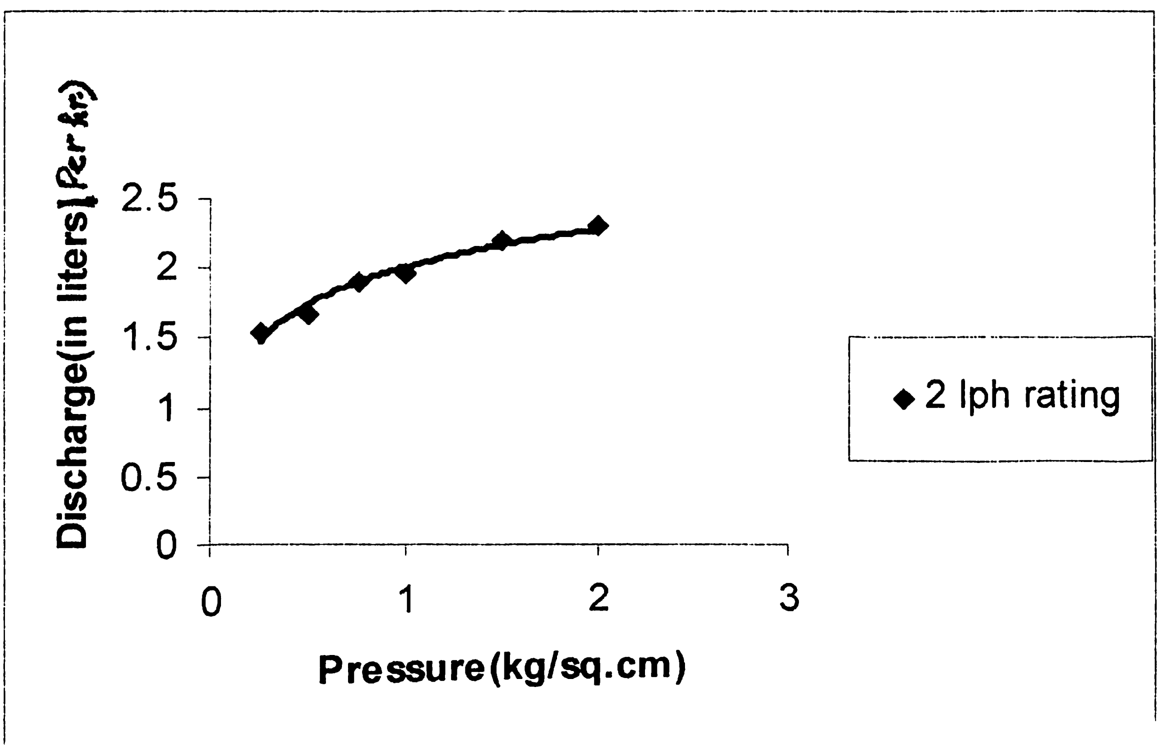


fig. 4.4

Pressure Discharge relationship for Self Pressure Compensating

emitters. The pressure-discharge curve is having the highest steepness among all pressure-discharge curves of tested emitters. The flow parameters are found 'x' = 0.5994, so in the J-Lock type emitters flow is laminar in nature. The equations of the best-fit curves of tested emitters and performance as found represented in below.

Table 4.1 Equations of best fit curves of tested emitters.

Sl. No.	Emitter type	Equation of the curve	R^2 Value	Remarks on Performance
1.	Turbo-key (2 lph)	$Q_2=1.7193\ x^{0.6397}$	0.8996	Good
2.	Turbo-key (4 lph)	$Q_4=3.6340\ x^{0.279}$	0.9101	Good
3.	Turbo-key (8 lph)	$Q_8=5.9296\ x^{0.3651}$	0.9284	Very good
4.	Turbo Seal (2 lph)	$Q_2=1.7933\ x^{0.6162}$	0.9402	Average
5.	Turbo Seal (4 lph)	$Q_4=3.2737\ x^{0.5546}$	0.9729	Average
6.	J lock (8 lph)	$Q_8=5.5734\ x^{0.5994}$	0.9787	Good
7.	Self Pressure Compensating (2 lph)	$Q_2=0.3889\ Ln(x) + 2.0072$	0.9707	Excellent

Table:4.2 The values of flow parameters(K) and (x) of tested emitters :

Sl. No.	Name	Discharge	'k'	'x'
1.	Turbo-key	2 lph	1.7193	0.6387
2.	Turbo-key	4 lph	3.6340	0.2790
3.	Turbo-key	8 lph	5.9296	0.3651
4.	Turbo Seal	2 lph	1.7936	0.6162
5.	Turbo Seal	4 lph	3.2737	0.5546
6.	J lock	8 lph	5.5734	0.5994
7.	Self Pressure Compensating	2 lph	2.06639	0.15451

4.2 MANUFACTURING COEFFICIENT OF VARIATION

The manufacturing coefficient of variation was calculated from observed data. The manufacturing coefficient of variation for the tested emitters is shown in Table 4.3.

From the Table 4.3 results we can observe that manufacturing coefficient of variation was lowest (2.11%) for Turbo Key (8 lph rating), while it is the highest 8.52% for J-Lock where as it values for Turbo Key (2 lph), Turbo Key (4 lph), Self-pressure Compensating (2 lph) and Turbo Seal (2 lph) and Turbo Seal (4 lph) were 4.11%, 2.75 %, 4.95%, 5.10%, 2.17% respectively. This indicates that the value of manufacturing co-efficient of variation for all the emitters were within the permissible limit.

TABLE – 4.3

Manufacturing Coefficient of Variation for Various Types of Emitters

Type of emitter	Manufacturing coefficient of variation
Turbo-key (2 lph rating)	4.11%
Turbo-key (4 lph rating)	2.75%
Turbo-key (8 lph rating)	2.11%
J-Lock (8 lph rating)	8.52%
Self-Pressure compensating (2 lph)	4.95%
Turbo Seal (2 lph rating)	5.10%
Turbo Seal (4 lph rating)	2.17%

4.3 Effect of Pressure on Emission Uniformity:

The observations of the emission uniformity at different operating pressure are presented at appendix:C.

4.3.1 Turbo Key emitters:

The Emission Uniformity for the Turbo Key emitters was determined for the pressure range of 0.25-2.00 kg/sq.cm with the increment of 0.25 kg/sq.cm. From the observed data the variation of uniformity with change in pressure is shown in fig 4.5. The results indicate that Emission Uniformity is quite low in lower pressure. It increases with the increase in pressure. The lowest Emission Uniformity was recorded at a pressure 0.5 kg/sq.cm, where as highest Emission Uniformity was recorded 98% at 1.5 kg/sq.cm. The Emission Uniformity for different rates of discharges 2 lph, 4 lph and 8 lph Turbo Key type emitters showed very high value, more than 90% when the pressure cross 1 kg/sq.cm which is minimum acceptable limit in drip system design. From the study it was found that the Turbo Key type emitters works satisfactorily at a pressure range 1.00 kg/sq.cm to 2.00 kg/sq.cm.

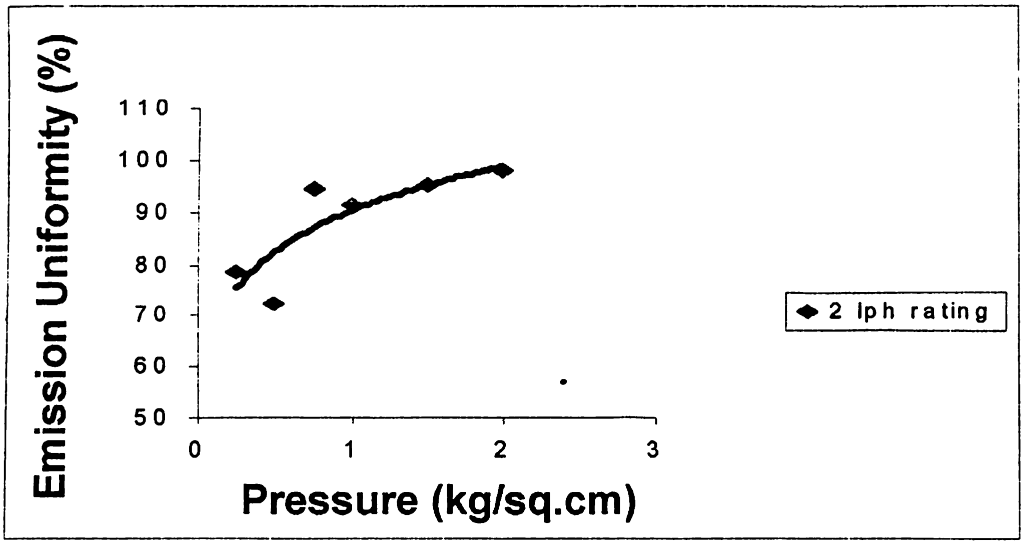
4.3.2 Turbo Seal:

The Emission Uniformity for the Turbo Seal emitters was determined for the pressure range of 0.25-2.00 kg/sq.cm with the increment of 0.25 kg/sq.cm.

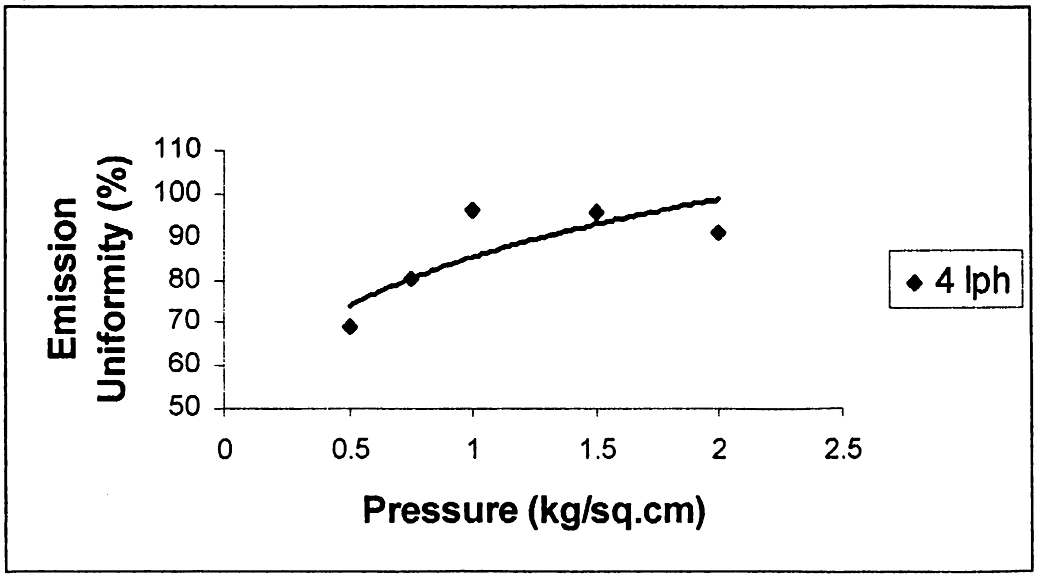
The performance of Turbo Seal type emitters not found as good, was expected. The variation of Emission Uniformity with change in pressure is shown in (fig 4.6). It was seen that the variation of Emission Uniformity is quite high and it does not follow any definite pattern, the minimum and maximum Emission Uniformity for 2 lph rating were recorded at 0.25 kg/sq.cm and at 2 kg/sq.cm pressures respectively. For 4 lph rating minimum and maximum Emission Uniformity were recorded at 0.25 kg/sq.cm and at 1 kg/sq.cm respectively, so there is no definite pattern for the change of Emission Uniformity with pressure for Turbo Seal type of emitters.

4.3.3 J–Lock :

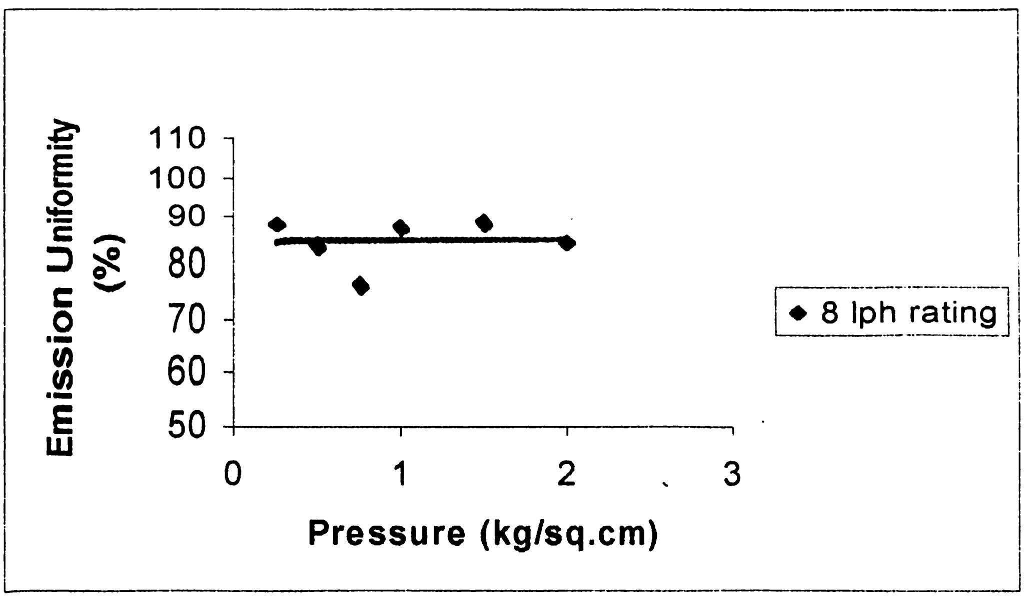
The Emission Uniformity for the J–Lock emitters was determined for the pressure range of 0.25-2.00 kg/sq.cm with the increment of 0.25 kg/sq.cm. From the observed data the variation of emission uniformity with change in pressure is shown in fig. 4.7.



(1)



(2)



(3)

fig. 4.5

'ressure - Emission Uniformity relationship for Turbo Key

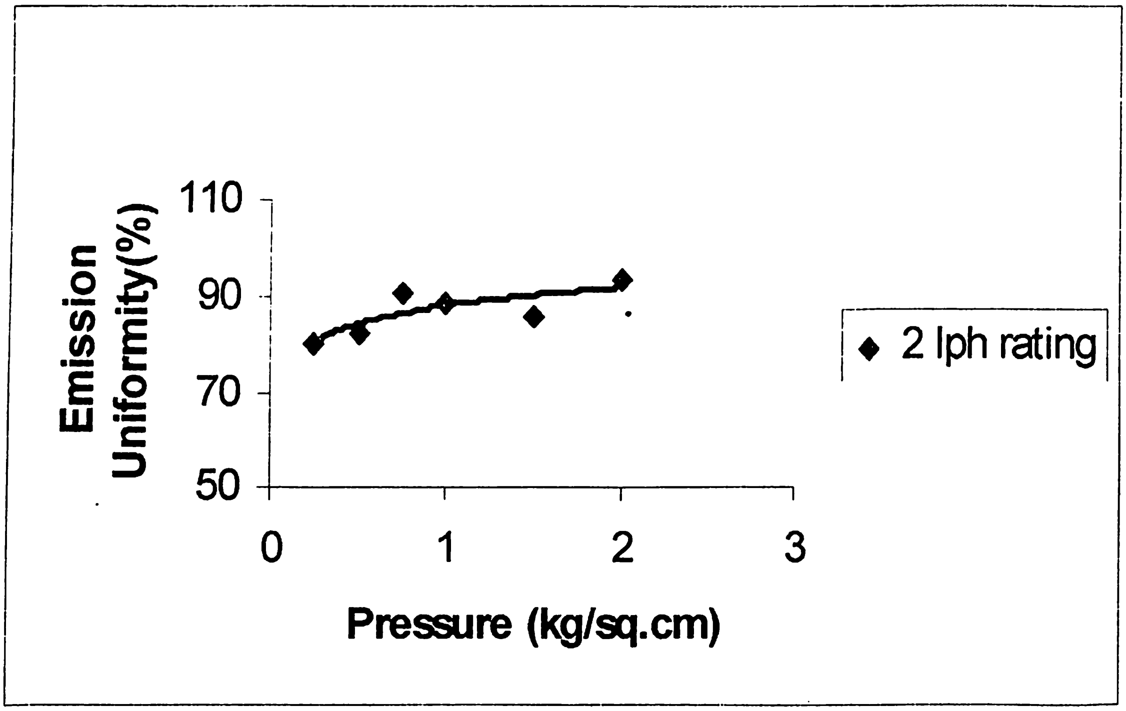


fig. 4.6.1

Pressure - Emission Uniformity relationship for Turbo Seal (2 lph)

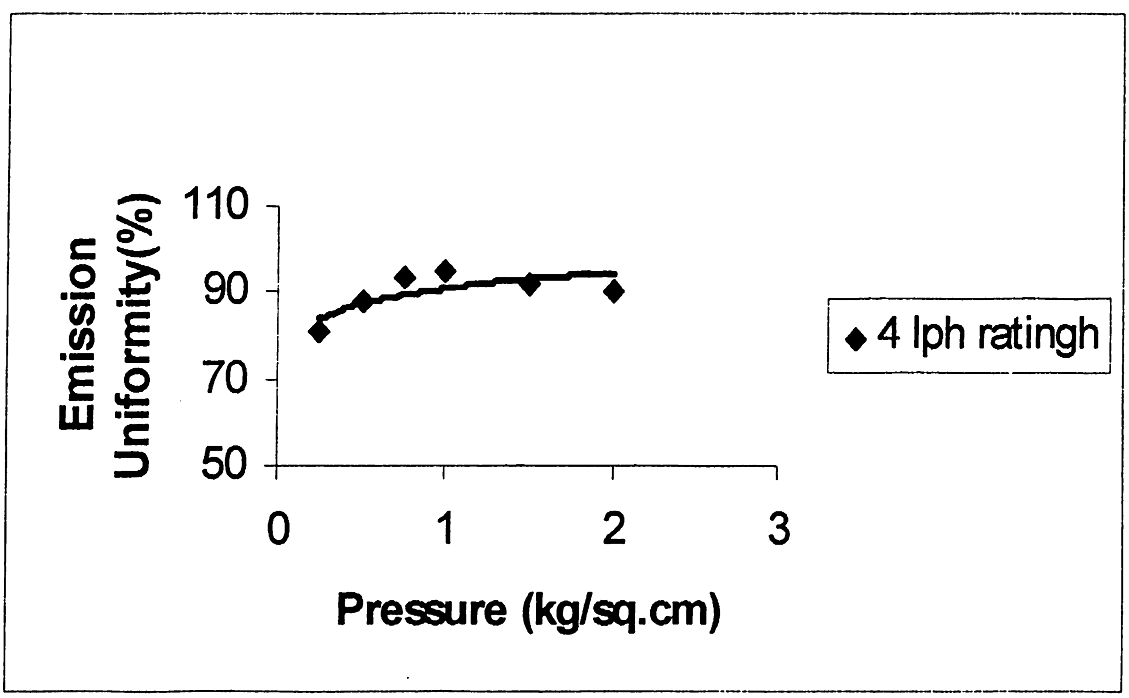


fig. 4.6.2

Pressure - Emission Uniformity relationship for Turbo Seal (4 lph)

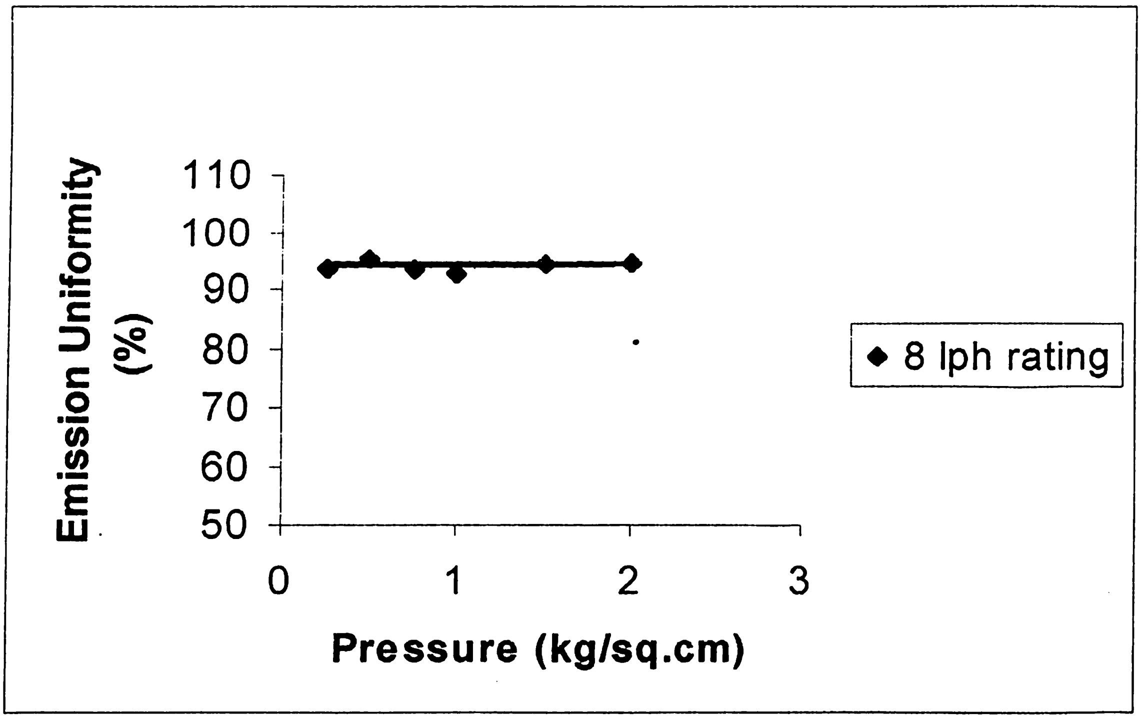


fig. 4.7

Pressure - Emission Uniformity relationship for J-Lock

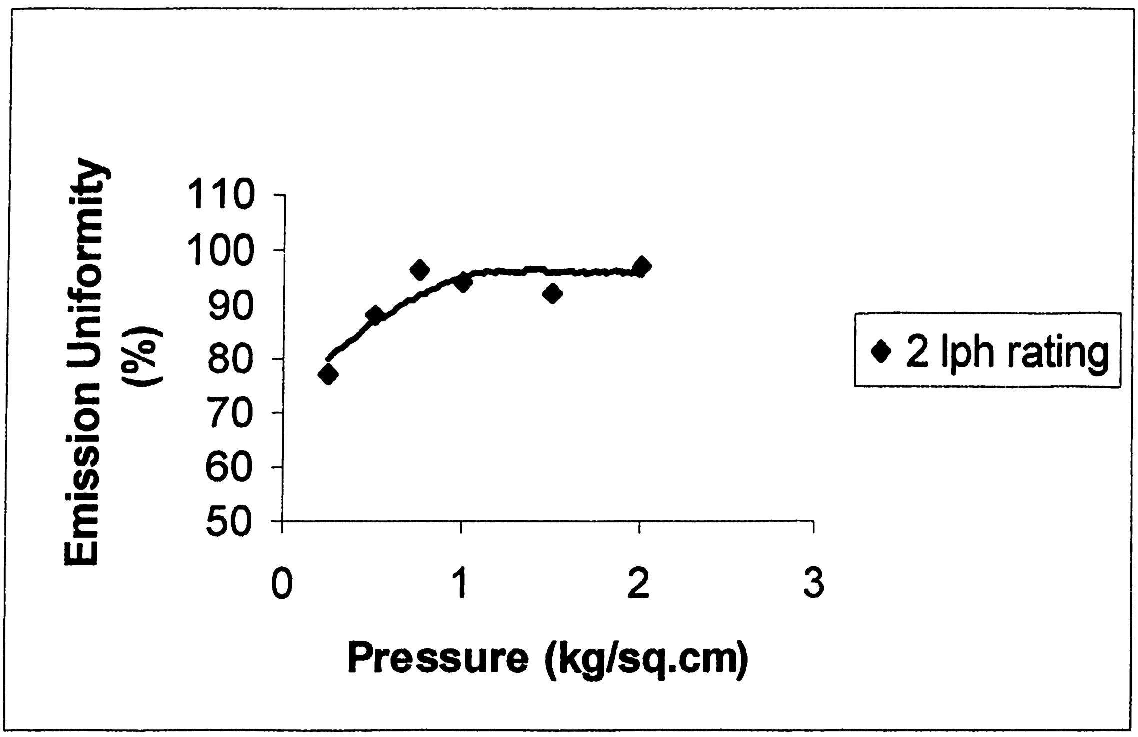


fig. 4.8

Pressure - Emission Uniformity relationship for Self Pressure Compensating

The Emission Uniformity of J-Lock found better than expected. In *J-Lock due to the off and on mechanism some disturbance in flow path was expected for which Emission Uniformity could have been affected but in our sample of J-Lock we found the Emission Uniformity of J-Lock is varying from 93% to 96%* which is very high. The minimum and maximum Emission Uniformity were recorded at 0.25 kg/sq.cm and at 2.0 kg/sq.cm respectively.

4.3.4 Self-Pressure Compensating:

The Emission Uniformity for the Self-Pressure Compensating emitters was determined for the pressure range of 0.25-2.00kg/sq.cm with the increment of 0.25 kg/sq.cm. From the observed data the variation of uniformity with change in pressure is shown in fig. 4.8.

It was found that, for self-Pressure compensating type of emitters Emission Uniformity remains almost steady at the pressure range 0.75 kg/sq.cm to 2.00 kg/sq.cm. Even at the lowest pressure 0.25 kg/sq.cm it showed 77.41%, which is considered very high at that pressure. So from the observation it was found that self-Pressure compensating type of emitter could be operated very successfully at a pressure range 0.75 kg/sq.cm to 2.00 kg/sq.cm. This type of emitter is very helpful in drip system design for slopy and undulating lands because it can allow higher-pressure variation and gives good result.

4.4 Study of Wetting Front Advance:

Study conducted on movement of water front at horizontal direction from point source on different discharge rates at Precision Farming Development Center,OUAT, Bhubaneswar. The observations recorded during the study for discharges of 2 lph, 4 lph and 8 lph for time period 0 to 360 minutes are presented in Appendix:E-2. The graphical representation is shown in fig. 4:9, the equation of best-fit curve is also represented in same fig. 4.9

Appendix: E and fig.4.9 indicates that the horizontal movement at any time from starting of water application is higher for higher rate of

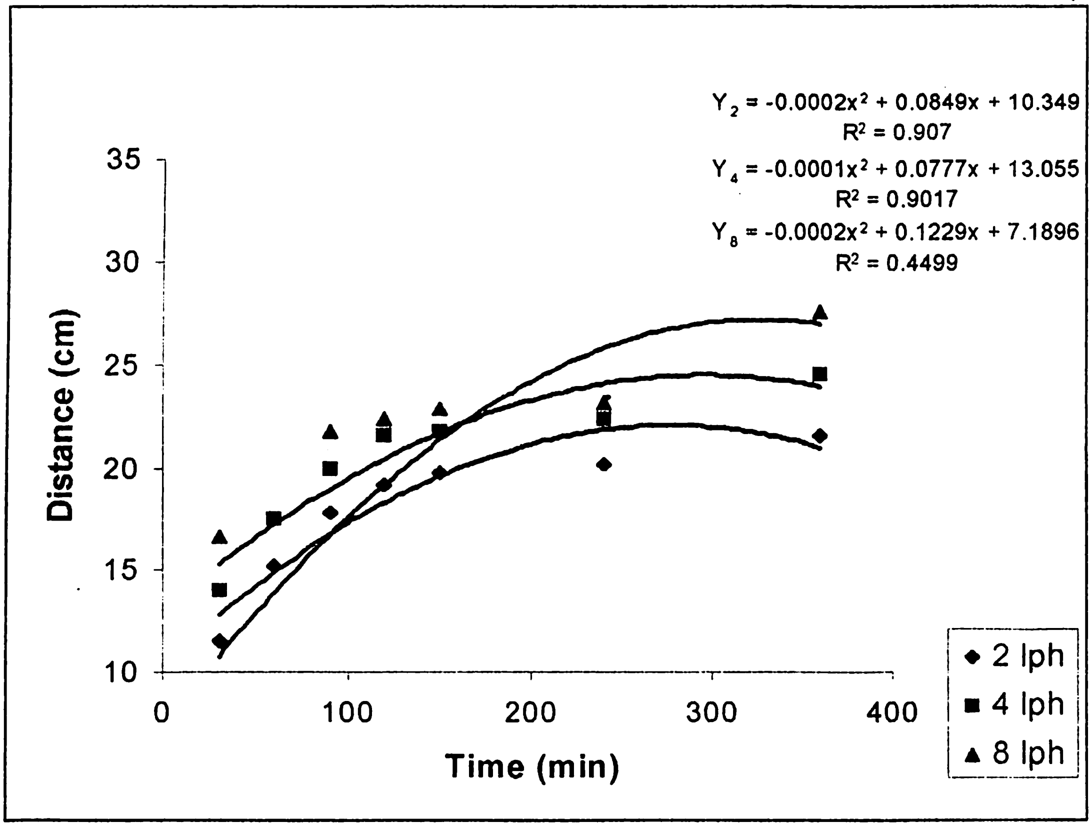


fig. 4.9
Water Front Movement with time

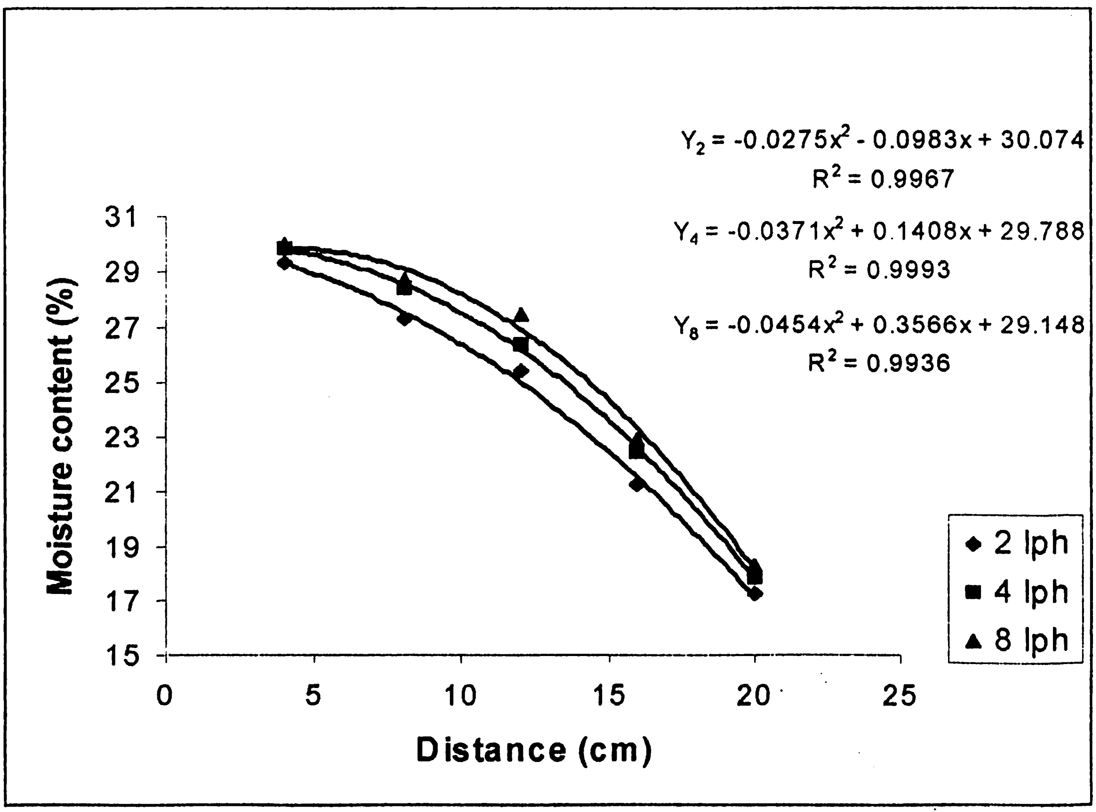


fig. 4.10
Variation of Volumetric Moisture content with Distance from point of application

discharges. It was observed that if application rate was doubled the increase in wetted diameter was roughly 22%.

Equations developed for best-fit curve was poly-nomial equation of second order proved to satisfy result with higher values of co-relation co-efficient. This trend is justified because of the rate of infiltration of soil is constant with higher rate of application of water. Waterfront advance rate also increases. Al-Qinna *et.al.* observed that to minimize the water loss through evaporation and to increase the soil water storage in the crop root zone, increase in emitter spacing should be accompanied by increasing application rate or emitter discharge so that more water can infiltrate into the soil and can be showed in root zone for meeting crop water requirement with minimum evaporation loss. The results obtained in study were in line with the above reports.

4.4.1 Volumetric Moisture Content:

Soil moisture content at radial distance of 4 cm, 8 cm, 12 cm, 16 cm and 20 cm from point of application were measured at the end of the experiment. At all points volumetric moisture contents were higher with increase in rate of application.

The increase in moisture content with increase in water application rate is justified because when rate of application increases, due to limited infiltration rate more water will remain in the upper layer of the soil and study of moisture content was conducted for surface soil. The observations were recorded in Appendix: E-1 and the changes of volumetric moisture content with distance from point of application were presented in fig.4.10.

4.5. THE EFFECT OF TEMPERATURE CHANGE ON DISCHARGE OF TESTED EMITTERS.

The temperature variation recorded in the flowing pipe water between morning and afternoon maximum 11°C. Discharge of the tested emitters was almost same with the field temperature variation. No significant discharge variation was recorded in discharge of tested emitters. However, need of detail and more precise studies were felt for other types of emitters.

SUMMARY AND CONCLUSIONS

CHAPTER – V

Need for efficient utilization of water, a precious natural resource, is now widely and thoroughly understood. It has generated much awareness among the researchers in all aspects including the agriculture, where the greatest opportunity for water saving exists through efficient methods of irrigation. Drip irrigation method is the most efficient method of irrigation, but the only problem is, it's high initial cost. Therefore, it is imperative to test, compare and select the most suitable emitter to meet the specific requirements so that maximum benefits can be accrued with less investment.

With the above view, the present work was undertaken with the following objectives:

1. To study the hydraulics of the different types of the drip emitters.
2. To study the water front advance pattern in the sandy loam soil with the point source.
3. To study the effect of temperature on emitter discharge.

A plot of 30 x 30 m at the precision farming development center in OUAT Bhubaneswar. The emitters tested were–Turbo Key, Turbo-seal, J-lock and Self-Pressure compensating types.

Parameters, which were studied, are, pressure-discharge relationship, manufacturing coefficient of variation and emission-uniformity. Required pressure was adjusted by ball-valve provided at the head of each lateral. For pressure discharge relation, observations were taken in the pressure range 0.25 to 2.00 kg/cm^2 in the increment of 0.25 kg/cm^2. Discharge was collected for 60 minutes period. For testing the manufacturing coefficient of variation, discharge variation of 5 nos. of emitters of same type was recorded. The EU was determined for the pressure range of 0.25 to 2.0 kg/cm^2.

The moisture front horizontal movement was studied. Soil moisture sampling was done and moisture content was determined by gravimetric method.

Effect of change of temperature on discharge of tested emitters exposed to the solar radiation in the field also studied and discharge was recorded at morning and afternoon. The maximum temperature variation in between morning 8 A.M. and afternoon 2 P.M. was recorded 11°C in the field condition during study period.

Observed data were analyzed and relationship between various pertinent variables were graphically presented.

Based on the experimental observations and results, the following conclusions were drawn.

1. For all the emitters tested pressure discharge relationship follows a power function. It was also concluded that flow in J-Lock and Turbo Seal (2 lph rating) is in the close to laminar region, while it is in turbulent region for remaining emitters.
2. Out of all the emitters tested Emission Uniformity of Turbo-key emitter at a pressure 1.5 kg/sq.m was highest (up to 97.9%), followed by self-compensating type of emitter. It was also found that Emission Uniformity of self-compensating remained fairly constant in the range of 0.75 kg/cm^2 to the test maximum test pressure range.
3. From the relative performance of all the emitters it was concluded that self-compensating emitter gave the best performance followed by Turbo-key and J-Lock and Turbo Seal.
4. The wetting front advance study for sandy loam soil indicated that if discharge is doubled it would result roughly 20% increase in wetted diameter, if all the other factors remain constant.
5. For tested emitters Turbo Key, Turbo Seal, J-Lock and Self Pressure Compensating types the effect of temperature change due to solar radiation in field, on discharge was found negligible.

SUGGESTIONS FOR FUTURE RESEARCH

CHAPTER – VI

i) Wetting patterns under Trickle Irrigation in Arid soil with surface crust may be studied.

ii) The variation of discharge with respect to temperature variations in field condition may be conducted for other type of emitters, which are available in the market.

iii) Yield response for each type of emitters may be studied for different crops.

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APPENDICES

APPENDIX: A

PROPERTIES OF THE SOIL OF THE EXPERIMENTAL PLOT

Sl. No.		Description	Value
1.		Textural classification	
	(a)	Coarse sand	33.00%
	(b)	Fine sand	38.50%
	(c)	Silt	17.50%
	(d)	Clay	11.00%
2.		Bulk density	1.66%
3.		Particle density	3.60%
4.		1/3 bar moisture	14.3%
5.		15 bar moisture	4.5%
6.		Water holding capacity	31%
7.		Hydraulic conductivity	4.5 cm/h

APPENDIX:B-1 Variation of discharge with Pressure for Turbo Key

Turbo Key			
Pressure (kg/cm^2)	Discharge		
	2 Lph	4 Lph	8 Lph
0.25	0.648	2.34	3.90
0.50	1.02	2.94	4.37
0.75	1.64	3.74	4.72
1.00	2.19	3.78	5.98
1.50	2.20	4.03	7.02
2.00	2.20	4.10	8.10

APPENDIX:B-2 Variation of discharge with Pressure for Turbo Seal

Turbo Seal		
Pressure (kg/cm^2)	Discharge	
	2 Lph	4 Lph
0.25	0.67	1.50
0.50	1.25	2.30
0.75	1.78	2.85
1.0	1.81	2.96
1.5	2.35	4.55
2.0	2.40	4.60

APPENDIX:B-3 Variation of discharge with Pressure for J-Lock

J-Lock	
Pressure(kg/cm^2)	Discharge (8 lph)
0.25	2.57
0.50	3.38
0.75	4.52
1.00	5.65
1.50	7.80
2.00	8.10

APPENDIX: B-4 Variation of discharge with Pressure for Self Pressure Compensating

Self Pressure Compensating	
Pressure (kg/cm^2)	Discharge (2 lph)
0.25	1.53
0.50	1.66
0.75	1.89
1.00	1.97
1.50	2.20
2.00	2.30

APPENDIX: C-1 Variation of Emission Uniformity with Pressure for Turbo Key

Turbo Key			
Pressure (kg/cm^2)	Emission Uniformity (%)		
	2 Lph	4 Lph	8 Lph
0.25	78.7	90.1	88.2
0.50	72.5	69.3	84.8
0.75	94.5	80.2	78.8
1.0	91.3	96.2	92.8
1.5	95.2	95.4	97.9
2.0	98.0	91.0	97.3

APPENDIX: C-2. Variation of Emission Uniformity with Pressure for Turbo Seal

Turbo Seal		
Pressure (kg/cm^2)	Emission Uniformity (%)	
	2 Lph	4 Lph
0.25	80.5	80.6
0.50	82.4	87.8
0.75	90.8	93.6
1.0	88.9	95.2
1.5	85.8	91.6
2.0	93.6	90.5

APPENDIX:C-3 Variation of Emission Uniformity with Pressure for J-Lock

J-Lock (8 lph)	
Pressure (kg/cm^2)	Emission Uniformity (%)
0.25	93.6
0.50	95.6
0.75	94.0
1.0	93.4
1.5	96.0
2.0	96.4

APPENDIX:C-4 Variation of Emission Uniformity with Pressure for Self-Pressure Compensating

Pressure (kg/cm^2)	Emission Uniformity (%)
	Self Pressure Compensating (2 Lph)
0.25	77.4
0.50	88.5
0.75	96.5
1.0	94.3
1.5	93.3
2.0	94.7

APPENDIX:D-1 Variation of discharge with different pressure for Turbo Key

Turbo Key						
Sl. No	Emitter No.	Press Kg/cm^2	Time (in hrs)	Discharge		
				2 lph	4 1ph	8 1ph
1.	E_1	0.25	1 hr	0.72	2.42	4.26
2.	E_2	0.25	1 hr	0.65	2.46	3.94
3.	E_3	0.25	1 hr	0.72	2.37	3.96
4.	E_4	0.25	1 hr	0.64	2.36	3.92
5.	E_5	0.25	1 hr	0.51	2.11	3.44

Turbo Key						
Sl. No	Emitter No.	Pressure Kg/cm^2	Time (in hrs)	Discharge		
				2 1ph	4 1ph	8 1ph
1.	E_1	0.5	1 hr	0.98	2.96	4.25
2.	E_2	0.5	1 hr	0.96	3.38	4.64
3.	E_3	0.5	1 hr	1.22	3.37	4.43
4.	E_4	0.5	1 hr	1.21	2.98	4.86
5.	E_5	0.5	1 hr	0.74	2.04	3.71

Turbo Key						
Sl. No.	Emitter No.	Pressure kg/cm^2	Time (in hrs)	Discharge		
				2 Lph	4 Lph	8 Lph
1.	E_1	0.75	1 hr	1.65	3.82	5.54
2.	E_2	0.75	1 hr	1.72	3.94	4.62
3.	E_3	0.75	1 hr	1.55	3.00	3.72
4.	E_4	0.75	1 hr	1.68	3.81	4.92
5.	E_5	0.75	1 hr	1.60	3.59	4.80

Turbo Key						
Sl. No.	Emitter No.	Pressure kg/cm^2	Time (in hrs)	Discharge		
				2 Lph	4 Lph	8 Lph
1.	E_1	1	1 hr	2.31	3.75	4.95
2.	E_2	1	1 hr	2.43	3.65	4.98
3.	E_3	1	1 hr	2.00	3.70	4.40
4.	E_4	1	1 hr	2.21	3.92	4.57
5.	E_5	1	1 hr	2.40	3.78	4.80

Turbo Key						
Sl. No.	Emitter No.	Pressure kg/cm^2	Time (in hrs)	Discharge		
				2 Lph	4 Lph	8 Lph
1.	E_1	1.5	1 hr	2.26	4.12	6.93
2.	E_2	1.5	1 hr	2.23	4.23	6.98
3.	E_3	1.5	1 hr	2.10	4.05	6.88
4.	E_4	1.5	1 hr	2.19	3.93	7.20
5.	E_6	1.5	1 hr	2.24	3.85	7.15

Turbo Key						
Sl. No.	Emitter No.	Pressure kg/cm^2	Time (in hrs)	Discharge		
				2 Lph	4 Lph	8 Lph
1.	E_1	2	1 hr	2.32	4.35	7.83
2.	E_2	2	1 hr	2.18	4.11	7.98
3.	E_3	2	1 hr	2.12	4.05	7.86
4.	E_4	2	1 hr	2.20	3.98	8.25
5.	E_5	2	1 hr	2.15	3.67	8.32

APPENDIX: D-2 Variation of discharge with different pressure for Turbo Seal

Turbo Seal					
Sl. No.	Emitter No.	Pressure (kg/sq.cm)	Time (in hr)	Discharge	
				2 lph	4 lph
1.	E_1	0.25	1 hr	0.54	1.41
2.	E_2	0.25	1 hr	0.69	1.52
3.	E_3	0.25	1 hr	0.66	1.56
4.	E_4	0.25	1 hr	0.78	1.68
5.	E_6	0.25	1 hr	0.68	1.53

Turbo Seal					
Sl. No.	Emitter No.	Pressure (kg/sq.cm)	Time (in hrs)	Discharge	
				2 lph	4 lph
1.	E_1	0.5	1 hr	1.03	2.02
2.	E_2	0.5	1 hr	1.28	2.36
3.	E_3	0.5	1 hr	1.26	2.34
4.	E_4	0.5	1 hr	1.35	2.42
5.	E_5	0.5	1 hr	1.26	2.38

Turbo Seal					
Sl. No.	Emitter No.	Pressure kg/cm^2	Time (in hrs)	Discharge	
				2 Lph	4 Lph
1.	E_1	0.75	1 hr	1.62	2.67
2.	E_2	0.75	1 hr	1.85	2.83
3.	E_3	0.75	1 hr	1.84	2.92
4.	E_4	0.75	1 hr	1.83	2.86
5.	E_5	0.75	1 hr	1.78	2.98

Turbo Seal					
Sl. No.	Emitter No.	Pressure kg/cm^2	Time (in hrs)	Discharge	
				2 Lph	4 Lph
1.	E_1	1	1 hr	1.61	2.82
2.	E_2	1	1 hr	1.86	3.15
3.	E_3	1	1 hr	1.88	2.95
4.	E_4	1	1 hr	1.84	2.92
5.	E_5	1	1 hr	1.86	2.96

Turbo Seal					
Sl. No.	Emitter No.	Pressure kg/cm^2	Time (in hrs)	Discharge	
				2 Lph	4 Lph
1.	E_1	1.5	1 hr	2.02	4.67
2.	E_2	1.5	1 hr	2.43	4.68
3.	E_3	1.5	1 hr	2.45	4.67
4.	E_4	1.5	1 hr	2.41	4.67
5.	E_5	1.5	1 hr	2.46	4.55

Turbo Seal					
Sl. No.	Emitter No.	Pressure kg/cm^2	Time (in hrs)	Discharge	
				2 Lph	4 Lph
1.	E_1	2.0	1 hr	2.20	4.15
2.	E_2	2.0	1 hr	2.35	4.75
3.	E_3	2.0	1 hr	2.41	4.69
4.	E_4	2.0	1 hr	2.40	4.65
5.	E_5	2.0	1 hr	2.39	4.68

APPENDIX: D-3 Variation of discharge with different pressure for J-Lock

J - Lock				
Sl. No.	Emitter No.	Pressure (kg/sq.cm)	Time (in hrs)	Discharge
				8 lph
1.	E_1	0.25	1 hr	2.63
2.	E_2	0.25	1 hr	2.78
3.	E_3	0.25	1 hr	2.59
4.	E_4	0.25	1 hr	2.21
5.	E_5	0.25	1 hr	2.66

J – Lock				
Sl. No.	Emitter No.	Pressure (kg/sq.cm)	Time (in hrs)	Discharge
				8 lph
1.	E_1	0.5	1 hr	3.41
2.	E_2	0.5	1 hr	3.45
3.	E_3	0.5	1 hr	3.48
4.	E_4	0.5	1 hr	3.14
5.	E_5	0.5	1 hr	3.46

J-Lock				
Sl. No.	Emitter No.	Pressure kg/cm^2	Time (in hrs)	Discharge
				8 lph
1.	E_1	0.75	1 hr	4.42
2.	E_2	0.75	1 hr	4.53
3.	E_3	0.75	1 hr	4.87
4.	E_4	0.75	1 hr	4.25
5.	E_5	0.75	1 hr	4.53

J-Lock				
Sl. No.	Emitter No.	Pressure kg/cm^2	Time (in hrs)	Discharge
				8 lph
1.	E_1	1	1 hr	5.62
2.	E_2	1	1 hr	5.88
3.	E_3	1	1 hr	6.06
4.	E_4	1	1 hr	5.28
5.	E_5	1	1 hr	5.42

J-Lock				
Sl. No.	Emitter No.	Pressure kg/cm^2	Time (in hrs)	Discharge 8 lph
1.	E_1	1.5	1 hr	7.52
2.	E_2	1.5	1 hr	7.73
3.	E_3	1.5	1 hr	8.25
4.	E_4	1.5	1 hr	7.48
5.	E_5	1.5	1 hr	7.97

J-Lock				
Sl. No.	Emitter No.	Pressure kg/cm^2	Time (in hrs)	Discharge 8 lph
1.	E_1	2	1 hr	8.34
2.	E_2	2	1 hr	8.16
3.	E_3	2	1 hr	8.23
4.	E_4	2	1 hr	7.82
5.	E_5	2	1 hr	7.99

APPENDIX: D-4 Variation of discharge with different pressure for Self Pressure Compensating

Self Pressure Compensating				
Sl. No.	Emitter No.	Pressure kg/cm^2	Time (in hrs)	Discharge 2 lph
1.	E_1	0.25	1 hr	1.54
2.	E_2	0.25	1 hr	1.56
3.	E_3	0.25	1 hr	1.60
4.	E_4	0.25	1 hr	1.52
5.	E_5	0.25	1 hr	1.48

Self Pressure Compensating				
Sl. No.	Emitter No.	Pressure kg/cm^2	Time (in hrs)	Discharge 2 lph
1.	E_1	0.5	1 hr	1.68
2.	E_2	0.5	1 hr	1.72
3.	E_3	0.5	1 hr	1.67
4.	E_4	0.5	1 hr	1.65
5.	E_5	0.5	1 hr	1.54

Self Pressure Compensating				
Sl. No.	Emitter No.	Pressure kg/cm^2	Time (in hrs)	Discharge 2 lph
1.	E_1	0.75	1 hr	1.62
2.	E_2	0.75	1 hr	1.60
3.	E_3	0.75	1 hr	1.55
4.	E_4	0.75	1 hr	1.58
5.	E_5	0.75	1 hr	1.52

Self Pressure Compensating				
Sl. No.	Emitter No.	Pressure kg/cm^2	Time (in hrs)	Discharge 2 lph
1.	E_1	1.00	1 hr	1.98
2.	E_2	1.00	1 hr	1.96
3.	E_3	1.00	1 hr	2.04
4.	E_4	1.00	1 hr	2.02
5.	E_5	1.00	1 hr	1.86

Self Pressure Compensating				
Sl. No.	Emitter No.	Pressure kg/cm^2	Time (in hrs)	Discharge
				2 lph
1.	E_1	1.5	1 hr	2.24
2.	E_2	1.5	1 hr	2.22
3.	E_3	1.5	1 hr	2.30
4.	E_4	1.5	1 hr	2.26
5.	E_5	1.5	1 hr	2.06

Self Pressure Compensating				
Sl. No.	Emitter No.	Pressure kg/cm^2	Time (in hrs)	Discharge
				2 lph
1.	E_1	2.0	1 hr	2.36
2.	E_2	2.0	1 hr	2.33
3.	E_3	2.0	1 hr	2.30
4.	E_4	2.0	1 hr	2.33
5.	E_5	2.0	1 hr	2.18

APPENDIX: E-1 Moisture Distribution Pattern along the wetting front when emitters are placed on the soil.
Table: i

Radial Distance	Moisture content (%) (After 150 mins)		
	2 lph	4 lph	8 lph
(0-4) cm	27.89%	28.37%	29.42%
(4-8) cm	24.36%	26.42%	26.84%
(8-12) cm	18.62%	19.65%	21.32%

Table : ii

Radial Distance	Moisture content (%) (After 240 mins)		
	2 lph	4 lph	8 lph
(0-4) cm	29.19%	29.74%	29.82%
(4-8) cm	26.28%	27.83%	28.57%
(8-12) cm	20.34%	22.73%	23.16%
(12-16) cm	18.54%	19.67%	20.12%

Table : iii

Radial Distance	Moisture content (%) (After 360 mins)		
	2 lph	4 lph	8 lph
(0-4) cm	29.31%	29.78%	29.94%
(4-8) cm	27.26%	28.44%	28.73%
(8-12) cm	25.34%	26.32%	27.45%
(12-16) cm	21.21%	22.42%	22.87%
(16-20) cm	17.19%	17.82%	18.23%

APPENDIX:E-2 Wetting front advance with time

(Pressure was fixed at 1.00kg/sq.cm, Turbo Key was used)

Sl. No.	Time, in min.	Distance (cm)		
		2 lph	4 lph	8 lph
1.	30	11.5	14.0	16.6
2.	60	15.2	17.5	19.3
3.	90	17.8	20.0	21.8
4.	120	19.2	21.6	22.4
5.	150	19.8	21.8	22.9
6.	240	20.2	22.4	23.2
7.	360	21.6	24.6	27.6