MOISTURE AND SALINITY STATUS UNDER MICRO-IRRIGATION SYSTEMS IN VERTISOLS

By

KAILAS TUKARAM KADLAG
B.Tech.(Agril.Engg.)

A thesis submitted to the

MAHATMA PHULE KRISHI VIDYAPEETH
RAHURI - 413 722, DIST. AHMEDNAGAR
(MAHARASHTRA)

In partial fulfilment of the requirements for the degree

of

MASTER OF TECHNOLOGY (AGRICULTURAL ENGINEERING)

in

IRRIGATION AND DRAINAGE ENGINEERING

DEPARTMENT OF IRRIGATION AND DRAINAGE ENGINEERING
FACULTY OF AGRICULTURAL ENGINEERING
MAHATMA PHULE KRISHI VIDYAPEETH
RAHURI-413 722, DIST. AHMEDNAGAR
MAHARASHTRA, INDIA

1995

MOISTURE AND SALINITY STATUS UNDER MICRO-IRRIGATION SYSTEMS IN VERTISOLS

By

KAILAS TUKARAM KADLAG
B.Tech.(Agril.Engg.)

A thesis submitted to the

MAHATMA PHULE KRISHI VIDYAPEETH,
RAHURI - 413 722, DIST. AHMEDNAGAR
(MAHARASHTRA)

In partial fulfilment of the requirements for the degree

of

MASTER OF TECHNOLOGY (AGRICULTURAL ENGINEERING)

in

IRRIGATION AND DRAINAGE ENGINEERING

Approved by

(Prof. N.N.Firake)
Chairman and Research Guide

(Prof. P.S. Pampattiwar)
Committee Member

(Prof. L.V.Pingle)
Committee Member

FACULTY OF AGRICULTURAL ENGINEERING
MAHATMA PHULE KRISHI VIDYAPEETH
RAHURI-413 722, DIST. AHMEDNAGAR
MAHARASHTRA, INDIA

1995

CANDIDATE'S DECLARATION

I hereby declare that this thesis or part thereof has not been submitted by me or any other person to any other University or Institute for a Degree or Diploma

Place : MPKV, Rahuri .

Dated : 6 / 9 / 1995

(K. T. Kadlag)

Prof. N. N. Firake
Assistant Professor of
Agricultural Engineering,
Inter Faculty Department of
Irrigation Water Management,
Post Graduate Institute,
Mahatma Phule Krishi Vidyapeeth,
Rahuri - 413 722, Dist. Ahmednagar,
Maharashtra State, India.

CERTIFICATE

*This is to certify that the thesis entitled "MOISTURE AND SALINITY STATUS UNDER MICRO-IRRIGATION SYSTEMS IN VERTISOLS", submitted to the Faculty of Agricultural Engineering, Mahatma Phule Krishi Vidyapeeth, Rahuri, Dist. Ahmednagar in partial fulfilment of the requirements for the degree of MASTER OF TECHNOLOGY (AGRICULTURAL ENGINEERING) in IRRIGATION AND DRAINAGE ENGINEERING, embodies the results of a piece of bonafide research work carried out by **Shri. K. T. Kadlag** under my guidance and supervision.*

The results embodied in this thesis have not been submitted to any other University or Institute for the award of any Degree or Diploma.

The assistance and help received during the course of this investigation and source of its literature have been duly acknowledged.

Place : MPKV, Rahuri.

(N.N.FIRAKE)
Research Guide

Dated : 6 / 9 / 1995

Prof. P. M. Thigle
Dean,
Faculty of Agricultural Engineering,
Mahatma Phule Krishi Vidyapeeth,
Rahuri - 413 722 , Dist. Ahmednagar,
Maharashtra State, India.

CERTIFICATE

This is to certify that the thesis entitled "MOISTURE AND SALINITY STATUS UNDER MICRO-IRRIGATION SYSTEMS IN VERTISOLS", submitted to the Faculty of Agricultural Engineering, Mahatma Phule Krishi Vidyapeeth, Rahuri Dist. Ahmednagar in partial fulfilment of the requirements for the degree of MASTER OF TECHNOLOGY (AGRICULTURAL ENGINEERING) in IRRIGATION AND DRAINAGE ENGINEERING, embodies the results of a piece of bonafide research work carried out by ***Shri. K. T.Kadlag*** *under* the guidance an supervision of **Prof. N. N. Firake,** Assistant Professor of Agricultural engineering, Inter Faculty Department of Irrigation Water Management, Post Graduate Institute, Mahatn Phule Krishi Vidyapeeth, Rahuri and no part of the thesis has been submitted for other Degree or Diploma.

Place : MPKV, Rahuri.

Dated : 16/9/1995.

(P. M. Thigle)

ACKNOWLEDGEMENT

Knowledge can only be acquired with the help of an able and experienced 'Guruvarya' . Really fortunate I am, for getting the guidance of Prof. N.N.Firake, Assistant Professor of Agricultural Engineering, Inter Faculty Department of Irrigation Water Management, Rahuri and Chairman of my Advisory Committee, who has provided me with constant encouragement, constructive criticism and sympathetic attitude throughout the course of research work and preparation of this manuscript.

I am thankful to Prof. B.M.Patil, Dean, Faculty of Agricultural Engineering, Rahuri for the encouragement and providing facilities for the study.

I would like to express my deep sense of appreciation and gratitude to Prof. P.S.Pampattiwar, Head, Department of Irrigation and Drainage Engineering and Prof. L.V.Pingle, Associate Professor, Department of Irrigation and Drainage Engineering, for being member of my Advisory Committee and for their useful suggestions and constant encouragement at all times.

My grateful thanks are also due to Prof. S.N.Suryawanshi, Associate Professor of Agricultural Engineering, Prof. R.M.Babar, Asst. Professor of Agronomy, Dr. R.S.Dhotre, Research Engineer, Groundwater Project, Department of Irrigation and Drainage Engineering, Prof. B.H.Khan, Assistant Professor of Statistics, for their timely help and kind suggestions rendered to me at various stages of my study.

I express my sincere thanks to Prof. A.A.Atre, Assistant Professor of Soil and Water Conservation Engineering *and Prof. M.G.Shinde, Assistant Professor of Soil and Water Conservation Engineering for their kind co-operation.*

My thanks are also due to Shri. M.M.Deshmukh, Research Associate, for his friendly help and encouragement.

I am also thankful to Mrs. J.K.Kumkar, Junior Research Engineer, for kindly help and staff of Department of Irrigation and Drainage Engineering and Inter Faculty Department of Irrigation Water Management for their time to time help during the experimentation of research work.

I fall short of words in expressing my thanks to my friends especially Uttam, Radhakrishna, Ravi, Sarang, Sunil, Umesh, Rupnawar, Hire, Limbulkar Sir, Pekhale, Gohad, Kadam, Pravin, Swami, Jadhav-Bandhu, Chandu, Wagh, Sandip, Avhad, Appa, Raghu, Gajakos, Darole, Zalte, Narkhede, Aragade and all other junior M.Tech. and B.Tech. friends.

Last, but never the least, I have no words to express my sincere gratitude to my beloved parents, grandfather, brothers-Patya, Dhanu, Devidas, Nandu, Pintoo and Balu and my relatives who always stood like a ladder for my success and whose personal sacrifice inspired me for bright career.

Place : MPKV, Rahuri.

Dated : 06/09/1995.

[K.T.KADLAG]

TABLE OF CONTENTS

TABLE OF CONTENTS CONTD...

TABLE OF CONTENTS CONTD...

LIST OF TABLES

LIST OF TABLES CONTD...

LIST OF FIGURES

LIST OF FIGURES CONTD . . .

LIST OF SYMBOLS

Symbol		Description
cc	:	Cubic centimetre
cm	:	Centimetre
dS/m	:	Deci Seimens per metre
EC , ECe	:	Electical conductivity
ESP	:	Exchangeable sodium per cent
g , gm	:	Gram
H	:	Operating pressure head
ha	:	Hectare
hr	:	Hour
Hp	:	Horse power
i.e.	:	That is
kg	:	Kilogram
kg/cm2	:	Kilogram per centimetre square
kPa	:	Kilo Pascals
lit	:	Litre
lph	:	Litre per hour
m	:	Metre
m2	:	Metre square
mm	:	Mili metre
mel-1	:	mmhos per centimetre
pH	:	Negative logarithm of hydrogen ion
Q, q	:	Discharge
r2	:	Correlation coefficient
t	:	Time
V	:	Volume of water
viz.	:	Namely
&	:	And
oC	:	Degree celcius
%	:	Per cent

LIST OF ABBREVIATIONS

Abbreviations		Description
Agri.	:	Agriculture
Agril.	:	Agricultural
Agron.	:	Agronomy
Amer.	:	American
Ann.	:	Annals
ASAE	:	American Society of Agricultural Engineers
ASCE	:	American Society of Civil Engineers
Ave.	:	Average
C	:	Salt concentration
c	:	Roughness coefficient
Conf.	:	Conference
Congr.	:	Congress
Cw	:	Salinity of water
d	:	depth of soil
dia.	:	diameter
Div.	:	Division
Drai.	:	Drainage
Edn.	:	Edition
Engg.	:	Engineering
Ep	:	Pan evaporation
et al.	:	and others
etc.	:	et cetera
EU	:	Emission uniformity
FAO	:	Food and Agricultural Organisation
F.C.	:	Field capacity
Fig.	:	Figure
G.I.	:	Galvanized iron
HL	:	Hydraulic head loss
Hort.	:	Horticultural
ICAR	:	Indian Council of Agricultural Research
ISAE	:	Indian Society of Agricultural Engineers
Intern.	:	International
Irrig.	:	Irrigation
IW	:	Irrigation water

Abbreviations contd ...

Abbreviations		Description
J.	:	Journal
L	:	Length of lateral
LDPE	:	Low density polyethylene
MAH	:	Maharashtra
Min.	:	Minute
Proc.	:	Proceedings
Porg.	:	Progressive
Publ.	:	Publication
PVC	:	Poly Vinyl Chloride
PWP	:	Permanent wilting point
Res.	:	Research
Reso.	:	Resource
Rm	:	Maximum radial spread
Rs	:	Radial spread
Sci.	:	Science
Soc.	:	Society
Sug.	:	Sugar
Tech.	:	Technology
Trans.	:	Transaction
UC	:	Uniformity coefficient
Univ.	:	University
Va	:	Vertical advance
Vm	:	Coefficient of manufacturing variation
Vol.	:	Volume

ABSTRACT

MOISTURE AND SALINITY STATUS UNDER MICRO-IRRIGATION SYSTEMS IN VERTISOLS

By

KAILAS TUKARAM KADLAG

A candidate for the degree of

MASTER OF TECHNOLOGY (AGRIL. ENGG.)

MAHATMA PHULE KRISHI VIDYAPEETH
RAHURI - 413 722

1995

Research Guide : **Prof. N. N. Firake**

Department : **Irrigation and Drainage Engineering**

The present investigation was carried out to study the hydraulic performance, moisture distribution pattern and salinity status under different micro-irrigation systems viz. dripper, strip tape and microsprinkler in vertisols during summer, 1994 at the Instructional Farm, Department of Irrigation and Drainage Engineering, Faculty of Agricultural Engineering, Mahatma Phule Krishi Vidyapeeth, Rahuri. The recommended operating pressure of dripper, strip tape and microsprinkler systems were 1.00, 0.75 and 1.50 kg/cm^2, respectively.

The hydraulic performance of these systems were evaluated in respect of pressure-discharge relationship, emission uniformity, uniformity coefficient and lateral head loss. The correlations between pressure head in kg/cm^2 and emitter discharge in lph for the different lateral lengths (i.e. 25, 50, 75 and 100 m) were developed in the form of $Q = a H^b$, in which a and b are constants. The emission uniformity (EU) at recommended H were in the range of 84.3 to 92.8 per cent, 92.9 to 97.8 per cent and 61.1 to 89.6 per cent, respectively for dripper, strip tape and microsprinkler systems for the different lateral lengths of 25 to 100 m the uniformity coefficient (UC) of the microsprinkler system was found in the range of 88.1 to 96.3 per cent. It was observed that the EU and UC decrease with increase in the lateral length.

Considering 20 per cent allowable head losses in the lateral at recommended pressure, the maximum lateral length of 67, 100 and 30 m , could be used respectively in dripper,strip tape and microsprinkler system.

The moisture distribution pattern in the soil was studied under different set of conditions of discharge rate (Q), water volumes (V) and time interval (t) under these systems. In drip system, the water volumes of 5, 10 and 15 lit were applied for different discharge of 3, 4 and 5 lph, and in case of strip tape system, the water volumes of 5, 10 and 15 lit were applied at 2, 3 and 4 lph/m, whereas in case of microsprinkler system, the water volumes of 40, 60 and 80 lit were applied at different discharge of 30, 35 and 40 lph for studying the moisture distribution pattern each at 0, 24 and 48 hour after irrigation. The moisture distribution pattern was studied by plotting the iso-moisture lines of 36 per cent (i.e. field capacity).

In drip system, the maximum radial spread and vertical advance of moisture at 4 lph discharge was in the range of 12.8 to 25.5 cm and 30.0 to 49.0 cm at 48 hr after irrigation, when the water was applied in the range of 5 to 15 lit. However, in strip tape system at 4 lph discharge the maximum radial spread and vertical advance of moisture was in the range of 10.5 to 16.0 and 26.0 to 35.0 cm at 48 hour after irrigation, when the water was applied in the range of 10 to 15 lit. Similarly, in microsprinkler system the vertical advance was 29.6 to 41.9 cm at 35 lph discharge at 48 hour after irrigation, when the water was applied in the range of 40 to 80 lit.

In general, it was found that as the Q increased, the maximum radial spread from emitter increased and vertical advance decreased at constant volume of water and elapsed time. It was observed that variation in moisture distribution pattern to the greater extent was due to different modes of water application. Considering the radial spread and vertical advance of moisture in the soil, the correlations were developed. The correlation between emitter discharge (Q) in lph, volume of water (V) in lit and maximum vertical advance (Va) in cm were developed in the polynomial form of three dimension and second order. Similarly, the correlation between volume of water (V) in lit, depth of soil (d) in cm and radial spread of wetting front (Rs) in cm were also developed in polynomial form of three dimension and third order.

The salt distribution under dripper, strip tape and microsprinkler emitters was studied in chilli at one month interval in clayey soil which was sodic in reaction. The salt distribution was studied by plotting the iso-salinity lines. It was observed that the salt distribution under these micro-irrigation systems was differed considerably due to the different modes of water application.

In dripper system, the salts were found concentrated at the periphery of wetted soil on soil surface, whereas in strip tape system the salts were concentrated at the edge of the wetted strip of soil on soil surface. However, in microsprinkler system, the salts were leached down below 45cm depth of soil over a period of 150 days. Amongst all these micro-irrigation systems, the microsprinkler system of irrigation was found effective in lowering the salinity level below the root zone of chilli.

Pages 1 to 162

1. INTRODUCTION

Indian agriculture depends mainly on the monsoon rains received from June through October. About 75 per cent of the cultivated area in the country depends on rain, even-after the spectacular achievements in increasing the irrigation potential. The area under irrigation increased from 38.5 M ha in 1970 to 59.3 M ha in 1989 and is anticipated to reach 84.0 M ha by the turn of the century (Anonymous, 1992).

Surface methods of irrigation are the most prominent method of irrigation in India, which have comparatively poor water use efficiency. Water was used indiscriminately with a belief that higher the amount of water applied, higher will be the crop yields. The application of excess water proved not only less crop yields but also created the problems of drainage and salinity , which ultimately resulted in uplift of lands for cultivation.

Maharashtra state is blessed with an abundance of the deep black soils. These soils are unique in their properties in the world. High clay content, dominance of montmorillonite clay mineral, low infiltration rate, slow permeability and inherent water logging tendency are some of the soil characteristics those concerned most while irrigating them. These characters , make these soils prone to deterioration in terms of waterlogging and salinity-alkalinity under irrigation.

In the arid and semi-arid regions, there is scarcity of water due to fluctuation in rainfall, occurrence of drought years and higher depth of ground water level. These facts necessitated to increase the productivity of crop per unit quantity of water. This very need has resulted in evolution of new methods of irrigation known as pressurised irrigation methods.

In case of pressurised irrigation methods, the micro-irrigation methods are better than sprinkler irrigation in respect of water saving and quantity and quality of farm produce. In water scarcity regions , it is possible to irrigate double the land with the help of micro-irrigation systems as compared to traditional irrigation methods (Sivanappan, 1987).

Micro-irrigation systems are of three types depending upon the mode of application of water.

(a) point source micro-irrigation systems i.e. drip irrigation with different types of emitting devices,viz. micro-tubes and drippers,

(b) line source micro-irrigation systems like biwall systems of different types; typhoon type; turbo-or T-tape, queen gil type and strip tape, and

(c) microsprinkler systems such as rotating and stationary microsprinklers.

In canal command areas at many locations there exists high water tables.As such these soils normally contain more NaCl and $CaCO_3$ than other salts, resulting in higher electrical conductivity values more than 5 dS/m. Soil salinity is also increasing due to use of well water, rich in Ca^{2+}, Mg^{2+}, Cl^{-}, SO_4^{2-} and HCO_3. The continuous use of saline water from such wells affect the crop growth. In such conditions the micro irrigation have special advantage of using poor quality of water effectively for irrigation, which is not achieved with any other method of surface irrigation.

Micro-irrigation systems can thus play a very important role in irrigated agriculture, in India, for maximisation of efficiency of water use, But, the initial cost of the system, technical knowledge and skilled labour are considered to be its limiting factors for large scale adoption in India. As both Central and State Governments are providing subsidies to farmers for adoption of these systems, the area under micro-irrigation is increasing day-by-day. The area of 32,000 he has been reported under micro-irrigation in Maharashtra (Sarangi, 1993).

As such,micro-irrigation systems are recently adopted in India, the data available on its hydraulic performance in the field and the moisture and salinity status in the soil below the emitter are scanty. As the moisture movement in the soil under micro-irrigation system is a function of many parameters, such as quantity of water applied discharge rate of emitter, elapsed time after irrigation, type of soil, type of micro-irrigation system, etc., it is very necessary to have sufficient information on these aspects. The information will be helpful in deciding spacing between the emitters and crop and also for proper design of the system. The effect of micro-irrigation systems on the development of salinity around emitters has not yet been studied widely. Similarly, no data is available on some latest developed micro-irrigation systems in different types of soils. In view of these above mentioned aspects, the research project entitled, **"Moisture and salinity status under *micro-irrigation* systems in vertisols"** was undertaken with the following objectives.

1] To study the pressure-discharge relationship, emission uniformity and/or uniformity coefficient of micro-irrigation systems.

2] To study the effect of emitter discharge rates and quantities of water on moisture movements.

3] To find out the salinity status around the emitter at 30 days interval after continuous alternate-day irrigations.

2. REVIEW OF LITERATURE

In India some research workers have attempted to evaluate micro-irrigation systems in respect of its hydraulic performance and moisture distribution, water saving, crop yield, water requirement and water use efficiency. The data generated on these aspects of micro-irrigation systems are scanty. The data on some recently developed micro-irrigation systems as well as on different types of soil are not available. However, the research work done in India and abroad by the researchers was studied critically and is reviewed under the following main topics.

- **2.1 Hydraulic performance**
- **2.2 Moisture distribution pattern**
- **2.3 Salinity status under micro-irrigatiobn emitters**

2.1.1 Point source micro-irrigation

Aljibury (1973) worked on drip irrigation practices and applications. He reported that in drip irrigation system about 40 to 50 per cent of allocated area per tree was wetted, whereas in sprinkler irrigation system 100 per cent area per tree was wetted.

Hanson (1973) studied hydraulics of trickle irrigation emitter lines and have found (C) values for trickle lines to vary from 98 to 136 depending on specific emitter type.

Keller and Karmeli (1974) suggested the emission uniformity as the criterion which should be around 90 % for practical purposes.

✓ Wu and Gitlin (1974) presented design of drip irrigation based on uniformity. The study showed that the friction drop was of exponential function with respect to the length of the pipe, whereas the discharge increased with respect to length. They used the curve of friction drop combined with the pressure gain or loss to determine the variation in discharge with pressure along the line. They reported that the discharge distribution of emitters could be estimated if the pressure distribution is known. They also introduced a design chart which consisted of the design pressure and length of the drip line, the total discharge, the slope of the line and uniformity coefficient.

Soloman (1979) recommended the coefficient of manufacturing variation (Vm) as the appropriate measure of unit to unit consistency in emitters. He defined the coefficients of manufacturing variation as the ratio of standard deviation to the mean flow rate from a suitable sample of emitter tested at a normal operating pressure. The values for coefficient of manufacturing variation (Vm) ranges from 0.02 to 0.40. He presented typical system for emission rate distribution which takes into account pipe network hydraulics, emitter flow rate sensitivity to pressure and manufacturing variation of the emitter.

The study conducted by Bralts et al. (1981) showed that hydraulic and manufacturing variation could be statistically combined and included in the design of equation for uniformity at single chamber drip irrigation lateral lines. Design curves and nomographs have been developed to simplify the inclusion of emitter manufacturing design to drip irrigation lateral lines.

Zur and Tal (1981) studied the emitter discharge sensitivity to pressure as expressed by the constants a and b, in the equation given below,

$$Q = a\,H^{b} \qquad \ldots(2.1)$$

where,

Q = emitter discharge, lph

H = pressure, kPa

a and b = constants.

The value of constant 'b', they found to vary from 0.43 to 0.86, depending on the flow regime and cross-sectional area for flow of each emitter type.

Vasanthakumar (1984) observed relatively smaller wetting front with lower volume of water application and vice versa.

Singh (1987) developed mathematical relationship to establish the relationship between head loss due to connection and operating head or lateral discharges. The values of Hazen-William's coefficient was found to be 103 to 118 for various operating heads as against 150 generally considered. Uniformity coefficients were worked out as suggested by Karmeli, Christiansen and Wilcox for different lateral lengths, dripper spacings and operating heads. The relation between discharge and lengths of microtube has also been reported.

Lagad (1989) evaluated pressure losses across emitters and microtubes. The emission uniformity for various combinations and hydraulic performance of six orifice type, on-line emitters and microtubes of three different diameters under laboratory conditions were worked out. The Hazen-William's roughness coefficient was computed to be approximately 133 to 135 and 107 to 108 for 12.5 and 16.0 mm lateral tubing, respectively.

2.1.2 Line source micro-irrigation

Bezdek and Soloman (1978) reported that even-after changing the value of roughness coefficient (C) used in Hazen-William's equation from 130 to 150, the head loss calculated by Darcy-Weishbach equation is more accurate for small diameter plastic tubing used for trickle lateral.

Suruwatri and Wu (1982) studied hydraulics of bi-wall line source irrigation laterals. They reported that the emitter flow through orifices in a bi-wall (dual chamber) lateral irrigation line was affected by the pressure variation inside the secondary chamber, due in part to the cutting effect, slope effect and plugging of inner or outer orifices and by outer orifice variation caused in manufacturing of the tubing. Both the cutting effect and the slope effect can be controlled by setting the cutting position in the middle of two inner orifices and by designing a multiple inlet system.

James Hardie (1984) provided system designers and operators with the information they need to properly design and operate a bi-wall line source. He provided flow rate data for various spacing and wall thickness combinations which are available. Design charts such as flow curves and pressure loss curves were developed.

Hande and Nongkynrich (1989) studied the hydraulics of bi-wall line source irrigation. They found that the discharge through emission orifice increased from 3.336 to 6.384 lph/m with increase in pressure head from 3 to 15 m. They further reported that the head loss increased from 0.18 to 0.40 m with the increase in operating head from 3 to 13 m of water. The curve obtained by plotting head loss versus discharge rate was parabolic in nature.

Rane (1991) studied the hydraulic performance of twin-wall (bi-wall) subsurface line source tubing. He observed that as the pressure increased from 0.5 to 2.0 kg/cm^2, on an average, the discharge of twin-wall per metre length increased from 1.92 to 5.60 lph. The emission uniformity of bi-wall was reported varying between 96.08 to 98.49 per cent for the operating pressures of 0.5 to 2.0 kg/cm^2, respectively.

Patel and Aware (1994) studied on the field evaluation of hydraulic performance of canewall tubing in black soil. They reported an increase in operating pressure from 0.4 to 1.2 kg/cm^2 increased canewall discharge from 3.33 to 4.68 lph/m for 100 m length of canewall. They also reported that increasing the canewall length from 25 to 100 m the discharge decreased from 4.67 to 3.75 lph/m at the pressure of 0.7 kg/cm^2. The head loss increased from 0.1 to 1.9 m when the length was increased from 25 to 100 m. The emission uniformity of canewall tubing system was reported as 97.1 per cent. They reported that the maximum length of canewall that can be used upto 70 m considering 20 per cent variation in head loss.

2.1.3 Microsprinkler irrigation

Bilanski and Kiddler (1958) studied factors that affect the distribution of water from a medium pressure rotary irrigation sprinklers. They determined that under zero wind conditions, the trajectory distance of the distribution pattern was increased only by 1.52 m by increasing the pressure from 207 to 414 kPa.

Seginer (1963) showed that the operating pressure in microsprinkler irrigation was the most important factor. The higher the pressure, the longer the range of drops (radius of wetting) and the finer the drops, the more even distribution of the water on the ground was achieved.

Pairs (1968) used catch-cans to collect spray samples from operating sprinkler system. Quart oil cans were placed in a grid system. Davis stated that each can represented 2 to 2.5 per cent of the pattern area for the purpose of identifying the uniformity of water distribution.

Suryawanshi et al. (1982) conducted studies on effect of wind on sprinkler distribution efficiency. They found that the uniformity coefficient of water distribution had an inverse relationship with the wind speed. They also reported that the uniformity coefficient was more than 82 per cent when the wind speed was equal to or more than 7.94 kmph.

Post et al.(1986) reported that the uniformity values are much lower in case of a microsprinkler as compared to the conventional overlapping type of sprinklers. The range of uniformity values for microsprinklers were 33 to 65 per cent. In general, it was also noticed that the coefficient of uniformity produced a higher value while the distribution uniformity produced a lower value.

Gutal et al.(1988) studied microsprinkler irrigation in groundnut. They used the microsprinklers at 1.5 kg/cm^2 pressure with the spacing of 3.0m x 3.0m. At 0.30 m riser height and 3.3 mm/hr application rate, they observed the diameter of wetted soil as 5 m. Further, they reported that the uniformity coefficient (UC) and distribution uniformity (DU) of microsprinkler were 60.8 and 36.4 per cent, respectively. The UC and DU were observed very poor due to high speed of prevailing wind i.e. 6 km/hr. The crop stand was reported to be remarkably uniform. It was also reported that microsprinkler might be used at riser height of 30 cm during morning hour to get the maximum coefficient of uniformity and distribution uniformity.

It was reported that the coefficient of uniformity of microsprinkler spaced at 1.2m x 1.2m and at 30 cm stake height was 76.25 per cent at 1 kg/cm^2 operating pressure. The precipitation rate was found decreased with increase in riser height with the maximum wetted diameter of soil of 3.3 m. Further, the rate of precipitation which was 4.6 mm/hr at 30 cm stake height was found to be dropped to 3.4 mm/hr at 45 cm stake height alongwith reduction in wetted diameter from 3.03 to 3.10 m (Anonymous, 1989).

Singh et al.(1990) reported that the variation in discharge along the lateral reduced with the reduction in operating pressure at the head of the lateral. The average values of sprinkler flow variation at pressure 2.0, 1.5 and 1.0 kg/cm^2 were found to be 15.81, 27.17 and 29.32 per cent, respectively. The discharge was found to be related with operating pressure by an equation,

$$Q = 62.25\ P^{0.58} \qquad \text{...(2.2)}$$

where,

Q = discharge, lph

P = operating pressure, kg/cm^2

Salunkhe (1991) conducted an experiment on microsprinklers of 33 and 57 lph discharge in clay loam soil. He reported uniformity coefficient values of 63.7 and 73.7 per cent for 33 and 57 lph microsprinkler, respectively at safe wind velocity and at operating pressure of 2.0 kg/cm^2. The emission uniformity (EU) were reported as 96.6 and 97.2 per cent for 33 and 57 lph microsprinkler, respectively.

Firake et al.(1992a) studied the different characteristics of low discharge (LD) microsprinkler and high discharge (HD) microsprinkler. They observed that the discharge decreased by 6.9 and 6.5 per cent due to the increased in length of lateral from 4 to 52 m of LD and HD microsprinklers, respectively. It was also observed that by increasing the operating pressure from 1 to 2.5 kg/cm^2, the discharge was found to be increased from 24 to 28.8 lph and 33.6 to 42.5 lph in case of LD and HD microsprinklers, respectively. The relationship between Q and H for LD and HD microsprinklers were:

$Q = 24.04\ H^{0.196}$ for LD microsprinkler ...(2.3)

($r^2 = 0.99$)

$Q = 33.80\ H^{0.259}$ for HD microsprinkler ...(2.4)

($r^2 = 0.99$)

where,

Q = discharge, lph

H = operating pressure, kg/cm^2

The low average values of coefficient of uniformity in low and high discharge microsprinklers were 60 and 70 per cent, respectively, were due to consideration of a large wetted diameter of 2.4 m.

Firake et al.(1992b) studied the effect of system variables on wetted area of soil in microsprinkler irrigation. They reported that the increase in stake height (h) of microsprinkler increased the diameter of wetted soil (D). A high discharge of microsprinkler resulted in larger 'D' than low discharge microsprinkler at the same stake height (h). An increase in pressure head (H) had more effect in increasing'D'. An increase in 'D' was more in case of higher discharge microsprinklers at same 'H'. Similarly, the increase in discharge (Q) increased 'D' as 'Q' is directly related with 'H'. It was also reported that the 'D' decreased with increase in lateral length. They further reported that the 'D' can be increased effectively by different system variables in descending order as: pressure head, stake height and high discharge microsprinklers.

Shinde and Darade (1993) evaluated the hydraulic performance of static microsprinkler system. They found the uniformity coefficient of a static microsprinkler as 64.14 per cent at 2 kg/cm^2 operating pressure. The uniformity coefficient, they reported, decreased with decrease in the operating pressure and increase in the lateral length. However, the emission uniformity of the system was reported excellent i.e. 91 per cent. They further also found that the diameter of wetted soil increased with increase in the pressure and stake height, whereas it decreased with increase in the length of lateral.

2.2 Moisture distribution pattern

2.2.1 Point source micro-irrigation

Dalton and Haminson (1971) conducted an experiment on drip irrigation for citrus and showed that drip irrigation supplied moisture in area around the plant where root system obtain it with no difficulty. Thus, plants are not subjected to extremes of wetting and drying of soil due to frequent supply of water.

Goldberg et al.(1971) showed that the distribution of soil moisture resulting from drip irrigation method was 2-dimensional with higher moisture content along and beneath the row and decreasing laterally.

Raats (1972) observed that soil moisture decreased with the distance from the source and hence the response was slower at distances away from the source.

Rolland (1972) examined the work of French researchers on movement and distribution of water in the soil profile in case of trickle irrigation. The results of various trials were enumerated as under.

1. The study of formation of the bulb was carried out in order to determine the spacing of tricklers. The soil involved was sandy at the surface and loam below to a deep level. The water was distributed by tricklers, continuously for three weeks at three rates of flow of 0.26, 0.56 and 0.81 lph. The soil was protected from rains by plastic sheets. The moisture was measured from

sections of profile. It was observed that there was a tendency towards the formation of inverted bulb in the soil with rapid descent of water in depth and little horizontal spread. The moistened diameter does not exceed 1.5 m. It was also observed that the weaker the flow, the more the bulb tends to extend downwards.

2. Similar study in clayey loam soil was conducted in another plot. The tested flow rates from tricklers were 0.48, 0.61 and 0.84 lph. It was found that the moisture spread fairly wide at the surface but there was little information downwards for low rates of flow. At 0.48 lph the diameter moistened was 3.0 m at the surface and 0.8m at the depth 0.5 m. At 0.84 lph, the diameter moistened was 4 m at the surface and 2.8 m at a depth of 1.4m.

3. The moistening study conducted in soil with sandy alluvial matter over stones and gravel for trickle discharge 0.4, 0.8, 1.2 and 1.6 lph indicated that outward spread of the bulb expanded distinctly as the flow increased. It was cylindrical in shape until it reaches the pebbly horizon which acts as draining layer. The moisture bulb will have minimum diameter of 2 m, which can be extended by increased flow.

4. The moisture measurement studies in calcareous loam on clayey soils were conducted on two plots. It was observed that the crescent shaped dry surface area on either sides of trench in calcareous loam while the dryness of top soil about 0.7 m from watering point was noted in clay soil.

Swaminathan (1972) found that in case of drip irrigation system soil moisture regime was around the field capacity zone. The distribution of water around the point source was longitudinal overlapping of wetting front by successive drippers. The ultimate moisture distribution was two-dimensional.

Cole and Till (1974) found that with one line of dripper, the mid-row was not wetted and excess water was found passing below the root zone. Using double row of drippers, most of the soil was wetted with only the surface soil between the drip lines remaining dry. But using drag hoses all the soil was wetted. The volume of soil wetted from a single line dripper was much less than the volume wetted by a double line of drippers. Since the same quantity of water was applied through the system, leaching was greater with the single line of dripper.

Roth (1974) observed that the wetted volume of soil was elongated in vertical direction rather than being a hemisphere. Higher the application rate, larger was the influence of gravity and as a result narrower was the wetted area.

Tscheschke et al.(1974) reported that the soil water potential decreased in the soil profile as a result of salt accumulation, with increased distance from trickle source.

Koo and Tucker (1975) observed that on sandy soils each emitter wetted an area resembling an elongated onion bulb. The maximum diameter of the bulb area ranged from 60 to 150 cm depending upon soil texture, with fine textured soil having more lateral movement than coarse textured soil. The area wetted by each emitter represented 2 to 15 per cent of the soil in the root zone depending on tree spacings. It was estimated that 15 to 30 per cent of soil area was influenced by drip irrigation.

Bar-Yosef and Sheikholslami (1976) found that in trickle irrigated sandy soil adding identical amount of water but increasing the trickle discharge rate, the vertical movement of wetting front increased and the horizontal movement decreased.

Hachum et al.(1976) revealed that for the same volume of water, the vertical penetration of wetting front decreased and the horizontal water movement increased as the water application rate increased.

Jury and Earl (1977) studied water movement in bare and cropped soil under isolated trickle emitters and observed that irrigation at one week interval re-sulted larger amount of water being transferred lateral-ly from the emitter than for daily irrigation of the same application rate and weekly volume of water.

Singh et al.(1978) reported that in drip irrigation to potatoes on loamy sand soil, the soil water content was about 15 per cent beneath the emitter, 7 per cent at a point 20 cm from the lateral.

Kaul (1979) studied hydraulics of soil moisture front in drip irrigation and observed that the soil moisture in the wetted zone resulting from a point source of water application, manifested itself by a rapid increase in the soil moisture content in the soil layer close to the point of water application. The zone was identified to the extent of about 15 cm depth and 20 cm diameter.

Levin and Bravedo (1979) reported that the soil moisture and root system distribution covered a wide area when trees are irrigated twice a week with 8lph tricklers. Daily irrigation compared with weekly irrigation caused appreciably narrower soil moisture distribution but quite similar root distribution pattern.

The distribution of water and salts in the soil under pot irrigation was compared with that of trickle irrigation in the field and showed that after 72 hr of redistribution, the wetted volumes were approximately equal for trickle and pot irrigation regime (Alemi,1981).

Khepar et al.(1983) observed that the moisture distribution depended on the rate of application, amount of water applied and initial moisture content. The findings of the study revealed that (i) the vertical component of wetting zone increased with rate of application in light textured soil, (ii) wetted volume of soil was increased with increased amount of water applied. Wetting front moved to the greater radial distance with increased amount of water, and (iii) in initially moist soil, wetting front extended both in radial and vertical directions.

In pitcher irrigation method, an increase in application of water resulted in increased horizontal wetted area (Reddy and Rao, 1983).

Sonawane (1983) conducted an experiment on moisture distribution pattern and nitrogen fertilizer application in drip irrigation for cotton in vertisols and observed that the application of water at the rate of 2.5 lit/day has resulted the downward movement of water to the depth of 18, 28, 33, 40, 45, 55 and 65 cm depth on 1st, 2nd, 3rd, 4th, 5th, 6th and 7th day, respectively and also observed that there was no much difference in vertical and horizontal water movement except that vertical movement was slightly higher than horizontal one.

Anonymous (1984) studied moisture distribution in drip irrigation and found that the moisture movement was dependent on emitter discharge rate and the vertical movement was high at higher discharge rate and horizontal movement was higher at lower discharge rate.

Gupta and Tyagi (1984) conducted a laboratory experiment to study effect of application rate and irrigation frequency on soil moisture distribution under trickle irrigation and indicated that the daily application at a lower emitter application rate (0.75 lph) is beneficial in keeping large per cent of applied water within upper 30 cm layer in comparison to one and two days irrigation intervals and it also prevents loss of irrigation water due to deep percolation.

Karmarkar (1985) conducted an experiment with an application of synthetic saline water through drip irrigation for tomato in vertisols and observed that the water content increased in the horizontal manner from 0.45 to 0.70 cm^3cm^{-3} at a distance and depth of 45 cm away from the emitter. Thus, in the moist soils, the vetrtical component of water movement was slightly higher than the horizontal component.

Phadtare (1985) studied the moisture distribution pattern in trickle irrigation in vertisols by applying fixed quantity of water (12 lit) at predetermined rate showed that the radial spread was more for lower discharge rate, whereas vertical advance was more for higher discharge rate.

Salih (1985) under comparative studies on drip irrigation in Iraq, he observed that water distributed homogeneously in the root zone of trees.

Sharma et al.(1987) observed no appreciable change in moisture content below 90 cm depth and average profile moisture content in lateral zone of 0-15 cm was nearly the same in the three treatments i.e. irrigation water with 0, 4 and 8 meL^{-1} application through drip.

Kulkarni (1988) compared surface and drip irrigation system for pomegranate and lime and found that moisture depletion was more than 55 per cent in surface irrigation, whereas the moisture depletion in drip irrigation was just around field capacity.

Nehra et al.(1991) studied on the water distribution pattern under trickle source in sandy loam soil. They developed the various empirical equations for vertical and horizontal advance of moisture. The logarithmic type of relationship to determine the horizontal advance (H) was as below.

$$H = 1.26\ Q^{0.754}\ t^{0.515} \qquad ...(2.5)$$

Similarly, in finding out the vertical advance of water (Y) the equation developed was

$$Y = 9.26\ Q^{0.175}\ t^{0.419} \qquad ...(2.6)$$

In above equations Q is the discharge rate in lph and t is elapsed time in hr.

Rane (1991) studied the moisture distribution pattern in the sandy clay loam soil under microtube system. He reported the maximum radial spread of wetting front at soil surface as 30.7 and 32.8 cm at 0 and 24 hr after irrigation, respectively when the system was operated at 1 kg/cm^2 .The vertical movement of water at 1 kg/cm^2 was found to be 58 cm. He also correlated the emitter discharge, vertical advance of wetting front and depth of soil.

Ghazy et al.(1992) studied the effect of the soil conditioners, polyacrylamide (PAM), polyurea polyalkyene (UR) and urea formaldehyde (UF) on moisture and salt distribution in trickle irrigated gravelly calcareous soils of Giza, Egypt and observed that the soil moisture content decreased with distance from the emitter for all the conditioners (UF = PAM > UR) and the greatest moisture content close to the root zone with UF.

Satpute et al.(1992) studied on effect of dripper discharge and volume of water on soil moisture distribution in clay and clay loam soils. They reported that with increase in the dripper discharge, vertical movement of wetting zone reduced and the horizontal movement increased in both the types of soils. The moisture distribution, they found, symmetrical in vertical and horizontal planes at 4 lph discharge in clay and clay loam soils. The increase in the volume of water application resulted in increase in the wetted soil volume. They further reported that narrow wetted bulb at 2 lph rounded at 4 lph and higher discharge rate in clay soil, whereas in clay loam soil it remained elongated narrow and increased in same pattern at higher discharge rate.

Goel et al.(1993) found that the water at higher application rate saturated the soil near the dripper and infiltration was slower in the begining, whereas the water penetrated deeper with lower dripper discharge because of availability of more time for infiltration.

Shinde and Darade (1993) studied on the moisture distribution in the soil under static microsprinkler system. They observed the variable moisture in the soil due to uneven sprinkling of water. The vertical movement of wetting front was reported in creased with increase in the operating pressure of the system and the elapsed time after irrigation. They further reported the effective area of wetted soil was to the extent of 13.85, 14.86 and 16.61 m^2 for 1.0, 1.5 and 2.0 kg/cm^2 pressure, respectively. The correlations between depth of wetting front, emitter discharge and operating pressure have been also presented.

2.2.2 Line source micro-irrigation

Busch and Kneebone (1969) studied the subsurface irrigation with perforated plastic pipes. With the development of plastic tubing, it became possible to rely on a burried perforated pipe as the water source and to distribute water underground with pressure above atmosphere. The positive pressure increased moisture gradients from the water source towards the surface, as well as in a downward direction. The possibilities for moisture conservation through pressure controlled, underground application were quite intiguing. The opportunities for evaporation at or above the surface are greatly reduced.

Cole (1971) worked on the subsurface

irrigation and presented on excellent comprehensive review of present knowledge pertaining to surface irrigation. Potential benefits of this method were listed by him as (a) water saving, (b) beneficial crop response, (c) labour saving, (d) fertilizer saving and pollution abutements, (e) weed and insect control cost saving, (f) possible use of saline water, (g) decreased evaporation losses, (h) uniform distribution of water and (i) no delay in cultural practices. Regarding crop response he summarized his remark as, "improvements in yield and quality and a shorter growing season emerge as general benefits associated with subsurface irrigation."

Gibson (1976) studied the hydraulics, mechanics and economics of subsurface irrigation in which the gross water applications required by the subsurface method are found to be less than the furrow or sprinkler irrigation.

Hiller and Howell (1978) studied the grain sorghum response to trickle and subsurface irrigation in which the sorghum growth was better under subsurface irrigation giving yield slightly less than the trickle irrigation method.

Kumkar (1990) studied the hydraulics and moisture distribution pattern in bi-wall subsurface irrigation. She observed that moisture distribution pattern under point source of bi-wall was semi-elliptical in shape [illegible] elongation along Y-axis. The rate of wetting [illegible] along vertical direction was higher as compared to spread along horizontal direction. The maximum moisture spread in horizontal plane was found to be within 30 to 45 m below the bi- wall source depending on lateral discharge. The mathematical equation to predict the discharge of any point on wetting front from bi-wall source was established.

Rane (1991) studied the moisture distribution pattern under bi-wall irrigation systems. He observed that the increase in operating pressure head increased the discharge, but the vertical movement of wetting front decreased due to the stagnated water at higher discharges. The radial spread of moisture from source increased with increase in discharge.

Patel and Aware (1994) studied on the moisture distribution pattern due to canewall tubing system in black soil. They found that the vertical movement of moisture at 3 lph/m canewall was more than that of 4 and 5 lph/m discharge with constant volume of water applied. The vertical movement of moisture decreased with increase in the canewall discharge and it was increased with the interval between successive irrigations. They further observed that the radial movement of moisture as 44, 52 and 54 cm (at 3 lph/m); 34, 39 and 45 cm (at 4 lph/m) and 33, 35 and 45 cm (at 5 lph/m) in 24 hr, respectively at 1, 2 and 3 days of irrigation interval.

2.2.3 Microsprinkler irrigation

Salunkhe (1991) studied the moisture distribution pattern in rotary microsprinkler system in sandy clay loam soil. He found that the vertical movement of water is a function of elapsed time after irrigation and operating pressure of the system. The vertical movement of moisture was reported increased with the elapsed time and decreased with the increase in the operating pressure. It was also observed that the moisture content of soil at any depth and time decreased with increase in the operating pressure or radius of the throw of water through the microsprinklers. If the operating pressures of the system is more (i.e. less depth of water application), the time required to saturate the root zone will be more and vice versa.

Shinde and Darade (1993) studied the distribution of moisture under static microsprinkler in clay loam soil at different operating pressures and elapsed time. It was reported that the moisture content of the soil at the same depth was not same which was exactly the reverse to that of rotary type of microsprinklers as reported by Salunkhe (1991). The moisture content was found some what on higher side between the distance of 0.6 to 1.5 m from the static microsprinkler. They also noticed that as the time elapsed, the moisture content at surface of soil decreased by 14.61 per cent in 24 hr. They developed some equations between vertical advance of wetting front, emitter discharge and operating pressure.

2.3 Salinity status under micro-irrigation emitters

Goldberg et al.(1971) studied the effect trickle irrigation intervals on soil moisture and salt distribution on sandy clay soil and found that the salts were concentrated in surface pocket and a deep layer with leached zone between them.

Goldberg et al.(1971) studied the effect of trickle irrigation on the distribution of roots, water and minerals. They found that the content of soluble salts, including those added as fertilizer, was higher in upper 3 cm, especially midway between adjacent nozzles. When`P' and `N' were added with irrigation water, `P' tended to accumulate beside and below the nozzles, while the `N' was leached below the nozzles and accumulated in the area between them.

Gustafson (1971) studied salinity in drip irrigation and observed that the salt accumulation in the active root zone of plant can be avoided by drip irrigation.

Shmueli and Goldberg (1971) compared sprinkler, furrow and trickle irrigation in muskmelon in an arid zone and reported that the soil chloride content during growing season varied according to irrigation method i.e. under trickle irrigation there was additional leaching of chlorides, especially in the 15 - 45 cm soil layer and there was a trend for the salt to accumulate in thin crust on the soil surface, in the region of the wetted strip of soil.

According to Bernstein and Francois (1973), salts were accumulated on surface of soil in midway between drip orifics and as well as at the periheri of wetted zone of soil when compared drip, furrow and sprinkler irrigation to pepper.

Cho and Yamato (1973) studied the effect of trickle irrigation method on salinity damage of crops in a green house experiment using a sand culture and reported that the salt concentration increased on the sand surface with sprinkler irrigation while with the trickle irrigation system, salinity decreased in the cones of wetting but increased in the outer cones.

Tscheschke et al. (1974) observed that the highest salt concentration occurred in the profiles irrigated with volumes of water below that evapotranspired by tomato plants, indicating the importance of avoiding under-irrigation, whenever highly saline warter is used.

Sivanappan and Chandrasekaran (1976) conducted an experiment on drip irrigation for banana and they observed that highely saline water can be best utilised with drip irrigation and also found that salts will accumulate at the edge of the wetted zone.

Singh et al. (1978) observed high concentration of salts in the surface 15-20 cm of soil at mid-point between the emitters and towards the wetting front in drip system. Salts were not leached to lower soil horizons.

According to Steven and Rawlins (1979), the nature of moisture flow from various irrigation systems could significantly influence the salt distribution profiles that exist in the soil. In case of drip irrigation,the deposition of salt was notised at the upper layers of the effective root zone.

Alemi (1981) reported that water applied at the rate of 130 ml/hr by the pot irrigation moved the salts to a radial distance of 41.5 cm in 390 hr. But, applying water by trickle irrigation at the rate of 1 lit/hr moved the salt 42 cm in 52.5 hr. For an equal amount of water applied, salt moved deeper in the profile at a lower application rate. More salt spreading was observed from the trickle source with higher application rate.

Steve et al.(1983) observed that the electrical conductivity of root zone soil extracts was lower for drip irrigation treatments than furrow irrigation.

Gupta and Tyagi (1984) observed not much differences in ECe into soil layers at all radial distances from emitter point at each irrigation frequency with lower (0.75 lit/hr) application rate but at 30, 45 and 60 cm depth the decrease in irrigation frequency caused more salt concentration at same application rate. At high application rate (1.50 lit/hr) salt concentration increased with depth at all radial distances from emitter point. More salt accumulated away from the emitter source at each frequency and application rates.

Bucks et al.(1985) compared trickle and furrow irrigation to grape on sandy soil and observed that the trickle treatments followed two-dimensional pattern of salt movement, where the highest salinity values were located near soil surface at distance of 1 to 2 ft from emitter. Below the soil surface, soil ECs of less than 1 dS/m were restricted to 2-3 ft strip on each side of vine row, while leaching of salts occured to a depth of at least 4 ft. In furrow irrigation, one dimensional salt movement was exhibited where soil depths of 2-3 ft remain leached.

Karmarkar (1985) observed that the salts were concentrated in the upper zone of soil profile (15 cm) when saline water of 1.5 to 3.0 mmhos/cm was applied, but the salts were displaced upto 30 cm depth when concentration of saline water increased to 4.0 mmhos/cm.

In drip irrigation, salt accumulation was detected only in small spots normally at the surface (Salih, 1985).

Sen and Bandyopadhyay (1985) showed that the displacement of salt increased with drip rate, but, the influence was large upto 20 cm distance. Possibly saline water can be used through drip irrigation at the rate of 0.5 lit/day without increase in salt concentration in the soil.

Sharma et al.(1987) observed that the chloride content was less than 7 meL^{-1} in entire root zone with the use of normal quality irrigation water through drip irrigation to horticultural crop. Chloride accumulation was more in 4 RSC water than 8 RSC water. Peak of chloride accumulation in profile appeared at 70- 80 cm depth and just underneath the tree trunk in 4 RSC water but it was below 45 cm lateral distance with 4 RSC water.

Kranjac (1988) compared drip and furrow irrigation with saline water on sandy clay soil and showed that most of the soluble salts remained at the soil surface. Increasing the water volume moved the salts further from irrigation source in both, drip and furrow irrigation, although drip irrigation gave a greater variation in salt distribution in soil profile than furrow irrigation. Over irrigation with 125 per cent of maximum evapotranspiration did not affect salt distribution, whereas the treatment of 50 per cent maximum evapotranspiration resulted in a high salt accumulation in the top of soil.

Kulkarni (1988) found that there was not any significant variation in EC and pH of soil in horizantal and vertical direction because irrigation water used to the pomegranate and lime through drip irrigation was of good quality.

Singh et al.(1989) showed minimum salt accumulation (1.4 dS/m) near the plants in the daily irrigated treatments as against one day and two days intervals which produced 2.1 dS/m and 2.3 dS/m salt concentration, respectively.

Nehra et al.(1991) studied on the salt distribution pattern under trickle source in sandy loam soil. They developed the empirical equation describing increase in salt concentration (C) as a function of discharge (q), volume of application (V) and salinity of water (Cw), which is

$$C = 0.036 \frac{q^{0.15} \times V^{0.40} \times Cw^{1.13}}{X^{0.01} \times Y^{0.02}} \quad \ldots(2.7)$$

in which,

X = horizontal distance from the point source

Y = vertical distance from the point source

They found that the salt moved to a more depth with low dripper discharge and salinity built up was higher near the point source and it decreased laterally as well as vertically away from the point source.

Sharma et al.(1991) studied on the salt distribution profile under drip system with saline water in sandy loam and loamy soil. They found that salinity built up was more with added saline water and salt accumulation was more in upper soil layers i.e. 5, 15 and 30 cm depths. The soil depth of 5 cm consisted of maximum salt concentration. They also observed that the salt accumulation was more on the soil surface around the periphery of wetted volume of soil. They recommended higher discharge of water of high salinity with drip system.

Ghazy et al.(1992) observed that the salt concentration in the soil increased with distance from the emitter and decreased with application of conditioners.

3. MATERIAL AND METHODS

The experiment to study the 'Moisture and salinity status under micro-irrigation systems in vertisols', was conducted in summer, 1994. The details of the material used and the methods adopted in conducting the present investigation are described in this chapter.

3.1 Material

3.1.1 Experimental site

The field experiment was conducted at the Instructional Farm of Department of Irrigation and Drainage Engineering, College of Agricultural Engineering, Mahatma Phule Krishi Vidyapeeth, Rahuri, (India), situated at an altitude of 657 m from mean sea-level. The latitude and longitude of Rahuri are **19^{o} 24' N and 74^{o} 39' E,** respectively.

3.1.2 Soil

According to the seventh approximation, the soils in deccan plateau are classified under the order 'Vertisols' (Shrinivasan et al., 1969). These soils are characterised by high productivity and cation exchange capacity, medium to low organic matter content and nitrogen, higher base saturation with dominant exchangeable complex as calcium. The dominant clay mineral is montmorillonite.

The soil of the experimental field was uniform and leveled. The soil was well drained consisting of two layers, viz. upper clay layer (0.80 m) and lower clay loam layer (2.65m) (Patel et al.,1988). In order to know the physical and chemical properties of the soil, the samples were collected from 0-15, 15-30, 30-45 and 45-60 cm soil layers at 5 randomly selected spots from the experimental area and composite sample was prepared for determination of physical and chemical properties of soil. The physical and chemical properties and methods used for their determination are given in Table 3.1.

3.1.3 Physical properties of soil

The physical properties of soil such as texture, infiltration rate, bulk density, particle density and total porosity were determined in order to know the characteristics of upper clay layer and to widen the applicability of the results of this experiment in other areas.

3.1.4 Chemical properties of soil and water

The chemical properties of soil such as pH, electrical conductivity (EC) were determined in order to know whether the soil is saline or alkaline. Similarly, the chemical properties of water were also determined to know its quality.

3.1.5 Climate

3.1.5.1 General

Climatically the area falls under semi-arid and tropical zone with annual rainfall varying from 307

Table 3.1. Methods adopted for determining the soil properties

Sr. No.	Soil property	Method adopted	Refernce
1	Particle size distribution	International pipette	Piper , 1966
2	Bulk density	core sampler	Dastane , 1972
3	Infiltration rate	Double ring infiltrometer	Dastane , 1972
4	Moisture retention characteristics (1/3 and 15 bar)	Pressure plate apparatus	Black , 1965
5	Soil pH (1:2.5 soil water ratio)	Glass electrode	Piper , 1966
6	Electrical conductivity (EC) (1:2.5 soil water ratio)	Digital conductometry	Piper , 1966

to 619 mm. The annual average being about 520 mm which is mostly concentrated during the monsoon months from July to October from south-west monsoon, which is nearly 80 per cent of the total precipitation. The distribution of rain is erratic and distributed in 15 to 45 rainy days. The tract is the rain shadow area lying on eastern sides of Western Ghat. The area chronically comes under drought prone having frequent famine condition i.e. once in three years.

The annual mean maximum temperature is 37.9 ^{o}C with a range from 33.0 to 43.0 ^{o}C . The annual mean minimum temperature is 17.2^{o}C with a range from 3.0 to 18.0 ^{o}C. The mean relative humidity at 0800 and 1700 hr is about 59 and 35 per cent, respectively. The mean pan evaporation ranged from 3.2 to 14.3 mm/day. Agro-climatically the area falls under scarcity zone of Maharashtra.

3.1.5.2 Meteorological observations

The meteorological data during the period of experimentation are presented in Table 3.2 and graphically shown in Fig. 3.1.

It was observed from the data that the precipitation received during the experimental period was 203.8 mm. The mean maximum and minimum temperature ranged between 28.66 and 40.37^{o}C and between 11.0 and 25.39^{o}C, respectively. The morning and evening relative humidity ranged between 58.0 and 83.0 per cent and between 16.0 and 73.29 per cent respectively. The mean

TABLE 3.2. Meteorological data recorded during experimental period (March to July, 1994)

Met. Week	Month	Date	Mean Temp, ^oC		Relative humidity, %		Mean evapo-ration, mm	Rainfall, mm	No. of rainy days
			Max	Min	Morn-ing	Even-ing			
9	Feb.	26-04	33.16	11.00	77.57	19.00	6.17	-	-
10	March	05-11	34.61	14.21	58.57	17.00	7.81	-	-
11		12-18	36.86	15.40	62.14	16.00	7.69	-	-
12		19-25	37.90	16.43	58.57	23.14	9.43	-	-
13		26-01	37.81	17.97	59.14	33.43	9.5	-	-
14	April	02-08	36.93	18.15	69.00	19.57	8.63	-	-
15		09-15	32.86	19.86	78.43	37.71	6.47	51.50	2
16		16-22	36.59	18.39	72.14	27.14	8.63	6.40	1
17		23-29	37.57	18.19	62.43	20.43	10.83	-	-
18		30-06	37.37	19.50	58.00	23.43	10.01	-	-
19	May	07-13	38.00	21.17	68.43	27.14	11.57	-	-
20		14-20	39.67	23.93	73.14	26.14	13.90	-	-
21		21-27	40.37	22.09	67.86	25.14	13.21	-	-
22		28-03	38.04	25.39	75.86	27.43	9.20	7.20	1
23	June	04-10	36.24	23.03	80.86	40.57	7.84	15.80	2
24		11-17	29.39	22.53	83.00	65.43	6.86	63.20	2
25		18-24	30.49	22.34	82.14	57.43	5.23	1.00	-
26		25-01	31.13	22.01	82.14	63.29	7.89	7.80	1
27	July	02-08	29.87	20.96	80.29	62.71	5.10	7.50	1
28		09-15	28.66	21.60	80.86	73.29	4.37	22.00	3
29		16-22	28.91	20.84	80.57	67.29	5.00	17.20	1
30		23-29	29.17	21.39	81.29	66.71	4.43	2.80	1
31		30-05	29.23	21.63	81.57	57.29	4.49	1.40	-

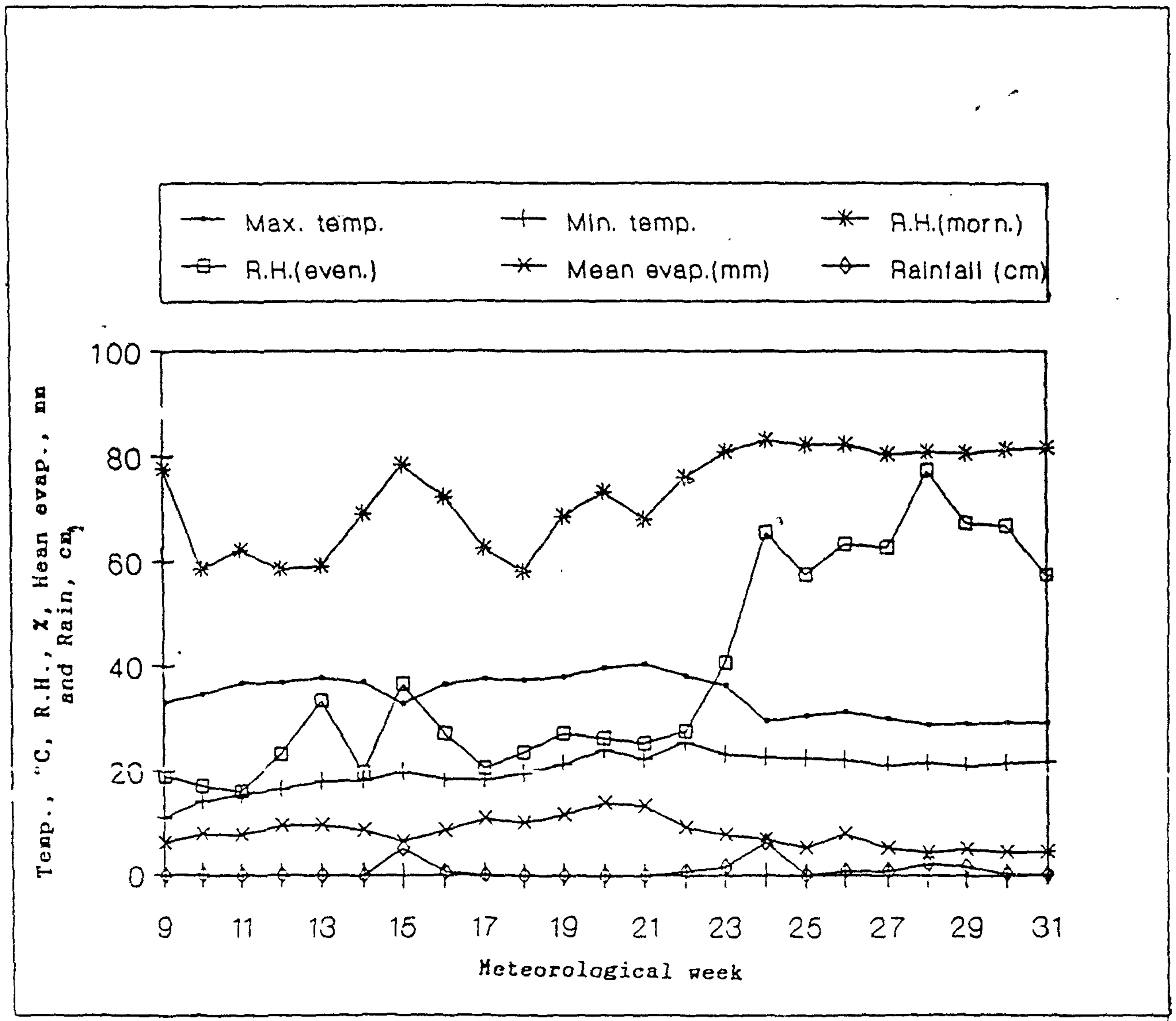


Fig. 3.1 : Average weekly meteorological data recorded during the experimental period (March to August, 1994)

pan evaporation ranged from 4.37 to 13.90 mm/day during March to July, 1994 i.e. 9th to 31st meteorological weeks, respectively.

3.1.6 Experimental set-up

3.1.6.1 System performance and moisture distribution study

The land was prepared by one ploughing and two harrowing operations for conducting the experiment.

The layout of the experimental set-up used for studying the system performance and moisture distribution patterns is shown in Fig. 3.2. The field was fairly levelled. The centrifugal pump of 3 H.P. equipped with by-pass arrangement was used to feed the micro-irrigation systems at requisite operating pressure. The pressure adjustment was achieved by controlling the discharge with the help of regulating valve provided on delivery side of the pump. Screen filter was provided on delivery side of the pump to ensure clean water supply and to minimize the risk of emitter clogging. A valve was provided on the each manifold for regulating the pressure head which could be read from the pressure gauge connected just after the valve.

The performance of different micro-irrigation systems such as turbo-key dripper system (point source application), strip tape system (line source application) and microsprinkler system was studied. Each system consisted of four 16 mm LDPE laterals with

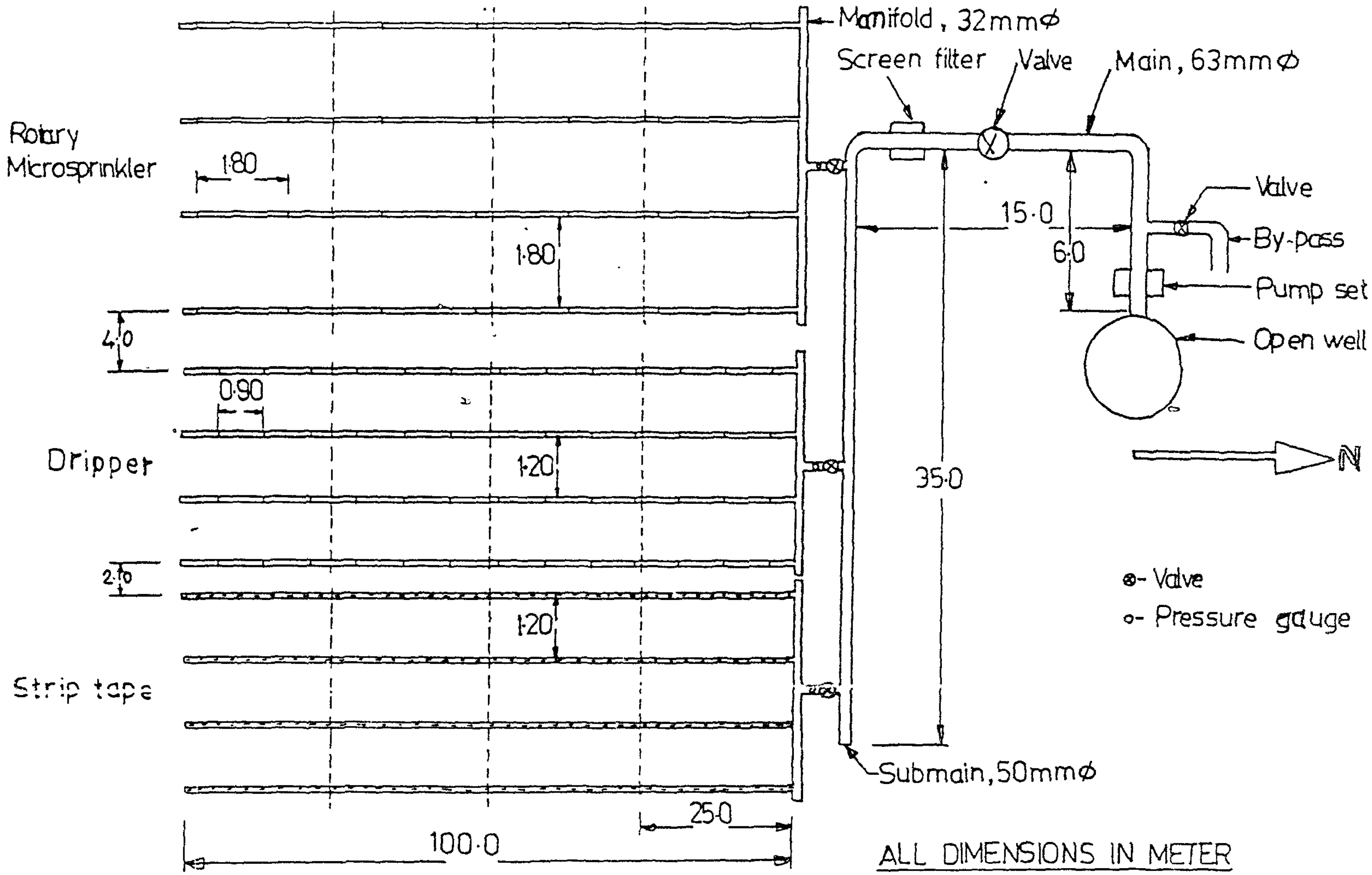


Fig. 3·2. Schematic layout of the experimental set-up for field evaluation of hydraulic performance of micro-irrigation systems.

desired spacings of emitters. The length of laterals used were 25m, 50m, 75m and 100m in each system. The strip tape was laid 10 cm below surface level for studying moisture distribution patterns.

Other details of micro-irrigation unit used were as follows.

i.	Type of main	:	G.I. pipeline already available, 63 mm diameter.
ii.	Type of submain	:	P.V.C. pipe, 50 mm diameter.
iii.	Type of manifold	:	P.V.C. pipe, 32 mm diameter.
iv.	Type of lateral	:	L D P E , 16 mm diameter.
v.	Details of micro-irrigation systems	:	The details are given in Table 3.3.

3.1.6.2 Salinity status

To study the salinity status under these micro-irrigation systems, the systems already installed in chilli crop were used. The layout of these systems is shown in Fig. 3.3. In this layout the plots of 9.00m x 3.60m size were prepared by Shinde (1995) for another purpose. The chilli crop (var. Agnirekha) was planted in pair-row technique with the spacings of 30cm x 45cm in dripper and strip tape system plots, whereas the normal spacings of 60cm x 45cm was adopted in microsprinkler system plot, as in microsprinkler system water is sprinkled over entire plot (Fig. 3.4). The buffer strip of 2.00m was kept between two treatment plots to avoid lateral movement of water.

The control unit of micro-irrigation systems

Table 3.3. Details of micro-irrigation systems

Sr. No.	Type of source	Emitting device	Recomme-nded operating pressure, kg/cm^2	Standard discharge, lph	Emitter spacing, cm	Lateral spacing, cm
1.	Point	Turbo-key on-line drippers	1.00	4.00	90.00	120.00
2.	Line	Strip tape with emission holes	0.70	3.50 per m	28.50	120.00
3.	Sprinkle	Rotary micro-sprinkler	1.50	36.00	180.00	180.00

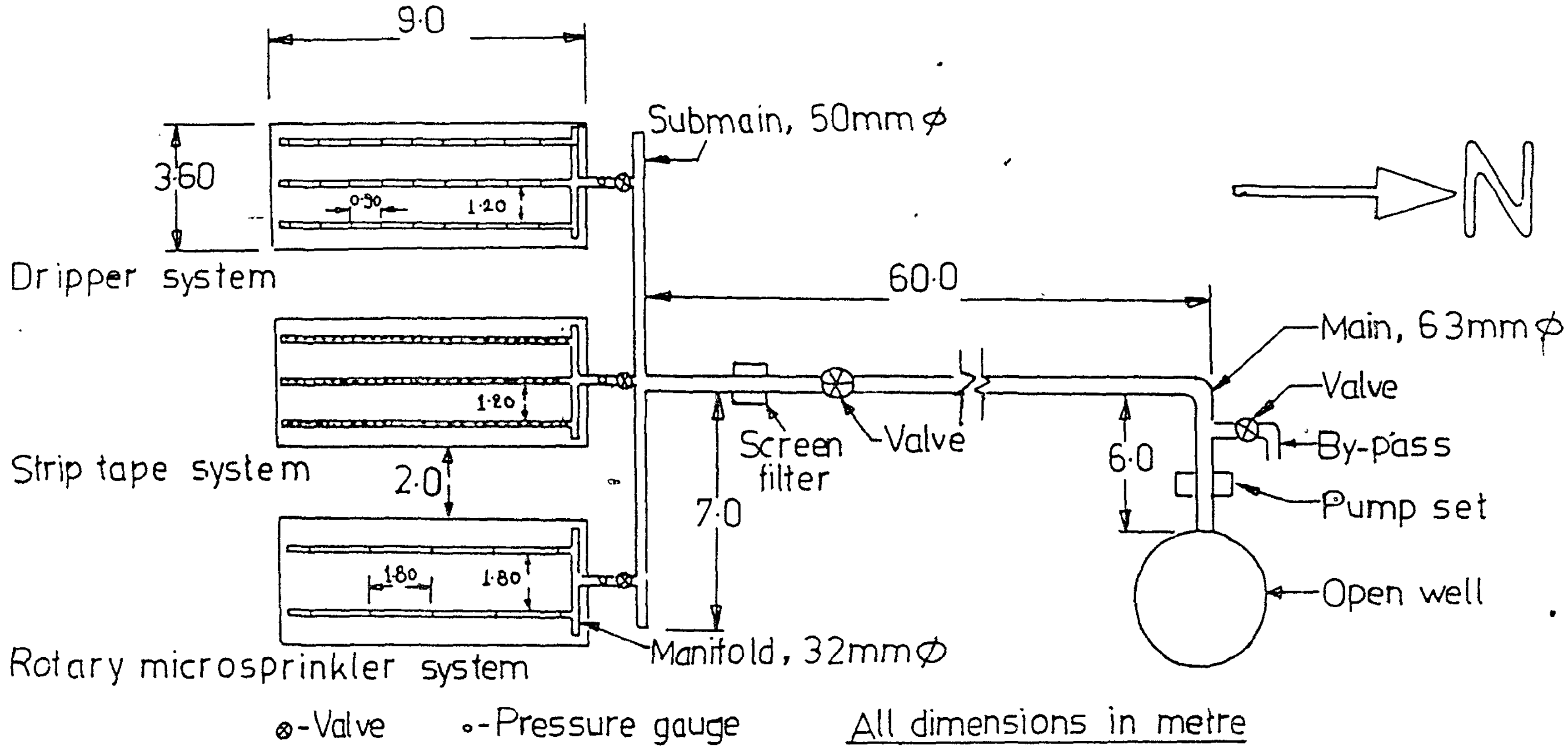


Fig. 3.3. Layout of the different micro-irrigation systems used for studying the salinity status in chilli.

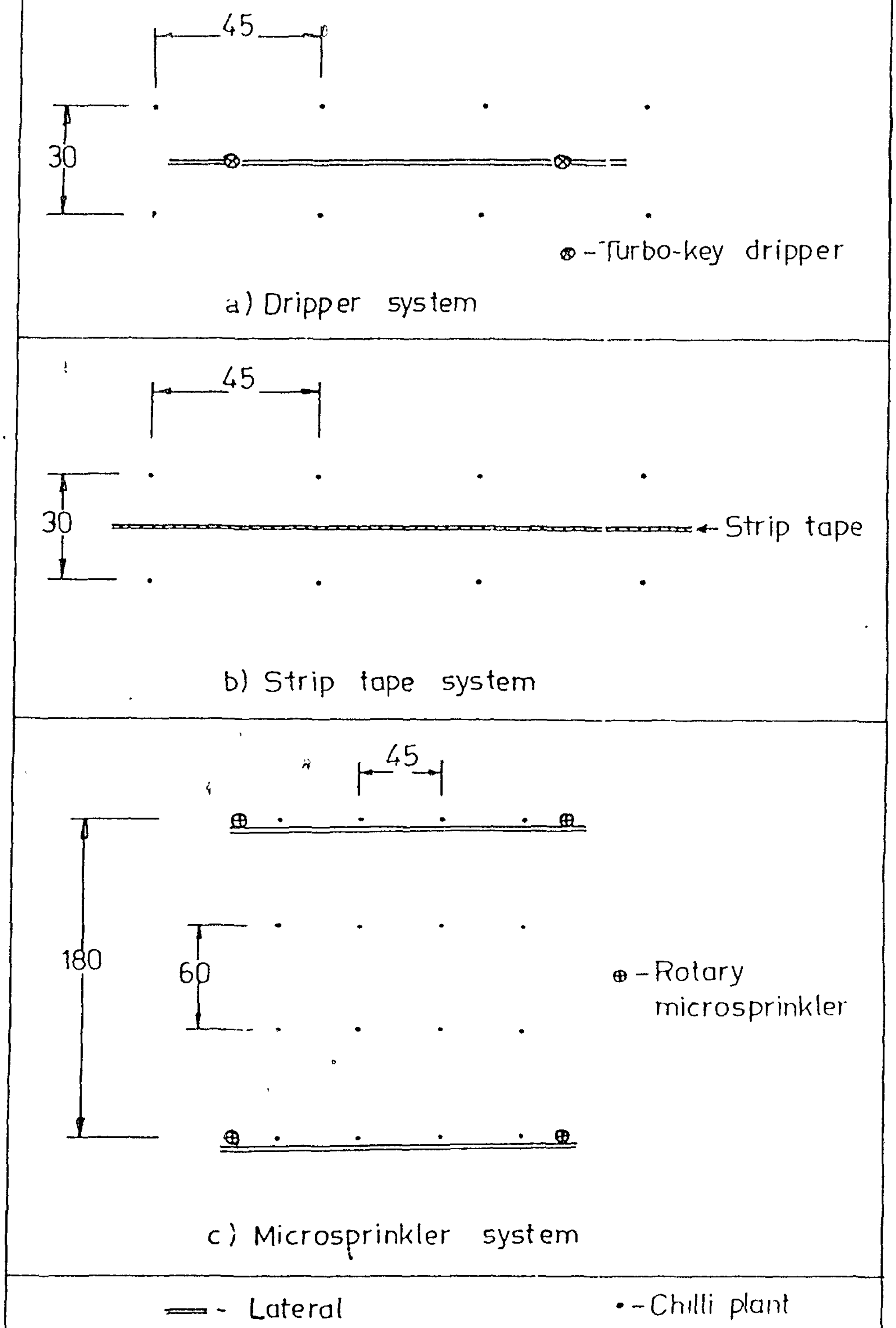


Fig. 3.4. Planting technique layout for different micro-irrigation systems in chilli .

consist of centrifugal pumpset, screen filter, control valves, pressure gauges and by-pass assembly. The system was operated by 3.00 H.P. electric motor. The strip tape was laid 15cm below the ground level.

Other details of these micro-irrigation systems are as below :

i.	Type of main	:	G.I. pipeline already available, 63mm diameter.
ii.	Type of submain	:	P.V.C. pipe, 50 mm diameter.
iii.	Type of manifold	:	P.V.C. pipe, 32mm diameter.
iv.	Type of lateral	:	L.D.P.E., 16mm diameter.
v.	Details of micro-irrigation systems	:	The details of micro-irrigation systems were same as reported in Table 3.3.

3.1.7 Pressure - discharge relationship

The relationship between pressure and discharge was studied in each micro-irrigation system for different lengths of laterals such as 25, 50, 75 and 100 m. The layout shown in Fig. 3.2 was used for this purpose. The plastic catch-cans were used to collect the emitter discharge at 4 locations on each lateral. The precise and accurate stop-watch was used to measure the time period. The collected water was measured with the help of measuring cylinder.

3.1.8 Emission uniformity (E U)

The material required for carrying out the tests were the same as required for pressure-discharge at different pressure heads of 5.0, 7.5, 10.0, 12.5, 15.0 and 17.5 m in case of drippers; at 5.0, 7.5 10.0, 12.5 and 15.0 m in strip tape system and at 10.0 , 12.5, 15.0, 17.5, 20.0 and 22.5 m in microsprinkler system. These pressure heads were regulated with the help of the controlling valve installed on the manifold.

3.2.1.2 Emission Uniformity

In finding out the emission uniformity (EU) of the system, the procedure suggested by Nakayama and Bucks (1986) was used. The data collected for pressure-discharge relationship study was used for computation of EU. The EU was determined for different combinations of operating pressure and the length of laterals for studying their effects on emission uniformity. The formulae for estimation of field EU and absolute EU, given by Nakayama and Bucks (1986), are given below.

a] Field emission uniformity (EU_f)

$$EU_f = \frac{q_{min}}{q_{ave}} \times 100 \qquad \ldots(3.1)$$

b] Absolute emission uniformity (EU_a)

$$EU_a = \left(\frac{q_{min}}{q_{ave}} + \frac{q_{ave}}{q_x} \right) \times \frac{1}{2} \times 100 \qquad \ldots(3.2)$$

in which,

q_{min} = minimum discharge rate , lph or lph/m

q_{ave} = average discharge rate , lph or lph/m

q_x = average of 1/8th of highest discharge rates,lph or lph/m

EUf and EVa are in per cent.

3.2.1.3 Uniformity Coefficient

In determining the uniformity coefficient (UC) of the rotary microsprinkler, the catch-cans were placed on a levelled surface of soil in the square of size 1.80m × 1.80m formed by four microsprinklers at grid spacing of 30cm (Fig. 3.5). The stake height of each rotary microsprinkler was kept 20 cm above the soil surface. The UC was determined for the lateral length of 25m at head, middle and tail end. The system was operated at 15m pressure head for half an hour continuously. Immediately after termination of the irrigation, the depth of collected volume of water in each catch-can was measured with the help of graduated cylinder. The depths observed were used for computing the uniformity coefficient of rotary microsprinkler by the following equation given by Christiansen (Michael, 1978).

$$UC = 100 \left(1 - \frac{\Sigma |x|}{m.n} \right) \qquad ...(3.3)$$

in which,

UC = uniformity coefficient, per cent.

$|x|$ = Numerical deviation of individual observed depth from average depth, mm.

m = Average depth of all observations, mm.

n = Total number of observation points.

3.2.1.4 Head loss in laterals

The pressure head at the inlet of lateral was taken from the pressure gauge installed on manifold, near the lateral. At tail end of same lateral, another

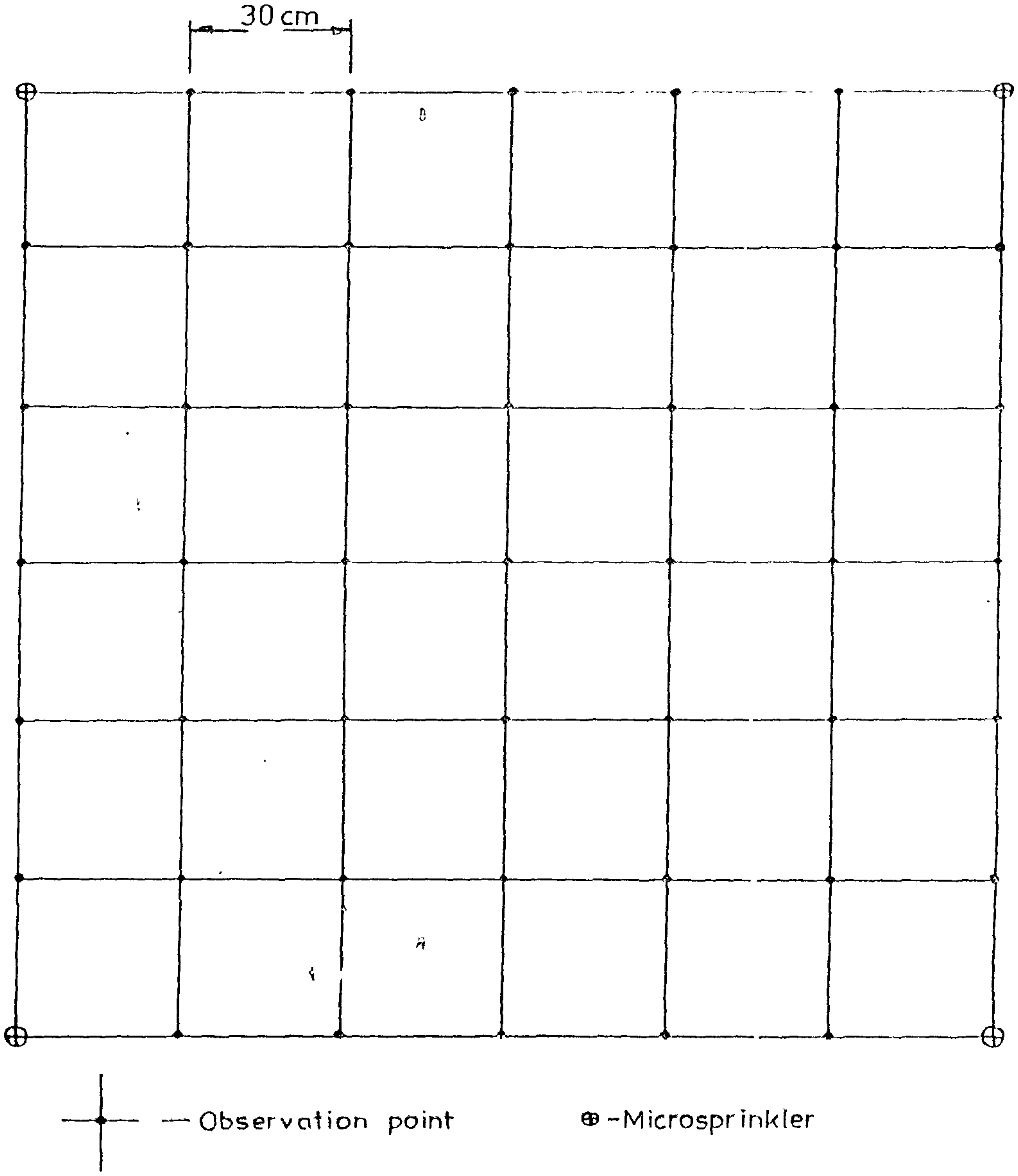


Fig. 35. Layout of grid points for determination of UC.

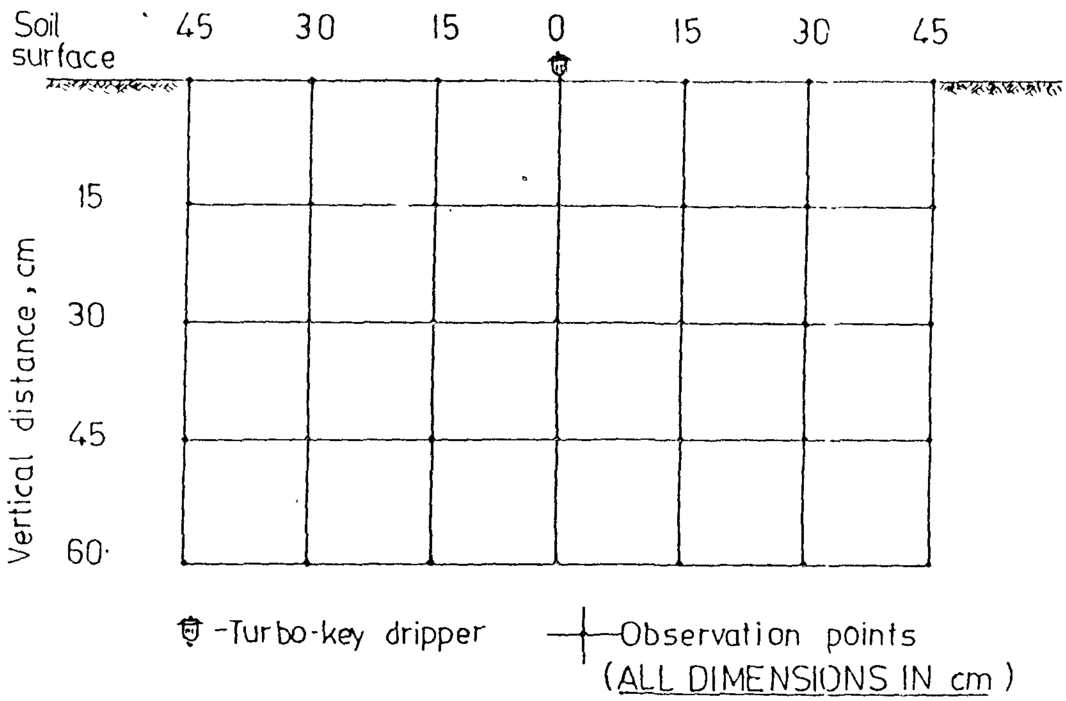
pressure gauge was installed to measure the pressure head at outlet. The difference between the pressure heads at inlet and at tail end of lateral was considered as a head loss in the lateral. The head loss in lateral was found at different pressure heads and 25, 50, 75 and 100 m length of laterals in each system.

3.2.2 Moisture distribution pattern

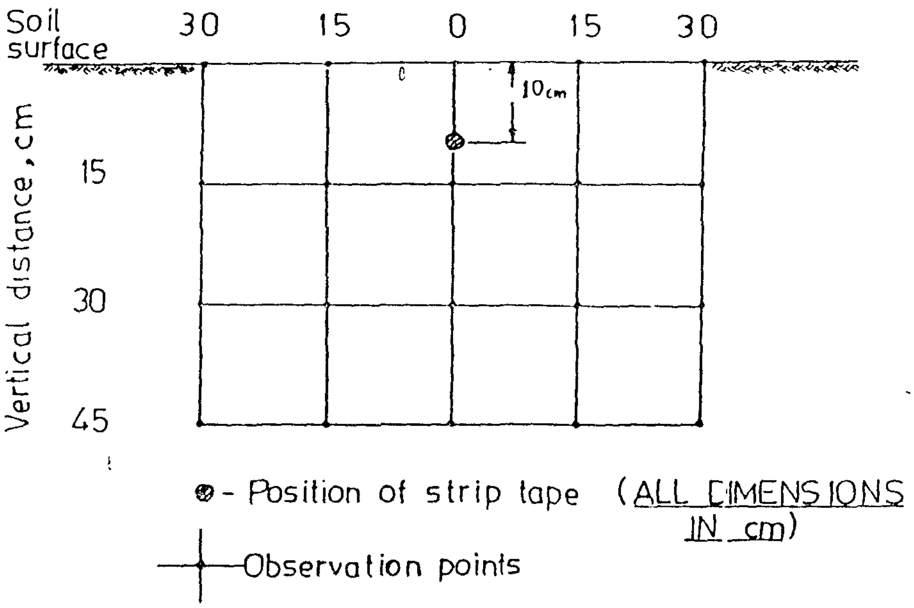
The moisture distribution pattern under different micro-irrigation systems was studied for different combinations of emitter discharge rates and quantities of water, as given below.

Sr.No.	Name of system	Discharge rate, lph	Quantities of water, lit
1.	Turbo-key on-line dripper	3	5, 10, 15
		4	5, 10, 15
		5	5, 10, 15
2.	Strip tape (sub surface)	2 per m	3, 5, 10
		3 per m	5, 10, 15
		4 per m	5, 10, 15
3.	Rotary microsprinkler	30	40, 60, 80
		35	40, 60, 80
		40	40, 60, 80

The quantities of water as above were applied on uniform and levelled soil surface. The soil samples before the application of water and after 0, 24 and 48 hr of application of water were collected with the help of screw auger. In case of turbo-key dripper and strip tape, a grid for collection of soil samples from different depths and radial distances was considered as shown in Fig. 3.6. For rotary



A) Dripper system.



B) Strip tape system

Fig. 36. Grid for recording observations of moisture content for moisture distribution study.

microsprinkler, the soil samples were collected from the grid points as shown in Fig. 3.7.

After samples were collected in boxes, the auger hole was refilled with the soil removed by the auger, so that there was no discrepancy in sample collection after termination of irrigation, at 24 hr after irrigation and 48 hr after irrigation. The moisture content of each sample was determined by gravimetric method.

The data pertaining to moisture content at various locations were used to find out the extent to which the wetting front of 36 per cent moisture (i.e. field capacity) has reached, under different set of conditions. The radial movements of moisture at various soil depths were determined and correlated.

3.2.3 Salinity status

The salinity status in the soil under different micro-irrigation systems due to their different modes of water application was studied by collecting soil samples upto 45 cm soil depth. The grids for collection of soil samples are depicted in Fig. 3.8 This study was carried out in already installed micro-irrigation systems in chili crop. The data regarding average volume of water applied by emitter, total rainfall and fertilizer applied, etc. are given in Table 3.4.

The soil samples were collected after 30, 60,

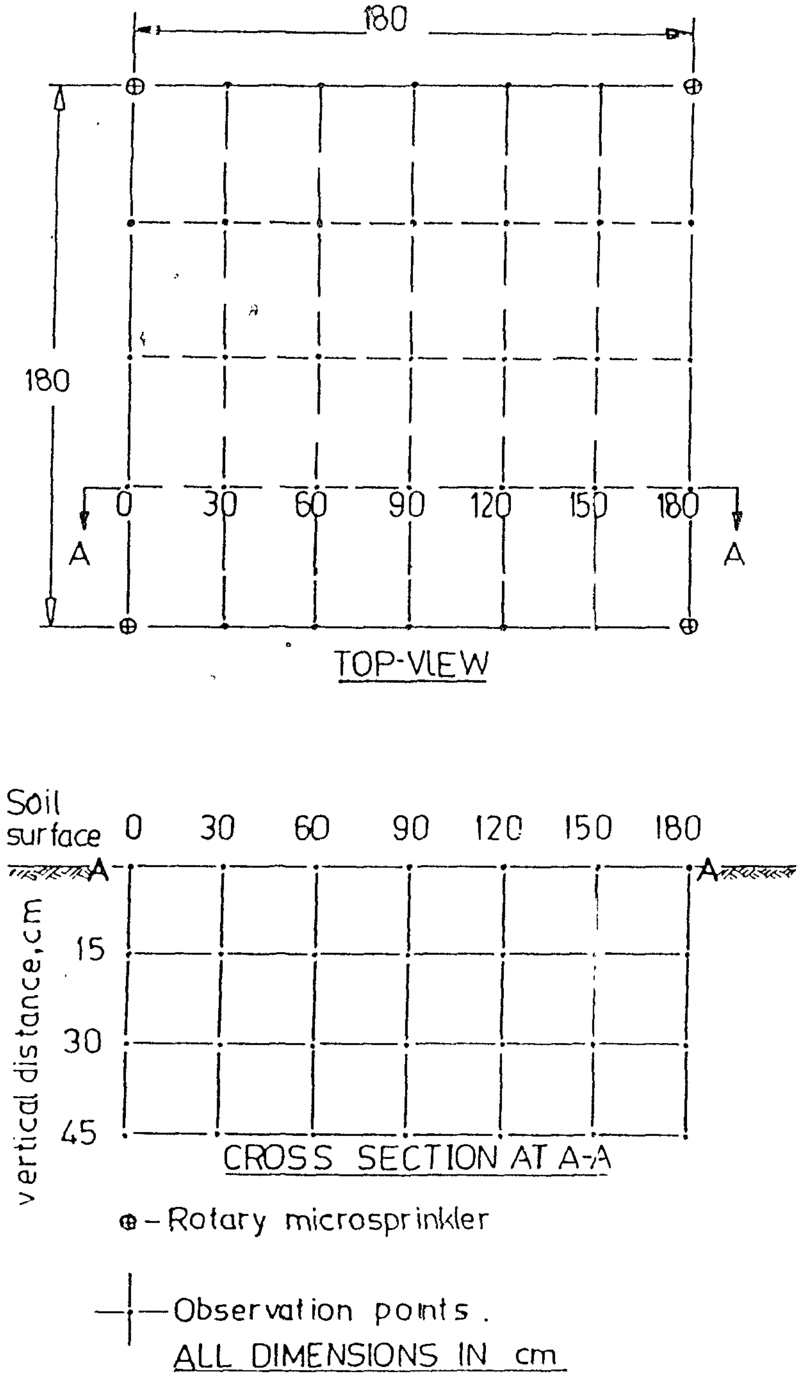
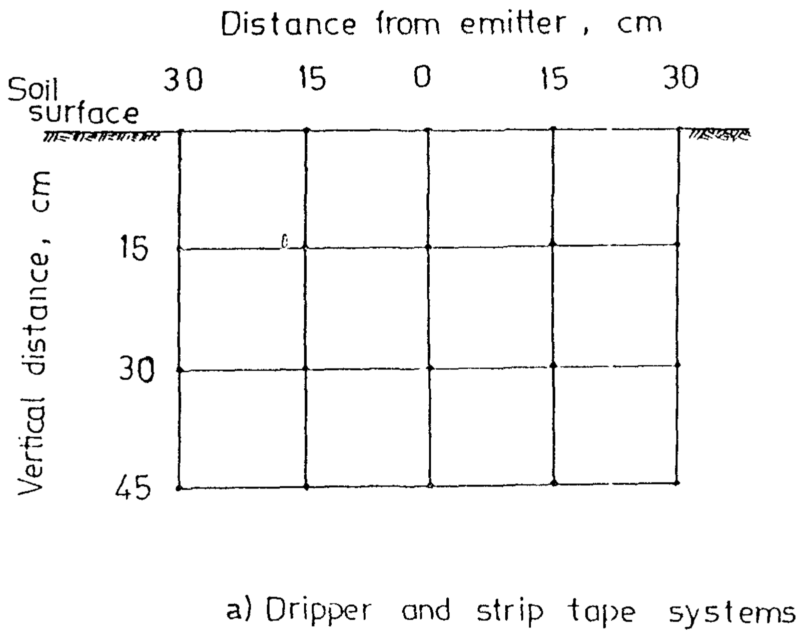


Fig. 3·7. Grid for recording observations of moisture content in microsprinkler.



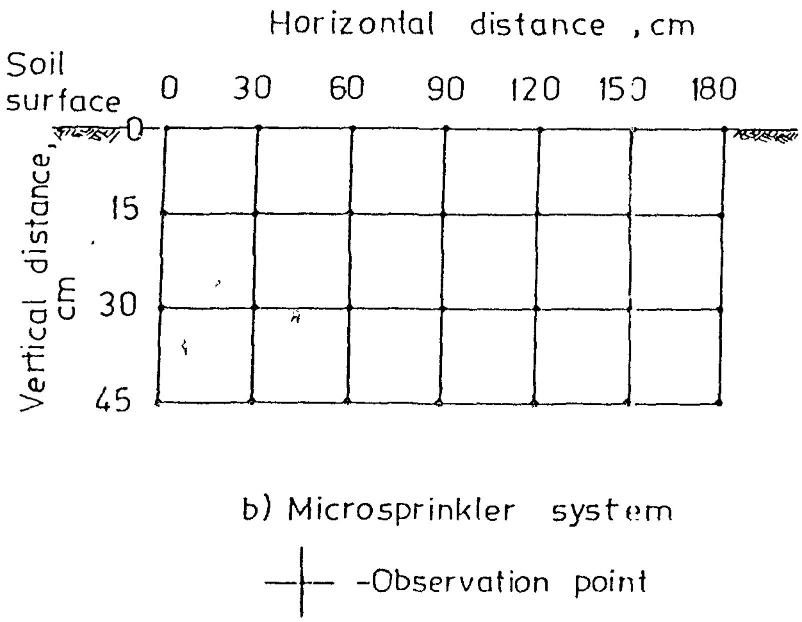


Fig.3·8. Grid for collection of soil samples for studying salinity status .

Table 3.4. Details of average water applied by different emitters, rainfall, fertilizer applied, etc. in chilli crop throughout the season.

Sr. No.	Month	Date of sampling	Elapsed time after trans-planting, days	Date of fertilizer application and quantity, kg/plot	Total rainfall, cm	Average volume of water applied at alternate day per emitter, lit		
						Dripper	Strip tape	Micro-sprinkler
1.	March	31.03.94	30	01.03.94 1.08 Suphala (15:15:15)	--	7.39	8.77 per m	23.69
2.	April	30.04.94	60	01.04.94 0.352 Urea (46)	5.79	8.52	9.47 per m	25.56
3.	May	30.05.94	90	--	0.72	11.28	12.53 per m	33.84
4.	June	--	--	--	8.78	--	--	--
5.	July	29.07.94	150	--	4.59	5.58	6.20 per m	16.75

Average emitter discharge :

1. Dripper = 3.84 lph
2. Strip tape = 3.00 lph/m
3. Microsprinkler = 33.72 lph

90 and 150 days after transplanting with the help of screw auger. After air drying the soil samples were gently crushed and sieved through 0.20mm mesh. In order to find out the salinity (EC) of these soil samples 5gm of soil was used. The soil water ratio used was 1:2.5. The digital electrical conductivity meter was used for determining the salinity status i.e. EC values.

The data of EC at various grid points under different micro-irrigation systems were used for plotting the contours of different levels of salinity (i.e. iso-salinity lines). The data obtained for studying different objectives in this investigation was used suitably by illustrating with graphs and figures at appropriate places.

4. RESULTS AND DISCUSSION

The observations and data analysed during the conduct the present investigation were studied critically and are reported in the appropriate manner in this chapter. The findings obtained are discussed in light of the previous literature. This chapter is broadly characterised in major topics as indicated below.

4.1 Pertinent physical and chemical properties of soil.

4.2 System performance.

4.3 Moisture distribution pattern.

4.4 Salt distribution studies.

4.1 Pertinent physical and chemical properties of soil

The pertinent physical and chemical properties of soil and the soil moisture constants are presented in Table 4.1. The soil of the experimental site was clay in texture with clay content of 50.11 per cent, 24.21 per cent sand and 25.68 per cent silt. The soil depth was 80 cm. The bulk density of the soil was 1.13 gm/cc. The field capacity and wilting point of the soil were 36.65 and 18.24 per cent, respectively. The basic infiltration rate and hydraulic conductivity of soil was 0.42 cm/hr and 1.20 m/day, respectively. The soil was sodic in reaction (pH 8.5) having electrical conductivity of 0.88 dS/m and ESP 22.50.

Table 4.1. Pertinent physical and chemical properties of soil and the soil moisture constants

Sr. No.	Soil properties	Upper layer
1.	Bulk density, g/cc	1.13
2.	Total porosity, per cent	49.55
3.	Depth of soil , cm	80.00
4.	Soil fractions	
	i] Sand, per cent	24.21
	ii] Silt , per cent	25.68
	iii] Clay, per cent	50.11
5.	Texture	Clay
6.	Hydraulic conductivity, m/day	1.20
7.	pH	8.50
8.	EC, dS/m	0.88
9.	Soil moisture constants :	
	a] Field capacity, per cent	36.65
	b] Permanent wilting point , per cent	18.24
	c] Available moisture, cm, in 45 cm.	9.36
	d] Infiltration rate, cm/hr	0.42

4.2 System performance

The system performance was studied in respect of the relation between pressure (H) and discharge (Q), emission uniformity (EU), uniformity coefficient (UC) of microsprinkler system and head loss (H_L) in the lateral lines.

4.2.1 Pressure discharge relationship

4.2.1.1 Dripper system

The data in respect of emitter discharges with respect to the pressure variation in different lateral lengths are given in Table 4.2 and depicted in Fig.4.1. It is observed that the discharge (Q) of dripper increased with increase in the operating pressure (H) in case of all the lateral lengths. It is also observed that the Q decreased with increase in the length of lateral at all H values. This was due to the head loss in the lateral. The decrease in the discharge was found in the range of 14.38 to 28.73 per cent, when the lateral length was increased from 25 to 100 m for the pressure of 0.50 to 1.75 kg/cm^2. As the pressure head increased from 0.50 to 1.75 kg/cm^2, on an average the discharge increased by 33.4, 34.3, 39.5 and 46.8 per cent, respectively for the lateral lengths of 25, 50, 75 and 100m. The average discharge at recommended operating pressure of 1.0kg/cm^2 was observed 3.89, 3.64, 3.46 and 3.20 lph for lateral lengths of 25, 50, 75 and 100m, respectively. The correlations between pressure head (H) in kg/cm^2 and dripper discharge (Q) in lph were developed as below.

Table 4.2. Pressure - discharge relationship for different lateral lengths in dripper system

Operating pressure (H), kg/cm^2	Average dripper discharge (Q), lph			
	Length of lateral , m			
	25	50	75	100
0.50	3.45	3.19	2.92	2.68
0.75	3.64	3.44	3.23	2.96
1.00	3.89	3.64	3.46	3.20
1.25	4.12	3.85	3.66	3.48
1.50	4.36	4.09	3.82	3.65
1.75	4.59	4.29	4.07	3.93

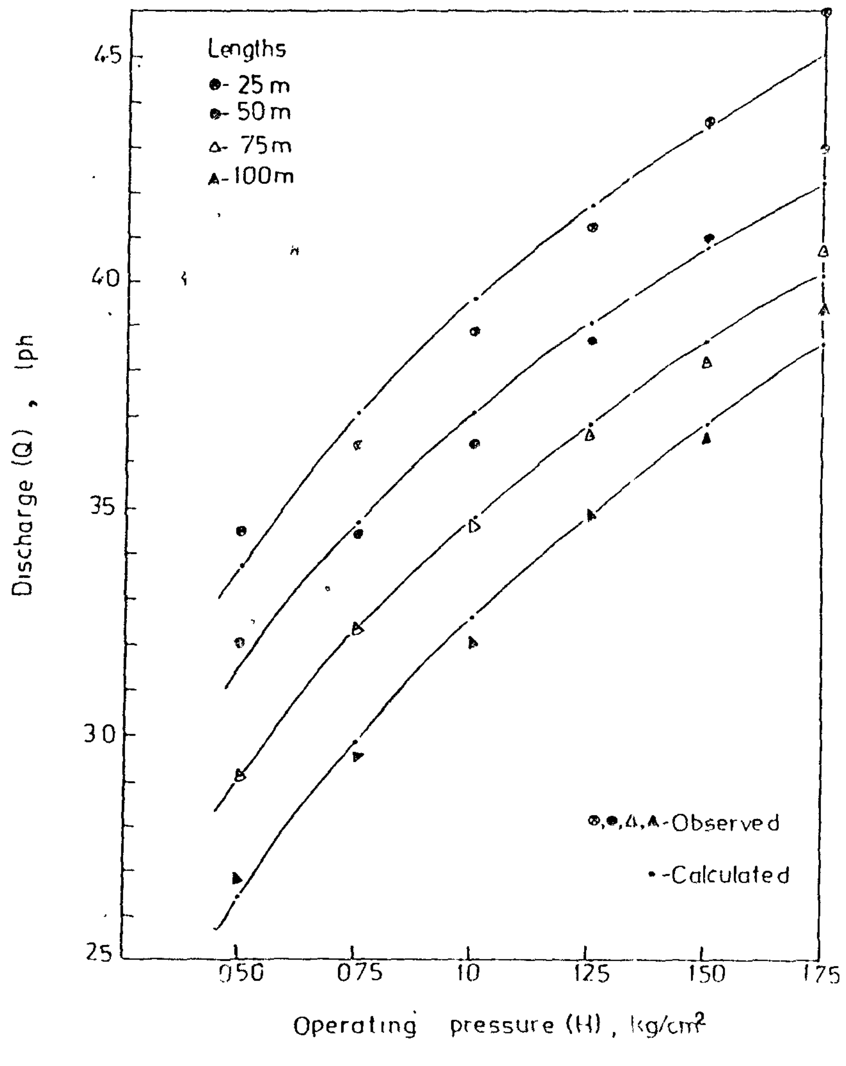


Fig 4·1. Pressure-discharge relationship observed for different length of lateral (L) in dripper system.

$$Q = 3.958\ H^{0.234} \quad \text{for } L=25 \text{ m} \qquad ...(4.1)$$

$(r^2 = 0.96)$

$$Q = 3.705\ H^{0.234} \quad \text{for } L=50 \text{ m} \qquad ...(4.2)$$

$(r^2 = 0.97)$

$$Q = 3.475\ H^{0.257} \quad \text{for } L=75 \text{ m} \qquad ...(4.3)$$

$(r^2 = 0.98)$

$$Q = 3.255\ H^{0.302} \quad \text{for } L=100 \text{ m} \qquad ...(4.4)$$

$(r^2 = 0.98)$

4.2.1.2 Strip tape system

Table 4.3 and Fig. 4.2 show the pressure-discharge relationship for strip tape having different lengths.It is seen from the Fig. 4.2 that the discharge (Q) of strip tape lateral increased with increase in the operating pressure (H) in case of all the lateral lengths. It is also observed that the Q decreased with increase in the length of lateral at all H values. This was due to the head loss in lateral. The decrease in the discharge was found in the range of 9.48 to 11.33 per cent for the pressure of 0.50 to 1.50 kg/cm^2 when the lateral length was increased from 25 to 100 m. As the pressure head increased from 0.50 to 1.50 kg/cm^2, on an average, the discharge increased by 40.9, 42.1, 42.7 and 40.2 per cent, respectively, for the strip tape of 25, 50, 75 and 100 m lengths. The average discharge at recommended operating pressure of o.75kg/cm^2 was observed 3.73, 3.66, 3.52 and 3.29 lph/m for the lateral lengths of 25, 50, 75 and 100m, respectively. The correlations between pressure head (H) in kg/cm^2 and strip tape discharge (Q) in lph/m were developed as below.

Table 4.3. Pressure - discharge relationship for different lateral lengths in strip tape system

Operating pressure (H), kg/cm^2	Average discharge (Q), lph/m			
	Length of lateral , m			
	25	50	75	100
0.50	2.88	2.75	2.65	2.58
0.75	3.48	3.38	3.26	3.15
1.00	3.73	3.67	3.54	3.35
1.25	3.89	3.81	3.69	3.50
1.50	4.06	3.91	3.78	3.60

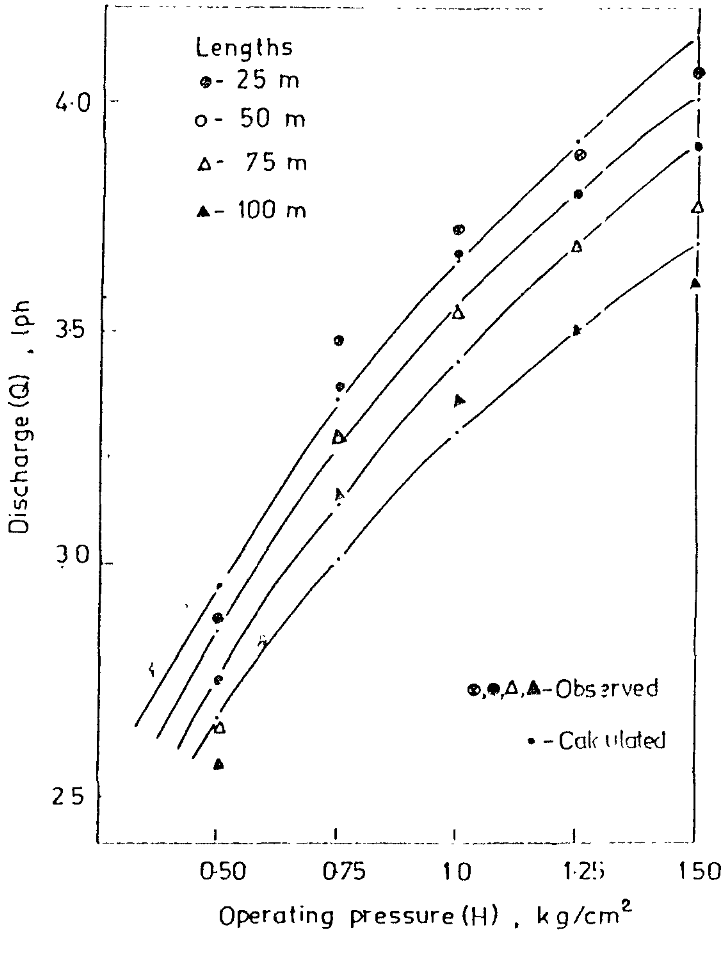


Fig.4·2. Pressure-discharge relationship for different length of strip tape (L) .

$$Q = 3.66\ H^{0.304} \quad \text{for } L=25m \quad ...(4.5)$$
$$(r^2 = 0.93)$$

$$Q = 3.556\ H^{0.317} \quad \text{for } L=50m \quad ...(4.6)$$
$$(r^2 = 0.91)$$

$$Q = 3.434\ H^{0.321} \quad \text{for } L=75m \quad ...(4.7)$$
$$(r^2 = 0.91)$$

$$Q = 3.281\ H^{0.297} \quad \text{for } L=100m \quad ...(4.8)$$
$$(r^2 = 0.92)$$

4.2.1.3 Microprinkler system

The data in respect of emitter discharges with respect to the pressure variation with different lateral lengths are given in Table 4.4 and depicted in Fig. 4.3. The similar results were obtained as in case of dripper and strip tape systems. It was noticed that the decrease in the discharge was found in the range of 44.09 to 49.09 per cent for the pressure of 1.0 to 2.25 kg/cm^2 when the length of lateral was increased from 25 to 100 m. As the pressure head increased from 1.0 to 2.25 kg/cm^2 , on an average, the discharge increased by 13.8, 16.4, 25.8 and 24.9 per cent , respectively, for the lateral lengths of 25, 50, 75 and 100m. The average discharge at recommended operating pressure of 1.50 kg/cm^2 was observed 32.70, 25.79, 21.45 and 17.30 lph for the lateral lengths of 25, 50, 75 and 100m, respectively. The correlations between pressure head (H) in kg/cm^2 and microsprinkler discharge (Q) in lph were developed as below.

$$Q = 30.521\ H^{0.160} \quad \text{for } L=25m \quad ...(4.9)$$
$$(r^2 = 0.97)$$

Table 4.4. Pressure - discharge relationship for different lateral lengths in microsprinkler system

Operating pressure (H), kg/cm^2	Average discharge (Q), lph Length of lateral, m			
	25	50	75	100
1.00	30.35	23.84	18.98	15.45
1.25	31.73	24.81	20.28	16.22
1.50	32.71	25.80	21.45	17.31
1.75	33.49	26.67	22.38	18.02
2.00	34.07	27.15	23.27	18.71
2.25	34.54	27.77	23.81	19.31

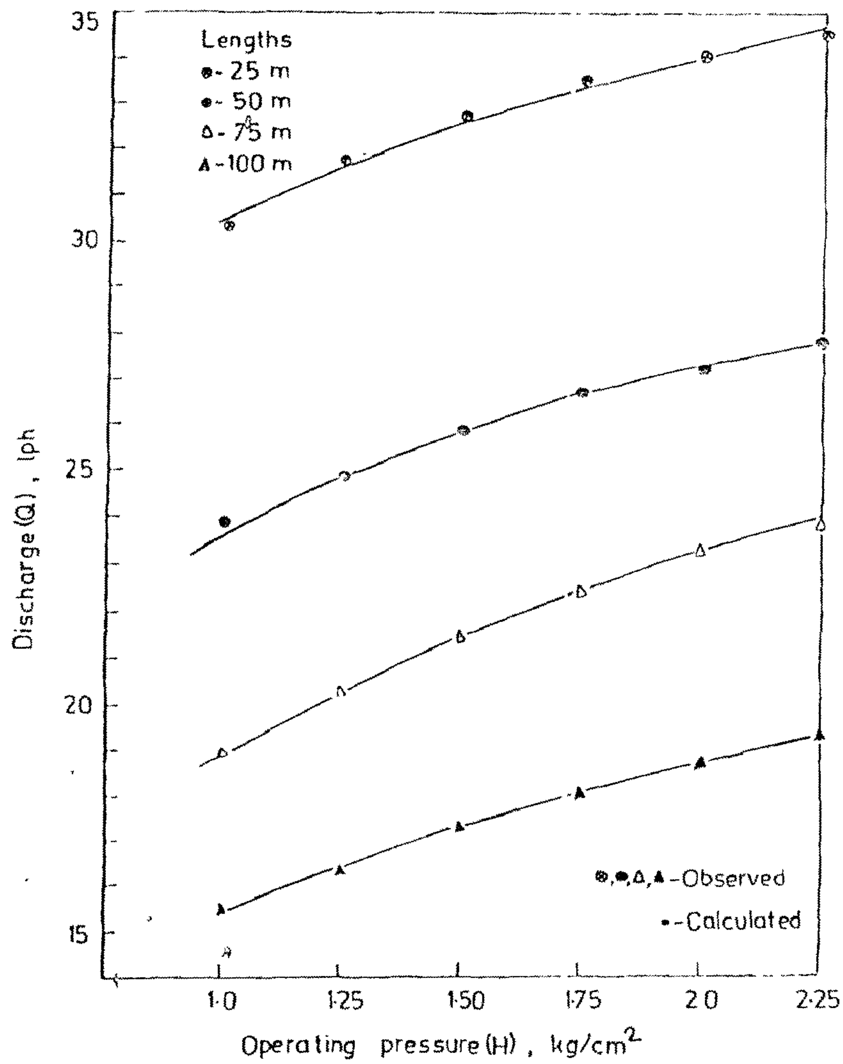


Fig.4.3. Pressure-discharge relationship observed for different length of lateral (L) in microsprinkler system

$$Q = 23.846\ H^{0.190} \quad \text{for } L=50m \qquad ...(4.10)$$

$(r^2 = 0.98)$

$$Q = 19.038\ H^{0.284} \quad \text{for } L=75m \qquad ...(4.11)$$

$(r^2 = 0.99)$

$$Q = 15.385\ H^{0.281} \quad \text{for } L=100m \qquad ...(4.12)$$

$(r^2 = 0.99)$

The similar results for pressure-discharge relationship have been reported by Lagad (1989), Salunkhe (1991) and Patel and Aware (1994).

4.2.2 Emission uniformity

4.2.2.1 Dripper system

The emission uniformity (EU) of drip system was determined by two different equations viz. field EU and absolute EU for different lengths of the lateral and operating pressures. The data of discharge collected at different locations on four laterals are given in Appendix-I(A). The different parameters needed in estimation of field EU and absolute EU are given in Table 4.5. The field EU was found on lower side than that of absolute EU. It is seen from the Table 4.5 that both the EU values were in the range of 89.4 to 92.8, 87.0 to 92.1, 84.3 to 91.9 and 85.1 to 91.8 per cent, respectively for the lateral lengths of 25, 50, 75 and 100 m. The average EU values show that lesser the lateral length, more the EU. In general, the EU of dripper system was excellent for all the lateral lengths as per the criteria given by Nakayama and Bucks (1986).

Table 4.5 Emmission uniformity estimated for different operating pressures and lateral lengths in dripper system

Sr. No.	Length of lateral, m	Pressure, kg/cm^2	q_{min}	q_{ave}	q_x	Emission uniformity, per cent Field EU	Absolute EU
1.	25	0.50	3.08	3.45	3.85	89.43	89.54
		0.75	3.26	3.63	4.03	89.80	90.04
		1.00	3.54	3.88	4.24	91.08	91.41
		1.25	3.76	4.12	4.51	91.12	91.23
		1.50	3.97	4.36	4.71	91.14	91.83
		1.75	4.26	4.60	4.94	92.63	92.82
2.	50	0.50	2.78	3.20	3.59	87.01	88.02
		0.75	3.02	3.44	3.82	87.90	88.95
		1.00	3.24	3.64	4.01	89.05	89.91
		1.25	3.46	3.85	4.26	89.64	90.07
		1.50	3.71	4.09	4.47	90.55	91.08
		1.75	3.94	4.29	4.64	91.65	92.06
3.	75	0.50	2.40	2.92	3.45	84.32	84.44
		0.75	2.86	3.23	3.62	88.49	88.85
		1.00	3.07	3.46	3.88	88.69	88.96
		1.25	3.25	3.66	4.08	88.92	89.28
		1.50	3.39	3.82	4.24	89.01	89.53
		1.75	3.73	4.07	4.42	91.72	91.93
4.	100	0.50	2.28	2.68	3.04	85.10	86.58
		0.75	2.59	2.96	3.30	87.60	88.63
		1.00	2.82	3.20	3.58	88.04	88.66
		1.25	3.07	3.48	3.86	88.16	89.17
		1.50	3.27	3.65	4.06	89.75	89.80
		1.75	3.61	3.93	4.28	91.82	91.82

q_{min} = Minimum discharge rate, lph

q_{ave} = Average discharge rate, lph

q_x = Average of 1/8th of highest discharge rates, lph

4.2.2.2 Strip tape system

The data of discharge collected at different four locations on four laterals for calculation of field EU and absolute EU are given in Appendix-I(B). The different parameters needed in estimation of field EU and absolute EU are given in Table 4.6. The field EU was found on lower side than that of absolute EU. It is seen from the Table 4.6 that both the EU values were in the range of 94.7 to 97.8, 95.4 to 97.2, 93.6 to 97.8 and 92.9 to 96.6 per cent, respectively for the strip tape lateral lengths of 25 , 50, 75 and 100 m. The average EU values at any strip tape lateral length and operating pressure was excellent as emission uniformity exceeded 90 per cent (Nakayama and Bucks, 1986). No any significant difference of operating pressure on EU was observed. This may be due to comparatively less head loss caused due to absence of emitting devices. Therefore, more than 100 m length of strip tape can be used in the field. The similar results are reported by Patel and Aware (1994).

4.2.2.3 Microsprinkler system

The data of discharge collected at different four locations on four laterals for calculation of field emission uniformity and absolute emission uniformity are given in Appendix-I(C). The different parameters needed in estimation of field EU and absolute EU are given in Table 4.7. The field EU was found on lower side than that of absolute EU. It is seen from the Table 4.7

Table 4.6. Emission uniformity estimated for different operating pressures and lateral lengths in strip tape system

Sr. No.	length of lateral, m	Pressure, kg/cm^2	q_{min}	q_{ave}	q_x	Emission uniformity, per cent	
						Field EU	Absolute EU
1.	25	0.50	2.73	2.88	3.02	94.72	95.01
		0.75	3.34	3.48	3.57	95.89	96.71
		1.00	3.64	3.73	3.81	97.65	97.77
		1.25	3.78	3.90	3.96	96.87	97.72
		1.50	3.93	4.06	4.18	96.73	96.94
2.	50	0.50	2.62	2.75	2.86	95.38	95.87
		0.75	3.27	3.38	3.46	96.82	97.23
		1.00	3.53	3.67	3.77	96.17	96.74
		1.25	3.65	3.81	3.94	95.96	96.33
		1.50	3.76	3.91	4.04	96.17	96.43
3.	75	0.50	2.48	2.65	2.74	93.56	95.10
		0.75	3.15	3.26	3.34	96.66	97.13
		1.00	3.36	3.54	3.65	94.88	95.89
		1.25	3.53	3.69	3.78	95.62	96.61
		1.50	3.69	3.78	3.86	97.74	97.80
4.	100	0.50	2.41	2.58	2.75	93.68	93.69
		0.75	2.96	3.15	3.25	93.98	95.46
		1.00	3.23	3.35	3.46	96.51	96.61
		1.25	3.25	3.50	3.65	92.88	94.39
		1.50	3.46	3.60	3.75	96.14	96.14

q_{min} = Minimum discharge rate, lph/m

q_{ave} = Average discharge rate, lph/m

q_x = Average of 1/8th of highest discharge rates, lph/m

Table 4.7 . Emission uniformity estimated for different operating pressures and lateral lengths in microsprinkler system

Sr. No.	length of lateral, m	Pressure, kg/cm^2	q_{min}	q_{ave}	q_x	Emission uniformity, per cent	
						Field EU	Absolute EU
1.	25	1.00	26.88	30.35	34.05	88.85	88.85
		1.25	28.26	31.73	35.52	89.05	89.19
		1.50	29.25	32.71	36.53	89.25	89.39
		1.75	29.97	33.49	37.33	89.47	89.59
		2.00	30.57	34.07	37.87	89.72	89.84
		2.25	31.11	34.54	38.23	90.05	90.20
2.	50	1.00	20.52	23.85	27.12	86.05	86.99
		1.25	21.66	24.81	28.27	87.32	87.52
		1.50	22.80	25.79	29.16	88.38	80.42
		1.75	23.67	26.67	30.02	88.73	88.80
		2.00	24.18	27.15	30.24	89.05	89.42
		2.25	24.78	27.77	30.85	89.24	89.62
3.	75	1.00	14.10	18.98	24.45	74.28	75.96
		1.25	15.15	20.28	25.65	74.71	76.88
		1.50	16.14	21.45	26.73	75.25	77.74
		1.75	16.89	22.38	27.47	75.46	78.47
		2.00	17.76	23.27	28.31	76.30	79.27
		2.25	18.87	23.81	28.78	79.24	80.98
4.	100	1.00	9.45	15.45	21.60	61.15	66.35
		1.25	10.77	16.22	22.08	66.38	69.93
		1.50	11.64	17.29	23.25	67.25	70.80
		1.75	12.51	18.03	23.82	69.39	72.54
		2.00	13.23	18.71	24.33	70.72	73.80
		2.25	14.25	19.31	24.69	73.79	76.00

q_{min} = Minimum discharge rate, lph

q_{ave} = Average discharge rate, lph

q_x = Average of 1/8th of highest discharge rates, lph that both the EU values were in the range of 88.8 to 90.2, 86.0 to 89.6 , 74.3 to 0.9 and 61.1 to 76.0 per cent, respectively for the lateral lengths of 25, 50, 75 and 100 m. The average EU values shows that lesser the lateral length, more the EU. The average EU for 75 and 100 m lateral lengths was low because of high discharge of (33 lph) microsprinklers. Therefore, the laterals of length up to 50m only can be used in the field as the EU was greater than 85 per cent (Michael, 1978).

4.2.3 Uniformity coefficient

The uniformity coefficient (UC) was determined in case of microsprinkler system at head, middle and tail end of lateral. The test was repeated three times to get good averages. The data of depth of water obtained in the catch-cans placed at various locations for computing UC are given in Appendix-II (A to C). The UC values reported in Table 4.8 show that the uniformity coefficient was in the range of 88.05 to 96.33 per cent. This shows that the application of water was excellent as per Michael (1978) as the water was applied uniformly all over the area by four microsprinklers to the extent more than 85 per cent.

4.2.4 Lateral head loss

4.2.4.1 Dripper system

The data of head loss (H_L) in lateral at different operating pressure and lateral lengths in case of dripper system are given in Table 4.9 and depicted in Fig. 4.4. The data show that the per cent head loss increased with increase in the pressure as well as the

Table 4.8. Uniformity coefficient obtained at head, middle and tail end of lateral in microsprinkler system

Test No.	Location	Parameters of equations			Uniformity coefficient (UC), per cent	Average UC, per cent
		$\Sigma\lvert x\rvert$	m	n		
1.	Head	15.21	6.83	45	95.04	
	Middle	19.44	7.11	45	93.92	93.28
	Tail	25.20	6.13	45	90.87	
2.	Head	10.62	6.42	45	96.33	
	Middle	21.37	5.60	45	91.52	92.85
	Tail	25.04	5.98	45	90.70	
3.	Head	13.62	6.13	45	95.06	
	Middle	21.28	6.57	45	92.80	91.97
	Tail	30.45	5.66	45	88.05	
	Overall uniformity coefficient (UC):					92.70

$\Sigma\lvert x\rvert$ = Summation of numerical deviation of individual observed depth from average depth, mm.

m = Average depth of all observations, mm.

n = Total number of observation points.

Table 4.9. Head loss as a function of lateral length (L) and different operating pressure (H) in dripper system

Sr. No.	Length of lateral (L), m	Pressure (H) at, kg/cm^2		Head loss (H_L), kg/cm^2	Per cent head loss
		Inlet	Tail end		
1.	25	0.50	0.475	0.025	5.00
		0.75	0.707	0.043	5.73
		1.00	0.935	0.065	6.50
		1.25	1.153	0.097	7.76
		1.50	1.360	0.140	9.33
		1.75	1.560	0.190	10.86
2.	50	0.50	0.440	0.060	12.00
		0.75	0.654	0.096	12.80
		1.00	0.865	0.135	13.50
		1.25	1.065	0.185	14.80
		1.50	1.250	0.250	16.66
		1.75	1.450	0.300	17.14
3.	75	0.50	0.401	0.099	19.80
		0.75	0.591	0.159	21.20
		1.00	0.770	0.230	23.00
		1.25	0.940	0.310	24.80
		1.50	1.100	0.400	26.66
		1.75	1.235	0.515	29.42
4.	100	0.50	0.340	0.160	32.00
		0.75	0.497	0.253	33.73
		1.00	0.640	0.360	36.00
		1.25	0.770	0.480	38.40
		1.50	0.877	0.623	41.53
		1.75	0.960	0.790	45.14

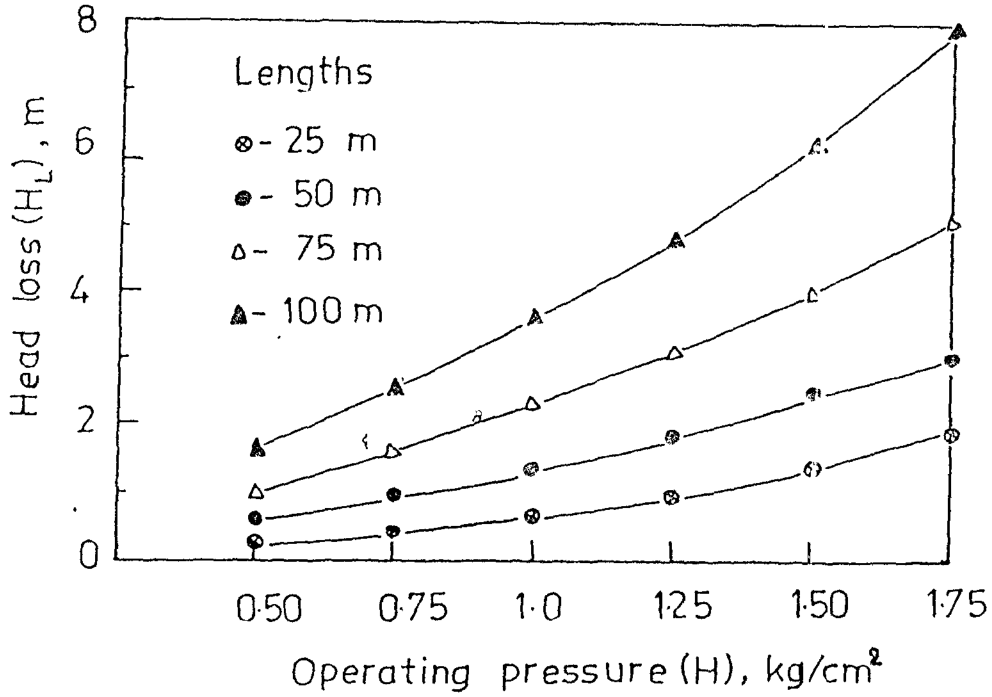


Fig.4·4. Effect of operating pressure on head loss in lateral of different lengths (L) in dripper system.

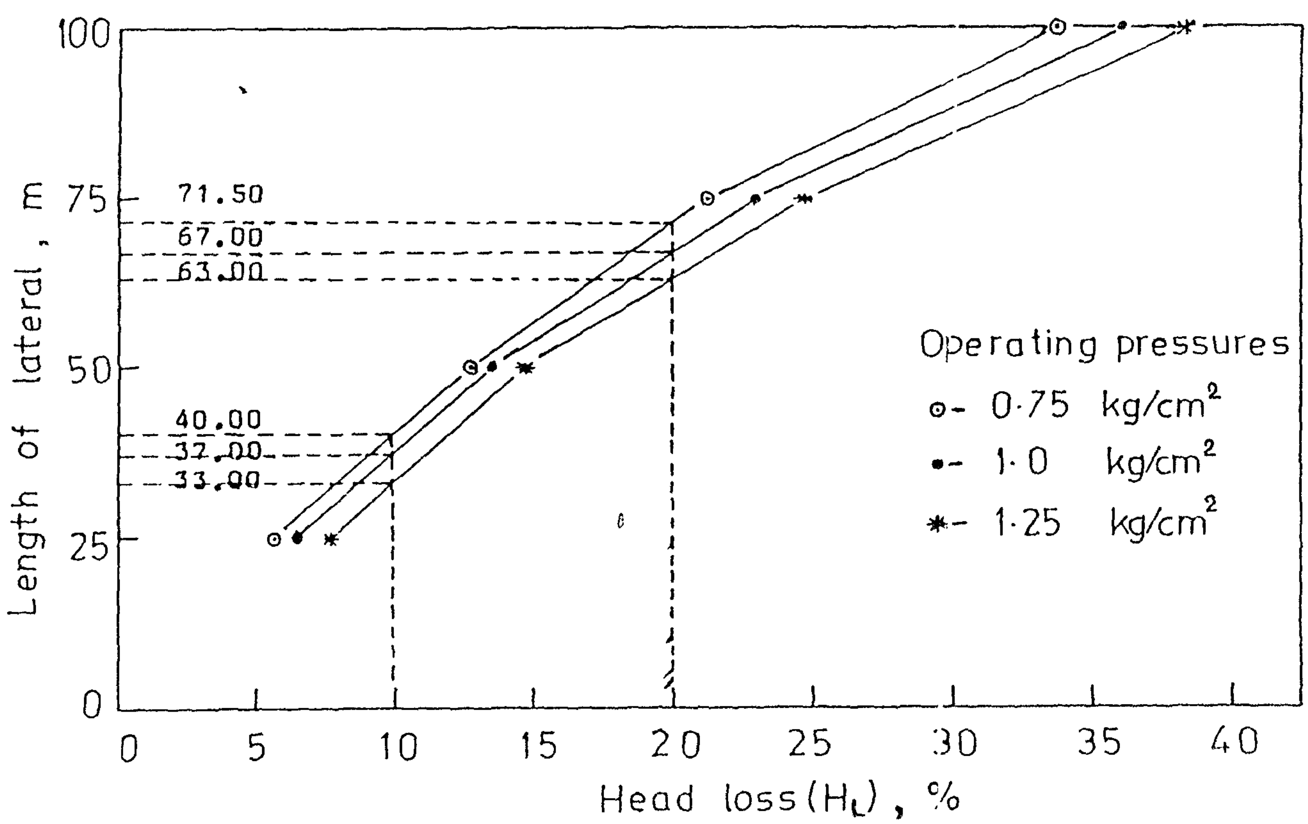


Fig.4·5. Length of Lateral as affected by head loss at different operating pressure (H) in dripper system.

length of lateral due to the resistance offered by the lateral inner surface. The head loss was found increased from 5.0 to 10.9, 12.0 to 17.1, 19.8 to 29.4 and 32.0 to 45.1 per cent, respectively for the lateral length of 25, 50,75 and 100m, when the inlet pressure at manifold was 0.50 to 1.75 kg/cm^2. The average H at 1.00 kg/cm^2 pressure was 6.5, 13.5, 23.0 and 36.0 per cent for the lateral lengths of 25, 50, 75 and 100 m, respectively. The data presented in Table 4.9 was used in Fig. 4.5 to find out the length of lateral that can be used with allowable head losses of 20 per cent. It is observed from the Fig. 4.5 that the maximum length of lateral, at recommended pressure of 1 kg/cm^2, can be used in the field upto 37 m considering 10 per cent permissible H_L and 67m for 20 per cent variation in head loss. Similarly, for 10 per cent variation in head loss, the maximum lateral length can be used as 40 and 33 m, respectively at 0.75 and 1.25 kg/cm^2 pressure. However, considering 20 per cent head loss variation, the maximum length of lateral can be used as 71.5 and 63 m at 0.75 and 1.25 kg/cm^2 pressure, respectively.

4.2.4.2 Strip tape system

The data of head loss (H_L) in lateral at different operating pressure and lateral lengths in case of strip tape system are given in Table 4.10 and depicted in Fig. 4.6. The data show that the per cent head loss increased with increase in the pressure as well as the length of lateral due to the resistance offered by the lateral inner surface. The head loss was

Table 4.10. Head loss as a function of length of strip tape (L) and different operating pressure (H)

Sr. No.	Length of lateral (L),m	Pressure (H) at, kg/cm^2		Head loss (H_L), kg/cm^2	Per cent head loss
		Inlet	Tail end		
1.	25	0.50	0.500	0.000	0.00
		0.75	0.740	0.010	1.33
		1.00	0.983	0.017	1.70
		1.25	1.225	0.025	2.00
		1.50	1.465	0.035	2.33
2.	50	0.50	0.486	0.014	2.80
		0.75	0.720	0.030	4.00
		1.00	0.952	0.048	4.80
		1.25	1.182	0.068	5.44
		1.50	1.400	0.100	6.66
3.	75	0.50	0.464	0.046	7.20
		0.75	0.688	0.062	8.26
		1.00	0.898	0.102	10.20
		1.25	1.113	0.137	10.96
		1.50	1.327	0.173	11.53
4.	100	0.50	0.432	0.068	13.60
		0.75	0.640	0.110	14.66
		1.00	0.843	0.157	15.70
		1.25	1.040	0.210	16.80
		1.50	1.240	0.260	17.33

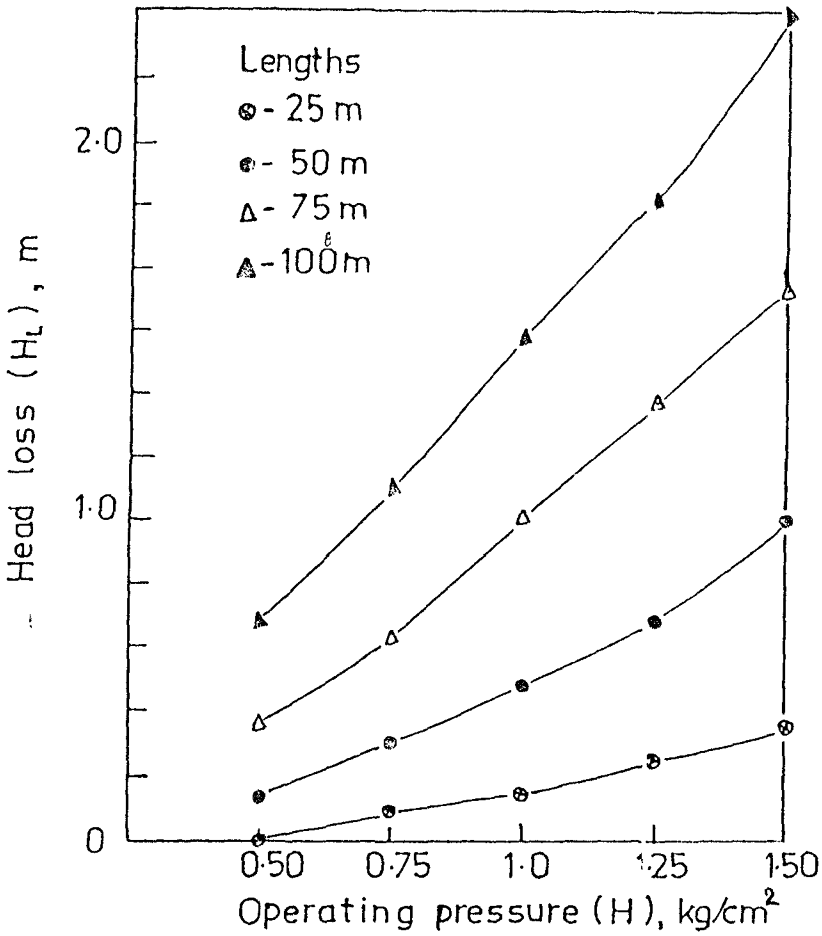


Fig.4·6. Effect of operating pressure on head loss in strip tape of different lengths (L).

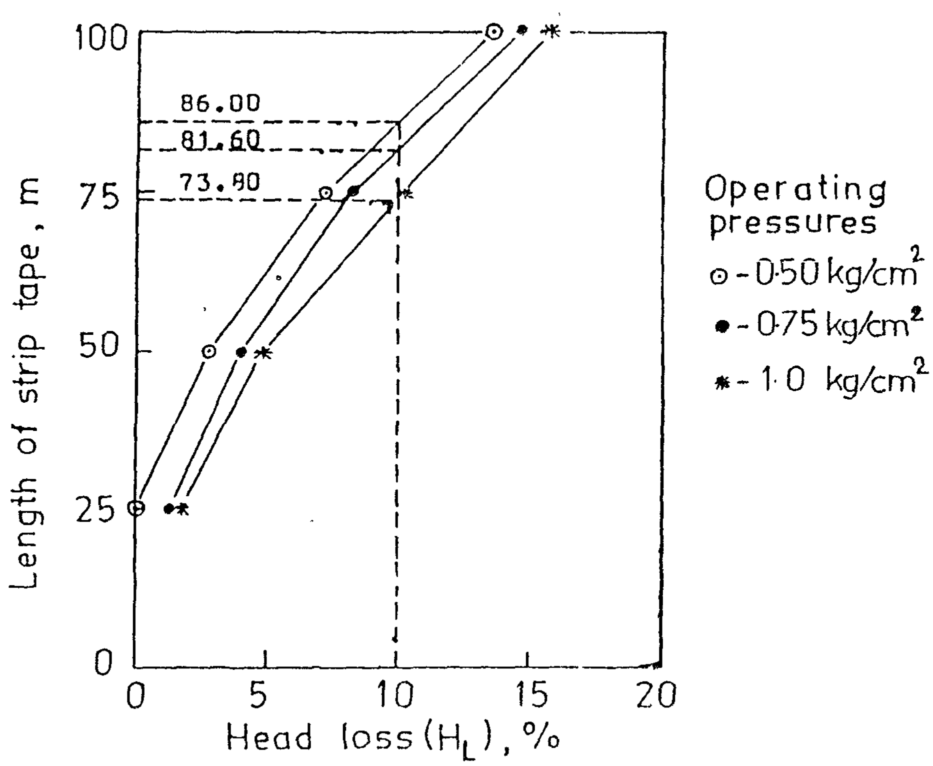


Fig.4·7. Length of strip tape as affected by head loss at different operating pressure (H).

found increased from 0.0 to 2.3, 2.8 to 6.7, 7.2 to 11.5 and 13.6 to 17.3 per cent, respectively for the lateral length of 25, 50, 75 and 100 m, when the inlet pressure at manifold was 0.50 to 1.50 kg/cm^2. The average H at 0.75 kg/cm^2 pressure was 1.3, 4.0, 8.3 and 14.7 per cent for the lateral lengths of 25, 50, 75 and 100 m, respectively. The data presented in Table 4.10 was used in Fig 4.7 to find out the length of lateral that can be used with allowable head losses of 20 per cent. It is observed from the Fig. 4.7 that the maximum lengths of strip tape lateral can be used in the field are up to 86, 82 and 74m, respectively for 0.50, 0.75 and 1.00 kg/cm^2 pressure, considering 10 per cent permissible head loss, whereas the length of strip tape goes beyond the 100 m for 20 per cent permissible head loss. This is due to the minimum head loss in strip tape lateral.

4.2.4.3 Microsprinkler system

Table 4.11 and Fig. 4.8 show that the per cent head loss increased with increase in the pressure as well as the length of lateral due to the resistance offered by the lateral inner surface. The head loss was found increased from 8.0 to 28.0, 33.0 to 53.3 , 59.0 to 72.9 and 77.0 to 84.9, respectively for the lateral length of 25, 50,75 and 100 m, when the inlet pressure at manifold was 1.00 to 2.25 kg/cm^2 The average H at 1.50 kg/cm^2 pressure was 14.7 , 40.7, 65.3 and 80.0 per cent, respectively for the lateral length of 25, 50, 75 and 100 m.

Table 4.11. Head loss as a function of lateral length (L) and different operating pressure (H) in microsprinkler system

Sr. No.	Length of lateral (L), m	Pressure (H) at, kg/cm^2 Inlet	Tail end	Head loss (H_L), kg/cm^2	Per cent head loss
1.	25	1.00	0.92	0.08	8.00
		1.25	1.11	0.14	11.20
		1.50	1.28	0.22	14.66
		1.75	1.41	0.34	19.43
		2.00	1.52	0.48	24.00
		2.25	1.62	0.63	28.00
2.	50	1.00	0.67	0.33	33.00
		1.25	0.79	0.46	36.80
		1.50	0.89	0.61	40.66
		1.75	0.95	0.80	45.71
		2.00	1.00	1.00	50.00
		2.25	1.05	1.20	53.33
3.	75	1.00	0.41	0.59	59.00
		1.25	0.47	0.78	62.40
		1.50	0.52	0.98	65.33
		1.75	0.56	1.19	68.00
		2.00	0.59	1.41	70.50
		2.25	0.61	1.64	72.89
4.	100	1.00	0.33	0.77	77.00
		1.25	0.27	0.98	78.40
		1.50	0.30	1.20	80.00
		1.75	0.32	1.43	81.71
		2.00	0.33	1.67	83.50
		2.25	0.34	1.91	84.89

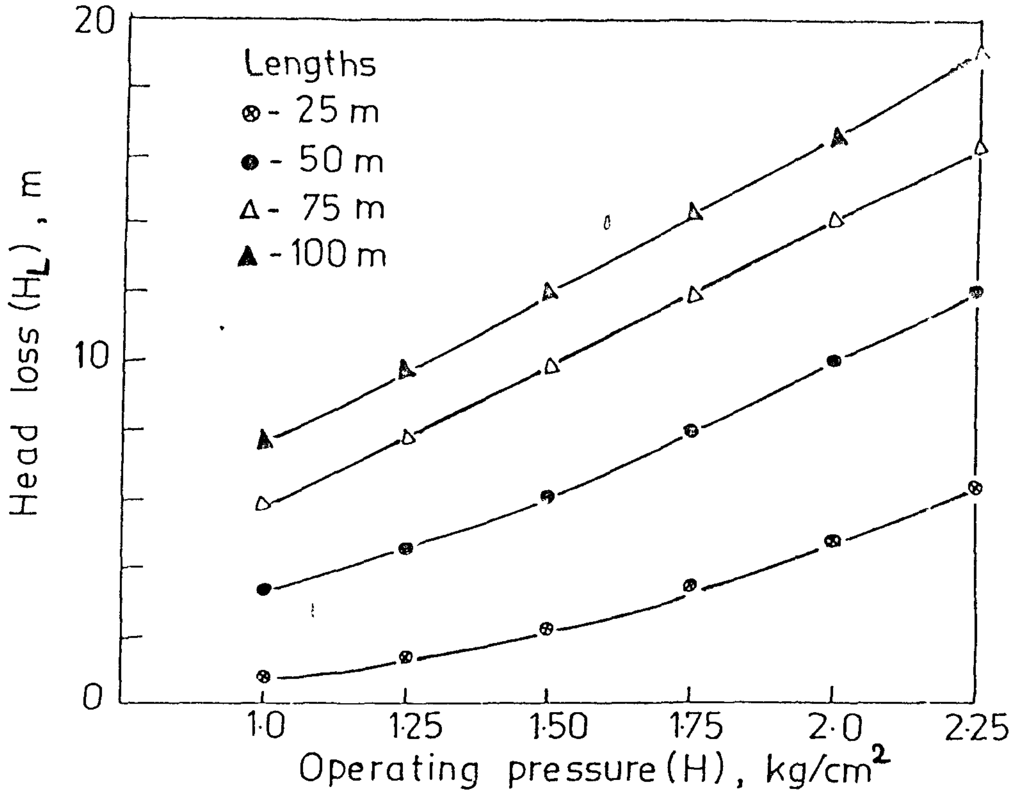


Fig.4·8. Effect of operating pressure on head loss in lateral of different lengths (L) in microsprinkler system.

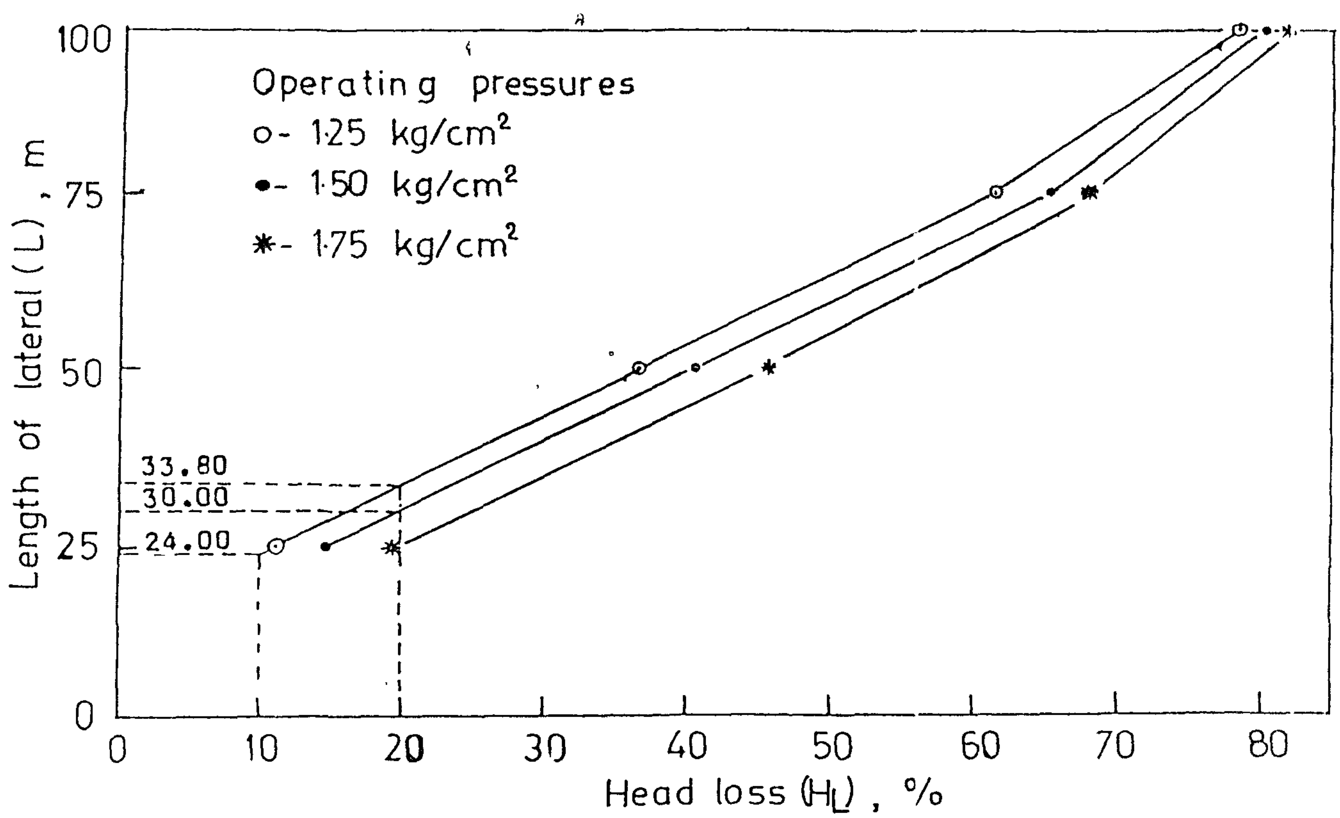


Fig.4·9. Length of lateral as affected by head loss at different operating pressure (H) in microsprinkler system.

The data presented in Table 4.11 was used in Fig. 4.9 to find out the length of lateral that can be used with allowable head losses of 20 percent. It is seen from the figure that the maximum length of microsprinkler lateral can be used in the field upto 24m, considering 10 per cent permissible head loss with 1.25 kg/cm^2 pressure and for 20 per cent variation in head loss these lengths were upto 34, 30 and 25 m for corresponding pressures of 1.25, 1.50 and 1.75 kg/cm^2, respectively.

4.3 Moisture distribution pattern

The data of moisture content at various grid points was collected after conducting trial of different combinations of emitter discharge rate (Q), quantities of water (V) and time intervals (t), in different micro-irrigation systems .

4.3.1. Dripper system

4.3.1.1 Effect of water volumes and elapsed time

The different tests were conducted by applying the water at the emitter discharges of 3, 4 and 5 lph for the different water quantities of 5, 10 and 15 litres. The moisture content data at grid points was collected at 0, 24 and 48 hr after irrigation and was used for plotting the iso-moisture lines of 36 per cent (i.e. field capacity) in Fig. 4.10 to 4.12. It is seen from these figures that the movement of the wetting front under the point source of dripper in radial and vertical planes was different for different combinations of Q . V and t. The movements of moisture contour of 36

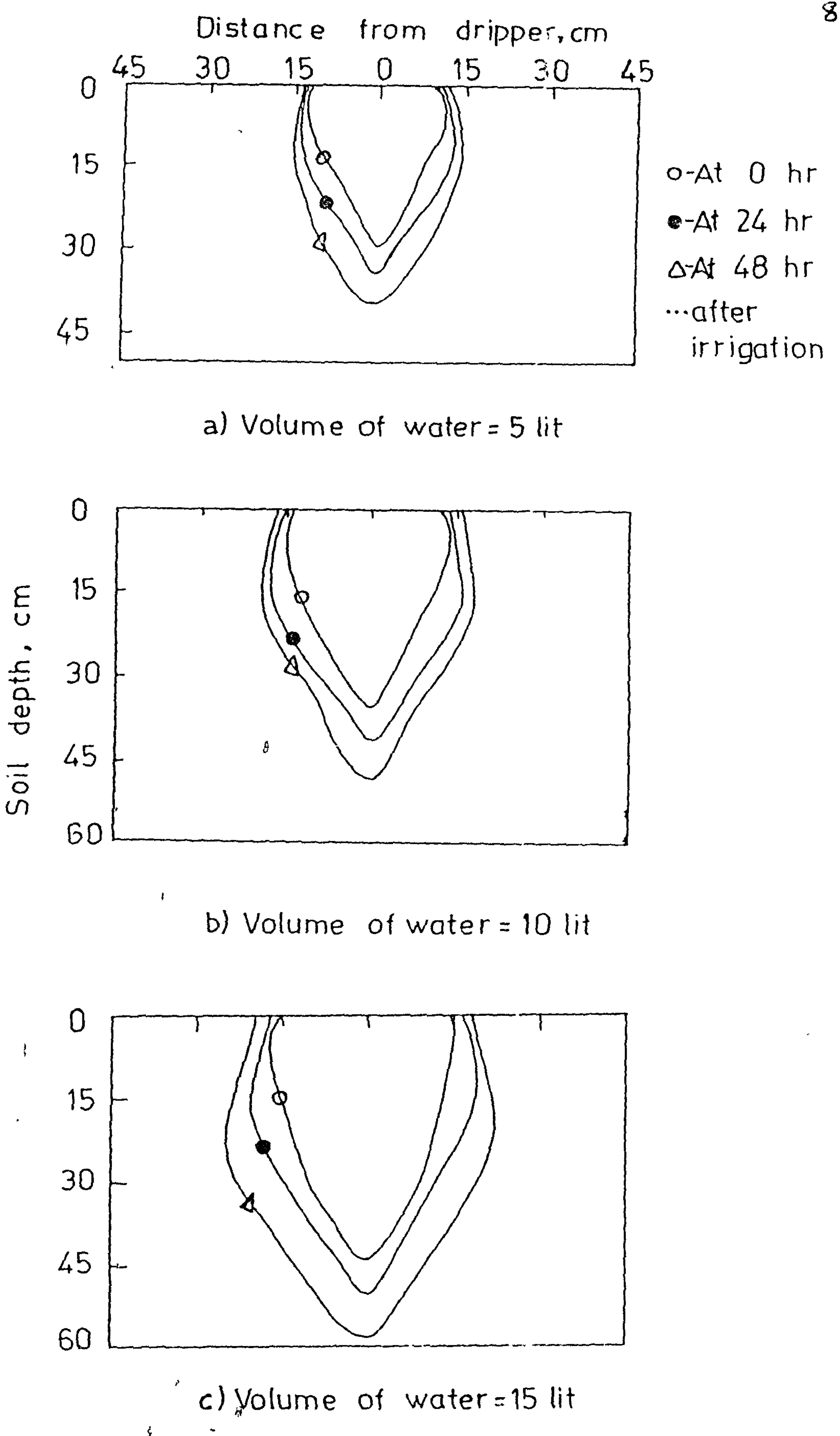
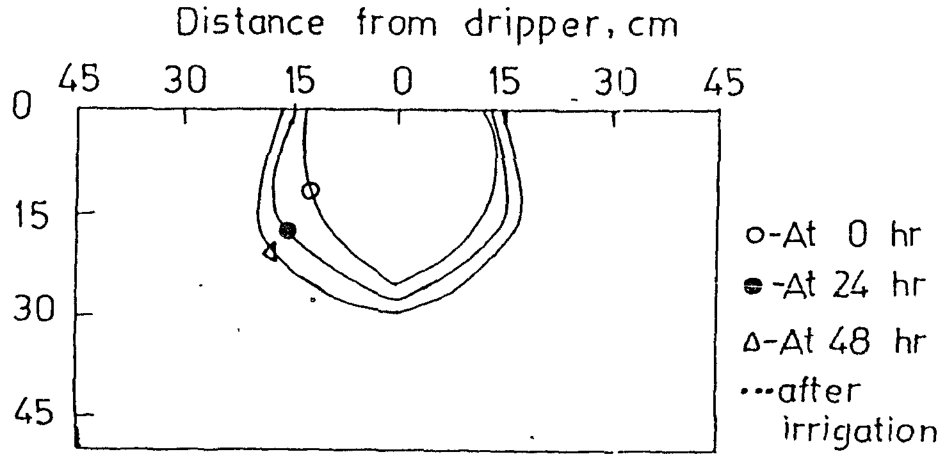
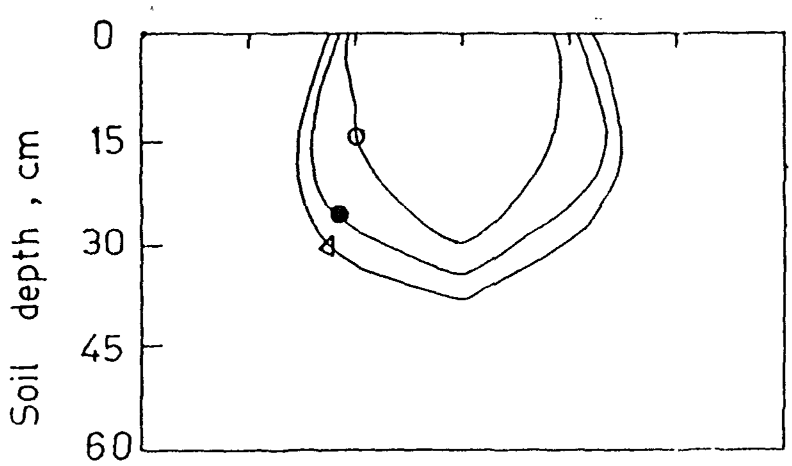


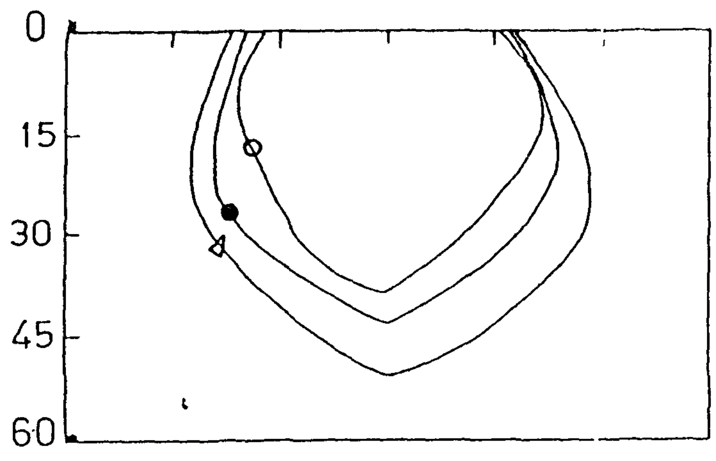
Fig.4.10. Movement of 36% moisture contour under dripper for different quantities of water at 3 lph discharge rate.



a) Volume of water= 5 lit



b) Volume of water=10 lit



c) Volume of water=15 lit

Fig.4.11. Movement of 36% moisture contour under dripper for different quantities of water at 4 lph discharge rate.

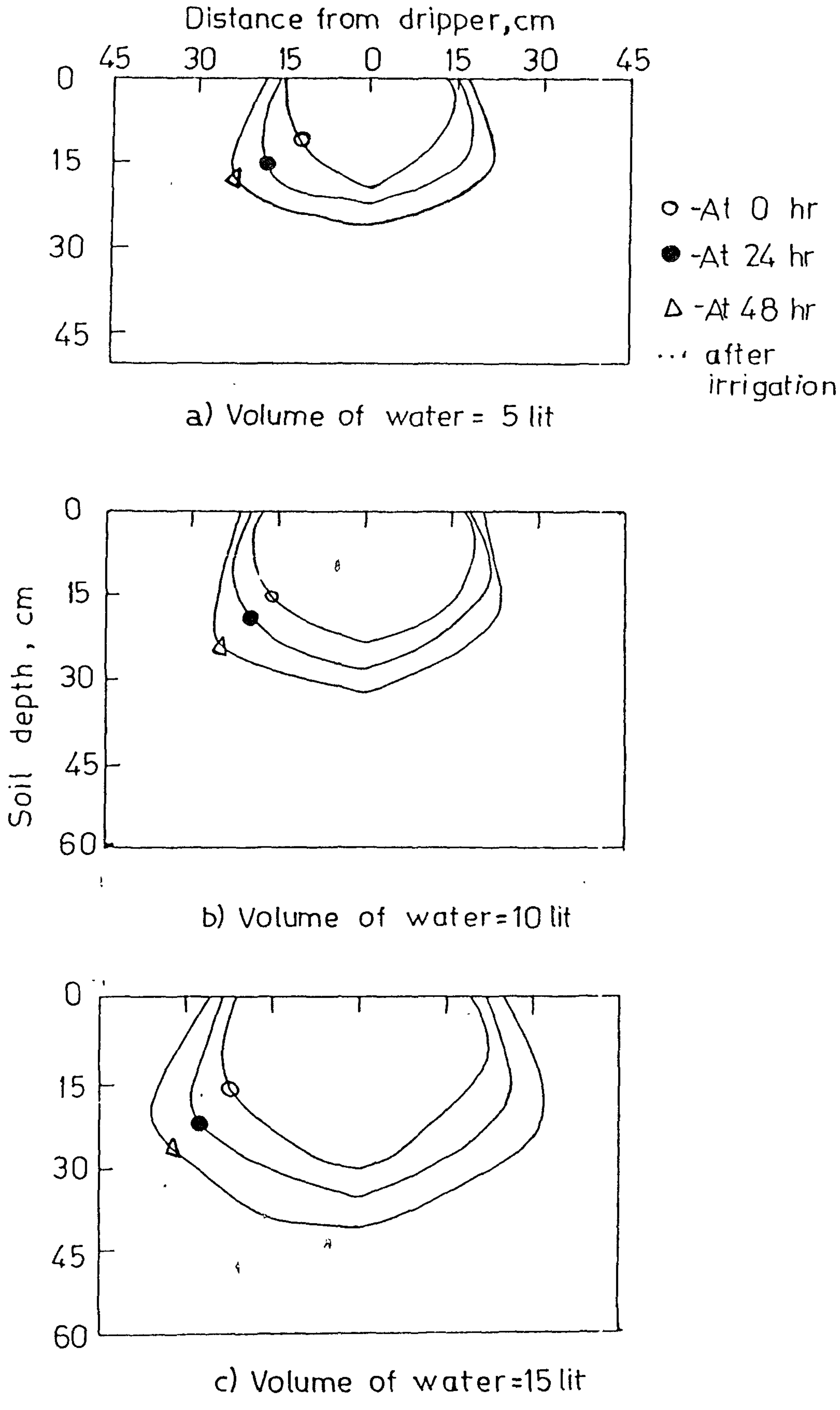


Fig.4.12. Movement of 36% moisture contour under dripper for different quantities of water at 5 lph discharge rate.

per cent for 3,4 and 5 lph are shown in Fig. 4.10, Fig. 4.11 and Fig 4.12 respectively. It is seen from these figures that the iso-moisture line of 36% moisture advanced with the elapsed time, after irrigation as well as with the increment in the volume of water. The extent to which the wetting front advanced radially and vertically under different set of condition are determined from the moisture distribution pattern (36% moisture contour) and are given in Table 4.12.

In case of 3 lph discharge rate of drippers, it is seen from the data presented in Table 4.12 that the maximum radial spread (Rm) and maximum vertical advance (Va) of wetting front increased with elapsed time (t) and volume of water (V). The maximum radial spread was ranged from 12.2 to 14.6 , 14.3 to 18.8 and 16.0 to 23.3 cm, respectively for 5,10 and 15 lit of water during 0 to 48 hr after irrigation. These values of maximum radial spread were noticed at the soil depths of 3.5 to 15.0, 5.0 to 17.5 and 6.0 to 20.0 cm for 5, 10 and 15 lit of water, respectively. The vertical advance of wetting front was 34.0, 41.5 and 50.5 cm at 24 hr after irrigation and 39.5, 48.0 and 58.0 cm at 48 hr after irrigation, respectively for 5,10 and 15 lit of water.

In case of 4 lph discharge rate, it is seen from the Table 4.12 that both the maximum radial spread and vertical advance increased with elapsed time and volume of water applied. The maximum radial spread was

Table 4.12. Maximum radial spread and vertical advance of wetting front in dripper system

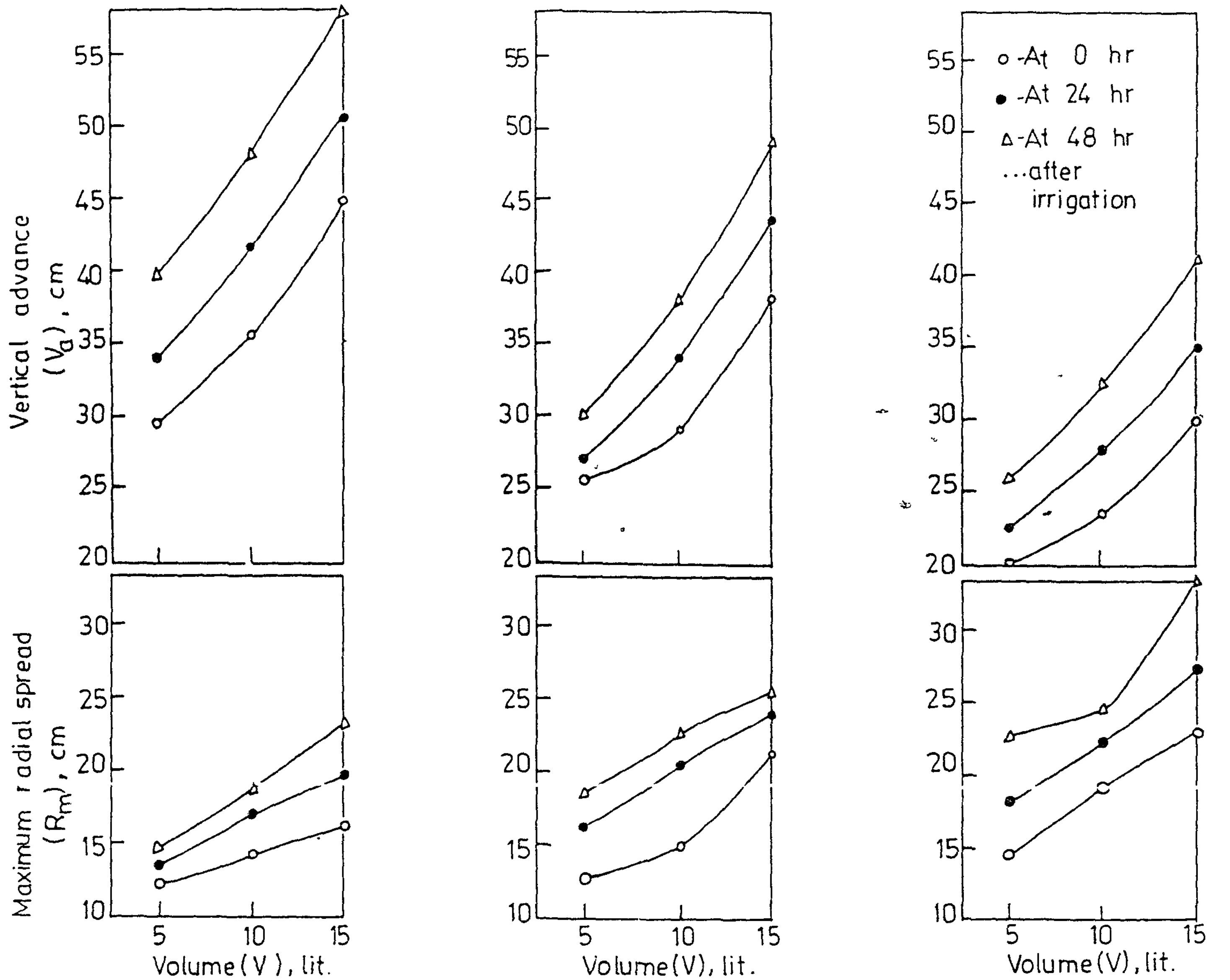
Sr. No.	Discharge (Q),lph	Quantity of water applied (V), lit	Time after irrig. (t), hr	Depth of soil at which maximum radial spread observed (d), cm	Maximum radial spread of moisture from emitter (Rm), cm	Maximum vertical advance of moisture (Vm), cm
1.	3	5	0	3.50	12.20	29.50
			24	9.00	13.50	34.00
			48	15.00	14.63	39.50
		10	0	5.00	14.25	35.50
			24	14.70	17.00	41.50
			48	17.50	18.75	48.00
		15	0	6.00	16.00	44.50
			24	15.00	19.50	50.50
			48	20.00	23.25	58.00
2.	4	5	0	4.50	12.80	25.50
			24	12.00	16.25	27.00
			48	15.00	18.50	30.00
		10	0	5.00	15.00	29.00
			24	14.50	20.50	34.00
			48	18.00	22.66	38.00
		15	0	7.50	21.25	38.00
			24	18.00	24.00	43.50
			48	23.00	25.50	49.00
3.	5	5	0	4.00	14.50	20.00
			24	9.00	18.25	22.50
			48	15.00	22.75	26.00
		10	0	6.00	19.25	23.50
			24	11.50	22.25	28.00
			48	18.50	24.50	32.50
		15	0	9.00	23.00	30.00
			24	16.50	27.75	35.00
			48	21.00	33.75	41.00

ranged from 12.8 to 18.5,15.0 to 22.7 and 21.2 to 25.5 cm, respectively for 5,10 and 15 lit of water during 0 to 48 hr after irrigation. These values of maximum radial spread were noticed at the soil depths of 4.5 to 15.0 , 5.0 to 18.0 and 7.5 to 23.0 cm for 5, 10 and 15 lit of water , respectively. The vertical advance was 27.0, 34.0 and 43.5 cm at 24 hr after irrigation, and 30.0, 38.0 and 49.0 cm at 48 hr after irrigation, respectively for 5,10 and 15 lit of water.

When discharge rate was changed to 5 lph, it is seen from Table 4.12 that the maximum radial spread and vertical advance increased with elapsed time and quantity of water applied. The maximum radial spread was ranged from 14.5 to 22.7 , 19.2 to 24.5 and 23.0 to 33.7 cm, respectively for 5, 10 and 15 lit of water during 0 to 48 hr after irrigation. These values of maximum radial spread were noticed at the soil depths of 4.0 to 15.0, 6.0 to 18.5 and 9.0 to 21.0 cm for 5,10 and 15 lit of water,respectively. The vertical advance was found 22.5, 28.0 and 35.0 cm at 24 hr after irrigation, and 26.0, 32.5 and 41.0 cm at 48 hr after irrigation for 5,10 and 15 lit of water, respectively.

4.3.1.2 Effect of dripper discharge

The effect of discharge rate on the maximum radial spread and vertical advance of wetting front was also studied and depicted in Fig. 4.13. It is seen that as the discharge rate of dripper increased, the maximum radial spread from emitter also increased and the vertical advance decreased, at constant volume of water



a) Discharge = 3 lph   b) Discharge = 4 lph   c) Discharge = 5 lph

Fig.4.13. Maximum radial spread and vertical advance of wetting front in dripper system.

and elapsed time. Irrespective of elapsed time, the increase in radial spread was 37.6, 32.0 and 43.8 per cent, respectively at 5, 10 and 15 lit of water when the dripper discharge was changed from 3 to 5 lph. The vertical advance of wetting front was decreased by 33.8, 32.5 and 30.7 per cent at 24 hr after irrigation and 34.2, 32.3 and 33.6 per cent at 48 hr after irrigation respectively at 5, 10 and 15 lit of water when the dripper discharge raised from 3 to 5 lph. The similar results have been reported by Satpute et al. (1992).

In general, it was observed that the radial spread of wetting front increased due to the increase in the following parameters in descending order as :

(i) Elapsed time after irrigation i.e. interval between two successive irrigations. If irrigation interval is more, the volume of water to be applied to the crop will naturally be more and hence radial spread of wetting front will be more, and

(ii) Discharge rate of dripper.

The vertical advance of wetting front could be increased due to the following parameters in descending order:

(i) by increasing irrigation interval, and

(ii) by decreasing dripper discharge.

4.3.1.3 Correlations developed

The correlations developed to determine the vertical advance (Va) of wetting front from emitter and

Table 4.13. The radial spread and maximum vertical advance of wetting front observed from moisture distribution pattern under different set of conditions in dripper system

Sr. No.	Discharge (Q), lph	Volume (V), lit	Time (t), hr	Radial spread (Rs), cm at the different soil depths (d), m				Maximum vertical advance (Va), cm
				0	15	30	45	
1.	3	5	0	10.75	10.75	0.00	0.00	29.50
			24	12.25	12.25	3.25	0.00	34.00
			48	12.75	14.50	8.50	0.00	39.50
		10	0	12.75	12.25	4.50	0.00	35.50
			24	14.25	16.75	8.75	0.00	41.50
			48	16.00	18.50	12.00	3.75	48.00
		15	0	15.00	14.00	9.50	0.00	44.50
			24	16.75	19.50	13.00	4.25	50.50
			48	19.00	22.72	20.50	11.75	58.00
2.	4	5	0	12.00	11.50	0.00	0.00	25.50
			24	13.50	16.00	0.00	0.00	27.00
			48	15.25	18.50	0.00	0.00	30.00
		10	0	14.50	13.50	0.00	0.00	29.00
			24	17.00	20.50	0.00	0.00	34.00
			48	18.50	22.50	18.50	0.00	38.00
		15	0	16.50	20.65	12.00	0.00	38.00
			24	18.25	23.75	19.25	0.00	43.50
			48	19.75	26.75	25.75	11.25	49.00
3.	5	5	0	13.75	8.75	0.00	0.00	20.00
			24	15.25	12.00	0.00	0.00	22.50
			48	17.50	22.75	0.00	0.00	26.00
		10	0	17.00	16.50	0.00	0.00	23.50
			24	18.75	21.25	0.00	0.00	28.00
			48	21.00	24.50	7.50	0.00	32.50
		15	0	20.25	21.25	0.00	0.00	30.00
			24	22.75	27.50	13.50	0.00	35.00
			48	25.25	33.00	26.00	0.00	41.00

Table 4.14. Details of the equations developed for determination of vertical advance and radial spread of moisture in respect of constant values and correlation coefficients for dripper system

Sr. No	Discharge (Q), lph	Time (t), hr	Constants in eq. 4.13 for vertical advance (Va) of water in soil							Constants in eq. 4.14 for radial spread (Rs) of moisture in the soil										
			A	B_1	B_2	C_1	C_2	C_3	r^2	A'	B_1'	B_2'	C_1'	C_2'	C_3'	D_1'	D_2'	D_3'	D_4'	r^2
1.	3	0	33.39	-0.83	0.72	-0.33	-0.25	0.07	0.99	18.07	-2.68	-0.04	0.32	0.04	-0.03	-0.01	-66.67×10^{-5}	-9.44×10^{-4}	5.02×10^{-4}	0.98
		24	48.39	-8.08	1.58	0.42	-0.19	0.04	0.99	23.14	-4.57	0.38	0.57	0.01	-0.03	-0.02	1.57×10^{-3}	-9.17×10^{-4}	5.18×10^{-4}	0.99
		48	78.11	-20.58	1.58	1.83	-0.17	0.04	0.99	11.33	42.07	0.47	0.07	-0.02	-0.02	-2.8×10^{-3}	2.43×10^{-3}	-2.5×10^{-3}	1.97×10^{-3}	0.99
2.	4	0	Same as above for `o ' hr							46.59	-11.26	0.07	1.01	0.14	-0.06	-0.03	-3.43×10^{-3}	-1.85×10^{-3}	1.05×10^{-3}	0.98
		24	Same as above for `24 ' hr							31.03	-6.19	0.59	0.71	0.04	-6.92×10^{-2}	-2.38×10^{-2}	3.63×10^{-3}	-2.42×10^{-3}	1.22×10^{-3}	0.96
		48	Same as above for `48 ' hr							21.47	-2.91	0.09	0.45	0.04	-0.03	-0.02	3.77×10^{-3}	-2.02×10^{-3}	4.65×10^{-4}	0.96
3.	5	0	Same as above for `o ' hr							29.78	-7.09	0.97	0.89	6.67×10^{-3}	-0.09	-0.03	4.0×10^{-4}	-6.67×10^{-4}	1.46×10^{-3}	0.98
		24	Same as above for `24 ' hr							34.17	-7.46	0.55	0.88	0.05	-0.07	-0.03	1.96×10^{-3}	-2.42×10^{-3}	1.41×10^{-3}	0.98
		48	Same as above for `48 ' hr							60.77	-14.91	0.28	1.58	0.13	-0.07	-4.97×10^{-2}	2.67×10^{-4}	-3.17×10^{-3}	1.26×10^{-3}	0.97

of 2, 3 and 4 lph/m length of strip tape and for the different water quantities of 3, 5, 10 and 15 lit. The moisture content data of soil at grid points was collected at 0, 24 and 48 hr after irrigation and was used for plotting iso-moisture lines of 36% in Fig.4.14 through 4.16. It is seen from these figures that the movement of wetting front under the line source of strip tape in radial and vertical planes was different for different combinations of discharge (Q), volume of water (V) and elapsed time (t). The iso-moisture line of 36% advanced with the elapsed time after irrigation as well as with the increment in the volume of water.

The data presented in Table 4.15 for the discharge rate of 2 lph/m show that the maximum radial spread (Rm) and vertical advance (Va) of wetting front increased with d and V. The maximum radial spread was ranged from 6.0 to 11.0, 9.0 to 12.0 and 9.8 to 12.2 cm, respectively for 3,5 and 10 lit of water, during 0 to 48 hr after irrigation. These maximum radial spread were noticed at the soil depths of 14.0 to 16.0, 14.0 to 19.0 and 14.0 to 18.5 cm for 3,5 and 10 lit of water, respectively at 48 hr after irrigation. The vertical advance of wetting front was 30.0, 33.0 and 36.0 cm at 24 hr after irrigation and 32.0, 36.0 and 39.5 cm at 48 hr after irrigation, respectively for 3,5 and 10 lit of water.

In case of 3 lph/m discharge of strip tape similar trend as above was observed. Table 4.15 show that the maximum radial spread was ranged from 10.5 to

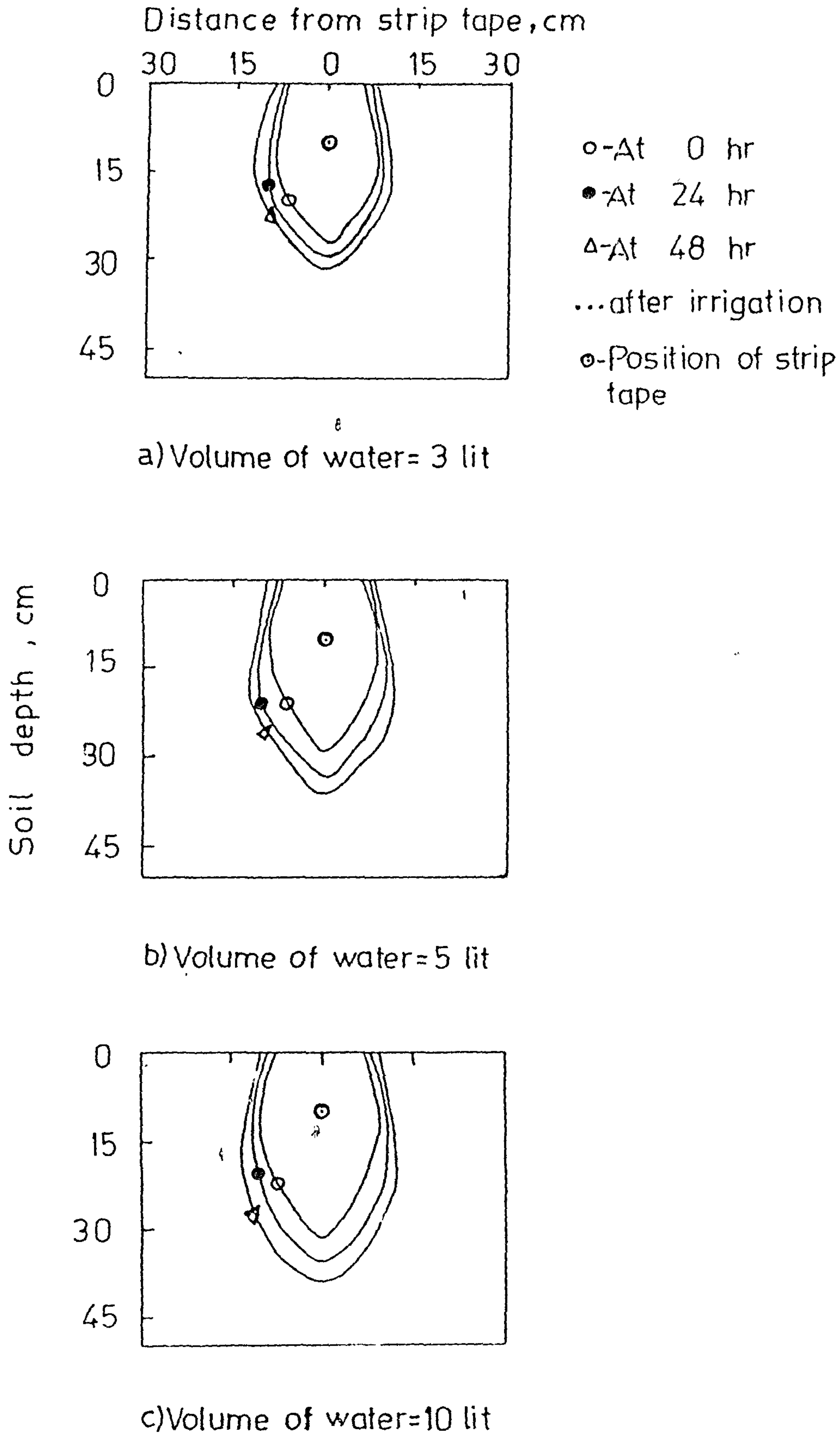


Fig.4.14. Movement of 36% moisture contour under strip tape for different quantities of water at 2 lph discharge rate.

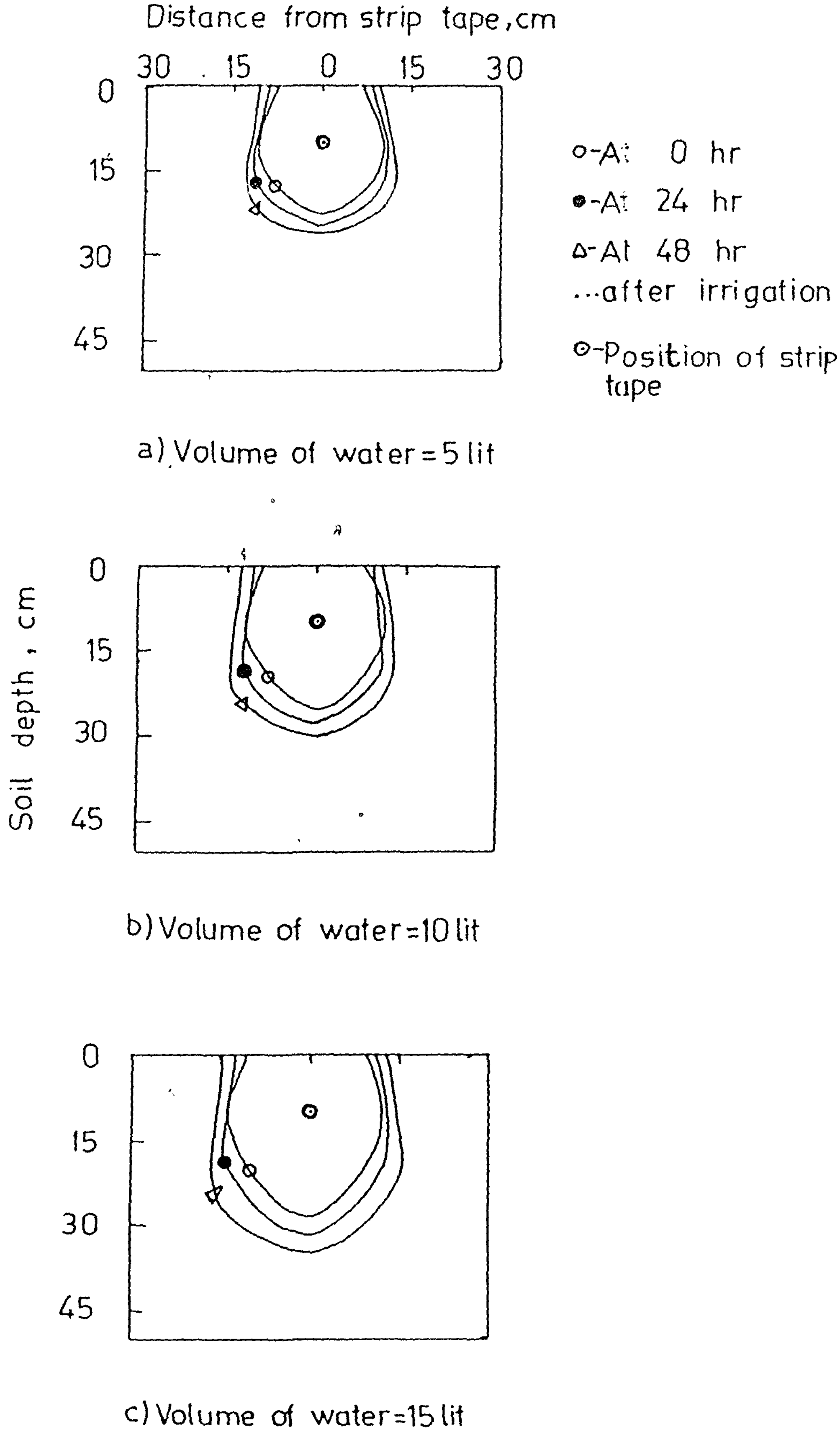


Fig.4.15 Movement of 36% moisture contour under strip tape for different quantities of water at 3 lph discharge rate .

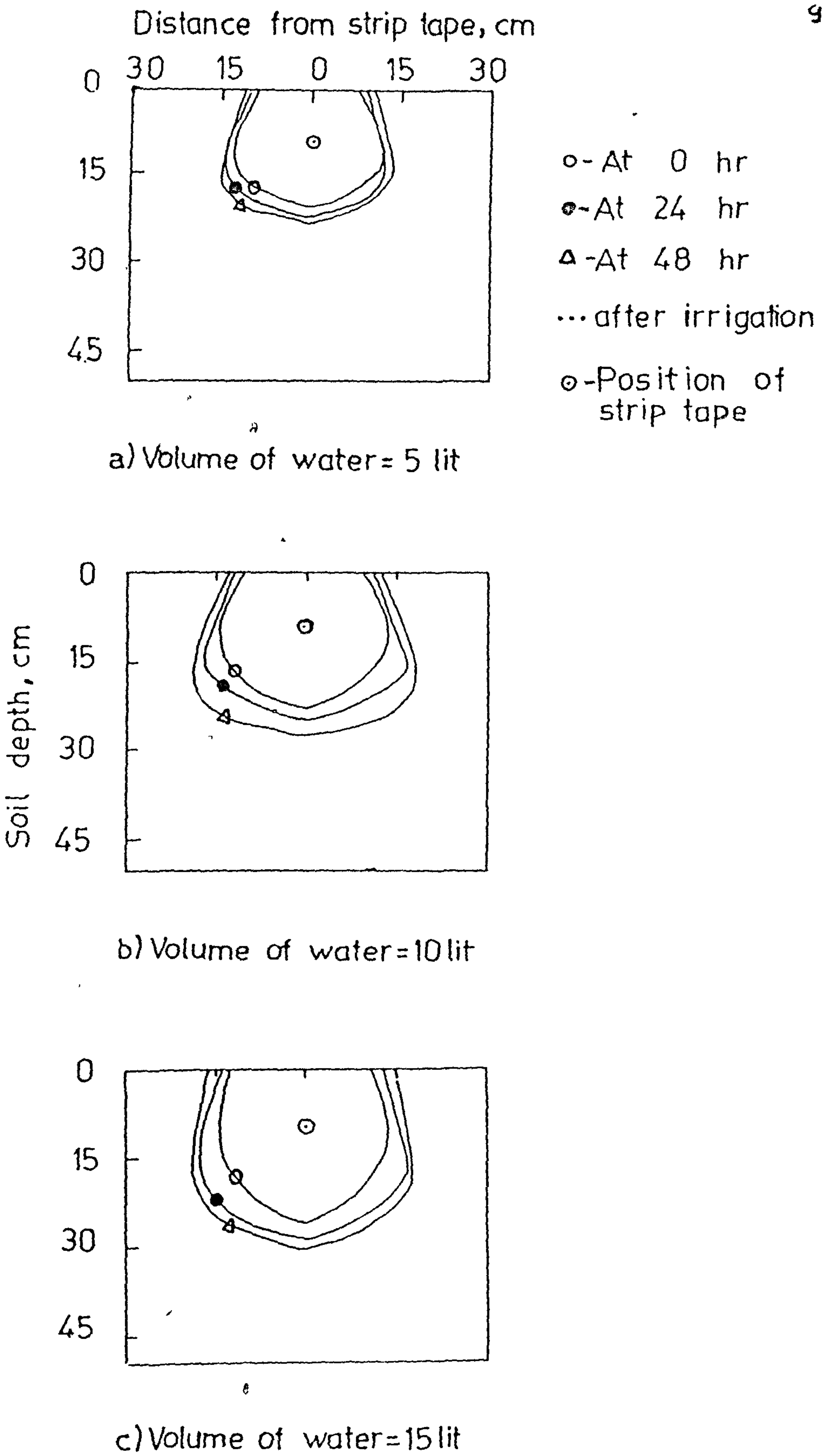


Fig.4.16. Movement of 36% moisture contour under strip tape for different quantities of water at 4 lph discharge rate.

Table 4.15 . Maximum radial spread and vertical advance of wetting front in strip tape system

Sr. No.	Discharge (Q),lph	Quantity of water applied (V), lit	Time after irrig. (t), hr	Depth of soil at which maximum radial spread observed (d), cm	Maximum radial spread of moisture from emitter (Rm), cm	Maximum vertical advance of moisture (Vm), cm
1.	2	3	0	14.00	6.00	27.50
			24	15.00	7.25	13.00
			48	16.00	11.00	32.00
		5	0	14.00	9.00	29.50
			24	17.30	10.50	33.00
			48	19.00	12.00	36.00
		10	0	14.00	9.85	32.00
			24	15.00	11.00	36.00
			48	18.50	12.20	39.50
2.	3	5	0	12.00	10.50	23.00
			24	15.00	11.00	24.50
			48	17.00	12.70	26.00
		10	0	12.00	11.50	25.50
			24	17.00	11.75	27.50
			48	19.00	13.50	30.00
		15	0	12.00	12.75	28.30
			24	16.00	13.75	31.50
			48	20.00	16.00	35.00
3.	4	5	0	13.00	12.25	17.00
			24	13.50	13.25	19.50
			48	15.00	14.20	21.50
		10	0	12.50	14.00	20.00
			24	15.00	16.75	23.00
			48	17.00	18.00	25.50
		15	0	12.00	14.25	23.50
			24	16.00	17.00	27.00
			48	18.00	18.25	31.00

12.7, 11.5 to 13.5 and 12.7 to 16.0 cm, respectively for 5, 10 and 15 lit of water applied. The values of maximum radial spread were noticed at the soil depths of 12.0 to 17.0, 12.0 to 19.0 and 12.0 to 20.0 cm for 5, 10 and 15 lit of water, respectively. The vertical advance was 24.5, 27.5 and 31.5 at 24 hr after irrigation, and 26.0, 30.0 and 35.0 at 48 hr after irrigation for 5, 10 and 15 lit of water, respectively.

When discharge rate was changed to 4 lph/m, it is seen from Table 4.15 that the maximum radial spread as well as vertical advance increased with elapsed time and quantity of water applied. The maximum radial spread was ranged from 12.3 to 14.2, 14.0 to 18.0 and 14.2 to 18.2, respectively for 5, 10 and 15 lit of water applied. These values of maximum radial spread were noticed at the soil depths of 13.0 to 15.0, 12.5 to 17.0 and 12.0 to 18.0 cm for 5, 10 and 15 lit of water, respectively. In strip tape line source, the vertical advance was found to be 19.5, 23.0 and 27.0 cm at 24 hr after irrigation and 21.5, 25.5 and 31.0 cm at 48 hr after irrigation, respectively for 5, 10 and 15 lit of water.

4.3.2.2 Effect of strip tape discharge

The effect of discharge rates on the maximum radial spread and vertical advance of wetting front was also studied and is depicted in Fig. 4.17. It is seen that as the discharge rate of strip tape increased, the radial spread from emitter also increased, whereas its vertical advance decreased, at constant volume of water

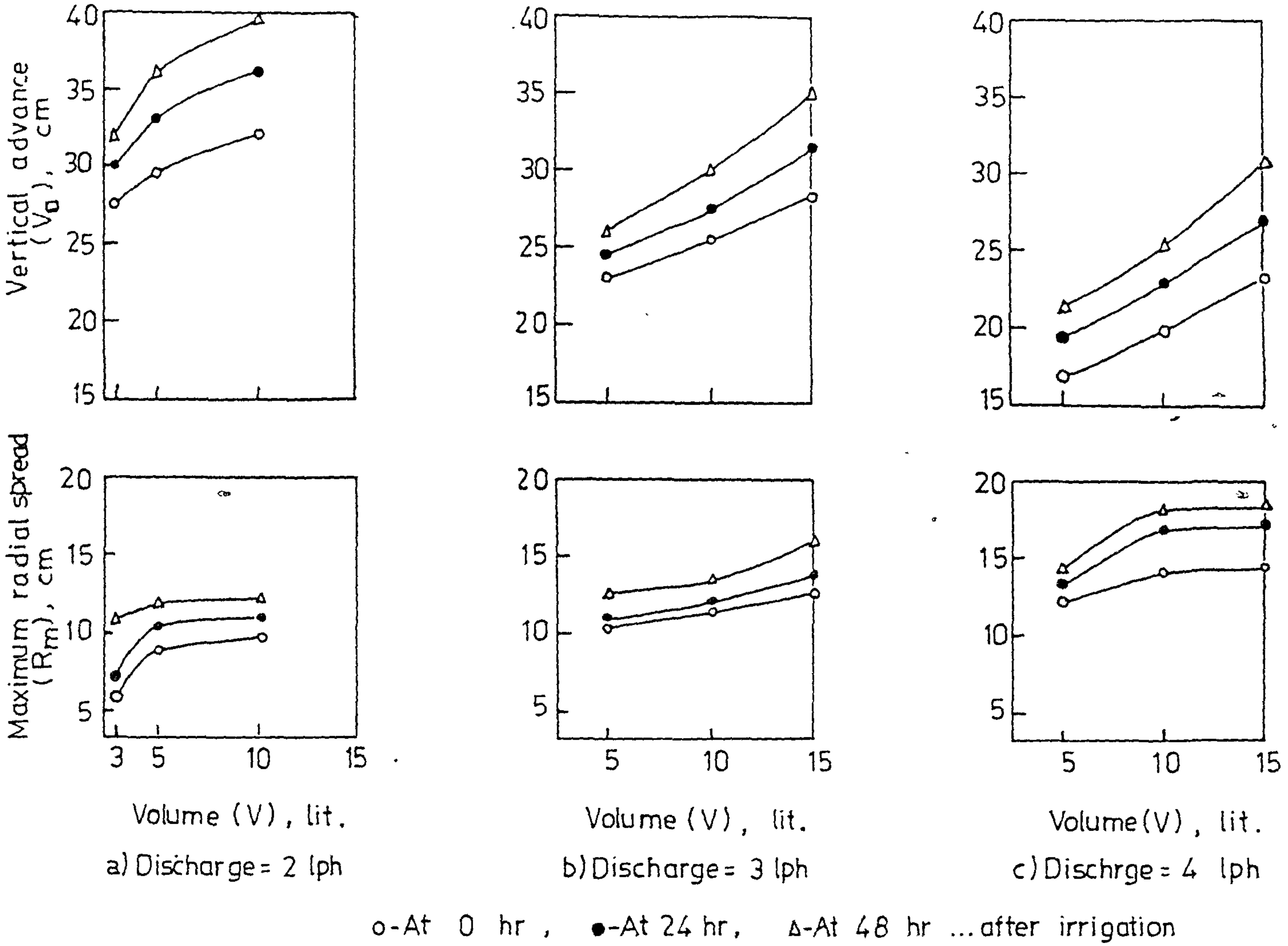


Fig.4.17. Maximum radial spread and vertical advance of wettingfront in strip tape system.

and elapsed time. Irrespective of elapsed time, the increase in radial spread was 26.0 and 47.5 per cent for 5 and 10 lit of water respectively when the discharge was raised from 2 to 4 lph/m. The vertical advance of water was decreased by 40.9 and 36.1 per cent at t=24 hr and 40.3 and 35.4 per cent at t=48 hr, respectively for 5 and 10 lit of water when the discharge was increased from 2 to 4 lph/m.

In general, it was observed that the radial spread of wetting front increased due to increase in the following parameters in descending order as :

(i) Elapsed time after irrigation i.e. irrigation interval, and

(ii) Discharge rate of strip tape.

The vertical advance of wetting front could be increased due to the following parameters in descending order.

(i) By increasing irrigation interval , and

(ii) By decreasing discharge of strip tape per metre length.

4.3.2.3 Correlations developed

The correlations were developed to determine the vertical advance and radial spread of wetting front from strip tape. The data presented in Table 4.16 was used for this purpose. The equations developed are in the same form as that of eq. 4.13 and 4.14. The constants in the equations developed under different set of conditions are reported in Table 4.17.

Table 4.16. The radial spread and maximum vertical advance of wetting front observed from moisture distribution pattern under different set of conditions in strip tape system

Sr. No.	Discharge (Q), lph	Volume (V), lit	Time (t), hr	Radial spread (Rs), cm at the different soil depths (d), m				Maximum vertical advance (Va), cm
				0	15	30	45	
1.	2	3	0	6.25	8.25	0.00	0.00	27.50
			24	7.25	9.50	0.00	0.00	30.00
			48	8.15	11.25	3.25	0.00	32.00
		5	0	6.50	8.75	0.00	0.00	29.50
			24	7.75	10.50	4.00	0.00	33.00
			48	8.87	11.90	7.25	0.00	36.00
		10	0	7.25	9.50	2.25	0.00	32.00
			24	8.50	11.00	7.25	0.00	36.00
			48	9.50	12.50	9.50	0.00	39.50
2.	3	5	0	7.25	8.75	0.00	0.00	23.00
			24	8.65	11.00	0.00	0.00	24.50
			48	10.00	12.50	0.00	0.00	26.00
		10	0	8.50	10.75	0.00	0.00	25.50
			24	10.00	11.65	0.00	0.00	27.50
			48	11.75	13.50	0.00	0.00	30.00
		15	0	10.00	12.00	0.00	0.00	28.30
			24	11.75	13.75	4.00	0.00	31.50
			48	13.75	15.75	10.50	0.00	35.00
3.	4	5	0	10.25	11.50	0.00	0.00	17.00
			24	11.00	13.00	0.00	0.00	19.50
			48	11.75	14.10	0.00	0.00	21.50
		10	0	11.50	13.00	0.00	0.00	20.00
			24	12.50	16.75	0.00	0.00	23.00
			48	13.75	18.25	0.00	0.00	25.50
		15	0	13.00	13.25	0.00	0.00	23.50
			24	14.25	17.00	0.00	0.00	27.00
			48	15.25	18.15	2.00	0.00	31.00

Table 4.17. Details of the equations developed for determination of vertical advance and ra6dial spread of moisture in respect of constant values and correlation coefficients for strip tape system

Sr. No	Dischrge (Q), lph	Time (t), hr	Constants in eq. 4.13 for vertical advance (Va) of water in soil							Constants in eq. 4.14 for radial spread (Rs) of moisture in the soil										
			A	B_1	B_2	C_1	C_2	C_3	r^2	A'	B_1'	B_2'	C_1'	C_2'	C_3'	D_1'	D_2'	D_3'	D_4'	r^2
1.	2	0	41.85	-8.71	0.55	0.39	-0.05	-6.30×10^{-3}	0.99	-5.41	7.37	0.79	-1.38	0.01	-0.06	0.07	4.52×10^{-4}	-4.17×10^{-4}	8.68×10^{-4}	0.99
		24	55.04	-16.90	0.82	1.76	-0.01	-2.56×10^{-3}	0.99	-1.16	5.09	0.40	-0.87	0.06	-0.04	0.04	-6.0×10^{-4}	-1.11×10^{-3}	5.83×10^{-4}	0.97
		48	63.52	-21.70	0.97	2.51	-0.02	1.65×10^{-3}	0.99	1.99	3.60	0.36	-0.58	0.05	-0.03	0.03	-6.02×10^{-4}	-8.83×10^{-4}	3.36×10^{-4}	0.98
2.	3	0	Same as above for 'o' hr							25.60	-7.09	1.10	0.81	-5.17×10^{-3}	-0.08	-0.03	2.81	-5.56×10^{-5}	1.13×10^{-3}	0.99
		24	Same as above for '24' hr							28.41	-7.17	0.94	0.78	9.28×10^{-3}	-0.04	-0.02	1.80×10^{-4}	-4.05×10^{-4}	1.11×10^{-3}	0.99
		48	Same as above for '48' hr							29.49	-6.77	0.61	0.72	0.02	-0.06	-0.02	1.13×10^{-3}	-1.11×10^{-3}	9.58×10^{-4}	0.97
3.	4	0	Same as above for 'o' hr							32.11	-8.36	1.22	0.95	-0.01	-0.08	-0.03	6.67×10^{-5}	1.11×10^{-4}	1.31×10^{-3}	0.99
		24	Same as above for '24' hr							37.21	-10.27	1.66	1.19	-0.01	-0.11	-0.04	3.67×10^{-4}	-8.33×10^{-5}	1.68×10^{-3}	0.99
		48	Same as above for '48' hr							40.28	-11.15	1.68	1.29	-0.01	-0.12	-0.04	1.03×10^{-3}	-2.83×10^{-4}	1.72×10^{-3}	0.99

4.3.3 Microsprinkler system

4.3.3.1 Effect of water volumes and elapsed time

The radial spread of moisture in microsprinkler system was definite (i.e. 180 cm) due to the spacing between two successive microsprinkler and laterals was 180 cm. The vertical advance of wetting front under four microsprinklers situated at four corners was studied for different discharge rates (30, 35 and 40 lph) and quantities of water (40, 60 and 80 lit) at 0, 24 and 48 hr after irrigation. The data of moisture content were used to study the movement of 36% iso-moisture lines and is plotted in Fig. 4.18 through 4.20 for different set of conditions. These iso-moisture lines were used in determining the average depth of soil to which the wetting front of 36% has advanced and are reported in Table 4.18 and shown in Fig. 4.21. It is seen from the data that the vertical advance (Va) increased with the elapsed time and volume of water (V). However, the increase in vertical advance was observed more with elapsed time as compared to increase in volume of water.

At 30 lph discharge of microsprinkler the vertical advance of wetting front was observed in the range of 5.1 to 30.6, 7.9 to 38.5 and 8.5 to 43.1 cm, respectively for 40, 60 and 80 lit of water during 0 to 48 hr after irrigation. The vertical advance of wetting front was 4.5 to 29.6, 6.9 to 37.3 and 7.8 to 41.9 cm at 35 lph discharge and 3.9 to 27.3, 6.1 to 35.8 and 7.2

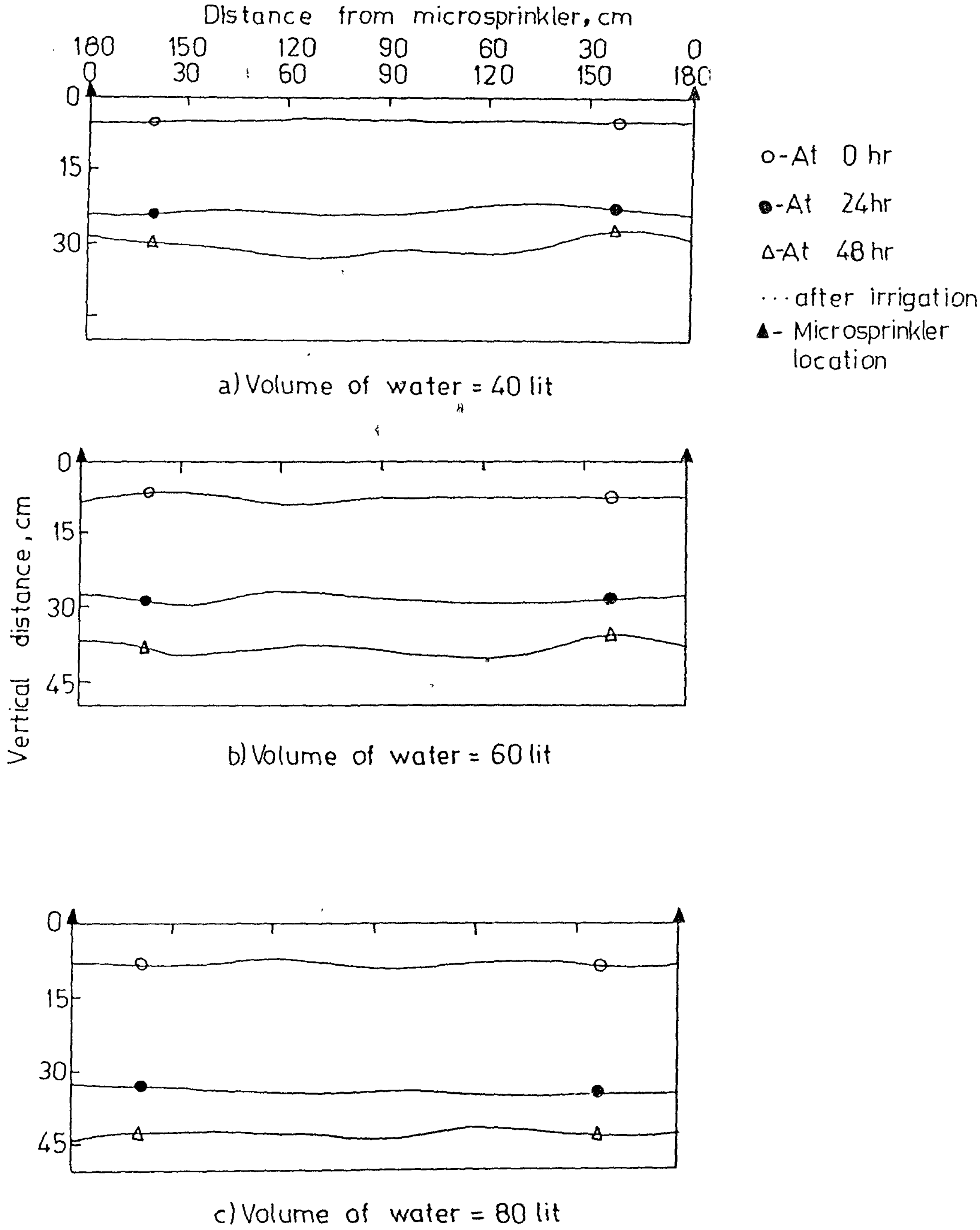


Fig.4.18. Movement of 36% moisture contour under rotary microsprinkler for different quantities of water at 30 lph discharge rate.

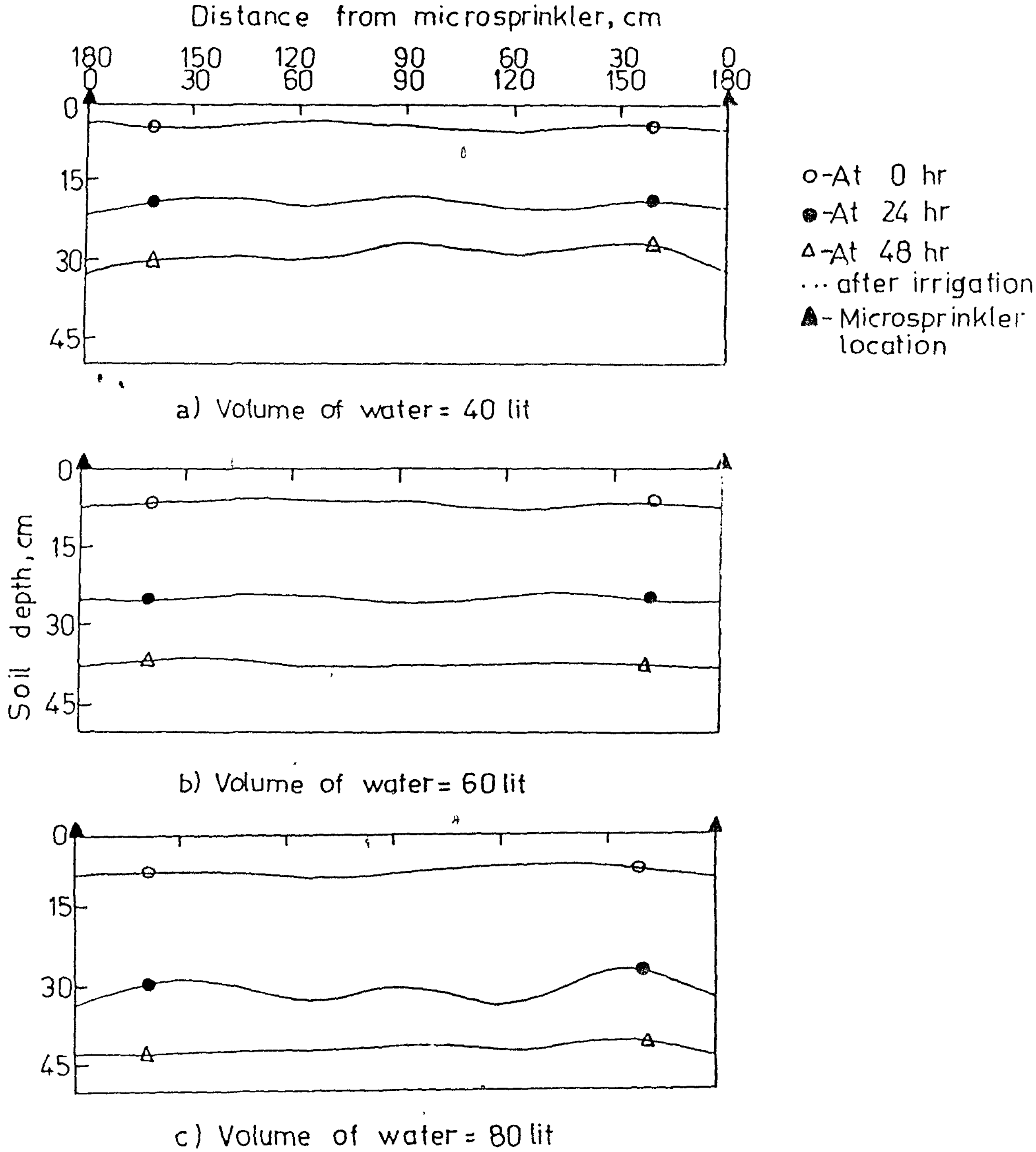


Fig.4.19. Movement of 36% moisture contour under rotary microsprinkler for different quantities of water at 35 lph discharge rate.

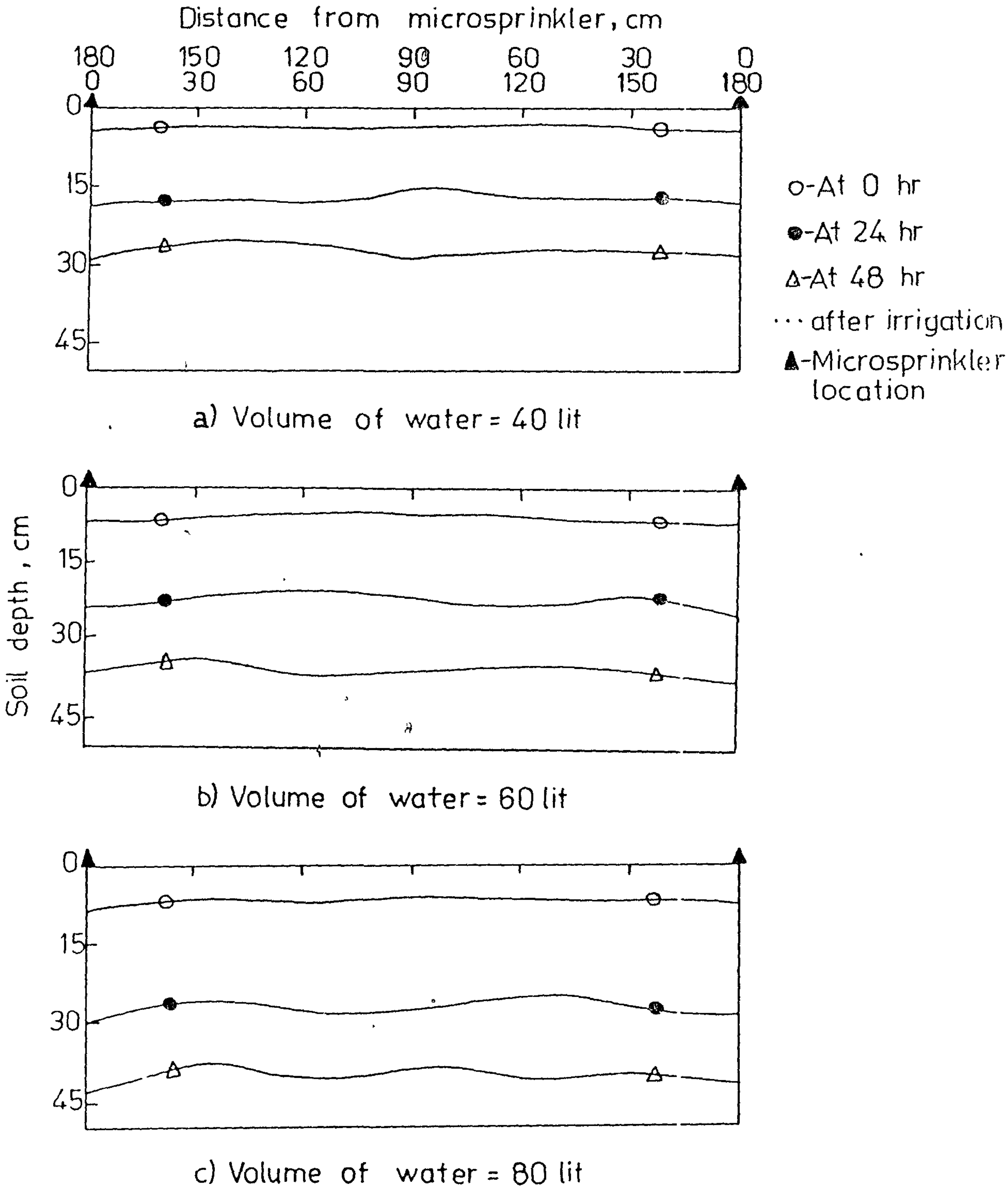


Fig.4.20 Movement of 36% moisture contour under rotary microsprinkler for different quantities of water at 40 lph discharge rate.

Table 4.18. The vertcal advance of wetting front observed from moisture distribution pattern under different set of conditions, in microsprinkler system

Sr.No.	Discharge (Q), lph	Volume (V), lit	Vertical advance (Va) , cm , after elapsed time (t) , hr		
			0	24	48
1.	30	40	5.14	23.50	30.60
		60	7.85	28.57	38.50
		80	8.50	34.50	43.14
2.	35	40	4.50	20.14	29.57
		60	6.97	25.12	37.26
		80	7.78	30.88	41.90
3.	40	40	3.91	17.24	27.33
		60	6.14	22.43	35.81
		80	7.20	27.57	40.50

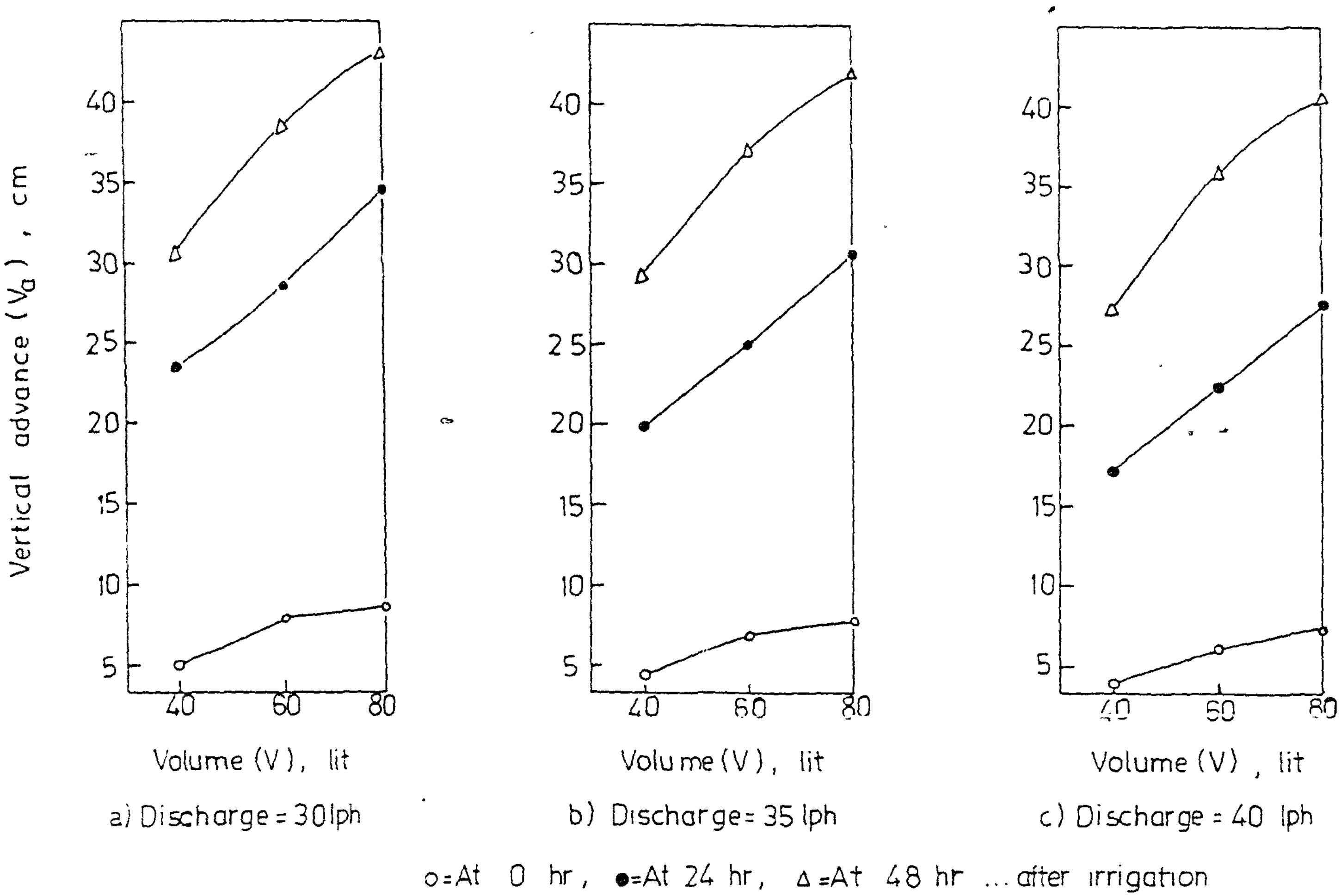


Fig. 4.21. Maximum vertical advance of wetting front in microsprinkler system.

to 40.5 cm at 40 lph discharge, respectively for 40, 60 and 80 lit of water during 0 to 48 hr after irrigation.

4.3.3.2 Effect of microsprinkler discharge

It is interesting to note that the vertical advance of wetting front reduced with increase in the discharge rate, at the constant volume of water. This was obviously due to the fact that more the discharge rate, more the operating pressure and hence more the wetted diameter of soil.

4.3.3.3 Correlations developed

The correlations were developed to determine the vertical advance of wetting front in the soil for the elapsed time of 0, 24 and 48 hr with the help of data presented in Table 4.18. The correlations developed were in the polynomial form in three dimensional and second order as given in eq. 4.13. The constants in the correlations developed under different set of conditions of Q, V and t are reported in Table 4.19.

4.4 Salt distribution studies

The salt distribution under different micro-irrigation systems was studied in respect of its movement in horizontal and vertical directions from the emitter at the end of each month from the transplanting of chilli.

4.4.1 Dripper system

The iso-salinity lines of different levels

Table 4.19. Details of the equation developed for determination of vertical advance of moisture in respect of constant values and correlation coefficients for microsprinkler system

Sr. No.	Time (t), hr	Constants in eq. 4.17 for vertical advance (Va) of moisture in soil.						r2
		A	B1	B2	C1	C2	C3	
1.	0	1.20	-0.24	0.33	1.60×10^{-3}	-1.75×10^{-4}	-2.04×10^{-3}	0.99
2.	24	43.08	-1.26	0.25	0.01	-1.67×10^{-3}	6.62×10^{-4}	0.99
3.	48	4.29	0.33	0.76	-0.01	1.67×10^{-3}	-4.20×10^{-2}	0.99

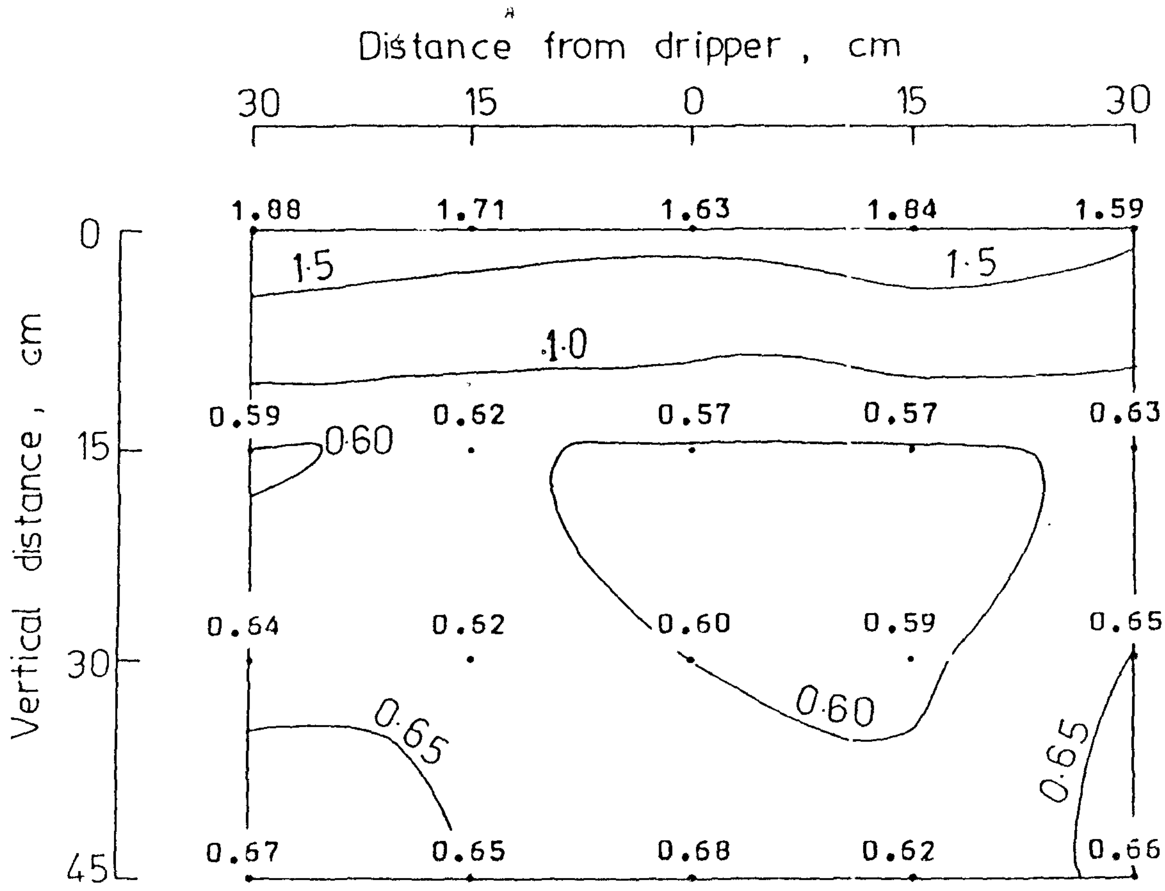
under dripper are shown in Fig. 4.22 alongwith the data of EC at different grid points. The iso-salinity lines show that there was distinct movement of salts due to the movement of water under dripper with the elapsed time. It was observed that the salts were concentrated at the periphery of the wetted soil at the soil surface. It was also noticed from the Fig. 4.22 that the salts were leached below the depth of 45 cm considerably after 150 days from transplanting of chilli. The efforts were made to simplify the data of salinity in order to study the lateral and vertical movements of the salts.

4.4.1.1 Lateral movement of the salts

The data of lateral movement of salts are given in Table 4.20 and depicted in Fig. 4.23. It is seen that at the soil surface the salinity of 1.63 dS/m under emitter was reduced to 0.36 (i.e.by 77.99 %), whereas at 15 and 30 cm from dripper, it was increased by 14.93 and 112.10 per cent, respectively during 30 days time period. It was also noticed that the increased salinity at 30 cm from emitter at 30 days was reduced by 31.52, 67.25 and 85.73 per cent after 60, 90 and 150 days ,respectively. This show that the salts were moved beyond 30 cm from the emitter i.e. at the periphery of the wetted soil surface. The little decrease in the salinity level was observed at the depths of 15, 30 and 45 cm.

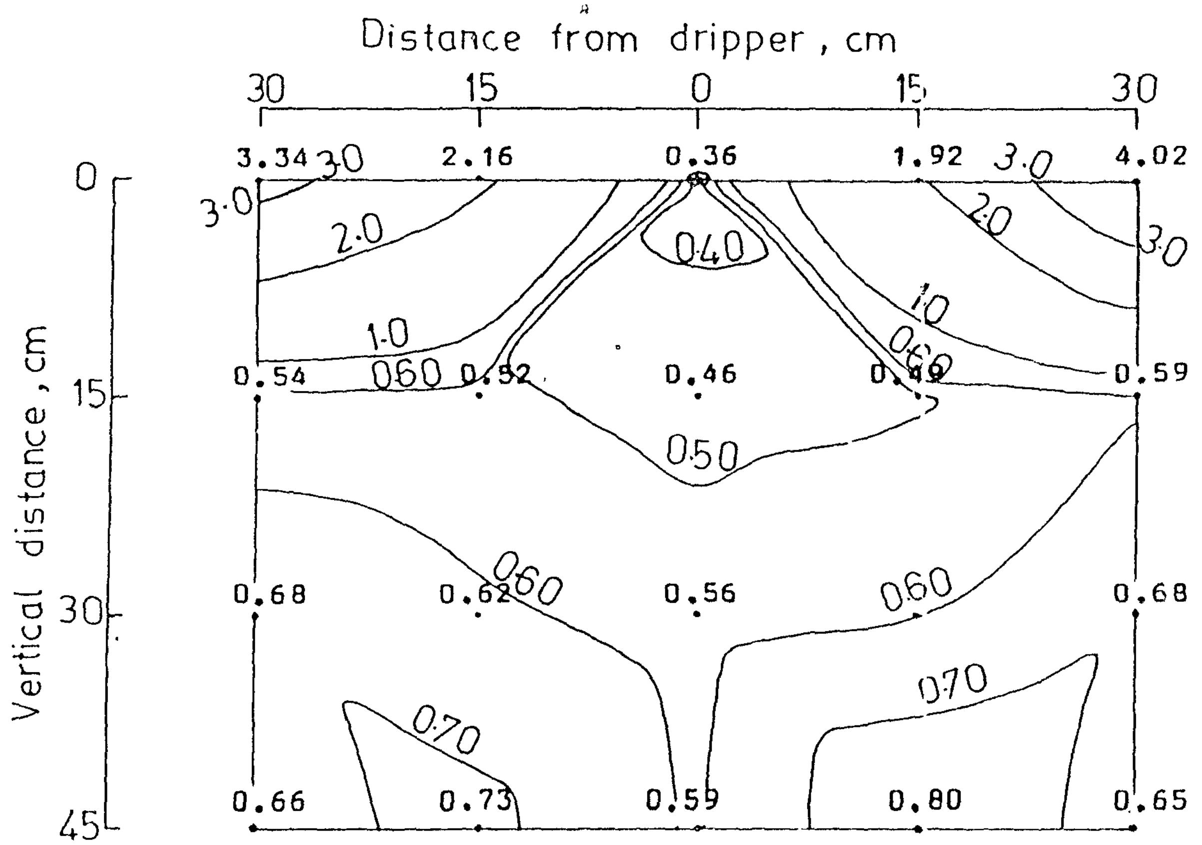
4.4.1.2 Vertical movement of salts

The data of vertical movements of salts with

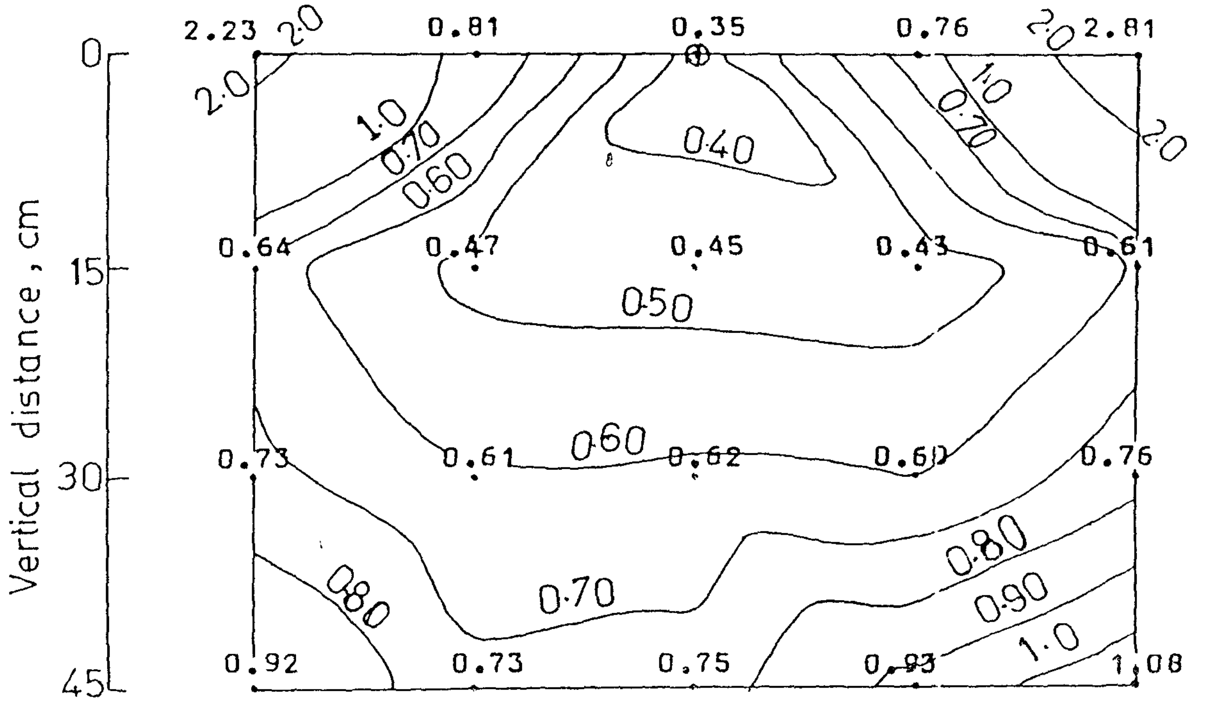


a) Initial salt status

contd ...

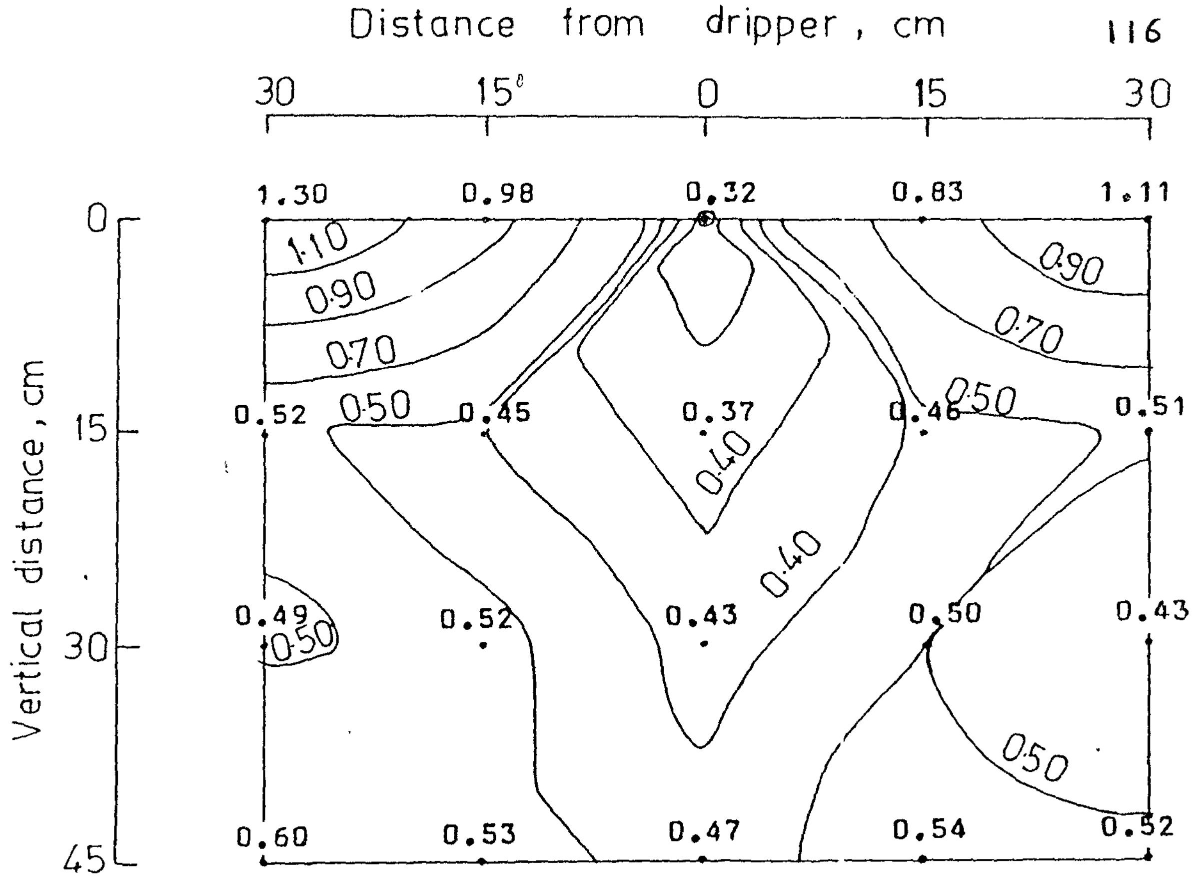


b) Salinity status at 30 days

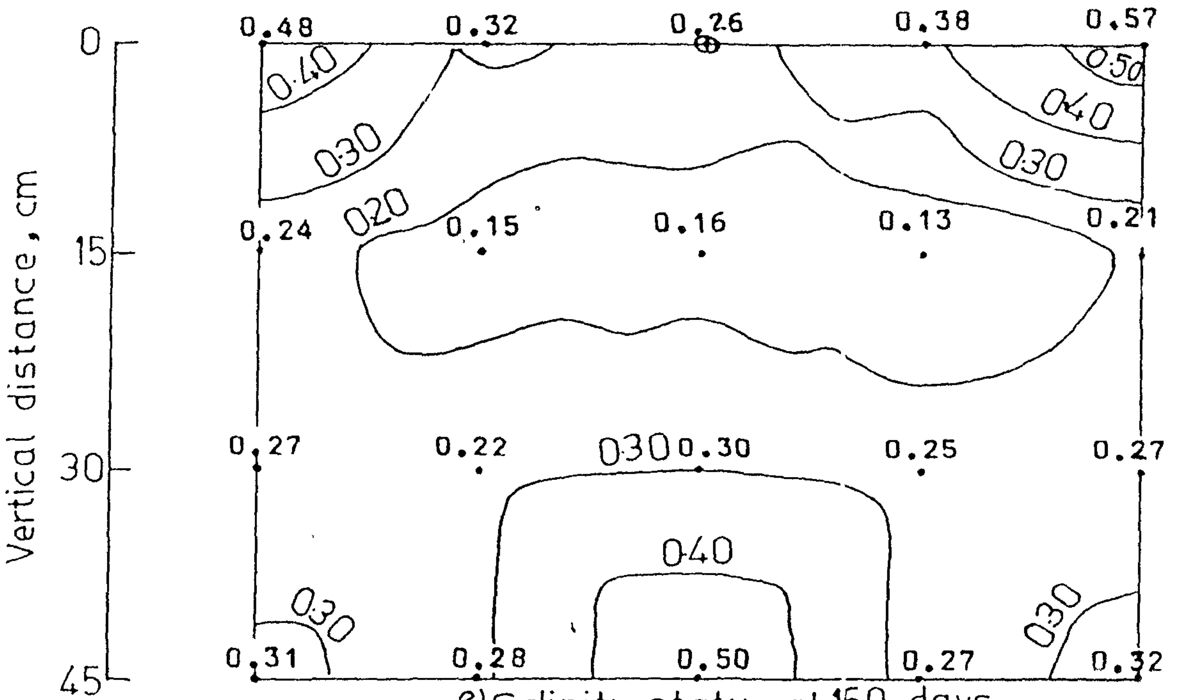


c) Salinity status at 60 days

Contd...



d) Salinity status at 90 days



e) Salinity status at 150 days

⊕ -Turbo-key dripper

Fig.4.22. Movement of salts under dripper system in chilli

Table 4.20. Average EC values at different distances from dripper, soil depth and time period in chilli

No. of days after transplanting	Soil depth, cm	Radial distance from strip tape, cm			Average EC, dS/m
		0	15	30	
Before transplanting	0	1.63	1.775	1.735	1.630
	15	0.57	0.595	0.610	0.596
	30	0.60	0.605	0.645	0.620
	45	0.68	0.635	0.665	0.656
30	0	0.36	2.040	3.680	2.360
	15	0.46	0.505	0.565	0.540
	30	0.56	0.615	0.680	0.628
	45	0.59	0.765	0.655	0.686
60	0	0.35	0.785	2.520	1.392
	15	0.45	0.450	0.625	0.500
	30	0.62	0.605	0.745	0.664
	45	0.75	0.815	1.000	0.882
90	0	0.32	0.905	1.205	0.908
	15	0.37	0.455	0.515	0.462
	30	0.43	0.510	0.460	0.474
	45	0.47	0.535	0.560	0.532
150	0	0.26	0.350	0.525	0.402
	15	0.16	0.140	0.225	0.178
	30	0.30	0.235	0.270	0.262
	45	0.50	0.275	0.315	0.336

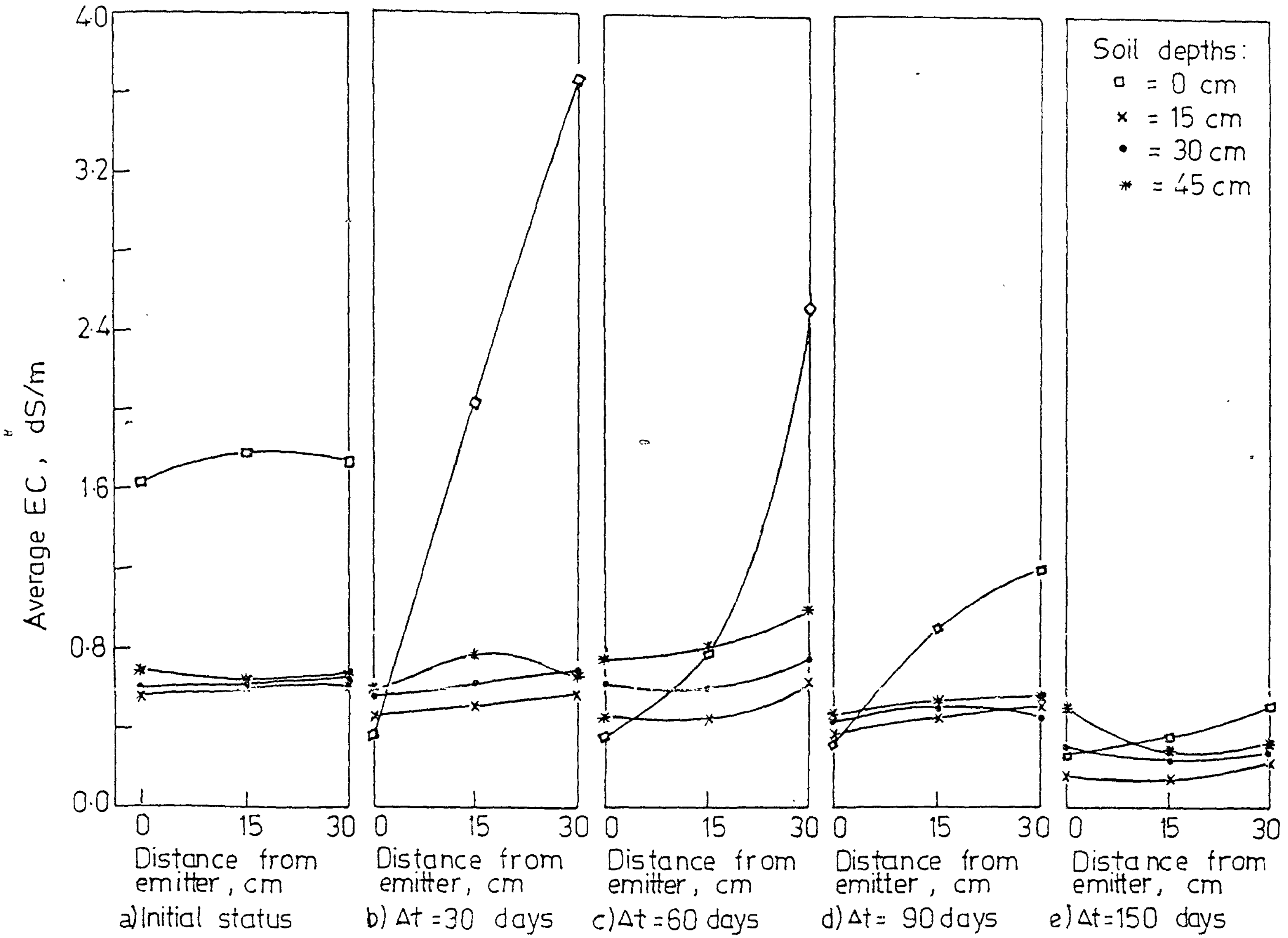


Fig. 4.23. Lateral movement of salts over time period under dripper system.

respect to time period are given in Table 4.20 and depicted in Fig. 4.24. It was observed that after 30 days, average salt concentration was increased at the soil surface because of movement of salts towards the periphery of the wetted soil. However, the salts were leached from 15 cm depth and hence the salt concentration was increased at 45 cm depth. After 60 days, the salt concentration at surface reduced which has resulted in increase in salt concentration at 30 and 45 cm depths. After 90 days the salt was reduced at all the soil depths and after 150 days, the average salt concentration was reduced by 1.33, 0.42, 0.36 and 0.32 dS/m at 0, 15, 30 and 45 cm soil depths, respectively.

4.4.2 Strip tape system

The iso-salinity lines of different levels under strip tape are shown in Fig. 4.25. The iso-salinity lines show that there was the distinct movement of salts due to the movement of water around strip tape with the elapsed time. It was observed that the salts were concentrated at the periphery of the wetted soil on the soil surface. It was also noticed from the Fig. 4.25 that the salts were leached below the depth of 45 cm considerably after 150 days from transplanting of chilli. The efforts were made to simplify the data of salinity in order to study the lateral and vertical movements of the salts.

4.4.2.1 Lateral movement of salts

The data of lateral movement of salts are given in Table 4.21 and shown in Fig. 4.26. It is seen

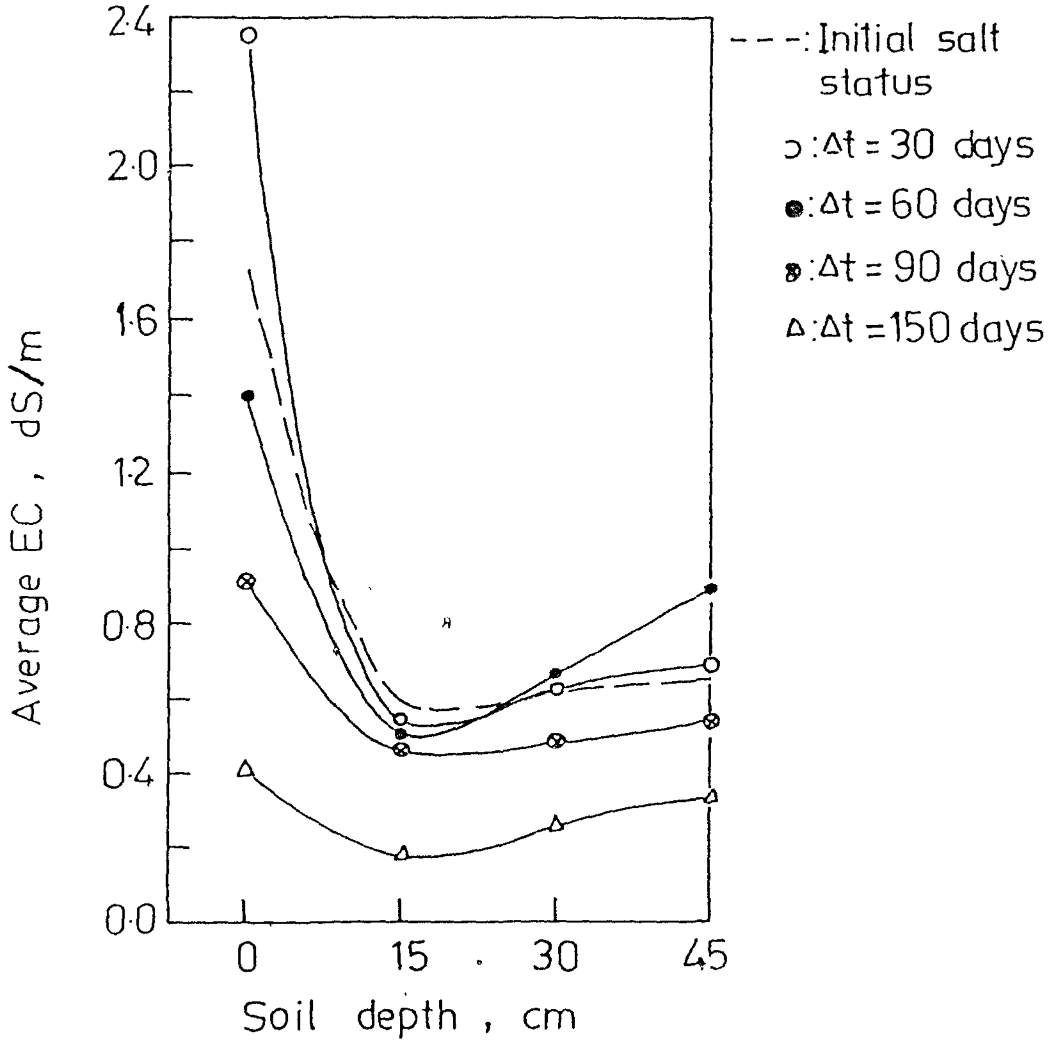
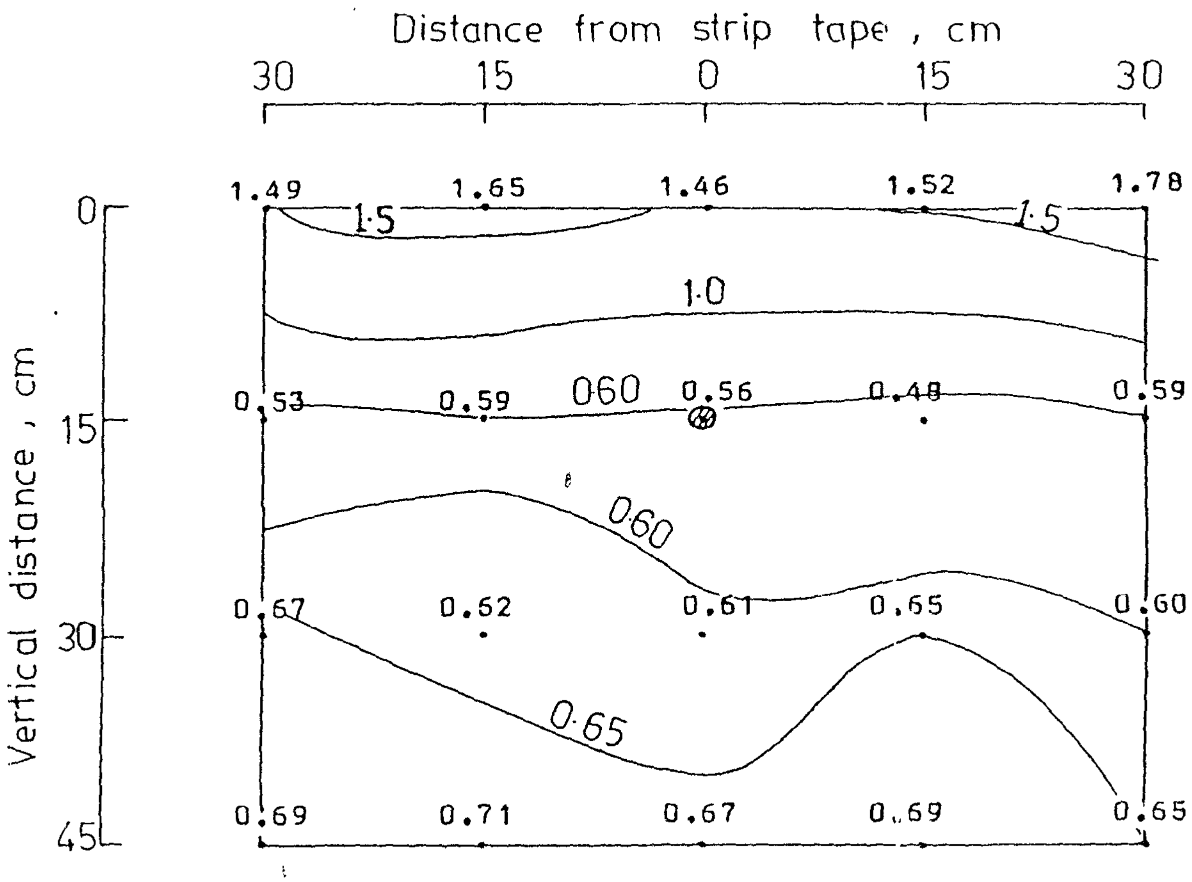


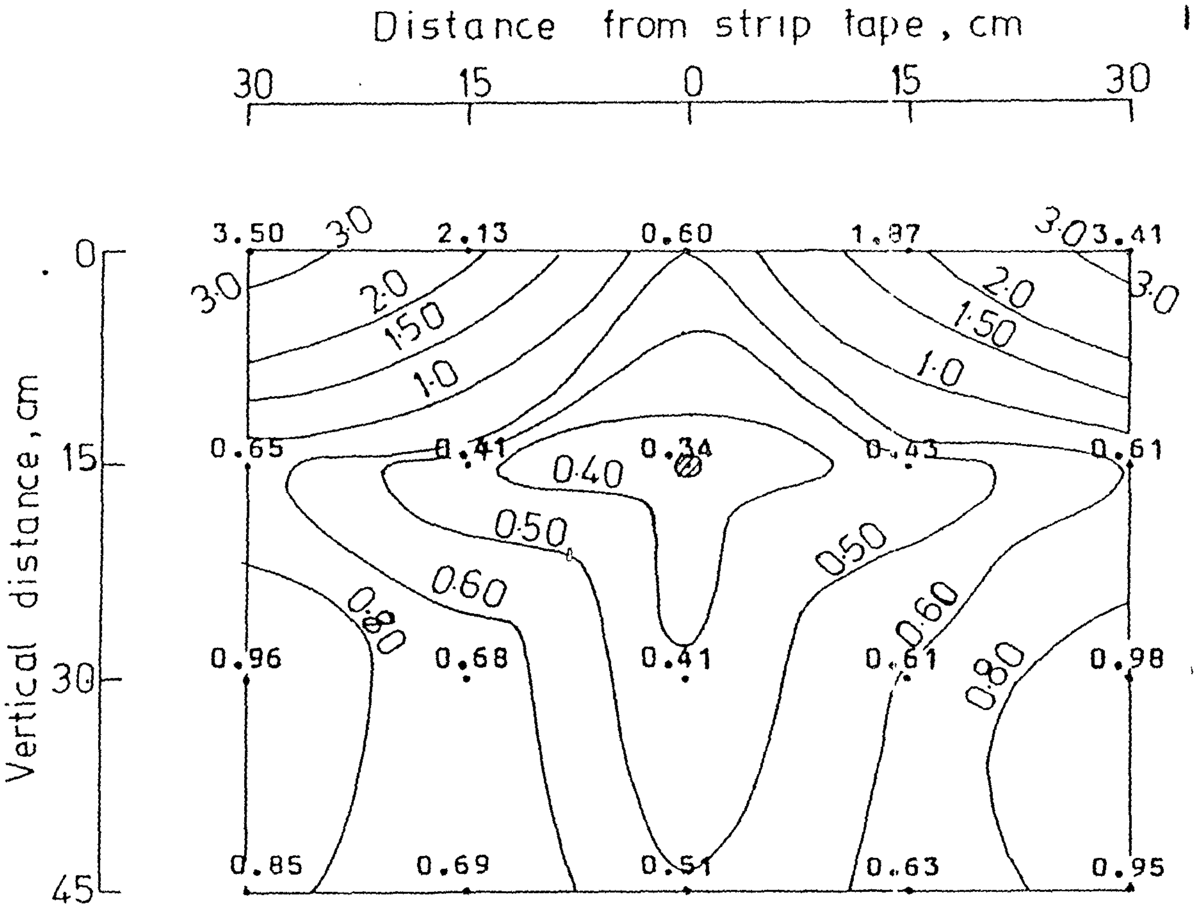
Fig. 4·24 . Vertical movement of salts under dripper system .



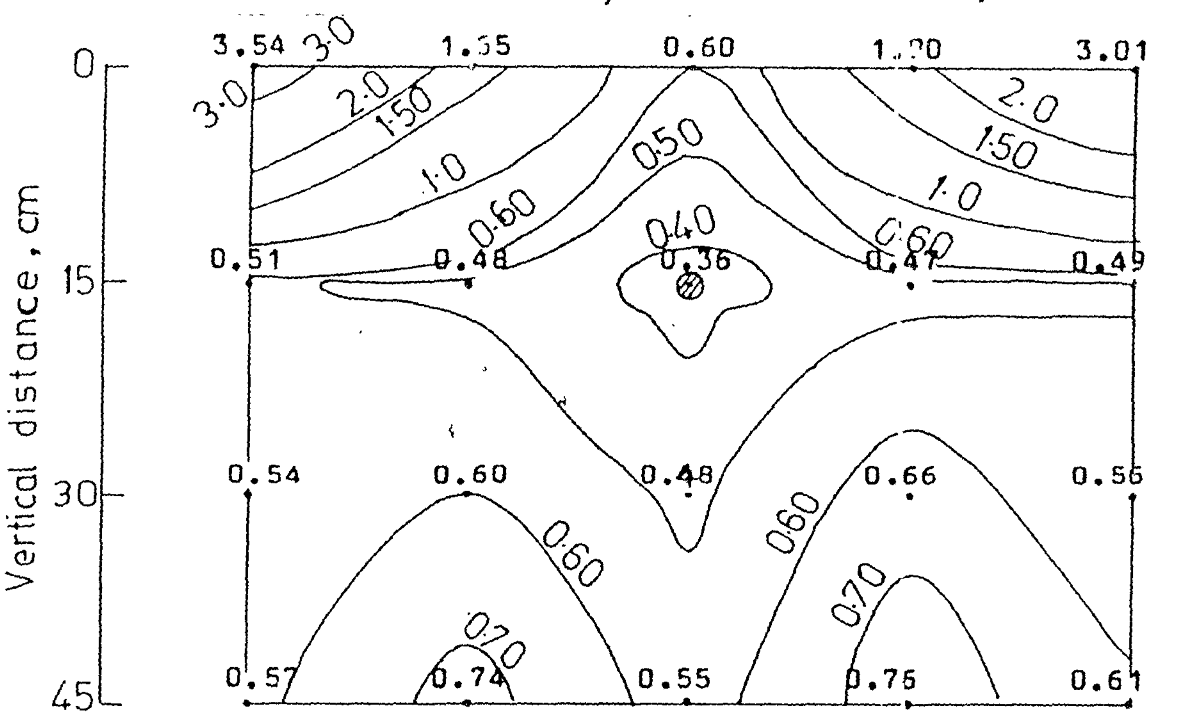
a)Initial salt status

⊗ - Strip tape placement

contd ...



b) Salinity status at 30 days



c) Salinity status at 60 days

⊘-strip tape placement

Contd...

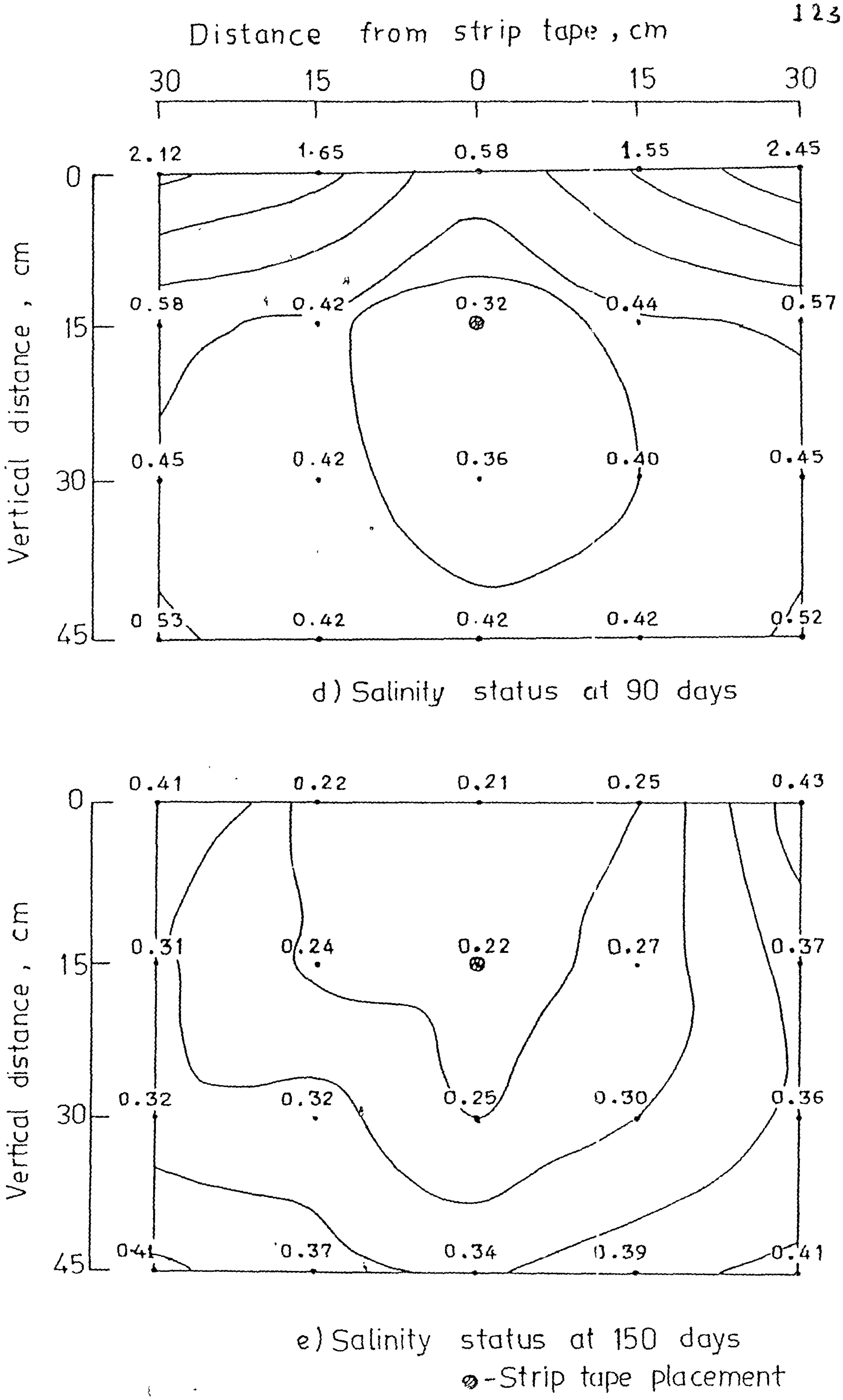


Fig.4.25. Movement of salts under strip tape system in chilli.

Table 4.21 Average EC values at different distances from strip tape, soil depth and time period in chilli

No. of days after transplanting	Soil depth, cm	Radial distance from strip tape, cm			Average EC, dS/m
		0	15	30	
Before transplaning	0	1.46	1.585	1.635	1.580
	15	0.56	0.535	0.560	0.550
	30	0.61	0.635	0.665	0.630
	45	0.67	0.700	0.670	0.682
30	0	0.60	2.000	3.455	2.302
	15	0.34	0.420	0.630	0.488
	30	0.41	0.645	0.970	0.728
	45	0.51	0.660	0.900	0.726
60	0	0.60	1.775	3.275	2.140
	15	0.36	0.475	0.500	0.462
	30	0.48	0.630	0.550	0.568
	45	0.55	0.750	0.590	0.646
90	0	0.58	1.600	2.285	1.670
	15	0.32	0.430	0.575	0.466
	30	0.36	0.410	0.450	0.418
	45	0.42	0.420	0.525	0.462
150	0	0.21	0.235	0.420	0.304
	15	0.22	0.255	0.340	0.282
	30	0.25	0.310	0.340	0.306
	45	0.34	0.380	0.410	0.384

from the figure that at the soil surface, the salinity of 1.46 dS/m above strip tape was reduced to 0.60 (i.e. by 58.9 per cent), whereas at 15 and 30 cm from emitter it was increased by 26.18 and 111.31 per cent, respectively during 30 days time period. It was also noticed that the increased salinity at 30 cm from emitter at 30 days was reduced by 5.21, 33.86 and 87.84 per cent after 60, 90 and 150 days, respectively. This show that the salts were moved beyond 30 cm from the emitter i.e. at the periphery of the wetted soil surface. At 15, 30 and 45 cm soil depths the salts concentration was increased after 30 days at a radial distance of 30 cm, which declined continuously after 60, 90 and 150 days.

4.4.2.2 Vertical movement of salts

The data of vertical movements of salts with respect to time period are given in Table 4.21 and depicted in Fig. 4.27. It was observed that after 30 days, average salt concentration was increased at the soil surface because of movements of salts towards the periphery of the wetted soil. After 30 days period, the salt concentration decreased at the soil depth of 15 cm but increased at surface of soil and 30 and 45 cm soil depths. After 60, 90 and 150 days, salts were leached below the 45 cm. After 150 days, the salt concentration was reduced by 1.28, 0.27, 0.32 and o.30 dS/m at 0, 15,30 and 45 cm soil depths, respectively.

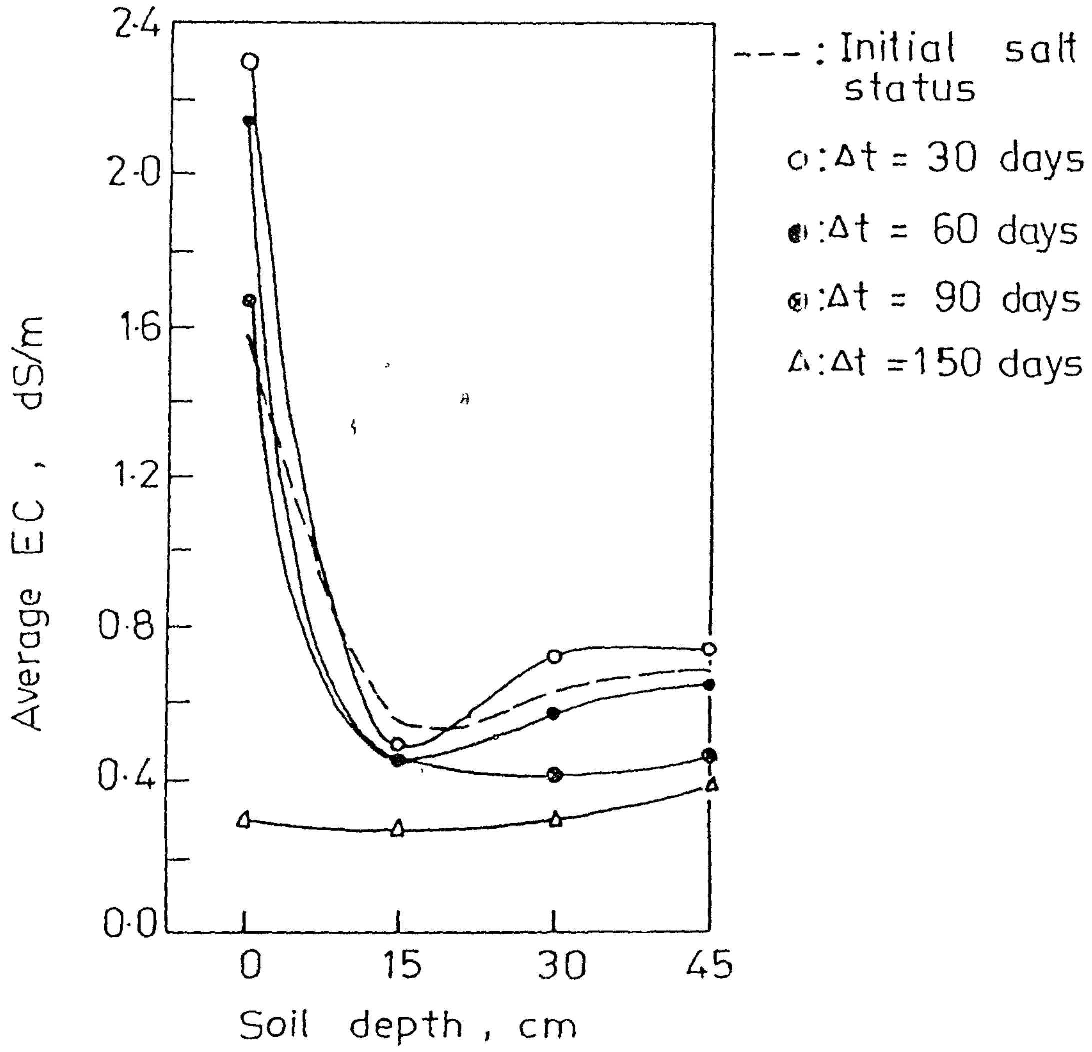
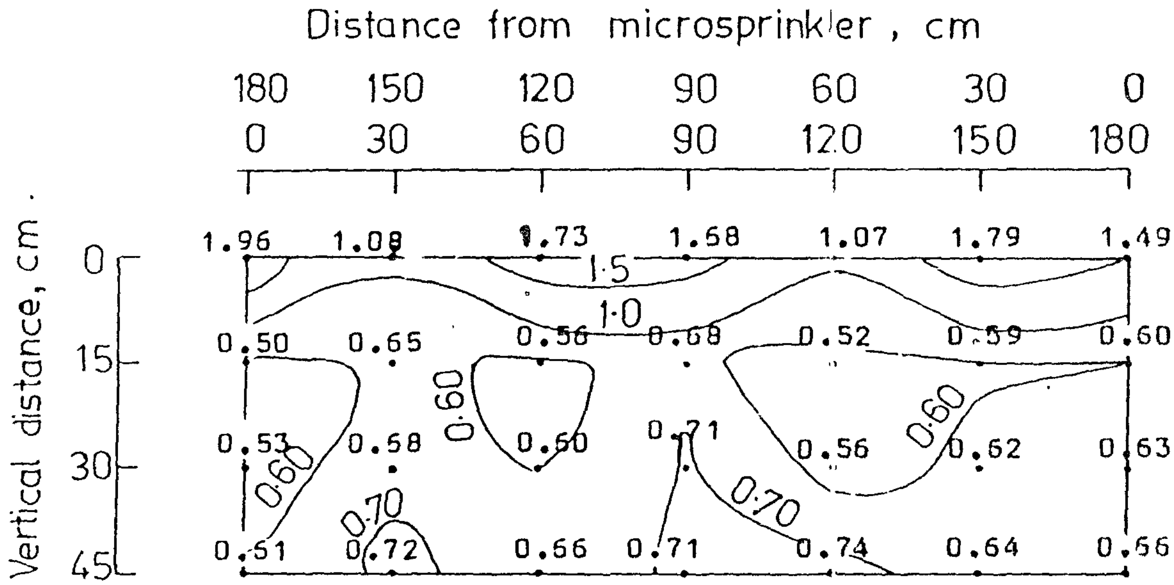


Fig.4·27. Vertical movement of salts under strip tape system.



a) Initial salt status

contd...

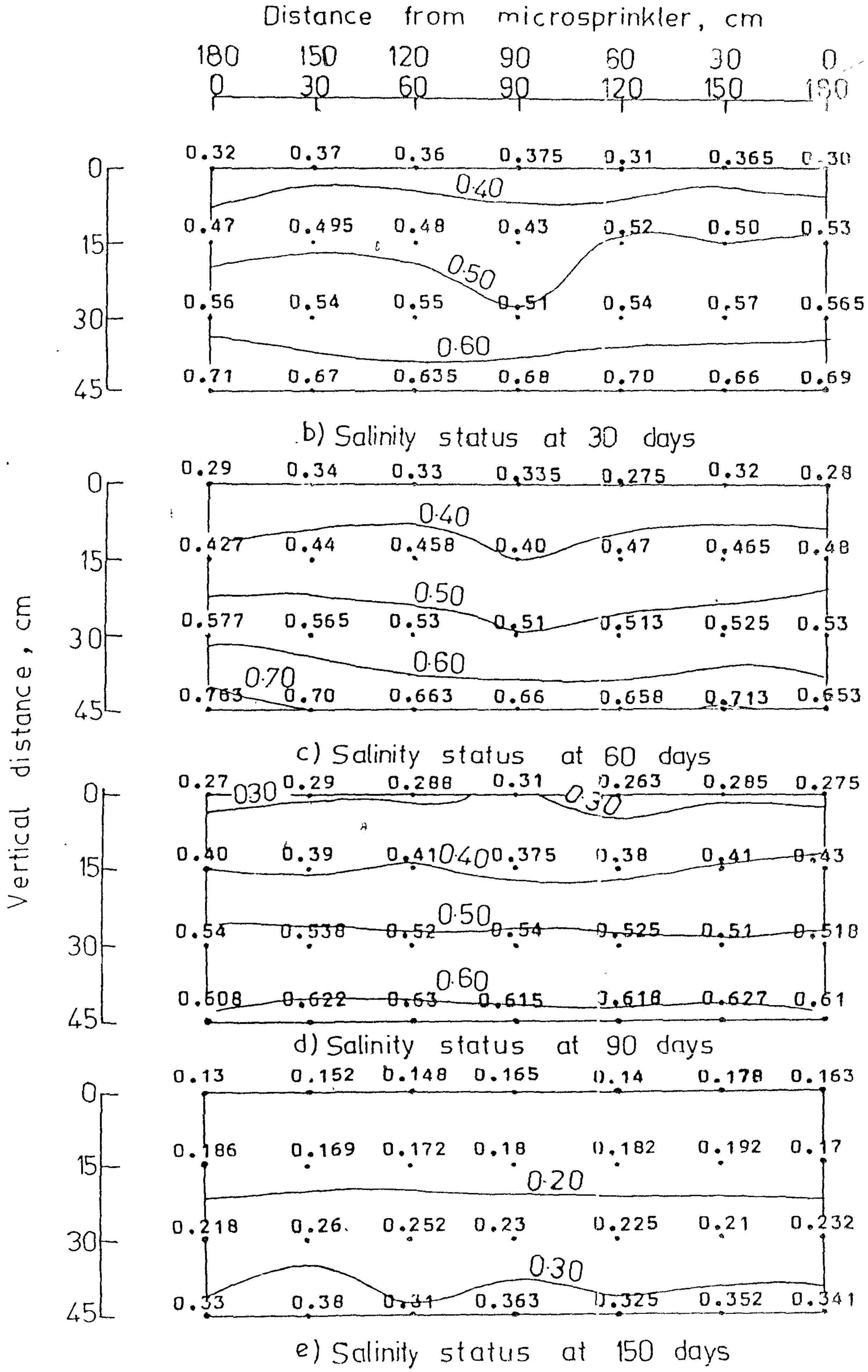


Fig.4.28. Movement of salts under microsprinkler system.

Table 4.22. Average EC values observed for different soil depths with time period under microsprinkler system in chilli

No. of days after transplanting	Soil depth, cm	Average EC, dS/m
Before transplanting	0	1.540
	15	0.586
	30	0.618
	45	0.677 -
30	0	0.343
	15	0.482
	30	0.548
	45	0.678-
60	0	0.310
	15	0.448
	30	0.536
	45	0.687
90	0	0.283
	15	0.399
	30	0.526
	45	0.618
150	0	0.154
	15	0.177
	30	0.232
	45	0.343

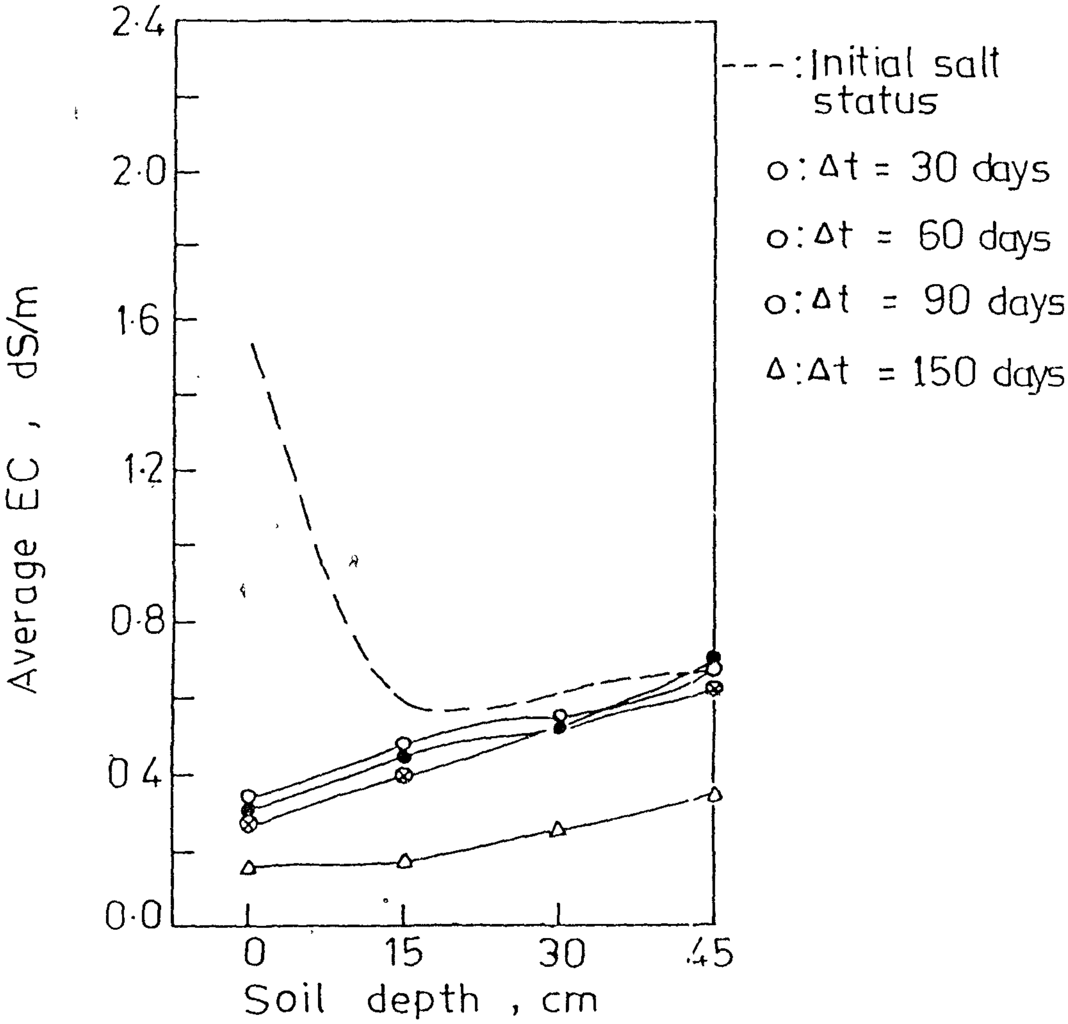


Fig.4·29. Vertical movement of salts under microsprinkler system .

by a point source and strip tape system where the application of water was by line source.

Chapter Opener Page

5. SUMMARY AND CONCLUSIONS

5.1 Summary

An experiment entitled "Moisture and salinity status under micro-irrigation systems in vertisols", was undertaken during 1994-95 at the Instructional Farm,Department of Irrigation and Drainage Engineering, Faculty of Agricultural Engineering, Rahuri.

In the present investigation, three micro-irrigation systems viz. dripper, strip tape and microsprinkler were studied in respect of the hydraulic performance, moisture distribution pattern and the salt distribution. The data obtained was analysed by using the standard methods wherever possible. The salinity status in these micro-irrigation systems was studied periodically in chilli crop.

5.1.1 Physical and chemical properties of soil

The soil of the experimental site was clay in texture having sand, silt and clay percentage as 24.21, 25.68 and 50.11, respectively. The moisture content at field capacity and permanent wilting point was 36.65 and 18.24 per cent, respectively indicating the available moisture of 9.36 cm. The bulk density of soil was 1.13 gm/cc. The soil was sodic in reaction having pH, 8.50 and EC, 0.88 dS/m.

5.1.2 System performance

5.1.2.1 Pressure-discharge relationship

It was observed that the emitter discharge (Q) increased with increase in the operating pressure (H) of the system at all the lengths of lateral i.e. 25, 50, 75 and 100 m. The emitter discharge was also decreased with increase in lateral length at all the 'H' values. The correlations between pressure head in kg/cm^2 and emitter discharge in lph for the lateral lengths of 25, 50, 75 and 100 m were developed in the following form

$$Q = aH^b \qquad \text{...(5.1)}$$

where,

a and b are the constants.

As the correlation coefficient (r^2) of these equations was found in between 0.91 to 0.98 , the correlation can be adopted practically.

5.1.2.1.1 Dripper system

The emitter discharge decreased from 14.38 to 28.73 % when the lateral length was increased from 25 to 100 m for the pressure of 0.5 to 1.75 kg/cm^2. The average 'Q' at recommended pressure (1 kg/cm^2) was 3.89, 3.64, 3.46 and 3.20 lph for the lateral lengths of 25, 50, 75 and 100 m, respectively.

5.1.2.1.2 Strip tape system

The decrease in the discharge per metre length of the strip tape was found in the range of 9.48 to 11.33 per cent when the lateral length was increased from 25 to 100 m and the pressure was 0.5 to 1.5 kg/cm^2. The average 'Q' at recommended pressure i.e. 0.75 kg/cm^2 was 3.73, 3.66, 3.52 and 3.29 lph/m for the lateral lengths of 25, 50, 75 and 100 m, respectively.

5.1.2.1.3 Microsprinkler system

As the length of lateral increased from 25 to 100 m, the decrease in the microsprinkler discharge was noticed in the range 44.09 to 49.09 % when the pressure was 1.0 to 2.25 kg/cm^2. The average discharge at recommended pressure was 32.70, 25.79, 21.45 and 17.31 lph for the lateral lengths of 25, 50, 75 and 100 m, respectively.

5.1.2.2 Emission uniformity

The field and absolute emission uniformities of the systems were determined for different lateral lengths as well as for the operating pressures. The field EU was on lower side as compared to absolute EU.

5.1.2.2.1 Dripper system

The EU of dripper system was found in the range of 89.4 to 92.8, 87.0 to 92.1, 84.3 to 91.9 and 85.1 to 91.8 %, respectively for 25, 50, 75 and 100 m lengths of lateral.

5.1.2.2.2 Strip tape system

Both the EU values in strip tape system were observed in the range of 94.7 to 97.8, 95.4 to 97.2, 93.6 to 97.8 and 92.9 to 96.6 %, respectively for the lengths of 25, 50, 75 and 100 m. It was also noticed that the EU values was not differed much due to change in the operating pressure. As the EU values are excellent (> 90 %), more than 100 m lengths of strip tape can be used at recommended pressure 0.75 kg/cm^2.

5.1.2.2.3 Microsprinkler system

The field and absolute EU values of the microsprinkler system were in the range of 88.8 to 90.2, 86.0 to 89.6, 74.3 to 80.9 and 61.1 to 76.0 % for the lateral lengths of 25, 50, 75 and 100 m, respectively. It was noticed that lesser the lateral length, more the EU.

5.1.2.3 Uniformity coefficient

The uniformity coefficient of microsprinkler system was found in the range 88.05 to 96.33% indicating that the application of water was excellent as UC exceeded 85 % (Michael,1978). The UC was decreased with the increase in the lateral length.

5.1.2.4 Lateral head loss

The data collected indicated that the per cent head loss in lateral increased with increase in pressure as well as the length of the lateral.

5.1.2.4.1 Dripper system

The head loss (H_L) in lateral in drip system was increased from 5.0 to 10.9, 12.0 to 17.1, 19.8 to 29.4 and 32.0 to 45.1 %, respectively for 25, 50, 75 and 100 m lateral lengths when the pressure was increased from 0.5 to 1.75 kg/cm^2. The average H at recommended pressure 1 kg/cm^2 was 6.5, 13.5, 23.0 and 36.0 %, respectively for the lateral lengths of 25, 50, 75 and 100 m.

The maximum lateral length of 37 and 67 m at 1 kg/cm^2 pressure could be used in the field considering 10 and 20 % permissible head loss in the lateral.

5.1.2.4.2 Strip tape system

The lateral head loss in strip tape was increased from 0.0 to 2.3, 2.8 to 6.7, 7.2 to 11.5 and 13.6 to 17.3 % for the lateral lengths of 25, 50, 75 and 100 m, respectively when the pressure was increased from 0.5 to 1.5 kg/cm^2. The average H at 0.75 kg/cm^2 was 1.3, 4.0, 8.3 and 14.7 % for the lateral lengths of 25, 50, 75 and 100 m, respectively. Considering 10 % head loss in lateral, the maximum length of strip tape could be used upto 82 m. The maximum length of strip tape more than 100 m could be used considering 20 % head loss in the lateral.

5.1.2.4.3 Microsprinkler system

The head loss was found increased from 8.0 to 28.0, 33.0 to 53.3, 59.0 to 72.9 and 77.0 to 84.5 %, respectively for the lateral of 25, 50, 75 and 100 m length when the pressure was increased from 1.0 to 2.25 kg/cm^2. The average H at 1.50 kg/cm^2 was 14.7, 40.7, 65.3 and 80.0 % for the lateral of 25, 50, 75 and 100 m, respectively. In microsprinkler system, the maximum lateral length of 30 m could be used at 1.5 kg/cm^2 pressure considering 20 % permissible H_L.

5.1.3 Moisture distribution pattern

The moisture distribution in the soil was studied under different set of conditions of discharge rate (Q), water volumes (V) and time interval (t) under point source application (dripper system), line source application (strip tape system) and microsprinkler system. The moisture distribution pattern was differed to the greater extent due to different mode of water application and as it is a function of Q, V and t.

5.1.3.1 Dripper system

The moisture pattern was studied for emitter discharge 3, 4 and 5 lph; water volumes 5, 10 and 15 lit and time interval 0, 24 and 48 hr. The maximum radial spread was ranged from 12.2 to 23.3, 12.8 to 25.5 and 14.5 to 33.7 cm, respectively for 3, 4 and 5 lph discharge when the volume was increased from 5 to 10 lit of water in 48 hr. The maximum vertical advance was 39.5 to 58.0, 30.0 to 49.0 and 26.0 to 41.0 cm, respectively for emitter discharge of 3, 4 and 5 lph when the volume was increased from 5 to 15 lit of water in 48 hr.

It was also found that as the 'Q' increased, the maximum radial spread from emitter increased and vertical advance decreased, at constant volume of water and elapsed time.

The following correlation was developed between emitter discharge (Q) in lph, volume of water(V) in lit and maximum vertical advance (Va) in cm at 0, 24 and 48 hr.

$$Va = A + B_1Q + B_2V + C_1Q^2 + C_2QV + C_3V^2 \qquad \ldots(5.2)$$

in which,

A, B_1, B_2, C_1 to C_3 are constants.

Similarly, the correlation between volume of water (V) in lit, depth of soil (d) in cm and radial spread of wetting front (Rs) in cm was developed for 0, 24 and 48 hr.

$$Rs = A' + B_1'V + B_2'd + C_1'V^2 + C_2'Vd + C_3'd^2 + D_1'V^3 + D_2'V^2d + D_3'Vd^2 + D_4'd^3 \qquad \ldots(5.3)$$

in which,

A', B_1', B_2, C_1' to C_3' and D_1' to D_4' are constants.

5.1.3.2. Strip tape system

The moisture distribution pattern was studied for the discharge of 2, 3 and 4 lph/m; water volumes 3, 5 and 10 lit for 2 lph/m discharge and 5, 10 and 15 lit for 3 and 4 lph/m each; and time interval 0, 24 and 48 hr.

The maximum radial spread was 6.0 to 12.2, 10.5 to 16.0 and 12.3 to 18.2 cm for the discharge rates of 2, 3 and 4 lph/m, respectively for aforesaid respective volume of water in 48 hr. The maximum vertical advance was 32.0 to 39.5, 26.0 to 35.0 and 21.5 to 31.0 cm for discharge rates of 2, 3 and 4 lph/m, respectively for aforesaid respective volumes of water in 48 hr.

It was also found that as the `Q' increased, the maximum radial spread from emitter increased and vertical advance decreased, at constant volume of water and elapsed time.

The similar correlations as that of dripper system were also developed for the strip tape system in determining the vertical advance and radial spread of wetting front.

5.1.3.3 Microsprinkler system

The moisture distribution pattern was studied for the emitter discharge 30, 35 and 40 lph; water volumes 40, 60 and 80 lit and time interval 0, 24 and 48 hr. The vertical advance was 30.6 to 43.1, 29.6 to 41.99 and 27.3 to 40.5 cm for the discharge rates of 30, 35 and 40 lph discharge when the volume was increased from 40 to 80 lit of water in 48 hr.

It was found that as the 'Q' increased, the vertical advance decreased, at constant volume of water and elapsed time.

For vertical advance of wetting front, the similar correlation as that of vertical advance in dripper system (eq. 5.2) was developed.

5.1.4 Salt distribution studies

The distribution of salt under dripper, strip tape and microsprinkler emitters was studied in chill crop at the time interval of one month. It was observed that the salt distribution under these micro-irrigation systems was differed considerably due to its different mode of water application.

5.1.4.1 Dripper system

It was found that the salts were concentrated at the periphery of wetted soil on the soil surface. This concentration of salts was increased by 112.1 % at 30 cm from the emitter at 30th day. However, the salinity at 30 cm from dripper at soil surface was reduced by 31.52, 67.25 and 85.73 % after 60, 90 and 150 days, respectively. After 150 days the average concentration was reduced by 1.33, 0.42, 0.36 and 0.32 dS/m at 0, 15, 30 and 45 cm soil depths, respectively.

5.1.4.2 Strip tape system

It was found that the salts were concentrated at the edge of wetted soil strip on the soil surface. This concentration of salts was increased by 111.3 % at 30 cm from the strip tape at 30th day. However, the salinity at 30 cm form strip tape soil surface was reduced by 18.0, 33.8 and 87.84 % after 60, 90 and 150 days, respectively. After 150 days, the average salt concentration was reduced by 1.28, 0.27, 0.32 and 0.30 dS/m at 0, 15, 30 and 45 cm soil depths, respectively.

5.1.4.3 Microsprinkler system

It was observed that the salts have leached down to the greater extent below 45 cm over the period of 150 days. After 150 days, the salinity was reduced by 90.3, 69.5, 62.9 and 50.0 % at 0, 15, 30 and 45 cm soil depths, respectively.

5.2 Conclusions

The following conclusions could be drawn from the findings of the present study.

1. The discharge of emitter or per metre length of lateral tubing increased with increase in the pressure head at any length of lateral. The variation in discharge was more in microsprinkler and minimum in strip tape system.

2. The emission uniformity (EU) of strip tape system was better as compared to dripper and microsprinkler systems. The EU decreased considerably in microsprinkler and dripper system due to increase in the length of lateral as compared to strip tape system.

3. The average uniformity coefficient (UC) of microsprinkler was excellent (94.2 %) at 1.80 m x 1.80 m spacing. The UC decreased with increase in the lateral length.

4. The lateral head loss was maximum in microsprinkler system and drip system as compared to strip tape system.

5. The moisture distribution in these micro-irrigation system was different considerably due to change in the volume of water, discharge rate of emitter and also with elapsed time after irrigation.

6. In case of drip and strip tape system, with the increase in the discharge rate, the radial spread

of moisture from emitter increased and the vertical advance of moisture decreased in clay soil, at the constant volume of water and elapsed time.

7. In case of microsprinkler system, the vertical advance of wetting front reduced with the increase in discharge rate of emitter in clay soil, at constant volume of water and elapsed time after irrigation.

8. The salt distribution under different types of emitters differed considerably due to the different mode of water application i.e. point source, line source and sprinkle.

9. The salt was found concentrated at the periphery of wetted soil in drip system and at the edge of wetted strip of soil in strip tape system, at soil surface.

10. The salts were found leached more effectively below the root zone of chilli (i.e.45 cm) in microsprinkler system in 150 days. No salt accumulation was noticed on the soil surface in microsprinkler systems.

6. LITERATURE CITED

Alemi, M.H. 1981. Distribution of water and salt in soil under trickle and pot irrigation regime. Agril. Water Management.3: 195-203.

Aljibury, R.K. 1973. Drip irrigation practices and applications. The Citrus Industry magazine, 59: 10-12.

Anonymous, 1984. Moisture distribution in drip irrigation. Annual Report, co-ordinated Project for Research on Water Management, M.P.K.V.,Rahuri. PP.84.

Anonymous, 1989. Comparative study of drip, microsprinkler, bi-wall and Border irrigation on groundnut. Unpublished Report of Research Review Sub. Committee (IDE) M.P.K.V.,Rahuri (M.S.). PP. 17-20.

* Anonymous, 1992. Agricultural Statistics at a Glance. Pub. by Ministry of Agriculture (May, 1992).

Bar-Yosef, B. and Sheikholslami, M.R.1976. Distribution of water and ions in soils irrigated and fertilized from a trickle source. Soil.Sci.Soc. Amer.J. 40: 575-582.

Bernstein, L.and Francois, L.E.1973. Comparisons of drip, furrow and sprinkler irrigation. Soil Sci. 115[1]: 73-76.

Bezdek, J.C. and Soloman K. 1978. Approximating friction factors for trickle tubing. Pro. ASCE. 104(IR4): 351-59.

Bilanski, W.K. and Kiddler B.H. 1958. Factors that affect the distribution of water from a medium pressure rotary irrigation sprinkler. Trans. ASAE, 1(1): 19-23.

Bralts, V.P., J.Pai Wu and Gitlin. 1981. Manufacturing variation and drip irrigation uniformity. Trans. ASAE, 24(1): 113-119.

Bresler, E., J.Heller, N.Diner,Ben Asher and Goldberg, D. 1971. Infiltration from a trickle source. II Soil. Sci. Soc. Amer. 35: 683-689.

Bucks, B.M., O.F. French, F.S. Nakayama and Farngmeir,D.D. 1985. Trickle irrigation management for grape production. Drip/Trickle Irrigation In Action. Proc. of third intern. drip/trickle irrig. Congr. Nov,18-21.

Busch,C.D. and Kneebone, W.R. 1969. Subsurface irrigation with perforated plastic pipe. Trans.ASAE. 9(1): 100-101.

* Cho, T. and Yamato, T. 1973. Saline water irrigation of sand by trickle method. Sand Dune Research Japan. 29(1): 37-46.

Cole, T.E. 1971. Subsurface and trickle irrigation : a survey potential and problems. Oak Ridge National Lab., NDIC, ORNL-NDEE. PP. 65.

Cole, P.J. and Till, M.R. 1974. Response of mature citrus trees on deep sandy soils to drip irrigation. Proc.Second Intern. Drip Irrig. Congr. San Diego,California. 525 -526.

Dalton, S. and Haminson, P.E. 1971. Drip irrigation for citrus. Citrus and Vegetable Magazine. 34: 8.

Firake, N.N., P.S.Pampattiwar and Salunkhe,D.S. 1992a. effect of system variables on wetted area of soil in microsprinkler irrigation. J.IWRS. 12(1 and 2): 92-95.

Firake, N.N., P.S.Pampattiwar and Salunkhe,D.S. 1992b. Evaluation of hydraulic performance of a microsprinkler irrigation system. Indian J.Agril.Engg.I(2). PP. 141-144.

Firake, N.N., S.S. Magar and Salunkhe, D.S. 1993. Effect of uniformity coefficient of water application on spacing between microsprinklers in vegetables. Mah.J. Hort. 7(1). (Submitted).

* Ghazy, A., M.A.Wahab and Selim, A.M. 1992. A study on moisture and salt distribution versus soil conditioners under drip irrigation. Irrigation and Drainage Abstracts.18(3): 361.

Gibson, W.1976. Hydraulics, mechanics and economics of subsurface and drip irrigation of Hawaiian sugarcane. Intern. Sugar. J. (Feb):40-43.

Goel,A.K.,R.K. Gupta and R.Kumar. 1993. Effect of drip discharge rate on soil moisture distribution pattern. J. Water Management 1(1): 50-51.

Goldberg, S.D., B.Gornat and Bar-Yosef, B.1971. The distribution of roots, water and minerals as a results of trickle irrigation. J.Amer.Soc.Hort.Sci. 96(5): 645-648.

Goldberg, S.D., M.Rinot and Karu, N. 1971. Effect of trickle irrigation intervals on distribution and utilization of soil moisture in vineyard. Soil.Sci.Soc.Amer. Proc. 35: 127-130.

Gupta, R.K. and Tyagi, N.K. 1984. Studies of irrigation techniques for use of saline water, Annual Report, C.S.S.R.I.,Karnal. PP. 114-115.

Gustafson, C.D. 1971. Salinity and drip irrigation. Citrograph. 66: 31-33.

Gutal, G.B., A.A.Chougule and Kulkarni, P.V. 1988. Comparative study of drip and microsprinkler irrigation on groundnut. Annual Report Research Review Sub. Committee (IDE). PP. 15-21.

Hande, L.J. and Nongkynrich, M.B. 1989. Hydraulics of bi-wall irrigation. B.Tech.Thesis. M.P.K.V., Rahuri (M.S.).

* Hanson, G.R. 1973. Hydraulics of trickle irrigation emitter lines. M.S.Thesis, Utah State University, Logan.

Hiller, E.A. and Howell, T.A. 1978. Grain sorghum responses to trickle and subsurface irrigation. ASAE paper, 72-74.

James Hardie, 1984. Hardie Irrigation-Micro-irrigation Design Manual.

Jury, W.A. and Earl, K.D. 1977. Water movement in bare and cropped soil under isolated trickle emitters. Soil.Sci.Soc.Amer.J. 41: 852-861.

Karmarkar, S.V. 1985. Application of saline water through drip irrigation system for tomato (Lycopersicon esculentum) in black cotton soil [Vertisols].M.Sc.Agri. Thesis submitted to M.P.K.V.,Rahuri.

* Kaul, R.K. 1979. Hydraulics at moisture front advance in drip irrigation. Ph.D.Thesis submitted to IARI,New Delhi,India.

Keller, J. and Karmeli.1974. Trickle irrigation design parameters. Trans. ASAE. 17(4): 678-685.

Khepar, S.D., P.K. Neog and Kaushal, M.P. 1983. Moisture and salt distribution pattern under drip irrigation. Background papers. National seminar on drip irrigation. Tamilnadu Agril. Univ., Coimbatore.

Koo, R.C.J.and Smajstrla, A.G. 1985. Trickle irrigation of citrus on sandy loam soils in a humid region. Drip/Trickle Irrigation in Action.Proc.Third Intern. Drip/Trickle Irrig.Congr.ASAE, Michigan, U.S.A.-1, PP. 212-215.

* Kranjac, B.G. 1988. Salt distribution in soils a comparative study on the influence of salt on irrigation with saline water using drip and furrow irrigation. Irrig. and Drain. Abs.(No.2317). 17(3): 296.

Kulkarni, A.A. 1988. Response of pomogranate and lime to trickle irrigation. M.Tech.(Agril. Engg.) Thesis submitted to M.P.K.V., Rahuri.

Lagad, S.M. 1989. Emitter and lateral tubing hydraulics in trickle irrigation.M.Tech. Thesis submitted to M.P.K.V., Rahuri.

Levin, I.A. and Bravedo, R. 1979. Soil moisture and root distribution in an apple orchards irrigated by tricklers. Plant and Soil. 52(1): 31-40.

Michael, A. M. 1978. Irrigation Theory and Practice. Vikas Publishing House Private Limited, New Delhi,PP. 1-801.

Nakayama, F.S. and Bucks, D.A. 1979. Emitter discharge rate and uniformity in a simulated field situation. ASAE paper No. 79-2100. Presented at ASAE National Meeting during 1978-79.

Nehra, V.S., Jaspal Singh and Tyagi, N.K. 1991. Emperical studies of water and salt distribution pattern under trickle source. J.Ind.Water Reso.Soc.11(3): 37-40.

Pairs, C.H. 1968. Water distribution under sprinkler irrigation. Trans. ASAE II(5):648-651.

Patel, N.J., P.D. Wagh and S.H. Karande. 1988. Studies on Reclaimation of Sodic Soil. A B.Tech.

Thesis, Mahatma Phule Krishi Vidyapeeth, Rahuri.

Patel, N.M. and Aware, V.V. 1994. Field evaluation of hydraulics performance of canewall irrigation system in vertisols. B.Tech. Thesis, Mahatma Phule Krishi Vidyapeeth, Rahuri.

Pathare, S.B. 1993. Design of microsprinkler system based on non-uniformity in sprinkling. Unpublished M.Tech.(Agril. Engg.)Thesis submitted to M.P.K.V., Rahuri(M.S.).

Post, S.C., D.E.Peck, R.A.Brendler, N.J.Sakovich and Waddle L. 1986. Evaluation of low flow sprinkler. Irrig. J. California Agril. Univ. California July.Aug.1986.PP. 27-29.

Raats, P.A.C. 1972. Steady infiltration from sources at arbitrary depth. Soil.Sci.Soc.Amer. Proc. 36:399-401.

Rane, A.D. 1991. Studies on moisture distribution pattern under microtube and bi-wall irrigation systems. A B.Tech. Thesis, Mahatma Phule Krishi Vidyapeeth, Rahuri.

Reddy, S.E. and Rao, S.N. 1983. Response of bittergaurde to pitcher system of irrigation. South Indian Horticulture. 31(2): 117-120.

Rolland, 1972. An examination of trickle irrigation technique including their applications with water of different qualities. Irrigation and Drainage paper. No. 14: 13-15.

* Roth, R.L., D.R.Rodney and Gardner, B.R. 1978. Comparison of irrigation methods, root stocks and fertilizer elements on valencia orange trees. Proc.Second Intern. Drip Irrig. Congr. U.S.A. PP. 103-108.

Sakore, D.K. 1992. Hydraulics of microsprikler. Unpublished B.Tech.(Agril.Engg.). Thesis submitted to M.P.K.V.,Rahuri(M.S.).

Salih, R.O. 1985. Comparative studies on drip irrigation in Iraq. Drip/Trickle Irrigation in Action. Proc.of third Intern. drip/trickle irrig. congr. ASAE, Michigan. U.S.A.-1 PP.181-185.

Salunkhe, D.S. 1991. Studies on moisture distribution pattern in microsprinkler system.B.Tech.

(Agril. Engg.) Thesis submitted to M.P.K.V., Rahuri.

Satpute, G.V., P.D.Nikhade and Dane, A.T. 1992. Effect of dripper discharge rate and volume on soil moisture distribution pattern. PKV Res. J. 16(1): 88-92.

Seginer, I. 1963. Water distribution from a medium pressure spriklers. Proc.ASCE.J.Irrig. Drain.Div. 89(IR-II).PP. 13-29.

Seginer, I. 1969. Wind variation and sprikler water distribution. Proc. ASCE.J.Irrig. Drain. Div. 95: 261-274.

Sen, H.S. and Bandyopadhyay, B.K. 1985. Water and salt movement through soil under different irrigation and soil management practices. Annual Report. C.S.S.R.I. Karnal. PP. 128-130.

Sharma, J.S., V.P.Singh and Gill, H.S. 1987. Effect of quality of irrigation water in drip irrigated horticultral crops. Annual Report. C.S.S.R.I. Karnal. PP.48-49.

Sharma, A., A.K.Singh and Babel M.S. 1991. Salt distribution profile under drip irrigation with saline water.J.Ind.Water Reso.Soc.11(3): 51-53.

Shinde, U.R. and Darade, R.S. 1993. Field evaluation of hydraulic performance of static microsprinkler irrigation system. Unpublished B.Tech.(Agril. Engg.)Thesis submitted to M.P.K.V.,Rahuri(M.S.).

Shmueli,M. and Goldberg, D. 1971. Sprinkler, furrow and trickle irrigation of muskmelon in an arid zone. Hort.Sci. 6(6): 557-559.

Shrinivasan, T.R., Y.P. Bali and Temhane, R.V.1969. Placement of black soils of India in the comprehensive soil classification system. 7th approximation. J. Indian Soil Sci. 17: 323-333.

Singh, S.D., J.P.Gupta and Singh, P. 1978. Water economy and saline water use by drip irrigation. Agronomy J. 70(6): 948-951.

Singh, A.K. 1987. Hydraulics of trickle irrigation. Unpublished M.Tech.Thesis, M.P.K.V., Rahuri(M.S.).

Singh, R.K., A.D.Sulieman and Karim, L. 1989. Movement of salt and water under trickle irrigation and its field evaluation. J.Agril.Engg. ISAE. 26(1):49-51.

Singh,J., A.K.Singh, S.Jain, R.Garg and Mathur, J.N. 1990. Microsprinkler performance, evaluation and constraints for its adoption.Proc.XIth Intern.Congr. The use of plastics in Agriculture, New Delhi. PP. 79-91.

Sivanappan, R.K. and Chandrasekaran, D. 1976. Drip irrigation a novel method to save water. Irrigation and Power. 33(4): 495-501.

Sivanappan, R.K., V. Kumar, and Padmakumari, O.P. 1987 Drip Irrigation. Kirthi Publ. HOuse Pvt. Ltd., Trivendrum. (India). PP. 1-44.

Soloman, K. 1979. Manufacturing variation of trickle emitters.Trans. ASAE. 22(5): 11034-38.

Sonawane, B.V. 1983. Moisture distribution pattern and nitrogen fertilizer application in drip irrigation system for cotton [Gossypium hirsutum.L.] in black soil [Vertisols] M.Sc.Agri. Thesis submitted to M.P.K.V.,Rahuri.

Steve, S.M., J.Lin, N.Hubbell and Samson, C.S. 1983. Drip irrigation and tomato yield under tropical conditions. Hort.Sci. 18(4): 460-461.

Steven, L.R. and Rawlins, L. 1979. Maintaining salinity control under drip irrigation. Amer.Vegetable Grower. 27(5): 929-933.

Suruwatri, C.A. and Wu, J.P. 1982. Hydraulics of bi-wall drip irrigation laterals. Paper, ASAE (1982), No.82-2063, PP. 24.

Suryawanshi, S.N., M.M.Sawant and Dhotre, R.S. 1982. Effect of wind on sprinkler water distribution efficiency. Agresco Report. 1981-82.

Swaminathan, K.R. 1972. Drip irrigation system. Indian Farming. 22: 56-61.

Tscheschke, P., J.F.Alfaro, J.Keller and Hanks,R.J. 1974. Trickle irrigation soil water potential as influenced by management of highly saline water. Soil.Sci. 117(4): 226-231.

Vasanthakumar, G.K. 1984. Efficiency and adoption of drip irrigation for tomato. A Thesis submitted to the University of Agril. Sciences, Banglore.

Wu, J.P., and Gitlin, H.M. 1974. Drip Irrigation design based on uniformity. Trans. ASAE. 17(3): 429-432.

Zur, B. and Tal, S. 1981. Emitter discharge sensitivity to pressure and temperature. J.of the Irrigation and Drainage Div. Proceedings of the ASCE. 107(IR-1): 1-9.

* - Originals not seen.

APPENDIX - I (A)

Data regarding discharge, in lph, collected at different operating pressure for pressure-discharge study and emission uniformity calculations in dripper system

Sr. No.	Length of lateral, m	Pressure at manifold, kg/cm2	Lateral No.	Average discharges at different quarters of lateral: First quarter	Second quarter	Third quarter	Fourth quarter
1.	2.	3.	4.	5.	6.	7.	8.
1.	25	0.50	1	3.870	3.612	3.396	3.252
			2	3.810	3.540	3.348	3.216
			3	3.740	3.492	3.276	3.156
			4	3.690	3.432	3.240	3.018
		0.75	1	4.058	3.756	3.636	3.420
			2	3.990	3.696	3.552	3.372
			3	3.960	3.660	3.528	3.312
			4	3.920	3.576	3.468	3.264
		1.00	1	4.260	4.044	3.828	3.696
			2	4.210	4.008	3.768	3.648
			3	4.170	3.960	3.732	3.600
			4	4.140	3.900	3.672	3.540
		1.25	1	4.540	4.272	4.104	3.948
			2	4.470	4.200	4.044	3.876
			3	4.416	4.128	3.984	3.816
			4	4.380	4.080	3.924	3.756
		1.50	1	4.740	4.536	4.332	4.164
			2	4.680	4.644	4.284	4.092
			3	4.632	4.404	4.260	4.032
			4	4.572	4.356	4.212	3.972
		1.75	1	4.968	4.752	4.572	4.428
			2	4.920	4.716	4.512	4.356
			3	4.920	4.608	4.452	4.296
			4	4.848	4.572	4.404	4.260
2	50	0.50	1	3.612	3.420	3.120	2.952
			2	3.576	3.348	3.084	2.904
			3	3.540	3.288	3.048	2.844
			4	3.468	3.216	2.988	2.784
		0.75	1	3.840	3.672	3.420	2.156
			2	3.804	3.588	3.360	3.108
			3	3.720	3.492	3.324	3.072
			4	3.696	3.480	3.288	3.024
		1.00	1	4.044	3.804	3.660	3.384
			2	3.972	3.756	3.564	3.360
			3	3.936	3.732	3.492	3.300
			4	3.864	3.648	3.456	3.240
		1.25	1	4.296	4.044	3.792	3.612
			2	4.224	3.996	3.732	3.552
			3	4.152	3.972	3.684	3.504
			4	4.104	3.888	3.672	3.456
		1.50	1	4.524	4.296	4.056	3.888
			2	4.416	4.236	3.996	3.804

1.	2.	3.	4.	5.	6.	7.	8.
			3	4.380	4.464	3.960	3.744
			4	4.320	4.104	3.924	3.708
		1.75	1	4.668	4.464	4.308	4.092
			2	4.620	4.380	4.224	4.044
			3	4.584	4.332	4.176	3.972
			4	4.500	4.332	4.080	3.936
3.	75	0.50	1	3.420	3.120	2.820	2.568
			2	3.480	3.072	2.724	2.520
			3	3.336	3.024	2.712	2.508
			4	3.300	2.952	2.664	2.460
		0.75	1	3.660	3.408	3.156	3.024
			2	3.576	3.348	3.108	2.952
			3	3.552	3.276	3.096	2.880
			4	3.492	3.240	3.012	2.856
		1.00	1	3.864	3.636	3.408	3.192
			2	3.816	3.540	3.300	3.144
			3	3.900	3.570	3.264	3.096
			4	3.780	3.600	3.228	3.072
		1.25	1	4.080	3.660	3.480	3.420
			2	3.984	3.840	3.600	3.372
			3	4.044	3.744	3.516	3.264
			4	4.080	3.720	3.456	3.252
		1.50	1	4.260	3.996	3.744	3.576
			2	4.176	3.960	3.726	3.516
			3	4.140	3.840	3.660	3.456
			4	4.212	3.816	3.636	3.396
		1.75	1	4.440	4.200	4.008	3.948
			2	4.392	4.140	3.960	3.888
			3	4.368	4.092	3.912	3.816
			4	4.332	4.020	3.852	3.732
4.	100	0.50	1	3.060	2.868	2.640	2.436
			2	3.024	2.820	2.616	2.388
			3	2.964	2.772	2.544	2.340
			4	2.880	2.712	2.520	2.280
		0.75	1	3.312	3.132	2.940	2.784
			2	3.288	3.060	2.880	2.700
			3	3.228	3.024	2.796	2.676
			4	3.192	2.976	2.760	2.542
		1.00	1	3.600	3.372	3.144	2.940
			2	3.576	3.336	3.084	2.880
			3	3.564	3.288	3.012	2.880
			4	3.540	3.228	2.988	2.820
		1.25	1	3.888	3.660	3.468	3.420
			2	3.840	3.612	3.420	3.168
			3	3.792	3.576	3.336	3.096
			4	3.732	3.552	3.300	3.072
		1.50	1	4.080	3.816	3.600	3.432
			2	4.044	3.744	3.564	3.384
			3	3.984	3.672	3.492	3.336
			4	3.936	3.612	3.432	3.276
		1.75	1	4.308	4.092	3.888	3.720
			2	4.260	4.020	3.852	3.672
			3	4.212	4.008	3.804	3.660
			4	4.164	3.936	3.732	3.612

APPENDIX - I (B)

Data regarding discharge, in lph/m, collected at different operating pressure for pressure-discharge study and emission uniformity calculations in strip tape system

Sr. No.	Length of lateral, m	Pressure at manifold, kg/cm2	Lateral No.	Average discharges at different quarters of lateral			
				First quarter	Second quarter	Third quarter	Fourth quarter
1.	2.	3.	4.	5.	6.	7.	8.
1.	25	0.50	1	2.793	2.877	2.940	2.835
			2	2.835	3.003	3.045	2.835
			3	2.961	2.856	2.835	2.940
			4	2.898	2.898	2.772	2.793
		0.75	1	3.528	3.576	3.570	3.381
			2	3.528	3.528	3.570	3.423
			3	3.486	3.444	3.486	3.486
			4	3.465	3.339	3.444	3.465
		1.00	1	3.801	3.654	3.738	3.643
			2	3.081	3.738	3.696	3.759
			3	3.696	3.780	3.696	3.822
			4	3.948	3.759	3.717	3.696
		1.25	1	3.948	3.822	3.927	3.884
			2	3.927	3.906	3.927	3.864
			3	3.927	3.906	3.822	3.780
			4	3.864	3.885	3.885	3.969
		1.50	1	3.990	4.200	4.032	3.990
			2	3.990	4.158	4.116	3.927
			3	4.095	4.158	4.116	3.990
			4	4.158	4.032	3.990	4.011
2	50	0.50	1	2.688	2.688	2.667	2.625
			2	2.730	2.730	2.835	2.772
			3	2.835	2.877	2.646	2.772
			4	2.751	2.793	2.835	2.793
		0.75	1	3.360	3.423	3.276	3.360
			2	3.465	3.318	3.402	3.360
			3	3.402	3.444	3.465	3.465
			4	3.297	3.402	3.381	3.318
		1.00	1	3.738	3.717	3.759	3.738
			2	3.549	3.528	3.696	3.675
			3	3.738	3.780	3.675	3.654
			4	3.633	3.612	3.612	3.591
		1.25	1	3.654	3.801	3.885	3.864
			2	3.654	3.801	3.882	3.780
			3	3.948	3.696	3.780	3.717
			4	3.927	3.864	3.717	3.948
		1.50	1	4.095	3.990	3.759	3.927
			2	3.843	3.927	3.948	2.822
			3	3.885	3.885	3.927	3.927
			4	3.948	3.864	3.927	3.864
3.	75	0.50	1	2.730	2.688	2.730	2.562
			2	2.625	2.604	2.625	2.688
			3	2.730	2.478	2.520	2.499

1.	2.	3.	4.	5.	6.	7.	8.
			4	2.730	2.751	2.688	2.730
		0.75	1	3.318	3.255	3.213	3.297
			2	3.234	3.255	3.150	3.171
			3	3.234	3.276	3.360	3.276
			4	3.255	3.318	3.297	3.234
		1.00	1	3.654	3.570	3.360	3.528
			2	3.633	3.570	3.423	3.570
			3	3.654	3.618	3.444	3.612
			4	3.528	3.486	3.444	3.570
		1.25	1	3.759	3.780	3.717	3.738
			2	3.696	3.780	3.696	3.675
			3	3.675	3.696	3.696	3.675
			4	3.612	3.696	3.528	3.612
		1.50	1	3.780	3.885	3.801	3.843
			2	3.822	3.822	3.780	3.780
			3	3.759	3.780	3.738	3.780
			4	3.717	3.780	3.696	3.738
4.	100	0.50	1	2.772	2.520	2.562	2.520
			2	2.646	2.688	2.478	2.415
			3	2.730	2.478	2.520	2.499
			4	2.730	2.667	2.520	2.499
		0.75	1	2.961	3.255	2.982	3.108
			2	3.150	3.150	3.150	3.192
			3	3.245	3.255	3.255	3.150
			4	3.150	3.150	3.171	3.087
		1.00	1	3.276	3.234	3.360	3.255
			2	3.402	3.360	3.360	3.339
			3	3.465	3.423	3.465	3.444
			4	3.381	3.255	3.318	3.276
		1.25	1	3.402	3.360	3.255	3.255
			2	3.570	3.528	3.444	3.465
			3	3.675	3.633	3.612	3.570
			4	3.591	3.633	3.507	3.570
		1.50	1	3.738	3.675	3.633	3.633
			2	3.759	3.675	3.528	3.654
			3	3.570	3.570	3.528	3.549
			4	3.465	3.654	3.465	3.570

APPENDIX - I (C)

Data regarding discharge, in lph, collected at different operating pressure for pressure-discharge study and emission uniformity calculations in microsprinkler system

Sr. No.	Length of lateral, m	Pressure at manifold, kg/cm2	Lateral No.	Average discharges at different quarters of lateral: First quarter	Second quarter	Third quarter	Fourth quarter
1.	2.	3.	4.	5.	6.	7.	8.
1.	25	1.00	1	32.94	31.53	29.88	28.62
			2	33.78	30.87	28.92	28.05
			3	32.46	31.23	29.22	26.60
			4	34.32	30.60	28.02	26.88
		1.25	1	34.71	32.16	30.06	29.64
			2	35.28	32.79	30.69	28.74
			3	34.35	31.71	29.61	29.13
			4	35.76	33.48	31.38	28.26
		1.50	1	36.00	33.07	32.10	30.42
			2	36.27	33.72	30.90	29.55
			3	35.61	62.64	30.93	29.91
			4	36.78	34.41	31.77	29.19
		1.75	1	36.63	33.84	31.86	31.38
			2	36.24	34.47	32.49	30.87
			3	37.65	33.39	31.41	30.36
			4	37.02	35.16	33.18	29.97
		2.00	1	36.90	34.50	32.49	31.95
			2	37.53	35.13	33.12	31.62
			3	34.45	34.05	32.04	30.96
			4	38.22	35.82	33.81	30.57
		2.25	1	37.26	35.01	32.97	32.55
			2	37.89	35.64	33.60	31.98
			3	36.81	34.56	32.52	31.62
			4	38.58	36.33	34.29	31.11
2	50	1.00	1	25.92	23.76	22.11	20.52
			2	27.42	24.27	22.62	21.14
			3	26.73	24.27	23.16	22.14
			4	26.82	25.11	23.70	20.94
		1.25	1	28.65	24.90	24.15	22.80
			2	27.69	24.75	23.46	22.26
			3	27.90	26.37	23.73	22.38
			4	27.27	25.77	23.16	21.66
		1.50	1	29.49	25.59	24.03	23.76
			2	28.50	27.15	25.05	23.07
			3	28.83	26.40	24.51	23.37
			4	28.29	26.55	25.35	22.80
		1.75	1	30.30	27.96	25.05	24.93
			2	29.34	27.03	24.81	24.51
			3	29.73	24.81	26.61	23.67
			4	29.10	26.58	25.92	24.06
		2.00	1	30.54	28.53	25.29	25.44

1.	2.	3.	4.	5.	6.	7.	8.
			2	29.61	27.69	26.85	22.02
			3	29.94	27.81	26.10	24.18
		2.25	4	29.34	27.27	26.25	24.57
			1	31.17	29.16	25.95	26.31
			2	30.30	28.20	27.42	25.59
			3	30.54	28.56	26.64	25.02
		1.00	4	30.06	27.63	26.94	24.78
3	75		1	24.15	19.83	17.73	15.30
			2	23.25	20.40	17.55	15.15
			3	23.70	20.64	16.89	14.85
		1.25	4	24.75	19.29	16.14	14.10
			1	23.85	21.30	18.66	16.74
			2	25.80	22.50	19.26	16.20
			3	25.50	22.35	17.40	15.60
		1.50	4	25.29	20.85	18.00	15.15
			1	27.00	23.55	20.40	17.79
			2	26.46	23.25	19.56	17.46
			3	25.74	22.83	19.29	16.86
		1.75	4	25.35	22.50	18.90	16.14
			1	26.25	24.18	20.52	18.54
			2	26.79	23.25	21.09	18.21
			3	27.03	23.26	21.33	17.61
		2.00	4	27.90	24.78	19.98	16.89
			1	27.09	23.94	21.15	19.02
			2	27.63	25.26	20.70	19.62
			3	27.87	25.68	22.71	17.76
		2.25	4	28.74	24.72	22.14	18.36
			1	27.57	25.20	21.66	20.37
			2	28.11	25.65	23.04	19.53
			3	28.35	25.50	22.77	19.26
		1.00	4	29.22	24.60	21.33	18.87
4.	100		1	18.90	16.50	14.16	12.00
			2	21.00	18.15	13.23	11.85
			3	19.80	17.55	13.23	11.85
		1.25	4	22.20	15.30	12.75	10.50
			1	20.85	17.70	14.04	13.05
			2	22.50	16.35	14.61	12.39
			3	20.40	17.10	15.36	11.61
		1.50	4	21.66	17.40	13.80	10.77
			1	23.58	17.40	16.35	13.20
			2	22.92	19.95	15.60	12.54
			3	20.40	18.60	14.70	11.79
		1.75	4	21.48	19.35	15.30	11.64
			1	22.68	20.25	17.61	13.98
			2	23.13	18.90	17.01	13.68
			3	23.49	17.70	15.96	12.99
		2.00	4	24.15	19.65	14.74	12.51
			1	23.16	20.85	16.41	14.85
			2	23.61	19.50	18.06	14.31
			3	24.03	18.30	17.46	15.45
		2.25	4	24.63	20.25	15.21	13.23
			1	23.52	18.75	18.00	16.14
			2	23.97	20.85	16.65	15.66
			3	24.39	19.65	17.40	15.00
			4	24.99	22.05	17.70	14.25

APPENDIX-II(A)

Depth of water collected at the head of lateral for computation of uniformity coefficient in microsprinkler irrigation system

Test No.	Distance from microsprinkler, cm	0	30	60	90	120	150	180
1.	0	-	6.63	6.13	6.54	6.34	6.90	-
	30	6.56	7.73	7.47	7.01	7.40	7.53	6.24
	60	6.32	7.47	7.27	6.56	6.88	7.21	6.61
	90	6.18	7.34	7.07	6.56	6.82	7.07	5.57
	120	6.83	7.59	7.21	6.95	6.82	6.95	6.05
	150	6.76	7.79	7.34	7.14	7.01	7.21	6.71
	180	-	6.03	5.56	6.82	6.55	6.79	-
2.	0	-	7.02	6.87	6.68	6.41	7.12	-
	30	6.46	6.49	6.17	6.10	6.62	7.14	7.22
	60	6.86	6.30	5.71	5.91	6.36	6.82	6.78
	90	7.26	6.04	5.52	5.39	5.84	6.36	5.75
	120	6.99	6.17	5.45	5.78	5.91	6.56	6.14
	150	6.85	6.43	6.23	6.04	6.49	7.01	7.56
	180	-	6.57	5.36	6.23	6.93	7.32	-
3.	0	-	6.92	6.09	6.48	5.77	5.91	-
	30	6.17	6.36	6.36	6.17	6.69	7.01	6.32
	60	6.73	6.23	5.84	5.78	6.88	6.17	6.18
	90	5.84	5.91	5.71	5.84	5.65	5.97	5.93
	120	5.67	6.04	6.04	5.52	5.84	6.30	5.46
	150	6.01	6.17	6.10	6.23	6.43	6.62	6.32
	180	-	6.44	6.13	5.69	5.40	6.48	-

APPENDIX-II(B)

Depth of water collected at the middle of lateral for computation of uniformity coefficient in microsprinkler irrigation system

Test No.	Distance from microsprinkler, cm	0	30	60	90	120	150	180
1.	0	-	7.81	7.65	6.43	6.30	6.12	-
	30	7.21	7.99	7.53	7.01	7.14	7.34	7.67
	60	6.58	7.79	7.21	6.69	6.82	7.07	7.40
	90	6.91	7.47	6.75	6.56	6.69	6.75	6.04
	120	6.69	7.86	7.53	7.07	7.01	7.21	6.38
	150	7.87	7.47	7.34	7.14	7.34	7.59	7.46
	180	-	7.22	6.41	6.22	6.19	7.01	-
2.	0	-	5.98	6.16	5.28	6.78	6.02	-
	30	6.52	5.97	5.91	5.84	5.65	5.58	6.03
	60	6.11	5.84	5.65	5.52	5.31	5.25	5.92
	90	5.88	5.45	4.48	4.41	4.74	4.87	6.32
	120	6.90	5.00	4.74	4.54	5.00	5.19	5.89
	150	6.49	5.06	4.87	4.61	5.06	5.39	6.44
	180	-	6.87	6.09	5.74	5.52	6.02	-
3.	0	-	6.43	5.40	5.21	6.67	6.91	-
	30	6.38	6.88	6.56	6.36	7.01	7.66	6.52
	60	5.89	6.49	6.43	6.17	7.07	7.34	5.71
	90	5.33	6.30	6.04	5.91	6.69	7.14	5.75
	120	6.97	6.82	6.95	6.56	7.21	7.53	6.14
	150	6.33	7.14	6.88	6.69	7.34	7.86	6.96
	180	-	6.63	5.94	5.57	6.91	7.24	-

APPENDIX-II(C)

Depth of water collected at the tail of lateral for computation of uniformity coefficient in microsprinkler irrigation system

Test No.	Distance from microsprinkler, cm	0	30	60	90	120	150	180
1.	0	-	5.84	5.75	5.04	5.26	5.33	-
	30	5.81	7.14	6.95	6.17	6.36	6.75	5.33
	60	5.27	6.82	6.56	5.84	6.04	6.56	5.77
	90	5.51	6.36	6.23	5.71	5.91	6.43	5.20
	120	5.08	7.01	6.82	6.49	7.07	7.21	5.53
	150	5.36	7.47	7.34	7.14	7.34	7.59	5.94
	180	-	5.14	5.41	5.26	5.65	5.31	-
2.	0	-	7.33	7.18	6.07	5.73	7.05	-
	30	7.48	6.04	5.52	5.31	5.91	6.30	6.69
	60	7.16	5.31	5.39	4.93	5.31	5.65	6.58
	90	5.88	5.25	5.06	4.35	5.19	5.31	5.86
	120	6.18	5.78	5.84	4.80	5.45	5.71	5.31
	150	7.12	6.43	6.10	5.45	5.65	5.84	6.90
	180	-	7.31	6.15	5.04	6.92	7.42	-
3.	0	-	7.83	6.15	6.76	5.98	7.32	-
	30	7.25	5.58	4.80	4.61	4.87	5.31	6.61
	60	6.19	5.00	4.48	4.35	4.93	5.00	6.40
	90	7.91	4.54	4.15	3.96	4.41	4.87	5.57
	120	6.96	4.80	4.28	4.41	4.93	5.19	6.70
	150	7.67	5.19	4.61	4.74	4.87	5.45	7.12
	180	-	6.94	6.31	5.95	6.61	7.35	-

VITA

KAILAS TUKARAM KADLAG
A candidate for the degree
of
MASTER OF TECHNOLOGY (AGRICULTURAL ENGINEERING)
in
IRRIGATION AND DRAINAGE ENGINEERING
1995

Title of Thesis	:	Moisture and salinity status under micro-irrigation stystems in vertisols
Major Field	:	Irrigation and Drainage Engineering

Biographical information :

i) Personal	:	Born at Kolhar Bk., Tal. Shrirampur, Dist. Ahmednagar on April 3rd, 1971. Son of Shri. Tukaram Shankar Kadlag.
ii) Educational	:	Attended Primary School at Pravaranagar, Secondary School at Sahyadri High School at Sangamner and Mahatma Gandhi Vidyalaya, Pravaranagar, Dist. Ahmednagar and Higher Secondary School at Mahatma Gandhi Vidyalaya and Junior College Pravaranagar, Dist.Ahmednagar. Received the Bachelor of Technology (Agril. Engg.) degree in First Class in 1992 from College of Agricultural Engineering, Mahatma Phule Krishi Vidyapeet Rahuri- 413 722, Dist. Ahmednagar. Recipient of the Gold Medal from Indian Society of Agricultural Engineers (ISAE) New Delhi for acheiving first rank in B.Tech. degree level for the year 1991-92. Recipient of the Gold Medal from Diama for securing highest C.G.P.A. in B.Tech. Course, 1991-92