EFFECT OF DIFFERENT IRRIGATION FREQUENCIES ON YIELD OF GARLIC (*Allium sativam* L) UNDER MICRO-SPRINKLER IRRIGATION SYSTEM

A thesis
Submitted to the

MAHATMA PHULE KRISHI VIDYAPEETH, RAHURI – 413722, DIST. AHMEDNAGAR, MAHARASHTRA, INDIA

In partial fulfillment of the requirements for the degree

of

MASTER OF TECHNOLOGY
(AGRICULTURAL ENGINEERING)

in

IRRIGATION AND DRAINAGE ENGINEERING

by

GANESH KISANRAO SHETE
B.Tech. (Agril. Engg.)

DEPARTMENT OF IRRIGATION AND DRAINAGE ENGINEERING
DR.ANNASAHEB SHINDE COLLEGE OF AGRICULTURAL ENGINEERING
MAHATMA PHULE KRISHI VIDYAPEETH, RAHURI (413722)
DIST. AHMEDNAGAR, M. S. (INDIA)

2003

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Approved by

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2003

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

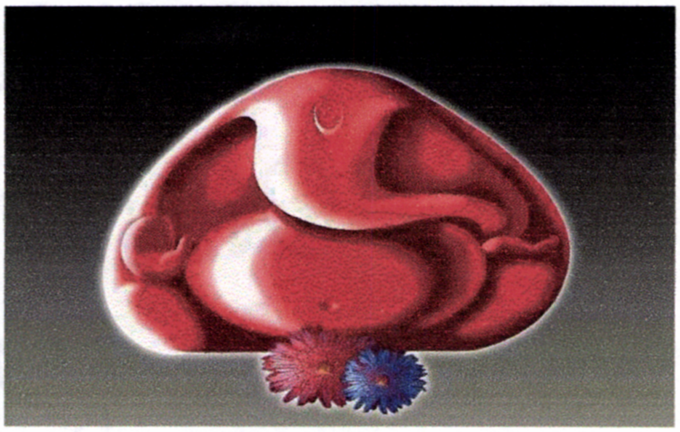
Degree or

Diploma.

Place : MPKV, Rahuri

Dated : / / 2003

(Shete G.K.)



DEDICATION

Affectionately Dedicated to

My Beloved Parents

and Guide

GANESH

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CERTIFICATE

This is to certify that the thesis entitled **"EFFECT OF DIFFERENT IRRIGATION FREQUENCIES ON YIELD OF GARLIC** (*Allium sativam* L.) **UNDER MICRO-SPRINKLER IRRIGATION SYSTEM** ", submitted to the faculty of Agricultural Engineering, Mahatma Phule Krishi Vidyapeeth, Rahuri, Dist. Ahmednagar (M.S.) in partial fulfillment of the requirement for the award of the degree of **MASTER OF TECHNOLOGY (AGRICULTURAL ENGINEERING) in IRRIGATION AND DRAINAGE ENGINEERING** embodies the results of *bonafide* research work carried out by Shri. Ganesh K. Shete under my guidance and supervision.

The results embodies in this thesis have not been submitted to any other university or institute for the award of Degree or Diploma.

The assistance and help received during the course of this investigation has been duly acknowledged.

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Place : MPKV, Rahuri

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ACKNOWLEDGEMENT

Knowledge can not be acquired without the help of an able and experienced 'Guruvarya'. Although the words hardly suffice at this moment, I avail this opportunity to express out deep sense of gratitude and indebtedness to my research guide Prof. V. S. Kadam, Associate Professor of Agricultural Engineering, Irrigation and Drainage Engineering Department, MPKV, Rahuri for his valuable inspiration, sincere extortion, scholastic guidance, generous treatment and constant encouragement through out this project work and help in the final shaping of this manuscript in the present form.

I am extremely grateful to Dr. H.G.More, Dean, Faculty of Agricultural Engineering, MPKV, Rahuri for the encouragement and providing facilities for the study.

I owe my heartiest thanks to Dr.R.S.Dhotre, Head, Department of Irrigation and Drainage Engineering, Faculty of Agricultural Engineering, MPKV, Rahuri for his valuable co-operation and guidance.

I wish to express my profound sense of gratitude to Prof. P. S. Pampattiwar, ex-Dean, College of Agricultural Engineering, MPKV, Rahuri, Dr. S. D. Gorantiwar, Associate Professor of Agricultural Engineering and Dr. S. N. Ambad, Assistant Professor, Plasticulture Development Centre, MPKV, Rahuri the members of my advisory committee for their valuable and versatile guidance during this project work.

I am indebted Indian Council of Agricultural Research, New Delhi who sponsored the Ad-hoc Project on "Study on Commercial Micro-sprinkler an their application to improve the productivity of Garlic and Onion" which allowed me to work. My profound thanks to Shri. S. A. Kadam, Research Associate working in the said ad-hoc project and Shri. S. R. Shelke for their timely help and co-operation during *the study period.*

My sincere thanks to Shri. N. T. Shelke and Shri. Kolge, Agriculture Assistants of Department of Irrigation and Drainage Engineering for their timely assistance and help whenever required.

I also express my sincere thanks to Shri. Gade Patil, Sangita Tai and other staff members, Deptt. of IDE, for their timely help and co-operation during study period.

I fall short of words in expressing my thanks to my dear friends Sanjay, Dnaynesh, Bhaskar, Vinayak, Gajaya, Pradeep, Rahul, Vishwas, Parish and 97 batch mates and all B. Tech and M. Tech friends for the constant encouragement and help during my project work.

While travelling on this path of education many bonds pushed me forth and lips but elixir in my under heart. I am very much thankful to my senior friend Ramchandra, Rahul, Sachin, Namdev, Dagadu, Shrimant, Uttam, Gajanan, Milind and all who encouraged me.

Finally, I wish to thank and express my deep respect to my beloved parents for their constant inspiration and guidance. No amount of words enough to describe their efforts in building up my education carrier and my all-round development.

Place : MPKV, Rahuri

Dated : / / 2003

(Shete G. K.)

CONTENTS

Contents contd...

Contents contd...

Contents contd...

Contents contd...

LIST OF TABLES

(List of Table Contd...)

LIST OF FIGURES

LIST OF PLATES

LIST OF SYMBOLS

Abst.	:	Abstract
Agric.	:	Agricultural
Agril.	:	Agriculture
ASAE	:	American society of Agril. Engineers
Ave	:	Average
CD	:	Critical difference
Conf.	:	Conference
CPE	:	Cumulative pan evaporation
D	:	Wetted throw diameter
DAS	:	Days after sowing
DF	:	Drying factor
Drai	:	Drainage
Edn.	:	Education
Engg.	:	Engineering
Dp	:	Depletion level, per cent
PE	:	Pan evaporation
ETc	:	Evapotranspiration of crop
F	:	Pan factor
FC	:	Field capacity
PWP	:	Permanent wilting point
ASM	:	Available soil moisture
Fig.	:	Figure
GI	:	Galvanized iron
h	:	Stake height
Hort.	:	Horticultural
ICAR	:	Indian council of Agricultural Research
Inter	:	International
Govt.	:	Government
IDE	:	Irrigation and Drainage Engineering
Irri.	:	Irrigation
WR	:	Water requirement
WUE	:	Water use efficiency
J	:	Journal
LDPE	:	Low Density Polyethylene
M. S.	:	Maharashtra
M/s	:	Messieurs

List of Symbols Contd..

BBF	:	Broad base furrows
MPKV	:	Mahatma Phule Krishi Vidyapeeth
N	:	North
pp	:	Pages
PR	:	Percentage reduction
Proc.	:	Proceeding
Q	:	Discharge
Res.	:	Research
Sci.	:	Science
SE	:	Standard error
Soc.	:	Society
Tech.	:	Technology
UC	:	Uniformity coefficient
Univ.	:	University
USA	:	United states of America
Vol.	:	Volume

LIST OF ABBREVIATIONS

%	:	Per cent
Mha		Million hectares
TMC	:	Thousand millions cubic feet
Rs.	:	Rupees
Rs/ha	:	Rupees per hectare
@	:	At the rate of
mm/hr	:	Millimeter per hour
ha	:	Hectare
m	:	Meter
CCA	:	Culturable command area
e. g.	:	For example
et al.	:	and others
g	:	Gram
hp	:	horse power
hrs.	:	hours
Kc	:	Crop coefficient
kg/ha	:	Kilogram per hectare
lph	:	Litre per hour
lps	:	Litre per second
cm	:	Centimeter
kg/cm^2	:	Kilogram per square centimeter
mm	:	Millimeter
Mt	:	Metric tonnes
q	:	Quintal
q/ha	:	Quintal per hectare
y	:	Yield
Yrs.	:	Years
etc.	:	et cetra
viz.,	:	Namely
i.e.	:	that is

ABSTRACT

EFFECT OF DIFFERENT IRRIGATION FREQUENCIES ON YIELD OF GARLIC (*Allium sativam* L.) UNDER MICRO-SPRINKLER IRRIGATION SYSTEM

by

Ganesh K. Shete

Mahatma Phule Krishi Vidyapeeth, Rahuri,
Dist. Ahmednagar (Maharashtra)
2003

Research Guide : **Prof. U. S. Kadam**

Department : Irrigation and Drainage Engineering

The study, "Effect of different irrigation frequencies on yield of garlic (*Allium sativam* L.) under micro-sprinkler irrigation system" was carried out at the Instructional Farm of Department of Irrigation and Drainage Engineering, Dr.A.S.College of Agricultural Engineering, MPKV, Rahuri. The soil of the experimental field was clayey type. The field capacity, permanent wilting point, bulk density and infiltration rate of the soil were 38.23 per cent, 19.80 per cent, 1.26 g/cm^3 and 0.42 cm/hr, respectively.

The experiment was laid out statistically with Randomised Block Design (RBD) with five treatments replicated for four times. The treatments T_1, T_2, T_3 and T_4 were based on different irrigation frequencies based on per cent moisture depletion levels i.e. 20 %, 30 %, 40 % and 50 %, respectively over available soil moisture (ASM) under micro-sprinkler irrigation system. In treatment T_5 (check basin) irrigation water of 70 mm depth was applied at a frequency of 10 days, as is being practiced by the farmers on their field, which was considered as control treatment. The necessary data such as soil moisture content before and after irrigation, biometric observations, yield contributing parameters, yield etc. were collected. The results of the investigation revealed that the irrigation treatment scheduled at 20 per cent of available moisture depletion level (T_1) was found superior and statistically significant. Highest yield of 67.56 q/ha and water use efficiency (WUE) of 84.20 kg/ha-cm was recorded in treatment T_1 (20 % moisture depletion level).

The water requirement and WUE under different treatments were found as 802.40 mm and 84.20 kg/ha-cm for 20 % moisture depletion level (T_1), 776.07 mm and 82.09 kg/ha-cm for 30 % depletion level (T_2), 754.60 mm and 77.29 kg/ha-cm for 40% moisture depletion level (T_3) and 707.00 mm and 60.55 kg/ha-cm for 50% moisture depletion level (T_4). The water requirement under control (T_5) was found maximum (940.00 mm) resulting in lower WUE (59.32 kg/ha-cm) than any other micro-sprinkler irrigated treatments. The attempt was also made to workout cost economics of micro-sprinkler irrigation system. The cost benefit ratio was found maximum (4.24) in treatment T_1 (20 % moisture depletion level).

Findings of the study led to conclude that, in clayey type of soil, for maximum yield and WUE, the irrigation for garlic crop be scheduled at an interval of 3 to 6 days (20 per cent of available moisture depletion level) with an average depth of 20 mm by micro-sprinkler irrigation system.

Pages 1 to 94

Introduction

1. INTRODUCTION

Water is one of the most important inputs for agricultural and economical development of the country. The rainfall, which receives during June to September in India, is very irregular and erratic, which affects the crop yield severely. The per capita water availability is declining with every passing day. There is less quantity of water available for agricultural crops due to stiff competition from non-agriculture uses. The agricultural growth and development can become sustainable only with the judicious and precise use of costly and limited water resource. It is the need of an hour to realise the importance of conservation and efficient utilisation of water.

A large irrigation potential has been created in India since independence, taking it from 22.6 Mha in 1951 to over 94.73 Mha at the end of 2000-2001. However, the area under irrigation was only 84.76 Mha in 2000 (Anonymous[a], 2002). It indicates that there is a gap between irrigation water resources created and its proper utilisation in qualitative as well as quantitative manner. It is necessary to increase the area under irrigation to meet the food demand of constantly growing population of the country, as its productivity is two to three times more than the rainfed agriculture. The geographical area of India is 328.72 Mha. Out of which 182.72 Mha is under cultivation. The area under irrigation is 84.76 Mha, which is 40 % of the total cultivable area. (Anonymous[a], 2002).

The geographical area of Maharashtra is 30.77 Mha. Out of which 21.89 Mha area is under cultivation and only 3.65 Mha area is under irrigation. (Economic Survey of Maharashtra, 2001-2002). This reveals that only 16.42 % of total cultivable area is under irrigation, which is far less when compared to average irrigated area at national level (40 %).

In India, the irrigation water is generally given by the surface irrigation method, which is inefficient. The age-old concept that "More the water, higher the crop yield" still persists with a majority of farmers. At present the irrigation efficiency of the conventional irrigation system is only 35 to 40 %. It means 60 % of the valuable irrigated water is being lost due to conveyance, seepage and deep percolation. The application of excess water not only causes reduction in yield but also creates the problems of salinity and water logging. The situation can only be improved by adoption of scientific layout, users participation in water distribution and whenever possibly by encouraging the farmers to adopt efficient water application methods like micro-irrigation systems and sprinklers.

Micro-irrigation method is not merely an irrigation technology; it is an integrated management tool in the hands of farmer. Many scientists observed that the yield of field crops have been increased considerably by adoption of micro-irrigation methods. The micro-irrigation systems are of three types depending upon the mode of application of water.

a) Point source of micro-irrigation system i.e. drip irrigation with different types of emitting devices *viz.,* microtubes and drippers.

b) Line source of micro-irrigation systems i.e. biwall, typhon types, turbo or T-type, queen grill type and strip type.

c) Micro-sprinkler system i.e. rotating and stationary.

The micro-sprinkler irrigation system has some merits over the sprinkler and drip method of irrigation. Compared to conventional sprinkler systems, the micro-sprinkler systems require less energy, less pressure and less discharge. It also eliminates conveyance, deep percolation and runoff losses. The major problem in drip irrigation system i.e. emitter clogging is avoided in this system. The initial investment is less in micro-sprinkler system as compared to drip and sprinkler system. Visual inspection of the micro-sprinklers is simple and fast.

Garlic (*Allium sativam* L.) is an important cash crop in India and the region. India has the second largest area under garlic in the world. At the end of 1999-2000, India had 1.44 lakh ha area under garlic and production was 4.953 lakh Mt of bulbs (Anonymous[b], 2002). In Maharashtra area under garlic is 6500 ha and production was 43600 Mt. (Indian Agriculture, 1999)

Garlic is commonly used as a spice and condiment in Indian diet. It has medicinal, nutritional and economic value. It has been used mostly for flavouring and seasoning vegetarian and non-vegetarian diets. Garlic is being used for several food preparations and it has considerable demand in many food industries. Garlic requires well drained, medium to rich soil and cool moist climate during growth period, however it requires relatively drier conditions at crop maturity. It is very sensitive to temperature as compared to other crops. The growth of bulb is better when day temperature is 25^0 C to 28^0C and night temperature 10^0C to 15^0C.It is grown as a rabi crop in Maharashtra.

Micro-sprinkler method is the most appropriate method of irrigation for the crop like garlic which is shallow rooted, densely planted and dwarf to medium height crop and needs low but frequent application of irrigation water. Soil water depletion is one of the criteria for scheduling of irrigation. Therefore study was aimed to locate the optimum point within the available range of soil moisture, when irrigation should be scheduled for maximum yield of garlic bulbs and water use efficiency.

Hence, an experiment entitled "Effect of different irrigation frequencies on yield of Garlic (*Allium sativam* L.) under micro-sprinkler irrigation system" was undertaken with the following specific objectives.

1. To estimate water requirement and water use efficiency under different irrigation frequencies.
2. To compare the micro-sprinkler irrigation system over control (check basin) for water use efficiency.
3. To workout cost economics of micro-sprinkler system of irrigation.
4. To determine appropriate scheduling criteria.

Review of Literature

2. REVIEW OF LITERATURE

Micro-irrigation is the application of low volume of water at low rate at a higher frequency. Various types of micro-irrigation systems are being evaluated over almost all parts of the world because of its superiority in terms of water saving, higher yield potential, labour saving, low input cost towards crop management practices, curtailment in expenditure on fertilizers; etc. Micro-sprinklers are categorized under micro-irrigation system. It has been proved in many cases that micro-sprinklers are superior over any other forms of micro-irrigations such as drip or trickle as problems like clogging, extensive pipe net-work in the field and large number of emission points are eliminated. Micro-sprinkler delivers water in low volume and wets small fraction of root zone. Micro-sprinkler method of irrigation can be appropriate method of irrigation for shallow rooted crops like garlic. The attempt was therefore made to know the response of micro-sprinkler to garlic. Findings reported by research workers in respect of performance of crop under micro-sprinkler irrigation method are reviewed in this chapter under following heads.

1. Performance of micro-sprinkler irrigation method.
2. Effect of micro-sprinkler irrigation method on yield and other yield attributing characters.
3. Effect of scheduling of irrigation on yield potential of garlic.

2.1 Performance of micro-sprinkler irrigation method.

Seginer (1963) showed that the operating pressure in micro-sprinkler irrigation was the most important factor. Radius of wetted area was found increased with increased operating pressure due to fineness of drop sizes resulting in more even distribution of precipitation.

Post *et al.* (1986) reported that the uniformity values are much lower in case of micro-sprinkler when compared with overlapping type of sprinklers. The range of uniformity values for micro-sprinkler was 33 to 65 per cent. In general, it was also noticed that the higher coefficient of uniformity and lower distribution uniformity values were observed.

Gutal *et al.* (1988) studied micro-sprinkler irrigation system for groundnut. For 1.5 kg/cm^2 pressure head, of 3 x 3 m spacing at 0.30 m stake height and 3.3 mm/hr application rate, it was observed that the diameter of wetted soil was 5 m. Further, they reported that the uniformity coefficient (UC) and distribution uniformity (DU) of micro-sprinkler were 60.8 and 36.4 per cent respectively. Lower values were due to high speed of prevailing wind i.e. 6 km/hr.

Singh and Singh (1990) reported micro-sprinkler as a low volume sprinkler, which operates at low pressure and it lies between sprinkler and trickle irrigation system and requires less energy than conventional sprinkler and less susceptible to clogging, than drip emitter. They observed the wetted diameter of soil in between 3 to 6 m due to micro-sprinkler at 1 to 2 kg/cm^2 operating pressure.

Singh *et al.* (1990) reported that the variation in discharge along the lateral reduced with the reduction in operating pressure at the head of lateral. The average values of micro-sprinkler flow variation at pressure 2.0, 1.5 and 1.0 kg/cm^2 were found to be 15.81, 27.17 and 19.32 per cent, respectively.

Salunkhe (1991) conducted an experiment on micro-sprinkler of 33 and 57 lph discharge in clay loam soil. He reported uniformity coefficient (UC) values of 63.7 and 73.7 percent, emission uniformity (EU) values of 96.6 and 97.3 percent for 33 and 57 lph micro-sprinkler respectively at safe wind velocity and operating pressure of 2 kg/cm^2

Firake and Salunkhe (1992) observed that micro-sprinkler discharge increased with increase in operating pressure. They also reported that effective wetted area of the soil should only be considered for calculation of uniformity coefficient of micro-sprinkler. It was also revealed that the downward vertical movement of water in the soil increased with increase in operating pressure.

Sakore (1992) observed that the UC could be increased from 66.37 to 91.40 per cent by reducing micro-sprinkler spacing from 200 to 100 cm. He reported that the values of UC were observed in the range of 11 to 60 per cent with the operating pressure of 1.2 to 1.8 kg/cm^2. The UC values showed a decrease with increase in operating pressure while they showed an increase as the stake heights were increased.

Darade and Shinde (1993) conducted an experiment on field evaluation of hydraulics of micro-sprinkler irrigation system. They studied the effect of operating pressure and lateral length on uniformity coefficient (UC). They found that UC of static micro-sprinkler decreased with decrease in pressure and increase in the lateral length.

Firake *et al.* (1993) observed the maximum uniformity coefficient i.e. 94.5 per cent at 1.62 m spacing of micro-sprinkler of 33 lph discharge. whereas the UC was 90 per cent at 1.80 m spacing of micro-sprinkler of 57 lph.

Aragade and Thombal (1994) studied the pressure discharge relationship, wetted throws and spray patterns of micro-sprinklers. The effect of pressure on diameter showed that, with increase in pressure, wetted throw diameter of micro-sprinkler also increased. It was also observed that, with increase in stake height wetted throw diameter decreased.

Shinde and Firake (1997) studied on wetted area of soil as influenced by system variable in static micro-sprinkler irrigation. They observed that both the pressure and stake height influenced wetted diameter of soil (D). It was revealed that D increased by 31. 5 % when pressure head was raised from 7.5 to 20 m. The increased in stake height from 10 to 20, 20 to 30 and 10 to 30 cm, increased D by 4.8, 1.6 and 6.5 %, respectively. The correlations between different parameters were developed with regression coefficient more than 0.95.

Shinde and Firake (1998) studied on moisture distribution pattern of static micro-sprinklers. They reported that increase in application rate of static micro-sprinkler increased the vertical depth of moisture considerably in soil. The length of lateral was 44. The emission uniformity of static micro-sprinkler system was reported as 90.3 to 91.6 % at 1.00 to 2.00 kg/cm^2 pressure. However, the uniformity coefficients of water application at head, middle and tail of lateral were 52.19, 47.77 and 45.66% at 1.5 kg/cm^2 and 66.71, 65.78 and 59.93 % at 2.0 kg/cm^2 pressure, respectively.

Sharma (2001) studied the hydraulic performance evaluation of different types of micro-sprinklers. The average discharge and wetted diameter of Platro-SP-2 was reported as 31.76 lph and 4.64 m, respectively, at 1.0 kg/cm^2 pressure. The pressure discharge relationships of the form $Q = a H^b$ were developed for all three micro-sprinklers under study and for SP-2, it was given as $Q = 32.272 H^{0.6387}$ and $R^2 = 0.9784$. High values of R^2 indicates the close goodness of fit.

2.2 Effect of micro-sprinkler irrigation method on yield and other yield attributing characters

Pampattiwar et. al. (1987) compared the sprinkler irrigation method with border irrigation method for garlic crop and found that increase in yield to the extent of 24.45 % and saving in water 33.33 % by sprinkler irrigation method.

Gorantiwar *et al* (1991) conducted an experiment on onion (v. N-2-4-1) during 1986-87 with 3 irrigation treatments. Border and sprinkler irrigation methods were used to apply 4 cm water (depth) at 50 mm CPE Highest yield (441.76 q/ha), water use efficiency (10.09 q/ha-cm) and bulk density of bulb (0.95 g/cm^3) were obtained with sprinkler irrigation.

Anonymous (1993) studied response of summer groundnut (ICGS-11) to frequent and light application of water through sprinkler. The significantly higher yield of dry pod (43.87q/ha) was obtained when the crop was irrigated at 40 mm CPE with 3 cm depth of water through sprinkler. The increase in dry pod and haulm yield by sprinkler method was to the extent of 23.12 and 10.81 per cent respectively, when compared to the application of irrigation at 80 mm CPE with 6 cm depth through border method of irrigation.

Anonymous[a] (1995) studied the performance of different planting techniques for economic design of micro-sprinkler irrigation system in summer groundnut. The pressure discharge relationship of micro-sprinkler was found very excellent with value of r^2 = 0.99 U. C. values of micro-sprinkler were found near about 94 per cent. On the basis of UC and EU of micro-sprinkler spacing of 1.5 x 1.5 m was recommended. In drip irrigation 66 per cent of total area was considered for irrigation and thus 17.37 cm (66 per cent of ET_C i.e. 26.32 cm) depth of irrigation water was applied in micro-sprinkler treatments as against 5 irrigations each of 6 cm in BBF treatments. Maximum yield as well as water use efficiency as 38.49 q/ha-cm and 158.96 kg/ha-cm were observed in micro-sprinkler treatment. The increase in yield and water saving were 47.41 and 27.13 per cent, respectively when compared to control treatment of surface irrigation.

Anonymous[b] (1995) studied the evaluation of micro-irrigation systems of different emission devices in summer groundnut. The emission uniformity (EU) was observed more than 90 per cent in all the micro-irrigation system. The maximum EU (94.00 per cent) was observed in biwall irrigation system. Due to micro-irrigations water saving was observed to the extent of 26.30 per cent. Maximum dry pod yield of 32.76 q/ha was observed in micro-sprinkler irrigation followed by 31.53, 31.08 and 30.34 q/ha in drippers (turbo key), biwall and micro-tube irrigation systems, respectively. Minimum yield of 22.64 q/ha was observed in border irrigation. Maximum percent increase in dry pod yield was found to tune of 49.69 per cent in micro-sprinkler irrigation. Similarly, maximum water use efficiency (0.50 q/ha-cm) was observed in micro-sprinkler irrigation system.

Dhanvijay (1995) reported that the summer groundnut grown on broad bed furrow (BBF) with daily irrigation through micro-sprinkler spaced at 150 x150 cm on sandy loam soil under Rahuri conditions showed that plant height, spread, number of branches, dry matter and pod yield were significantly more over surface irrigation.

Kadam (1996) studied the effect of frequency on yield of kharif groundnut (*Arachis hypogea* L.) with solar photovoltaic operated micro-sprinkler system. The results of the experiment indicated that irrigating groundnut every three days by micro-sprinkler system was the best treatment as it produced more yield (24.13 q \ha). The water use efficiency and consumptive use efficiency also found maximum in three days irrigation interval treatment. They were 0.86 and 0.98 kg per ha-cm, respectively.

Gite (1999) conducted the study on evaluation of different micro-sprinkler systems and planting layouts for rabi onion. The results of the investigation revealed that broad bed furrow (BBF) with micro-sprinkler spaced at 180 x 180 cm, on sandy clay loam soil under Rahuri condition showed better performance in respect of growth, yield and quality parameters in rabi onion.

Srivastava *et al.* (1999) determined the water use efficiencies of cabbage irrigated by micro-sprinkler, drip, micro tube or surface irrigation methods in India. Cabbage was planted at a spacing of 50 x 60 cm. The highest yield was obtained in the micro-sprinkler irrigation treatment (40.23 t/ha) followed by drip irrigation (38.97 t/ha), surface irrigation (33.54 t/ha). Water use efficiency was highest for drip irrigation, followed by micro-tube irrigation, micro-sprinkler irrigation and surface irrigation. Compared with surface irrigation, percentage water saving were 61.44, 59.28 and 36.8 % for micro-tube, drip and micro-sprinkler methods, respectively

Rathod (2001) studied the effect of scheduling of irrigation on yield of onion through micro-sprinkler irrigation system. The experiment was conducted with five treatments based on CPE levels (20 mm CPE, 30 mm CPE, 40 mm CPE and 50 mm CPE) and replicated for four times. The results of the experiment indicated that the treatment scheduled at lower CPE

(20 mm) was the best treatment as it produces more yield of bulbs (442.05 q /ha) and highest water use efficiency (955.16 kg/ha-cm) which was significantly superior over all other treatments. The consumptive use of onion crop was observed highest (462.80 mm) in treatment T_1 (20 mm CPE).

Gurav (2002) studied the effect of different soil moisture regimes on yield potential of onion (*Allium cepa*.L.) under micro-sprinkler irrigation system. The experiment was conducted with five treatments based on percent moisture depletion levels (20%, 30%, 40% and 50%) and replicated for four times. The results of the investigation revealed that the irrigation treatment scheduled at 20 per cent of available moisture depletion level was found superior and statistically significant. Highest yield of 494.37 q/ha and WUE of 961.82 kg/ha-cm were recorded in said treatment.

2.3 Effect of scheduling of irrigation on yield potential of garlic.

Pawar (1995) conducted the study on yield response of garlic (*Allium sativum* L.) to micro-sprinkler irrigation operated by solar photovoltaic pumping system. Irrigations were scheduled on every alternate day on the basis of pan evaporation. The results of the investigations revealed that the soil status was maintained closer to field capacity. Micro-sprinklers spaced at 1.75 x 1.75 m resulted in maximum yield of garlic (57.44 q/ha), highest water use efficiency (143.00 kg/ha-cm), maximum coefficient of uniformity (92.13 per cent) and benefit cost ratio (2.96) when compared to any other micro-sprinkler spacing. Closer spacing improved the coefficient of uniformity nearer to 100 per cent and higher uniformity resulted in higher yield. Lower spacing of micro-sprinkler increased the seasonal total cost of the system. However, additional investment was found justified because of additional returns as was reflected by higher benefit cost ratios in case of lower spacing.

Anonymous (2001) conducted an experiment on irrigation studies in Garlic. The investigation was carried out on Garlic variety G-41 during rabi season 2000-01 in RBD, with three replications. The plant spacing of 10X15 cm was maintained in a plot size of 1.2 m X 40 m. the treatments consisted of drip irrigation and sprinkler irrigation at 50, 75 and 100 % PE along with surface irrigation @ 7 cm depth at 50 mm CPE as a control. Among the various treatments, T-3 (drip irrigation-100%PE) recorded the highest yield in garlic i.e. 14.8 t/ha. The yield increases over surface was 14.8 % and water saving was 44 %. In sprinkler irrigation, T-6 (100%PE) recorded highest yield i.e. 12.8 t/ha and water use efficiency as 257.4 kg/ha-cm. The highest water use efficiency was observed at 50 % PE i.e. 318 kg/ha-cm.

Material and Methods

3. MATERIAL AND METHODS

The field experiment entitled, "Effect of Different Irrigation Frequencies on yield of Garlic (*Allium sativam* L.) under Micro-sprinkler Irrigation System" was conducted at Instructional Farm of Department of Irrigation and Drainage Engineering, Dr. A. S. College of Agril. Engg., MPKV, Rahuri. The objectives of the study were;

1. To estimate water requirement and water use efficiency under different irrigation frequencies.
2. To compare the micro-sprinkler irrigation system over control (check basin) for water use efficiency.
3. To workout cost economics of micro-sprinkler system of irrigation.
4. To determine appropriate scheduling criteria.

In order to achieve the above objectives, soil properties of experimental field, yield contributing parameters and yield of test crop and performance of micro-sprinkler irrigation method were studied and evaluated by adopting standard procedures. The details of material used and methods adopted in the present investigation are described in this chapter.

3.1 Material

3.1.1 Experimental site

The experiment was conducted at Instructional Farm of Dr.A.S.College of Agricultural Engineering, MPKV, Rahuri during the period from December 2001 to April, 2002. The altitude of the experimental site is 657 m from mean sea level (MSL). The latitude and longitudes are 19°21' N and 74°39' E, respectively.

3.1.2 Micro-sprinkler irrigation system

3.1.2.1 Micro-sprinkler make and specifications

Micro-sprinklers manufactured by M/s Plastro Irrigation Systems were used in the present study. The details of the micro-sprinklers as supplied by the firm are given in Table 3.1

Table 3.1 Specifications of micro-sprinklers

Code and nozzle colour	Nozzle size (mm)	Pressure		Diameter of throw (m)	Discharge (lph)
T-Blue		Kpa	Kg/cm^2		
(Threaded)	0.75	150	1.5	5.80	44
		200	2.0	5.60	51

The code for stake of micro-sprinkler was T-Blue. The size of the connector tube was 8.0 mm. The height of stake was 25 cm. However, this height was raised to 50 cm by making local modifications, in order to suit the height of plant. The inlet connection was of barbed type. The spacing between two micro-sprinklers along the lateral was 1.75 m and spacing between laterals was taken 1.75 m.

3.1.2.2 Lateral, submain and main

The LDPE lateral of 16 mm diameter was used. These laterals were connected to 25 mm GI submain pipe which was subsequently connected to 50 mm of GI main pipe.

3.1.2.3 Pumping unit

The centrifugal pump of 5 HP was used to lift the water from shallow open well to operate the micro-sprinkler irrigation system to irrigate the garlic crop as per the irrigation schedule.

3.2 Methods

3.2.1 Physical properties of the soil

To fulfill the objectives of the present study, the important physical properties of the soil of the experimental field were studied by adopting the standard procedures and methods as given in Table 3.2.

Table 3.2 Methods to find out physical properties of soil

Sr. No.	Particulars	Methods
1	Particle size distribution	Sieve analysis
2	Textural class	Triangular diagram
3	Field capacity, per cent	Pressure plate apparatus
4	Permanent wilting point, per cent	Pressure plate apparatus
5	Bulk density, gm/cm^3	Core-sampler method
6	Infiltration rate, cm/hr	Double ring infiltrometer

3.2.2 Treatment details

Irrigation was scheduled on the basis of different irrigation frequencies, which were calculated on the basis of per cent depletion of available soil moisture to assess the effect of irrigation frequency on yield of garlic as well as to determine optimal scheduling criteria. Accordingly different treatments of depletion levels were included in study. Also in order to compare the yield of garlic bulbs under micro-sprinkler irrigation method over conventional irrigation method i.e. surface irrigation method was also included as a control. The details are as given in Table 3.3

Table 3.3 The treatment details based on depletion levels

Sr. No.	Treatment	Moisture depletion level (%)
1	T_1	20
2	T_2	30
3	T_3	40
4	T_4	50
5	T_5	Control

3.2.3 Experimental layout

Layout of the experiment along with other details such as plot size, main, submain etc is shown in Fig. 3.1. The gross size of experimental plot was 25.5 m wide and 32.25 m long. The plot size of each treatment was 5.25 x 5.25 m. The buffer strip of 1.5 m was kept in between two treatments

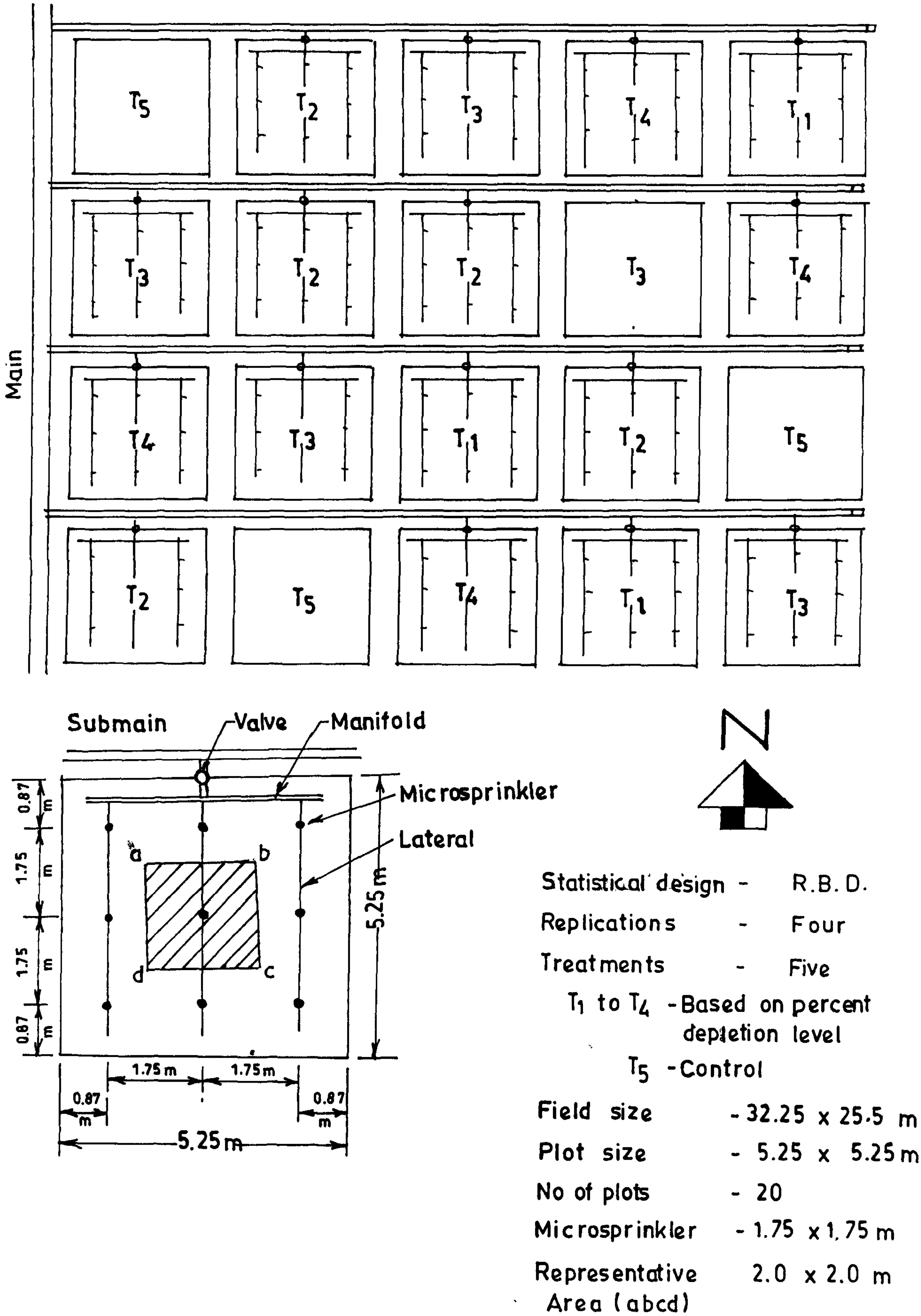


Fig. 3.1 Experimental layout

and two replications. Five treatments were replicated for four times. The statistical design adopted was Randomized Block Design.

3.2.4 Representative area for data collection

The representative area of 2 x 2 m^2 was selected from centrally located micro-sprinkler in each treatmental plot where precipitation from the all-adjoining micro-sprinklers was received. This area was used for the purpose of observations in respect of average depth of precipitation, soil moisture status, non-uniformity in sprinkling, biometric observations of garlic crop such as plant height, bulb size, yield etc.

3.2.5 Calibration of the micro-sprinkler system

In order to determine the average rate of precipitation of micro-sprinkler and time of application to apply desired depth in each treatment considering different moisture depletion levels, the system was calibrated at 50 cm stake height. To determine application rate precipitation was collected in catch cans spaced at a grid of 50 x 50 cm. In order to get the representative precipitation rates, the tests were replicated at least for three times. During the test time, constant stake height (50 cm), micro-sprinkler spacing (1.75 m X 1.75 m) and pressure (1.0 kg/cm^2) at delivery side was maintained.

3.2.5.1 Average rate of precipitation

Over the entire plot size, precipitation was collected in the catch cans spaced at a grid of 50 x 50 cm. The micro-sprinklers in each treatment were operated for a fixed time of half an hour. The average rate of precipitation for each treatment was calculated from the precipitation collected in the catch cans.

3.2.5.2 Uniformity Coefficient (UC)

Non-uniformity in sprinkling of micro-sprinklers was expressed in terms of coefficient of uniformity (UC). The coefficient of uniformity was worked out by using Christiansen's formula (Michel, 1978) given by the equation (3.1).

$$UC = 100 \left(1 - \frac{\Sigma X}{m \times n}\right) \qquad \text{.................. (3.1)}$$

Where,

UC = Uniformity Coefficient of micro-sprinklers, per cent

ΣX = Absolute deviation of individual observation, from average of observations (depth), mm

m = Average depth of all observations, mm

n = Number of observation

3.2.6 Irrigation scheduling

For maximum crop production, the optimum water is to be supplied at regular frequency to meet the water demand of the crop. Soil moisture deficit approach is one of the best approaches of irrigation scheduling. Thereafter the irrigation was scheduled on percent available moisture depletion level. The depth of irrigation was based on the percent moisture depletion from total available soil moisture. Irrigation frequency for depletion level treatments was worked out by considering 5 years average monthly pan evaporation.

In the control (check basin) treatment, water was applied by conventional method. Check basin (5.25 x 5.25 m) was prepared as per the design considerations suggested by Mahatma Phule Krishi Vidyapeeth, Rahuri. The depth of water i.e.70 mm was applied at an interval of 10 days. Where as the discharge in check basin was maintained as 3 lps and is measured by direct volume method.

3.2.6.1 Total available water

Soil moisture between field capacity and permanent wilting point is referred to as readily available moisture. It is the total moisture available to plant use. The net quantity of total available water in terms of depth was worked out by using the relationship given by equation (3.2)

$$TAW = \frac{(FC - PWP)}{100} \times BD \times D \qquad \ldots\ldots\ldots\ldots\ldots (3.2)$$

Where,

TAW = Total available water, mm

FC = Field capacity of soil, per cent

PWP = Permanent wilting point of soil, per cent

BD = Bulk density of soil, gm/cm^3

D = Root zone depth of garlic, mm

The root zone depth of garlic was considered 200 mm for initial stage (0-20 days) and 450 mm for further crop growth period.

3.2.6.2 Net depth of irrigation

The net quantity of water to be applied in terms of depth was worked out by using the equation (3.3)

$$Di = (TAW \times Dp) / 100 \quad \text{................(3.3)}$$

Where,

Di = Net depth of irrigation, mm

TAW = Total available water, mm

Dp = Depletion level, per cent

For the present study the depletion levels (Dp) were taken as 20, 30, 40 and 50 per cent for the treatment T_1, T_2, T_3 and T_4 respectively.

3.2.6.3 Gross depth of irrigation

Gross depth of irrigation was computed by using equation (3.4)

$$Dg = \frac{Di}{UC} \quad \text{................ (3.4)}$$

Where,

Dg = Gross depth of irrigation, mm

UC = Uniformity Coefficient, per cent

Di = Net depth of irrigation, mm

3.2.6.4 Time of operation

The time of irrigation for each treatment was worked out by using the relationship given by equation 3.5

$$To = \frac{Dg}{Pi} \times 60 \qquad \text{............ (3.5)}$$

Where,

To = Time of operation, minute

Dg = Gross depth of irrigation, mm

Pi = Precipitation rate , mm/hr

3.2.6.5 Potential Evapotranspiration

The value of potential evapotranspiration is calculated by using relationship given by equation 3.6

$$PET = PE \times F \qquad \text{................ (3.6)}$$

Where,

PE = Average pan-evaporation over the growth stage period of garlic, mm/day

F = Pan factor, taken as 0.8

The average pan evaporation over the growth period of garlic was calculated from average pan evaporation of last five years. The monthly averages of pan evaporation from last five years are given in Table 3.4

Table 3.4 Monthly averages of pan evaporation (mm/day)

Month	Average pan evaporation (mm/day)
December	4.37
January	4.60
February	5.90
March	7.14
April	8.70

3.2.6.6 Irrigation frequency

Irrigation frequency was determined considering net depth of irrigation, potential evapotranspiration (PET) for two days immediately after irrigation and crop evapotranspiration (ETc), mm/day by using the equations 3.7, 3.8 and 3.9 as under,

$$Dir = Di - (PET \times 2) \qquad \ldots\ldots\ldots\ldots (3.7)$$

Where,

Dir = Net depth remaining after 2 days after irrigation, mm

Di = Net depth of irrigation to be applied, mm

PET = Potential evapotranspiration, mm/day

The crop evapotranspiration is calculated by using crop coefficients as,

$$ETc = PET \times Kc \qquad \text{................ (3.8)}$$

Where,

ETc = Crop evapotranspiration, mm/day

PET = Potential evapotranspiration, mm/day

Kc = Crop coefficient

The values of crop coefficients are as per growth stages. They are taken as per FAO bulletin 1980 vol.33.

Table 3.5 Crop coefficient (Kc) at different growth stages

Duration in days after sowing	Crop stage	Kc
0-20	Initial	0.50
21-50	Crop development	0.75
51-85	Mid season	1.025
86 - upto harvest	Late season	0.875

Irrigation frequency in days is calculated as,

$$IF = \frac{Dir}{ETc} + 2 \qquad \text{............ (3.9)}$$

Where,

IF = Irrigation frequency in days

Dir = Net depth remaining after 2 days after irrigation, mm

ETc = Crop evapotranspiration, mm/day

3.2.7 Soil moisture studies

The soil samples were taken from the representative area at a depth of 30 cm before and after each irrigation by screw auger to know the soil moisture status. The gravimetric method was adopted to determine the soil moisture content. After determination of the moisture status in each treatment the percent moisture depletion levels were worked out by equation 3.11.

$$ASM = FC - PWP \qquad \ldots\ldots\ldots\ldots (3.10)$$

Where,

ASM = Available soil moisture in per cent

FC = Field capacity of soil, per cent

PWP = Permanent wilting point of soil, per cent

$$Md = \frac{FC - Mbi}{ASM} \times 100 \qquad \ldots\ldots\ldots\ldots (3.11)$$

Where,

Md = Moisture depletion over available soil moisture, per cent

Mbi = Moisture content of soil before irrigation , per cent

FC = Field capacity of soil, per cent

3.3 Agronomic details

3.3.1 Crop

Local name	:	Lasun
Common name	:	Garlic
Botanical name	:	*Allium sativam* L.
Variety	:	G-41

3.3.2 Agronomic practices

The details regarding the agronomic practices carried out in the experimental field are given as below

3.3.3 Land preparation

One ploughing was done on 3rd December, 2001 with tractor drawn mould board plough, which was followed by disc harrowing on 7th December.

3.3.4 Sowing

The sowing of garlic cloves was done on 22nd December 2001. G-41 variety of garlic was used. Garlic cloves were separated and good quality uniform cloves were used for sowing. Garlic cloves were sown at the spacing of 10 x 15 cm. Immediately after sowing all treatments were irrigated at a depth of 50 mm on 22nd and 24th of December, 2001 to bring adequate moisture content in the field for proper germination.

3.3.5 Fertilizers

The recommended fertilizer dose i.e. 100 kg N, 50 kg P_2O_5 and 50 kg K_2O per hectare was applied as 50 kg N, 50 kg P_2O_5 and 50 kg K_2O, as basal dose at the time of sowing on 22nd December, 2001 and 50 kg N was given one month after sowing i.e. on 22nd January, 2002.

3.3.6 Weeding

Heavy infestation of weed was observed after the sowing of the crop. To control the weeds, three weddings were undertaken on 14th January, 12th February and 10th March, 2002 with the help of manual laborer.

3.3.7 Plant protection

To protect the crop from pests and diseases, two spraying were carried out. They were Bavistein (2 gm/lit) on 4th February and Desis (2 gm/lit) on 4th March, 2002.

3.3.8 Harvesting

The crop was harvested during 14th to 16th May, 2002. Representative areas of each treatment were selected for comparing yields from different treatments.

3.3.9 Drying

The harvested bulbs along with stalk were kept for sun drying. The observations of weighing of samples were taken after every alternate day till they attained the constant weight.

3.4 Biometric and other observations

3.4.1 Sampling technique

The various biometric observations were recorded on five randomly selected plants of garlic from the representative area of each treatment during the entire crop season. These plants were suitably tagged for their identifications.

3.4.2 Plant height

The plant height was recorded by measuring the length of shoot from ground level upto the top of the completely open leaf at an interval of 30 days.

3.4.3 Plant count

The plant count was recorded by counting all the plants from each treatment on the 30^{th} day after sowing.

3.5 Yield contributing characters

3.5.1 Bulb size

The diameter of the bulbs harvested from five observational plants from representative area of each treatment were measured with the help of Vernier Calliper along the three co-ordinate i.e. X, Y and Z. The mean polar diameter, mean equatorial diameter and geometric mean diameter of bulbs of garlic were calculated using equations 3.12, 3.13 and 3.14

$$\text{Mean polar diameter} = \frac{A + B}{2} \qquad \text{.......... (3.12)}$$

Where,

A = diameter along x-axis, mm

B = diameter along y-axis, mm

Mean equatorial diameter = C, mm ....(3.13)

Where,

C = diameter along Z axis, mm

$$D = (A \times B \times C)^{1/3} \qquad \text{........... (3.14)}$$

Where,

D = Geometric mean diameter of bulb, mm

3.5.2 Average weight of garlic bulb

The average weight of each garlic bulb was recorded from five observation plants immediately after harvest.

3.5.3 Number of cloves per bulb

The numbers of cloves were recorded from the five observational plants immediately after harvest.

3.6 Yield

3.6.1 Yield of garlic bulbs

The dry weight of garlic bulb along with the stalk from the representative area of each treatment was recorded. Then the bulbs were separated from the stalks and the weight of bulbs from representative area of each treatment was recorded.

3.6.2 Yield of stalks

The yield of stalks from representative area of each treatment was also recorded and expressed as kg/ha.

3.6.3 Bulb to stalk ratio

The ratios of bulb yield to stalk yield were worked out for each treatment.

3.6.4 Drying factor (DF)

Drying factor which is the ratio of dry weight to wet weight (recorded immediately after harvest) were worked out for each treatment.

3.6.5 Percentage reduction

Percentage reduction in weight after drying were worked out using equation 3.15

$$PR = (1 - DF) \times 100 \qquad \text{..............} (3.15)$$

Where,

PR = Percentage reduction in weight after drying

DF = Drying factor

3.7 Water requirement

The irrigations were scheduled on the basis of percent depletion levels. The depth applied during each irrigation was worked out by percent allowable depletion. The computation of depth to be applied is presented in section 3.2. The treatments were differed on the basis of irrigation frequencies and not on irrigation depth.

3.8 Water use efficiency

Water use efficiency in different treatments was calculated by using the relationship given by equation 3.16

$$WUE = \frac{Y}{WR} \qquad \text{.............. (3.16)}$$

Where,

WUE = Water use efficiency, kg/ha-cm

Y = Yield of garlic, kg/ha

WR = Total amount of water applied in the field, cm

3.9 Cost economics

Cost economics of micro-sprinkler irrigation system was worked out to find the net returns and benefit cost ratio. For this purpose the life period of micro-sprinkler system was considered as 8 years. Standard market rates of 2003 were taken for each item of the system. A plot of one hectare area each for all treatments was considered for the comparison. Fixed cost, operating cost, total cost and net benefit from the system were calculated as follows :

3.9.1 Fixed cost

Fixed cost comprised of interest on initial cost and depreciation of the system. The interest calculated on capital was 15 per cent per annum. The depreciation on the system was worked out by straight line method as given by equation 3.17

$$D = \frac{I - S}{L} \qquad \text{.............. (3.17)}$$

Where,

D = Depreciation, Rs/ha per annum

I = Initial cost of the system, Rs/ha

S = Salvage value, 10 per cent of initial cost, Rs./ha

L = Expected life period of the system

3.9.2 Operating cost

Operating cost is the amount, which is actually paid by the cultivator in cash throughout the cultivation process. Total operating cost comprised of operating cost of the system plus interest on operating cost at

15 per cent annum rate. The operating cost includes cost on hired human labour, seeds, fertilizers, water charges, supervision charges and interest on working capital.

3.9.3 Total cost

Total cost comprised of fixed cost plus operating cost. Total cost per hectare was calculated for comparison hectare basis.

3.9.4 Net returns and benefit cost ratio

Net returns were obtained by subtracting the total cost from gross returns. The benefit-cost ratio was calculated by dividing total returns by total cost.

3.10 Statistical analysis

The statistical analysis of the data was carried out by analysis of variance method by simple RBD (Panse and Sukhatme, 1967). Standard error (S. E.±) of the mean was worked out for each factor. Whenever the results were significant critical differences (CD.) at 5 per cent level of significance were worked out. The data are suitably illustrated with graphs and figures at appropriate places.

Results and Discussion

4. RESULTS AND DISCUSSION

Micro-sprinkler method is the most appropriate method of irrigation for the crop like garlic which is shallow rooted, close growing and dwarf to medium height and needs low but frequent application of water. Considering the merit of this system, it was tested for its influence on the yield of garlic under different irrigation frequencies with the specific objectives. The procedure adopted and material of the experiment has been described in the earlier chapter. The pertaining data was collected, recorded and interpreted in integrated manner. The results of the studies are reported and discussed in this chapter.

4.1 Physical properties of the soil

The methods to determine various physical properties of soil are described in section 3.2.1. The numerical values of these properties are presented in Table 4.1

Table 4.1 Physical properties of the soil

Sr. No.	Particulars	Results
1	Particle size distribution	
	i) Sand, %	24.20
	ii) Silt, %	25.68
	iii) Clay, %	50.12
2	Textural class	Clayey
3	Field capacity, %	38.23
4	Permanent wilting point, %	19.80
5	Bulk density, g/cm^3	1.26
6	Infiltration rate, cm/hr	0.42

From the table 4.1 it was revealed that, the textural class of the soil of experimental field was found to be clayey as can be seen from the percent of sand, silt and clay present in the soil. The field capacity, wilting point and bulk density were found to be 38.23 %, 19.80% and 1.26 g/cc respectively.

4.2 Irrigation

4.2.1 Average discharge of micro-sprinkler, uniformity coefficient and average rate of precipitation

The average discharge, average rate of precipitation, average radial throw and uniformity coefficient were determined by adopting the standard procedure as described in section 3.2.5. The micro-sprinklers from all the treatmental plots were operated simultaneously at the operating pressure of 1 kg/cm^2. The observations and sample calculation are given in Appendix-I. Average discharge of micro-sprinkler and average wetted diameter were obtained as 37.83 lph and 4.64 m, respectively. Similarly the average rate of precipitation and uniformity coefficient (UC) were obtained as 12.34 mm/hr and 85 per cent, respectively. The values of uniformity coefficient was consistent with those observed by Gutal *et al.* (1988), Salunkhe (1991), Firake *et al.* (1993). Gutal *et al.* (1988) obtained uniformity coefficient of 60.80 per cent at spacing of 3 x 3 m at operating pressure of 1.5 kg/cm^2. Salunkhe (1991) reported uniformity coefficients in the range of 63.7 to 73.7 per cent at an operating pressure of 2.0 kg/cm^2.

Firake *et al.* (1993) observed uniformity coefficient of 90 per cent at 1.8 m spacing for 57 lph discharge.

4.2.2 Irrigation scheduling

4.2.2.1 Depth of irrigation

Treatments T_1, T_2, T_3 and T_4 were based on per cent depletion levels of total available moisture i.e. 20 %, 30 %, 40 % and 50 % respectively. Therefore, the irrigation depth varied for the different irrigation treatments. The gross depth of irrigation for each treatment per irrigation were calculated by adopting the procedure described in section 3.2.6 and reported in Table 4.2

Table 4.2 Depth of irrigation (mm) per irrigation for different treatments

Sr. No.	Treatment	Root zone depth (mm)	Total available water (mm)	Net depth of irrigation (mm)	Gross depth of irrigation (mm)
1	T_1	200 (0-20 DAS)	46.40	9.28	10.92
		450 (21 DAS to harvest)	104.50	20.90	24.58
2	T_2	200 (0-20 DAS)	46.24	13.92	16.37
		450 (21 DAS to harvest)	104.50	31.35	36.88
3	T_3	200 (0-20 DAS)	46.40	18.56	21.83
		450 (21 DAS to harvest)	104.50	41.80	49.17
4	T_4	200 (0-20 DAS)	46.40	23.20	27.29
		450 (21 DAS to harvest)	104.50	52.25	61.47

Note : Average uniformity coefficient (UC) = 0.85

The quantity of total available water varied due to varied depth at initial and further growing stages of crop. The root zone depth was considered 20 cm for initial stage (0-20 days after sowing) and 45 cm for remaining crop period.

From Table 4.2 it was revealed that, the gross depths of irrigation (mm) at initial crop stage i.e. 0 to 20 days after sowing and for rest of the period were maximum i.e. 27.20 mm and 61.40 mm, respectively in treatment T_4 (50% moisture depletion level) and lowest gross depth of irrigation i. e. 10.90 mm (0 to 20 days after sowing) in treatment T_1 (20 % moisture depletion) and 24.50 mm (20 days after sowing to last watering).

In general the gross depth of irrigation per irrigation increased with increase in percentage depletion level.

For control treatment (T_5) water was applied by conventional method. Seven cm depth of water was applied at an interval of 10 days. The rate of water application was measured directly by volume method and kept constant throughout irrigation by means of flow control valve.

4.2.2.2 Irrigation Frequency

The irrigation frequencies for the treatment T_1 to T_4 were based on pan evaporation and crop coefficient. They were varied according to different growth stages of crop. The procedure to compute the irrigation frequency was described in section 3.2.6. Sample calculation to determine irrigation depth and frequency is given in Appendix – II. The computed irrigation intervals are presented in Table 4.3

Table 4.3 Irrigation frequencies in days for different depletion level treatments

Crop growth stages	Irrigation interval			
	T_1	T_2	T_3	T_4
Initial growing stage (0-20 DAS)	3	6	8	11
Crop development stage (21-50 DAS)	6	9	13	16
Mid season stage (51-85 DAS)	4	6	8	10
Late season stage (86 DAS to last watering)	3	5	7	9

It is seen that the irrigation interval at each stage is minimum in 20 per cent depletion treatment (T_1) and maximum in treatment T_4 (50 % depletion level). The irrigation interval was more at crop development stage and minimum for initial and late season stages.

4.2.2.3 Number of irrigations and total depth of irrigation

The dates of irrigations, the depths of irrigations and time of operation during each irrigation in different treatments are presented in Appendix II. The number of irrigations and total depth of irrigation that obtained in each treatment is given in Table 4.4

Table 4.4 Number of irrigations and total depth of irrigation applied in different treatments.

Sr. No.	Treatments	Number of irrigations	Total depth of irrigation (mm)
1	T_1	32	702.40 +100* = 802.40
2	T_2	20	676.07 + 100 = 776.07
3	T_3	15	654.60 + 100 = 754.60
4	T_4	11	607.00 + 100 = 707.00
5	T_5 (control)	12	840.00 + 100 = 940.00

(* Note : Two irrigations of 50 mm were given to all treatments immediately after sowing and two days after sowing before the first irrigation according to irrigation frequencies.)

From Table 4.4 it was revealed that the maximum irrigation water (940.00 mm) was given in control treatment (T_5) followed by T_1 (802.40 mm), T_2 (776.07 mm), T_3 (754.60 mm) and T_4 (707.00 mm). The little variation in total depth of irrigation in treatments T_1 to T_4 was due to different Kc factors, irrigation frequencies and irrigation cut of dates.

4.3 Soil moisture studies

The irrigations were scheduled as per irrigation frequencies, which were calculated on the basis of per cent moisture depletion levels. In order to know the per cent depletion level attained in each treatment, the observations of soil moisture before irrigation and after irrigation were collected as per the procedure described in section 3.2.7

The per cent depletion level attained over available soil moisture was worked out for each treatment as described in section 3.2.7 and reported in Tables 4.5, 4.6, 4.7, 4.8 and 4.9. The moisture regimes attained in each treatment are presented graphically in Fig. 4.1 and 4.2

Table 4.5 Soil moisture statuses in treatment T_1 during crop period

Irrigation No.	Date	Moisture content		Per cent depletion over ASM (%)
		Before irrigation	After irrigation	
1	27.12.2001	34.85	38.45	19.85
2	30.12.2001	33.80	37.58	18.99
3	2.1.2002	35.20	38.80	19.53
4	5.1.2002	35.11	38.77	19.85
5	8.1.2002	34.20	38.02	20.72
6	11.1.2002	34.58	38.40	20.72
7	17.1.2002	34.00	38.08	22.15
8	23.1.2002	34.88	38.48	19.53
9	29.1.2002	34.40	38.28	21.00
10	4.2.2002	34.45	38.21	20.40
11	10.2.2002	34.60	38.40	20.61
12	14.2.2002	34.44	38.38	21.37
13	18.2.2002	34.89	38.49	19.53
14	22.2.2002	34.21	37.77	19.31
15	26.2.2002	35.01	38.99	21.59
16	2.3.2002	34.50	38.20	20.00
17	6.3.2002	34.59	38.30	20.13
18	10.3.2002	34.12	38.00	21.00
19	14.3.2002	33.89	37.95	22.00
20	18.3.2002	35.03	38.79	20.40
21	21.3.2002	34.50	38.25	20.34
22	24.3.2002	33.25	37.29	21.92
23	27.3.2002	34.94	38.81	20.99
24	30.3.2002	32.53	36.50	21.50
25	2.4.2002	34.69	38.48	20.56
26	5.4.2002	34.20	38.23	20.23
27	8.4.2002	34.44	38.33	21.10
28	11.4.2002	34.60	38.44	20.83
29	14.4.2002	34.15	38.10	21.40
30	17.4.2002	34.55	38.33	20.51
31	20.4.2002	34.25	38.12	20.99
32	23.4.2002	34.77	38.49	20.18
Average per cent depletion over ASM (%)				20.60

Table 4.6 Soil moisture status in treatment T_2 during crop period

Irrigation No.	Date	Moisture content		Per cent depletion over ASM (%)
		Before irrigation	After irrigation	
1	30.12.2001	32.93	38.38	29.57
2	5.1.2002	32.70	38.32	30.49
3	11.1.2002	32.66	38.18	29.95
4	17.1.2002	32.88	38.39	29.89
5	26.1.2002	32.04	37.80	31.20
6	4.2.2002	32.44	38.12	30.81
7	13.2.2002	32.70	38.20	29.84
8	19.2.2002	32.92	38.48	30.16
9	25.2.2002	32.48	38.11	30.54
10	3.3.2002	32.39	38.20	31.50
11	9.3.2002	32.98	38.56	30.27
12	15.3.2002	33.12	39.01	31.57
13	21.3.2002	32.70	38.98	31.30
14	26.3.2002	32.63	38.33	30.54
15	31.3.2002	32.45	38.19	30.10
16	5.4.2002	31.28	38.12	30.76
17	10.4.2002	32.13	37.48	32.00
18	15.4.2002	32.13	38.35	33.74
19	20.4.2002	32.70	38.42	31.00
20	25.4.2002	32.77	38.30	30.01
Average per cent depletion over ASM (%)				30.76

Table 4.7 Soil moisture status in treatment T_3 during crop period

Irrigation No.	Date	Moisture content		Per cent depletion over ASM (%)
		Before irrigation	After irrigation	
1	1.1.2002	30.31	37.90	41.15
2	9.1.2002	30.53	38.00	40.50
3	17.1.2002	30.60	38.10	41.50
4	30.1.2002	30.85	38.25	40.15
5	12.2.2002	30.65	38.22	41.07
6	20.2.2002	30.90	38.50	41.23
7	28.2.2002	30.93	38.33	40.15
8	8.3.2002	30.31	38.20	42.80
9	16.3.2002	29.94	37.90	43.15
10	23.3.2002	31.20	38.85	41.50
11	30.3.2002	30.20	37.75	40.96
12	6.4.2002	30.78	38.40	41.30
13	13.4.2002	30.52	38.43	42.90
14	20.4.2002	30.12	38.35	44.65
15	27.4.2002	30.25	38.12	42.70
Average per cent depletion over ASM (%)				41.71

Table 4.8 Soil moisture status in treatment T_4 during crop period

Irrigation No.	Date	Moisture content		Per cent depletion over ASM (%)
		Before irrigation	After irrigation	
1	4.1.2002	29.15	38.43	50.35
2	15.1.2002	29.02	38.20	49.81
3	31.1.2002	28.70	38.15	51.25
4	16.2.2002	28.85	38.05	49.91
5	26.2.2002	28.59	37.99	51.00
6	8.3.2002	28.49	38.12	52.20
7	18.3.2002	29.72	39.25	51.70
8	27.3.2002	28.90	38.20	50.46
9	5.4.2002	28.78	38.12	50.67
10	14.4.2002	28.68	38.08	51.00
11	23.4.2002	28.38	38.00	52.15
Average per cent depletion over ASM (%)				50.95

Table 4.9 Soil moisture status in treatment T_5 during crop period

Irrigation No.	Date	Moisture content		Per cent depletion over ASM (%)
		Before irrigation	After irrigation	
1	2.1.2002	30.82	39.50	45.42
2	12.1.2002	29.26	38.20	48.50
3	22.1.2002	30.92	38.90	43.29
4	1.2.2002	31.26	39.10	42.50
5	11.2.2002	29.72	38.25	46.25
6	21.2.2002	28.68	37.46	47.59
7	3.3.2002	31.36	39.58	44.58
8	13.3.2002	30.01	38.12	43.99
9	23.3.2002	29.77	37.99	44.58
10	2.4.2002	29.53	38.23	47.20
11	12.4.2002	29.71	38.25	46.31
12	22.4.2002	30.19	38.90	47.25
Average per cent depletion over ASM (%)				45.62

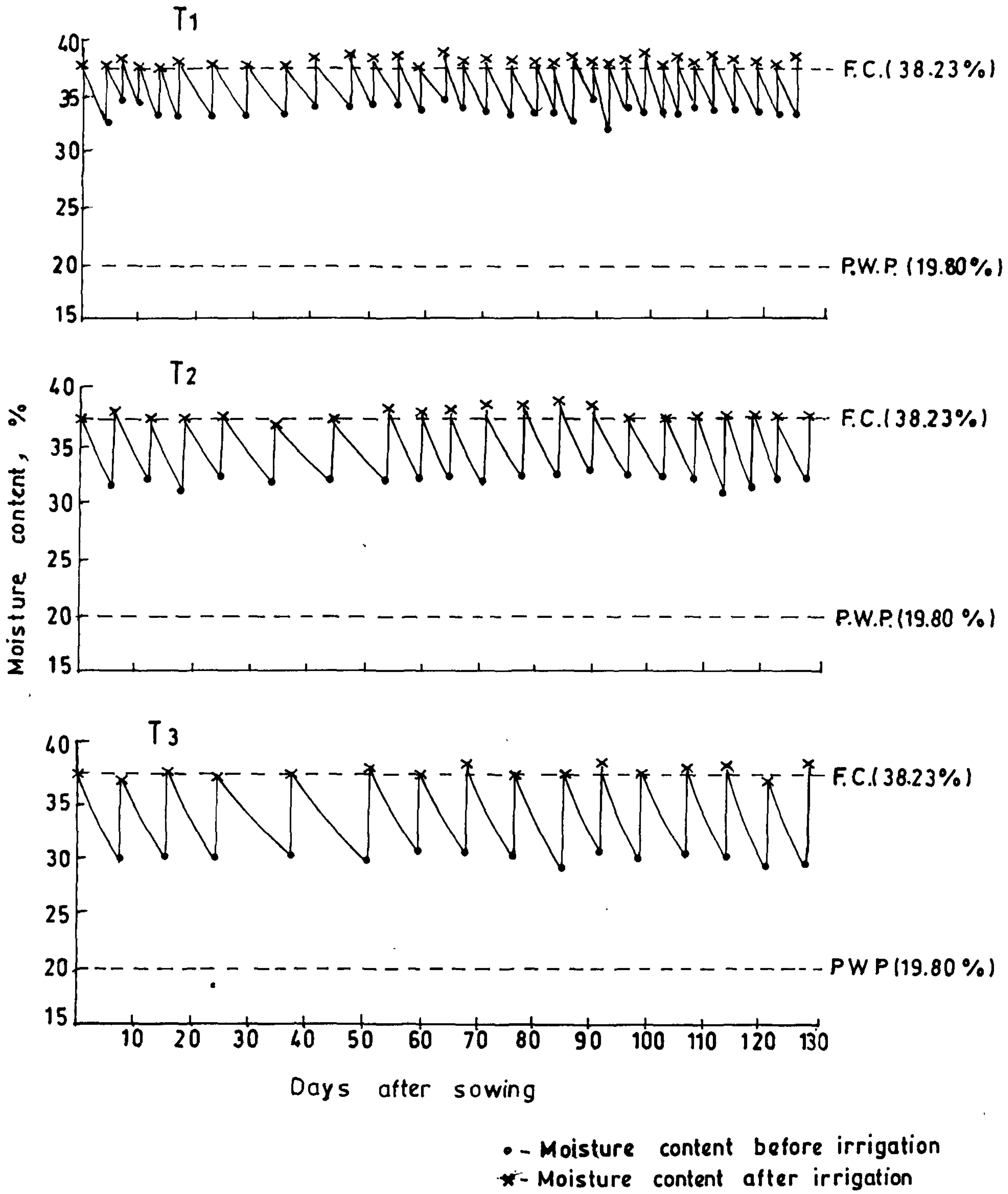


Fig.4.1 Soil moisture contents before and after irrigation in different treatments (T1 T2 and T3)

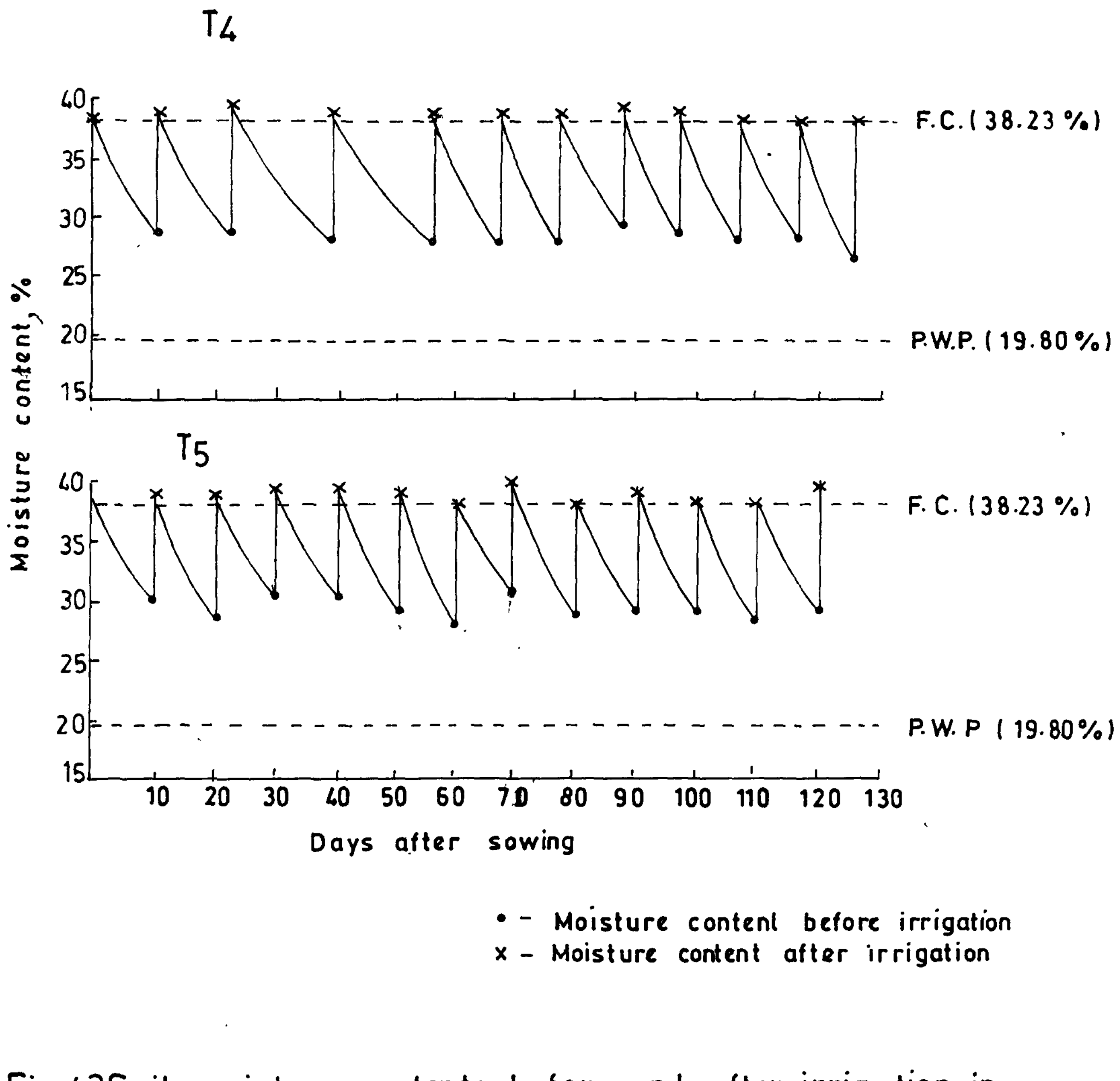


Fig.4.2 Soil moisture contents before and after irrigation in different treatments (T4 and T5).

From the table 4.5, 4.6, 4.7, 4.8 and 4.9 it was revealed that, during entire period of the crop i.e. at every irrigation, the actual percent moisture depletion was almost nearest to the predetermined percent depletion level in different treatments. The average percentage soil moisture depletion over available soil moisture were 20.60 per cent, 30.76 per cent, 41.71 per cent, 50.95 per cent and 45.62 per cent in treatments T_1, T_2, T_3, T_4, and T_5, respectively.

The observations of soil moisture after irrigation in treatments T_1 to T_4 show that the soil moisture was fairly maintained nearer to the field capacity. Thus, it can be concluded that correct depths of irrigations were applied by micro-sprinkler irrigation system. The moisture content after irrigation in control treatment was higher than the field capacity; this indicates that the extra quantity of water was applied than the requirement. This affected adversely on yield and water use efficiency.

4.4 Biometric observation

4.4.1 Plant population

The data pertaining to the plant population 30 days after sowing was recorded by adopting the procedure described in section 3.4.3 and presented in Table 4.10

Table 4.10 Plant population observed in different treatments.

Treatment	Representative area (m^2)	Theoretical plant population	Actual plant population	Per cent plant population
T_1	4.00	267	253	94.75
T_2	4.00	267	249	93.25
T_3	4.00	267	246	92.13
T_4	4.00	267	243	91.01
T_5	4.00	267	252	94.38
SE ±	-	-	0.10	
CD at 5 %	-	-	3.40	
General mean	-	-	248.6	93.10

From the Table 4.10 the maximum plant population was observed in treatment T_1 (94.75 %) whereas it was lowest in treatment T_4 (91.01 %). Average plant population was observed as 93.10 %. From this data it was observed that, there was little variation in plant population in different treatments. It may be due different irrigation frequencies in different treatments.

4.4.2 Mean plant height

The observations of mean plant height were recorded periodically by adopting the standard procedures as described in section 3.4 and reported in Table 4.11 and graphically in Fig. 4.3

Table 4.11 Mean plant height (cm) of garlic influenced periodically by different treatments

Treatment	Plant height (cm) days after sowing					
	30	60	90	120	At harvest	Average
T_1	31.98	55.40	68.25	66.55	63.95	57.23
T_2	30.54	51.71	64.85	63.12	61.37	54.32
T_3	29.34	46.66	59.53	57.58	56.57	49.95
T_4	27.58	43.66	53.85	52.65	50.77	45.68
T_5	28.74	45.84	57.95	55.35	53.60	48.29
F test	Sig.	Sig.	Sig.	Sig.	Sig.	-
SE ±	0.64	0.56	0.41	0.73	0.79	-
CD at 5 %	1.98	1.74	1.28	2.27	2.45	-
General mean	29.64	48.66	60.70	58.99	57.19	-

From Table 4.11, it was revealed that, the maximum mean plant height up to harvest was 57.23 cm attained by the plants in treatment T_1 due to low but frequent irrigations, followed by T_2 (54.32 cm), T_3 (49.94 cm) and T_5 (48.28 cm) and minimum plant height was observed (45.68 cm) in treatment T_4 .

The mean plant height increased rapidly from 29.64 cm to 60.70 cm between 30 days to 90 days after sowing. Thereafter plant height was observed to be somewhat less due to collapsing of completely open tip of the leaves.

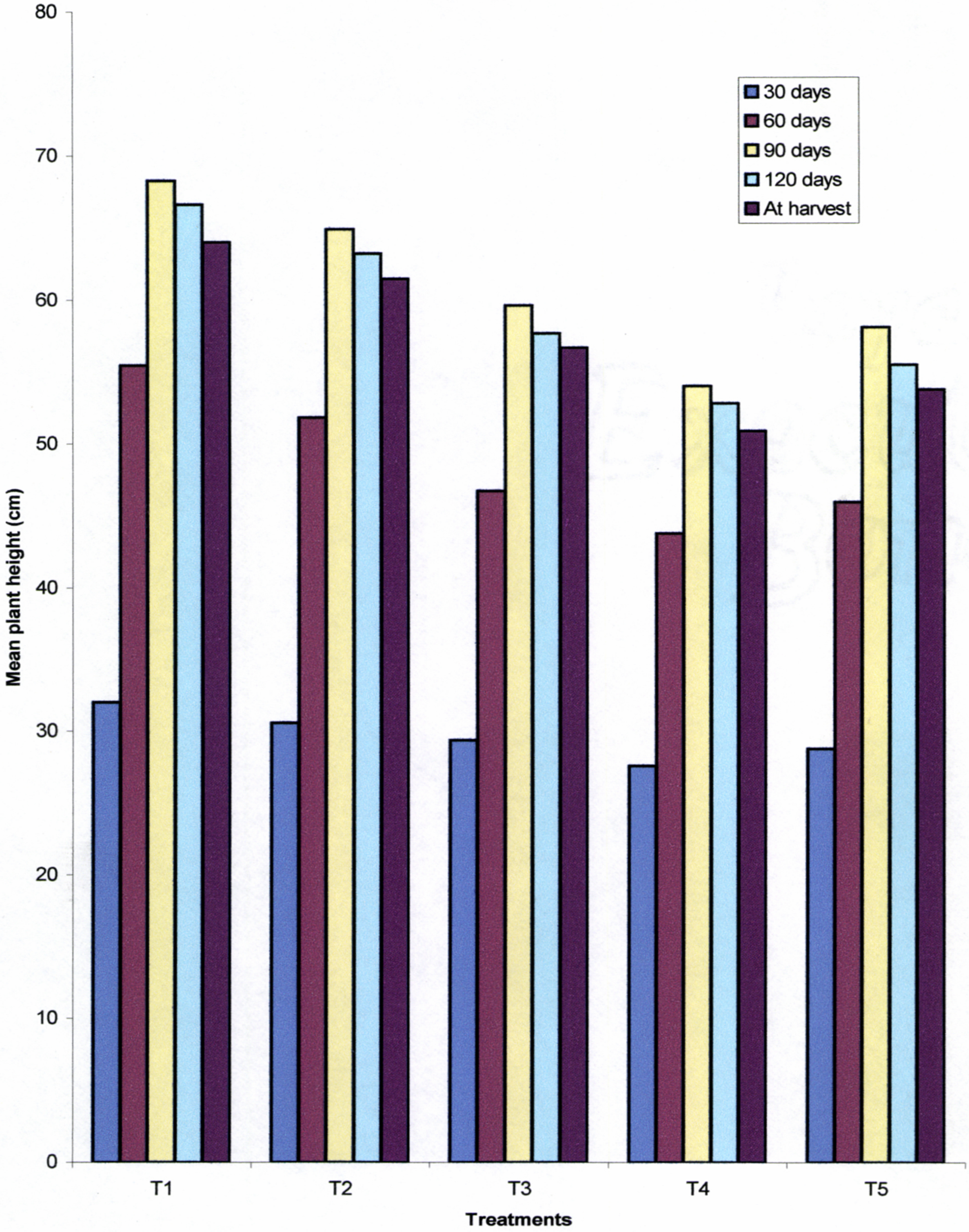


Fig.4.3 Mean plant height of garlic influenced periodically by different treatments.

Plate No. 1 Crop stand after 30 days of sowing in treatment T_1

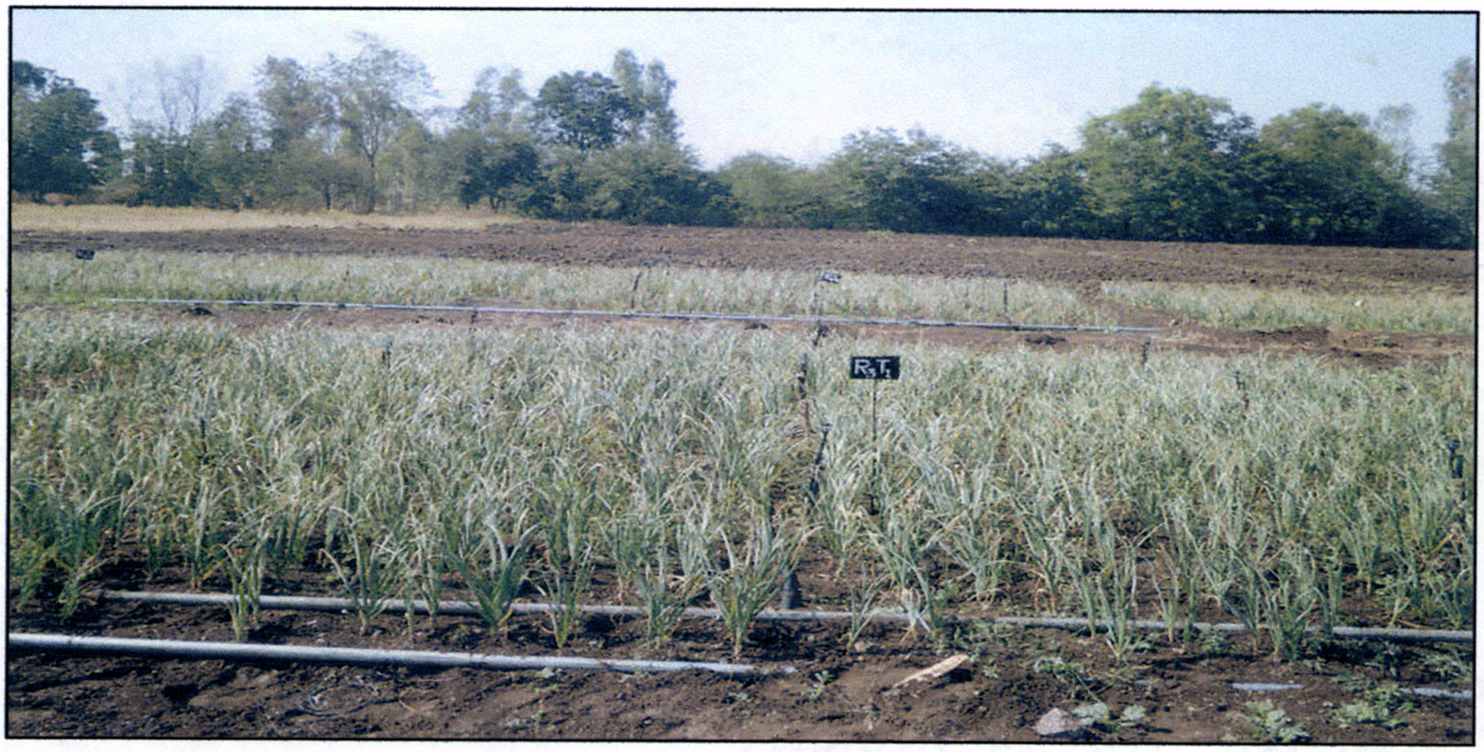


Plate No. 2 Crop stand after 90 days of sowing in treatment T_1

Plate No. 3 Crop stand after 30 days of sowing in treatment T_2

Plate No. 4 Crop stand after 90 days of sowing in treatment T_2

Plate No. 5 Crop stand after 30 days of sowing in treatment T_3

Plate No. 6 Crop stand after 90 days of sowing in treatment T_3

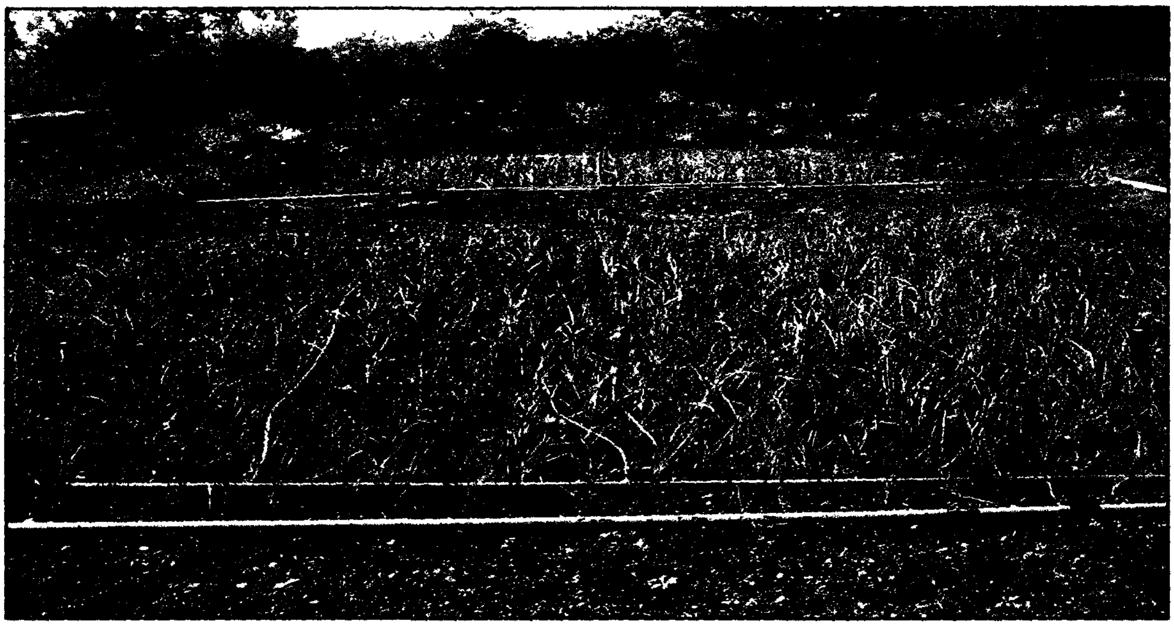


Plate No. 7 Crop stand after 30 days of sowing in treatment T_4

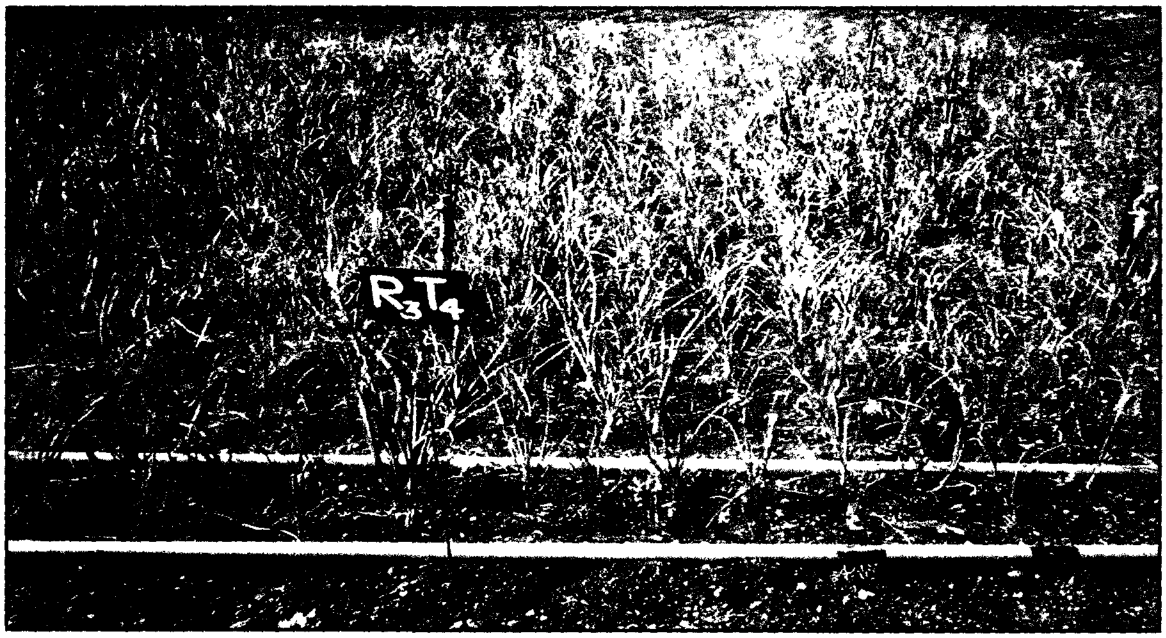


Plate No. 8 Crop stand after 90 days of sowing in treatment T_4

Plate No. 9 Crop stand after 30 days of sowing in treatment T_5

Plate No. 10 Crop stand after 90 days of sowing in treatment T_5

From the data it was revealed that at 30 DAS, 60 DAS, 90 DAS, 120 DAS and at harvest, the maximum plant heights were recorded in treatment T_1 (31.98, 55.40, 68.25, 66.58, and 63.95 cm, respectively) and found to be significantly superior over all the treatments followed by T_2 (30.54, 51.71, 64.85, 63.12, and 61.37 cm, respectively), T_3 (29.34, 46.66, 59.53, 57.58 and 56.57 cm, respectively) and T_5 (28.74, 45.84, 57.95, 55.35 and 53.60 cm, respectively). The lowest plant heights were recorded in treatment T_4 (27.58, 43.66, 53.85, 52.65 and 50.77 cm, respectively), at 30,60,90,120 DAS and at harvest respectively. The plant height was maximum in treatment T_1 over all other treatments because of high irrigation frequency and less moisture depletion level which resulted the soil moisture content before irrigation closer to field capacity.

4.5 Yield contributing characters

The data pertaining to the mean polar diameter, equatorial diameter, geometric mean diameter (mm), number of cloves and weight of each garlic bulb (g) as observed in the different treatments was collected by adopting the procedures as described in section 3.5 and presented in Table 4.12 and graphically depicted in Fig.4.4

Table 4.12 Mean polar diameter, equatorial diameter, geometric mean diameter), average wt of bulb (g) and number of cloves at harvest as influenced by different treatments.

Treatment	Polar diameter of bulb (mm)	Equatorial diameter (mm)	Geometric mean diameter (mm)	Average weight of bulb (g)	Number of cloves per bulb
T_1	39.40	36.00	36.45	20.25	9.60
T_2	36.75	32.00	34.76	17.85	8.25
T_3	30.85	27.65	28.80	14.40	8.08
T_4	25.30	23.45	24.93	10.54	7.10
T_5	28.55	25.34	26.89	12.96	7.52
F test	Sig.	Sig.	Sig.	Sig.	Sig.
SE ±	1.065	1.714	1.310	0.892	0.183
C.D. at 5 %	3.282	5.407	4.039	2.750	0.564
General mean	32.138	28.888	30.576	15.128	8.108

From Table 4.12 and Fig. 4.4, it was revealed that the mean polar diameter, equatorial diameter of bulb, geometric mean diameter of bulb were observed maximum in treatment T_1 i.e. 39.40, 36.00 & 36.45 mm, respectively which was significantly superior over all other treatments followed by T_2 (36.75, 32.00 & 34.76 mm, respectively), T_3 (30.85, 27.65 & 28.80 mm, respectively) and T_5 (28.55, 25.34 & 26.89 mm, respectively).

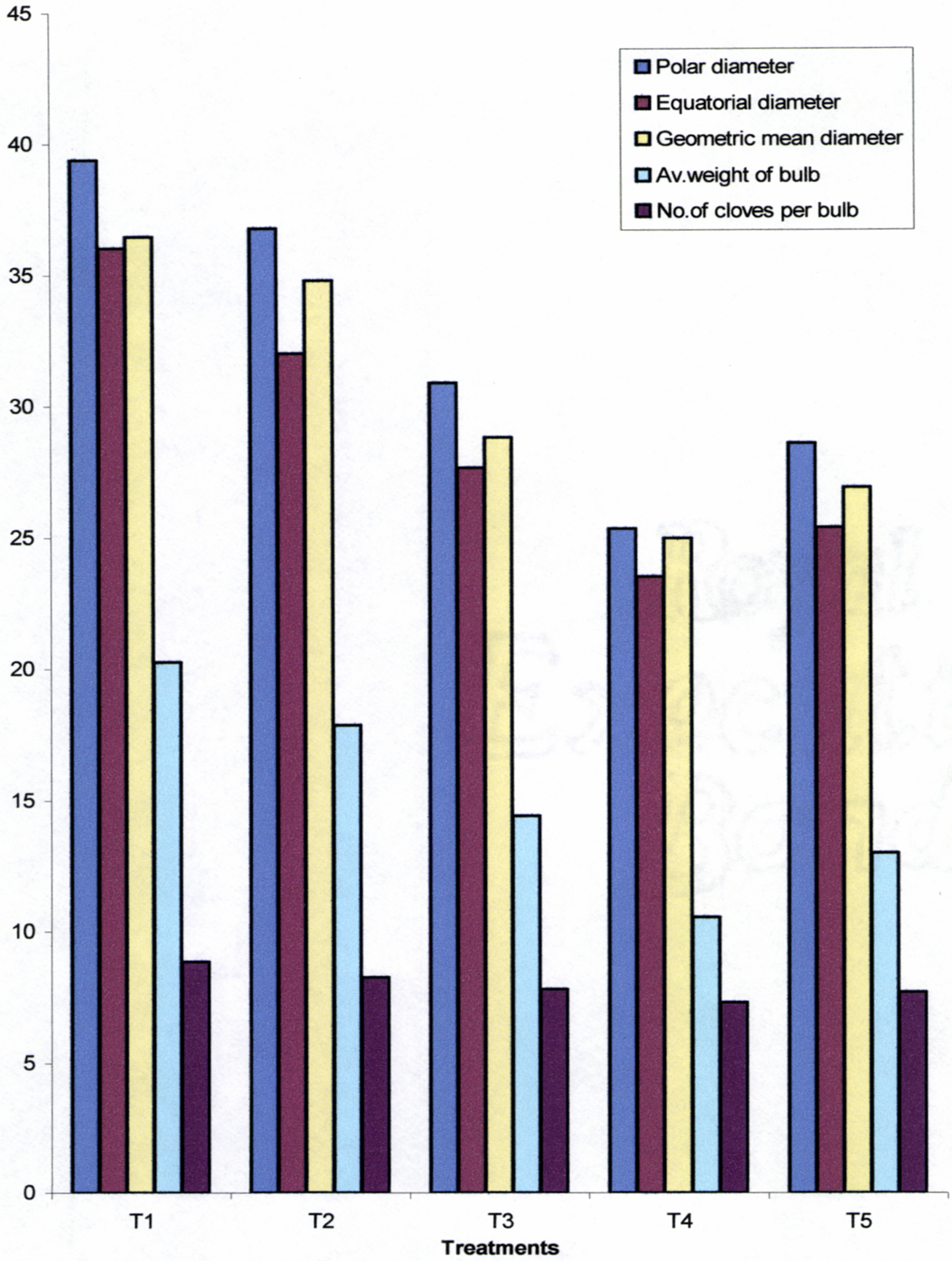


Fig.4.4 Polar diameter, equatorial diameter, geometric mean diameter, average weight of garlic bulb, number of cloves per bulb as influenced by different treatments.

The mean polar diameter, equatorial diameter of bulb, geometric mean diameter of bulb were observed minimum in treatment T_4 i.e. 25.30, 23.45 and 24.93 mm, respectively. The average weight of garlic bulb was observed maximum in treatment T_1 (20.25 gm) that was significantly superior over all other treatments.

The average number of cloves per bulb was observed maximum in treatment T_1 i.e. 9.60. However it was observed lower in treatment T_2 i.e.7.10.

All yield contributing characters showed the superiority in treatment T_1 (20 per cent depletion level) as compared to other treatments. This revealed that garlic crop responds frequent but light irrigation.

4.6 Yield

The data pertaining to the yield of garlic at harvest and after sun drying, drying factor and percentage reduction in weight as influenced by different treatments are presented in Table 4.13 and graphically depicted in Fig 4.5.

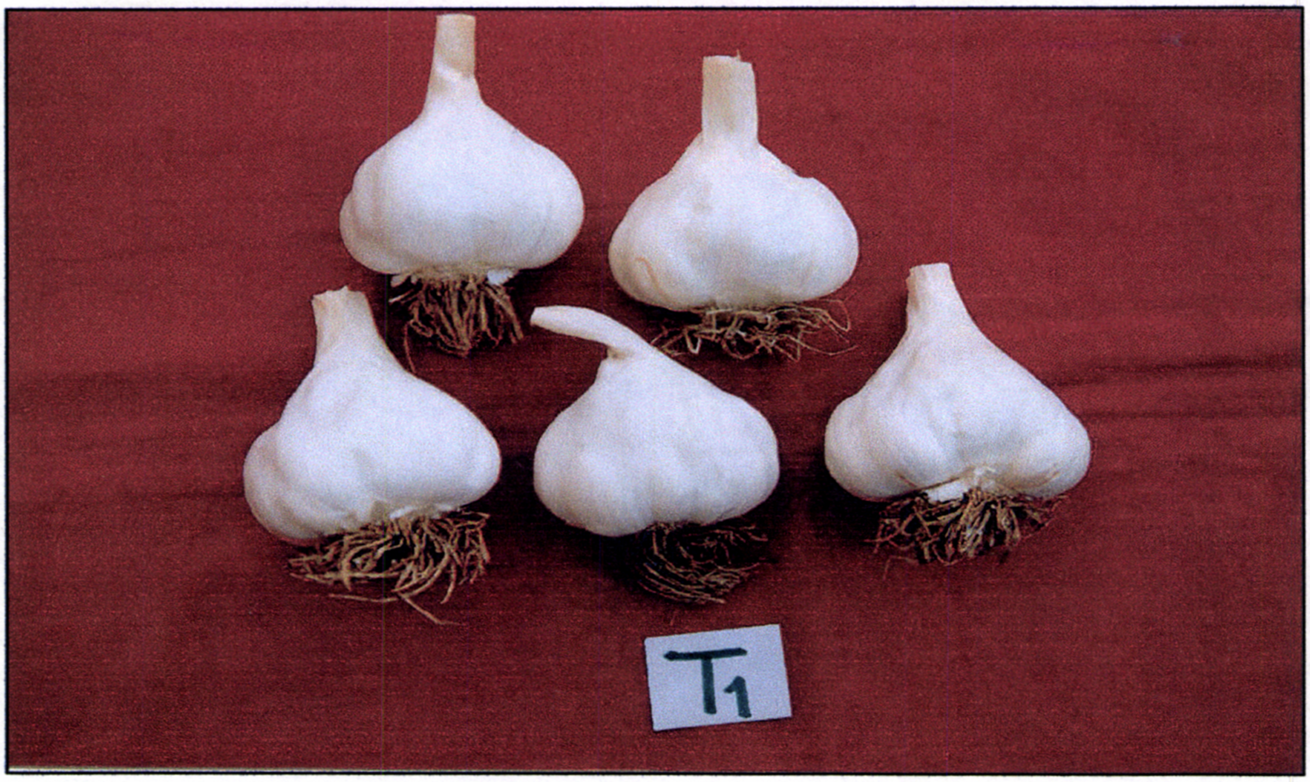


Plate No. 11 Garlic bulbs observed in treatment T_1

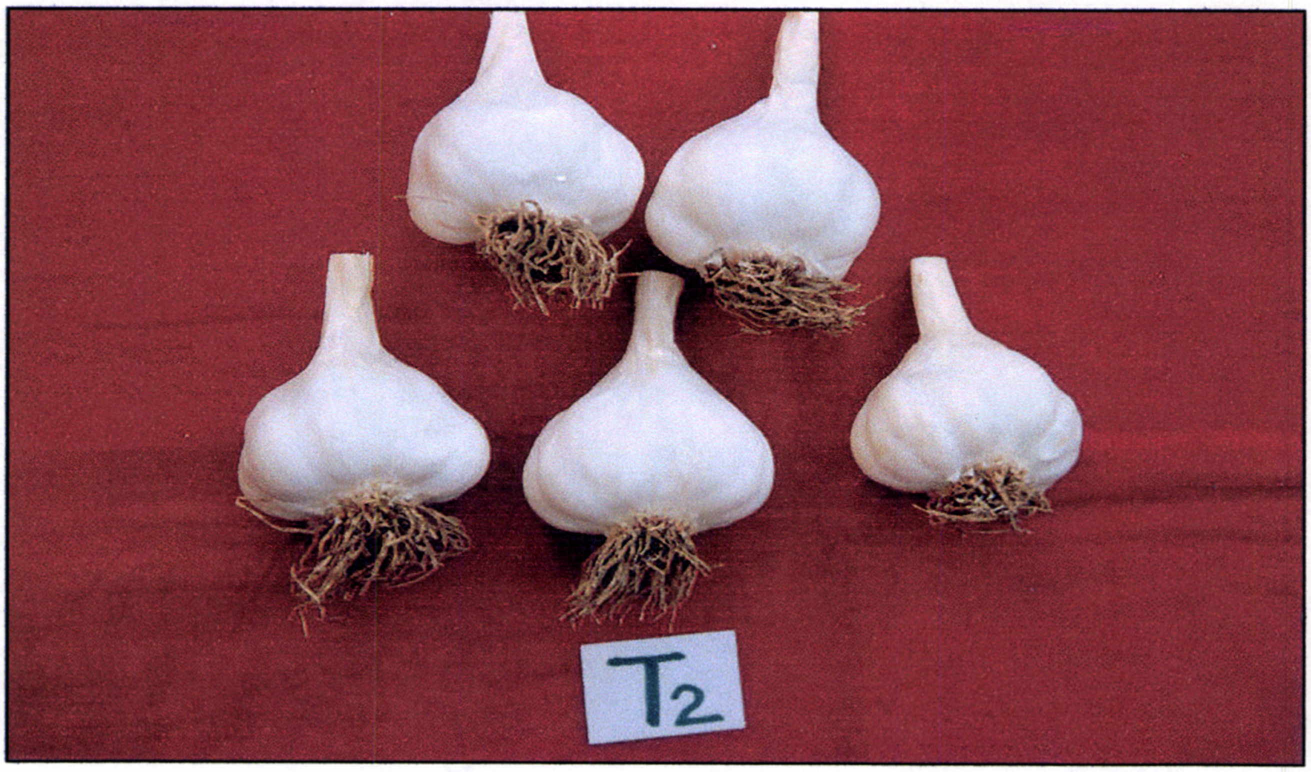


Plate No. 12 Garlic bulbs observed in treatment T_2

Plate No. 13 Garlic bulbs observed in treatment T_3

Plate No. 14 Garlic bulbs observed in treatment T_4

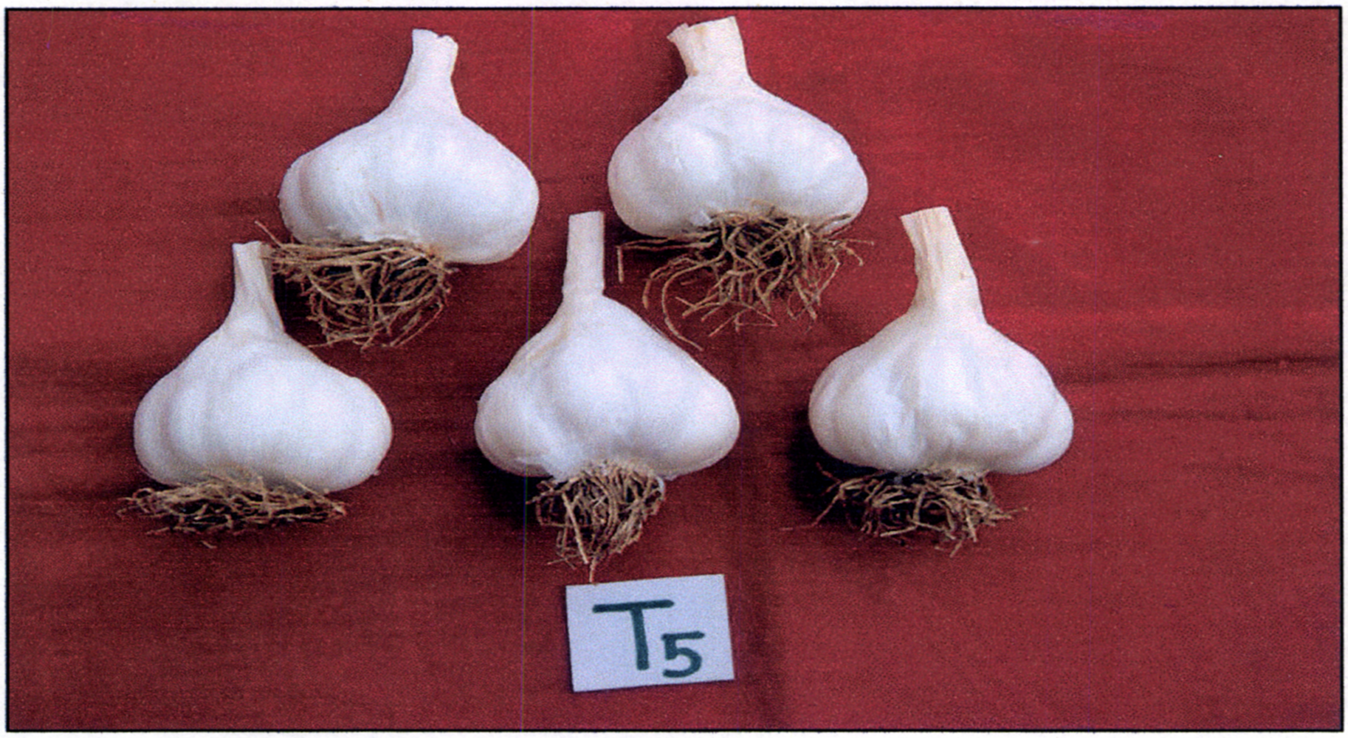


Plate No. 15 Garlic bulbs observed in treatment T_5

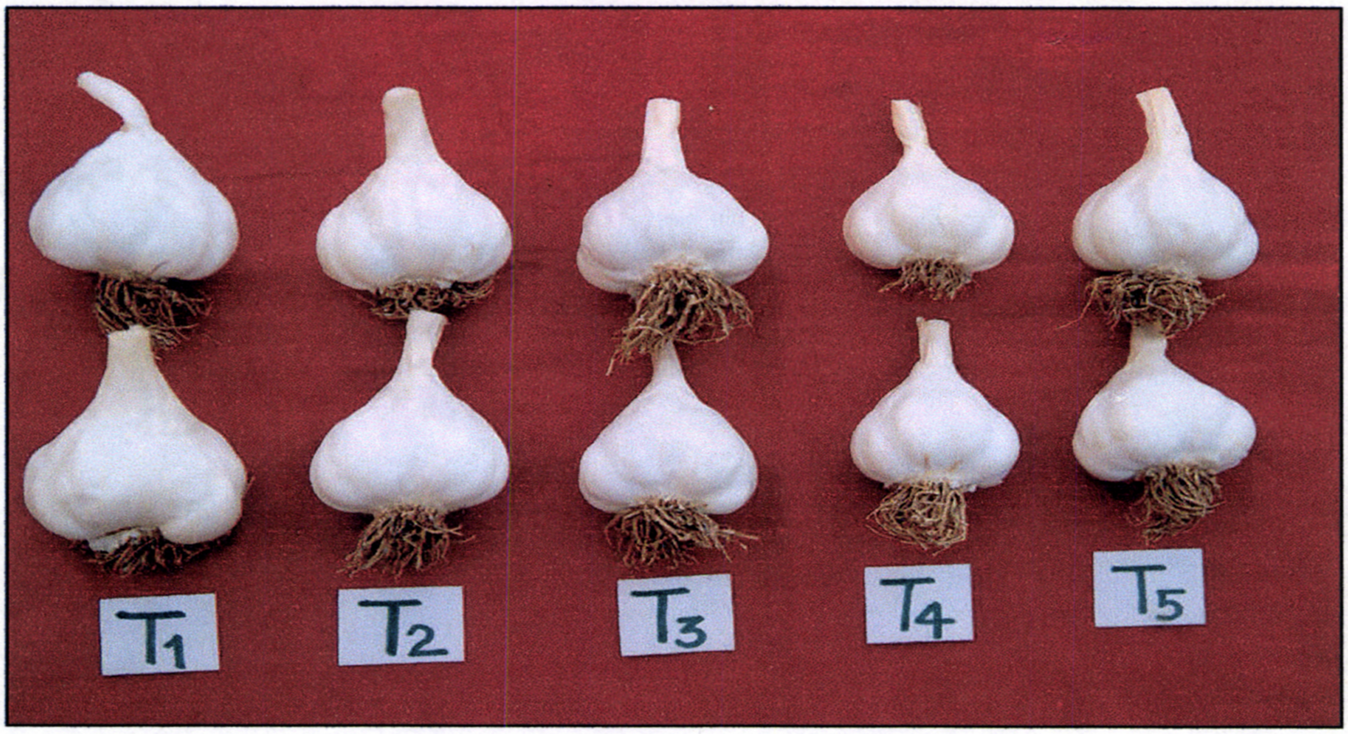


Plate No. 16 Garlic bulbs observed in different treatments

Table 4.13 Mean yield of garlic at harvest and after drying (q/ha), drying factor and percentage reduction in weight in different treatments.

Treatment	Yield at harvest (q/ha)	Yield after drying (q/ha)	Drying factor	Percentage reduction in weight	Per cent increase in yield over control	
					Yield at harvest	Yield after drying
T_1	109.687	82.531	0.754	24.575	22.92	20.13
T_2	101.218	76.991	0.769	23.925	13.43	12.06
T_3	91.280	70.456	0.772	22.750	2.29	2.551
T_4	66.718	53.144	0.796	20.250	-	-
T_5	89.230	68.700	0.770	23.000	-	-
F test	Sig	Sig.	-	-	-	-
SE ±	3.147	2.119	-	-	-	-
C. D. at 5 %	9.699	6.530	-	-	-	-
General mean	91.626	70.531	0.771	22.900	-	-

4.6.1 Yield of garlic at harvest and after drying

From Table 4.13 it was revealed that, the yield of garlic immediately at harvest and after drying was found maximum in treatment T_1 (109.68 q/ha and 82.53 q/ha respectively) that are significantly superior over all other treatments. The minimum yield of garlic immediately at harvest and

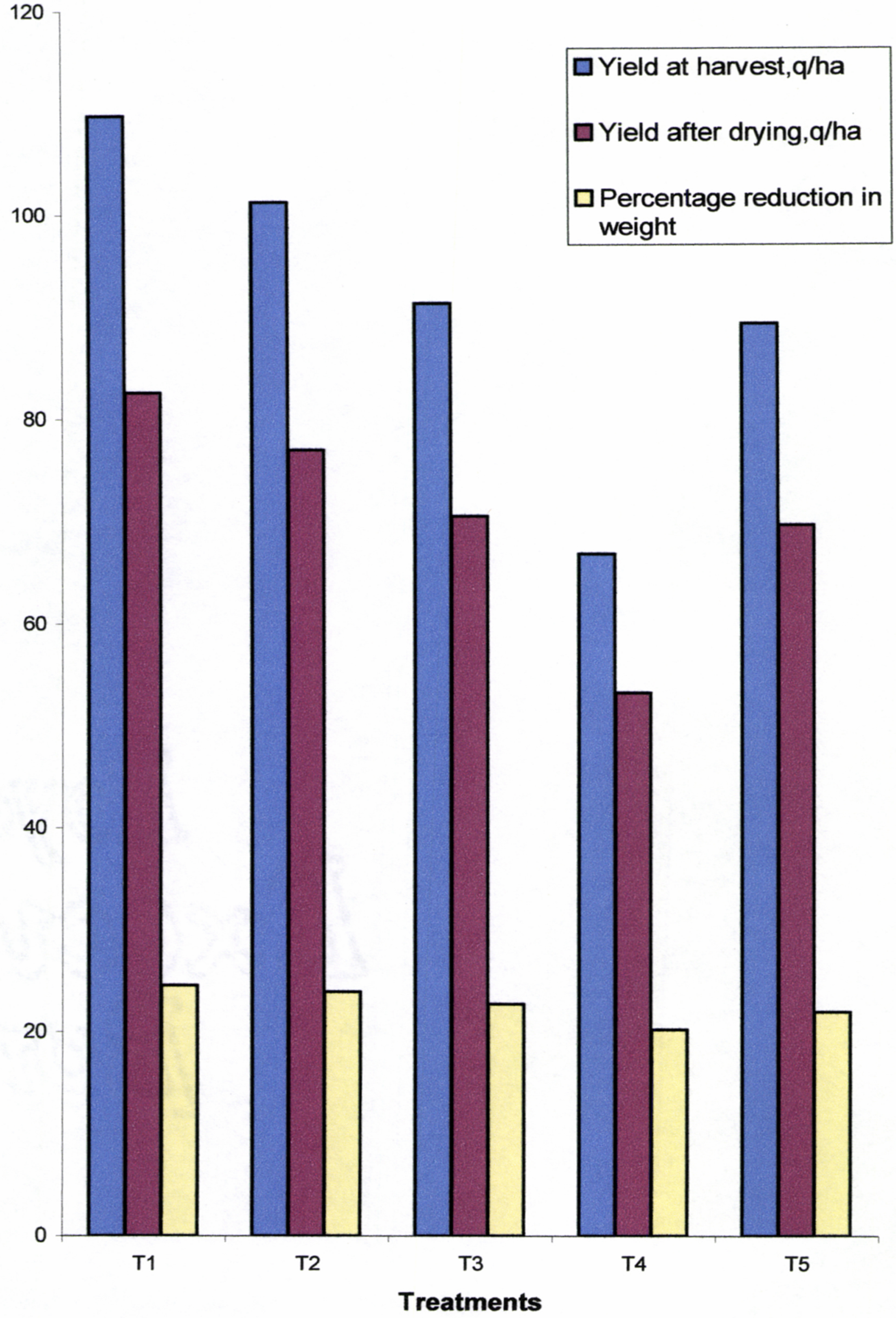


Fig.4.5 Yield of garlic at harvest, on drying and percentage reduction in weight of garlic as influenced by different treatments.

after drying were observed in treatment T_4 (66.71 q/ha and 53.14 q/ha respectively)

The per cent increase in yields over control (T_5) at harvest and after drying observed in treatment T_1, T_2 & T_3 were 22.92, 13.43, 2.29 and 20.13, 12.06, 2.55 per cent respectively. However, in treatment T_4 the yield at harvest (66.71 q/ha) and yield after drying (53.14 q/ha) was lower than that of control (T_5) 89.23 q/ha & 68.70 q/ha, respectively. This is due to the higher irrigation interval i.e. 9 to 16 days, which resulted in moisture stress in treatment T_4 and affected the growth of plant.

4.6.2 Drying factor and percentage reduction in weight of garlic

From Table 4.13 it was revealed that the average drying factor and percentage reduction for all treatment were 0.77 and 22.90 per cent, respectively. These two parameters were found almost constant varying within 10 % and were not influenced by different treatments. Drying factor is useful in predicting the yield of dry bulb if weight at harvest is known. Also percentage reduction in weight of freshly harvested garlic on its drying. These two parameters influenced the cost economics of the crop.

4.6.3 Yield of bulbs, yield of stalks and bulb to stalk ratio

The observations of yield of bulbs, stalks and bulb to stalk ratio were recorded as per procedure described in section 3.6 and the data pertaining to these parameters as influenced by different treatments is reported in Table 4.14 and graphically depicted in Fig. 4.6

Table 4.14 Mean yield of garlic bulbs (q/ha), yield of stalks (q/ha) and bulb to stalk ratio as influenced by different treatments after drying

Treatment	Yield of garlic bulbs (q/ha)	Yield of stalks (q/ha)	Bulb to stalk ratio	Per cent increase in yield over control	
				Yield of bulbs	Yield of stalks
T_1	67.568	14.96	4.51	21.16	15.69
T_2	63.710	13.28	4.79	14.24	2.70
T_3	58.325	12.13	4.80	4.58	-
T_4	42.810	10.33	4.14	-	-
T_5	55.767	12.93	4.31	-	-
F test	Sig.	Sig.	Sig.	-	-
SE ±	1.473	0.338	0.198	-	-
C. D. at 5 %	4.539	1.043	0.611	-	-
General mean	57.636	12.726	4.51	-	-

The mean yield of garlic bulbs was 57.636 q/ha. The yield of bulbs was observed maximum (67.568 q/ha) in treatment T_1 (Irrigation frequency at 20 per cent depletion level) and was significantly superior over all other treatments. Treatment T_4 (Irrigation frequency at 50 per cent depletion level) recorded the lowest yield of bulbs (55.767 q/ha). These results are similar to those reported by Pawar (1995) and Anonymous (2001).

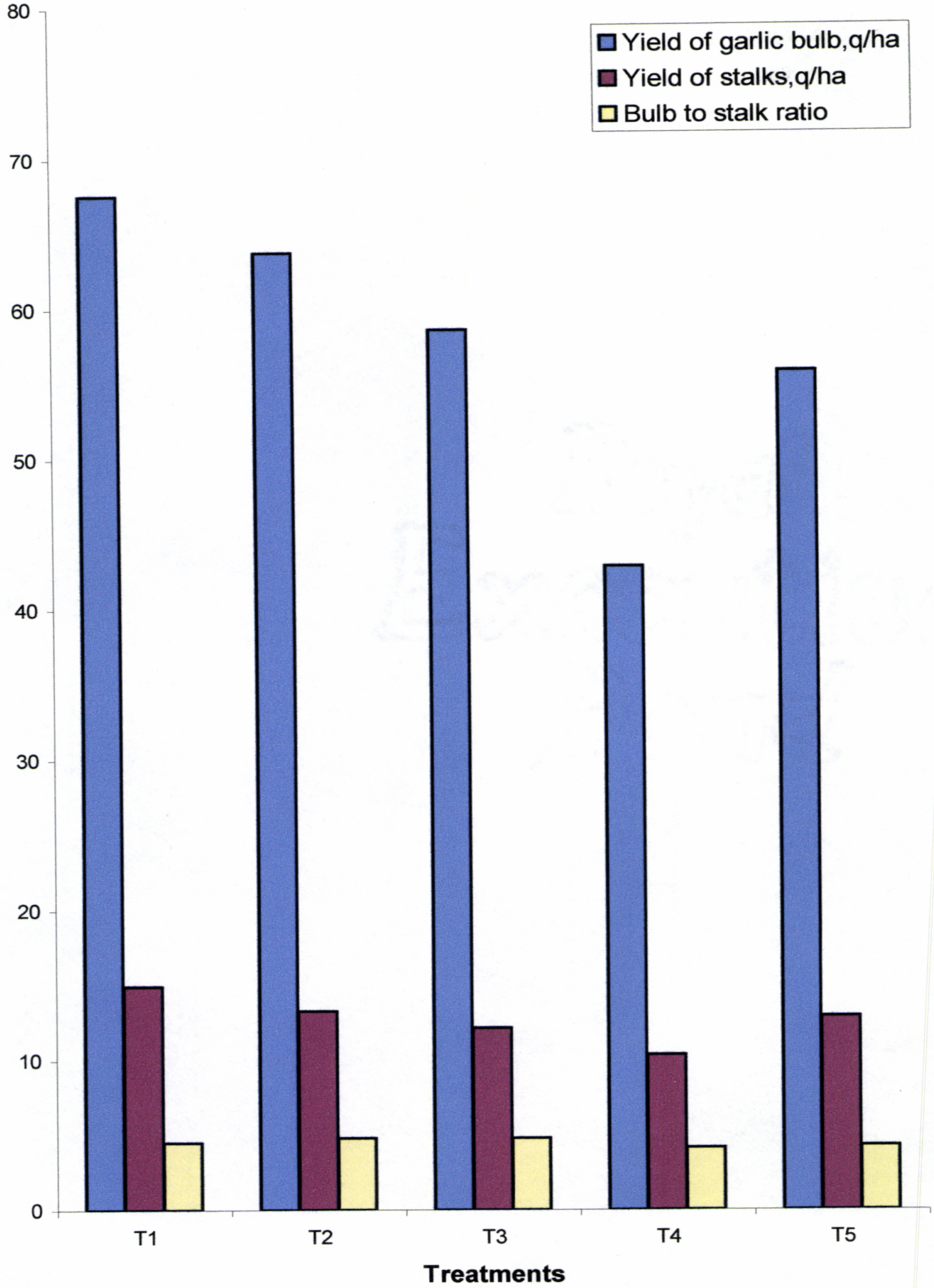


Fig.4.6 Yield of garlic bulbs, yield of stalks and bulb to stalk ratio as observed in different treatments.

The per cent increase in the yield of garlic over control (T_5) was observed as 21.16 %, 14.24 % and 4.58 % in treatments T_1, T_2 & T_3 respectively. However, the yield of garlic in treatment T_4 observed lower than that of control. This is because of the less available soil moisture depletion level (50.95 %) was more than that of control (45.62 %).

The data pertaining to the yield of stalks revealed that the mean yield of stalks was 12.726 q/ha. Treatment T_1 was significantly superior over all other treatment and recorded maximum yield of stalks (14.96 q/ha). Treatment T_4 recorded the lowest yield of stalk (10.33 q/ha). An increase in the yield of stalk was observed in treatments T_1, & T_2 over control (T_5), was 15.69 % & 2.70 % respectively. Treatment T_4 (10.33 q/ha) recorded less yield of stalks than that of control (12.93 q/ha).

Similarly the data presented in Table 4.14 pertaining to the bulb to stalk ratio revealed that mean bulb to stalk ratio was 4.51. Treatment T_1 recorded the bulb to stalk ratio as 4.51. Treatment T_4 recorded the lowest bulb to stalk ratio (4.14). The bulb to stalk ratio was higher in treatment T_1, T_2 & T_3 (4.51, 4.79 & 4.80, respectively) than that of control (4.31).

4.7 Water requirement at different irrigation frequencies

The water requirement in each treatment was computed as described in 3.7 and reported in Table 4.15. Water requirement of garlic due to different irrigation frequencies based on depletion level was the total amount of water applied in each treatment.

Table 4.15 Water requirement of garlic under different irrigation frequencies

Treatment	Water requirement (mm)
T_1 (20 % depletion level)	802.40
T_2 (30 % depletion level)	776.07
T_3 (40 % depletion level)	754.60
T_4 (50 % depletion level)	707.00
T_5 (Control)	940.00

From Table 4.15, water requirement was higher in treatment T_1 (20 % depletion level) i.e. 802.40 mm and lowest in treatment T_4 (50 % depletion level) i.e.707.00 mm. The water requirement of control (T_5) i.e.940 mm was higher than that of T_1 (802.40 mm), T_2 (776.07), T_3 (754.60 mm) and T_4 (707.00 mm). Thus percent saving in water observed 17.14, 21.12, 24.56 and 32.95 over control in treatment T_1, T_2, T_3 and T_4 respectively. Though the per cent moisture depletion in treatment T_4 and control was nearly closer, the total depth of water applied in treatment T_4 (707.00 mm) was less than that of control (T_5) i.e. 940.00, which indicates that micro-sprinkler is not only a water saving technique but an integrated water management tool as it helps in avoiding problems like water table built up and salinity in future as a result of continuous excessive use of water.

4.8 Water use efficiency

Water use efficiency as observed in different treatments were determined by adopting the method described in section 3.8 and presented in Table 4.16

Table 4.16 The WUE as influenced by different irrigation frequencies.

Treatment	Water requirement (mm)	Yield (q/ha)	WUE (kg/ha-cm)
T_1	802.40	67.568	84.207
T_2	776.07	63.710	82.093
T_3	754.60	58.325	77.292
T_4	707.00	42.810	60.551
T_5	940.00	55.767	59.326

From Table 4.16 it was revealed that the WUE is maximum (84.20 kg/ha-cm) in T_1 treatment (20% depletion level) and it decreased with increase in percent moisture depletion levels. The WUE is minimum in control (T_4) treatment (59.32 kg/ha-cm) than any other treatment.

The yield of garlic in treatment T_1 was found higher (67.568 q/ha) than all other treatment was mainly due to frequent and light irrigations. The percentage increase in WUE over control was observed to be 41.92, 38.37, 30.28 and 2.06 in treatment T_1, T_2, T_3 and T_4 respectively. WUE gradually decreased with increase in depletion level indicates an inefficient utilisation of applied irrigation water.

4.9 Appropriate scheduling criteria

It was revealed from the yield data observed in different treatments based on different irrigation frequencies calculated on the basis of per cent moisture depletion levels i.e. 20 %, 30 %, 40 % and 50%, that the maximum yield of garlic bulbs (67.568 q/ha) was obtained in treatment T_1 (20 % moisture depletion level). It means that, the garlic crop responded to lighter but frequent irrigation. Lighter and frequent application of irrigation water is possible with maximum irrigation efficiency only with pressurised irrigation systems. Micro-sprinkler is one such type. Thus the findings lead to draw the conclusion that garlic crop be irrigated at 20 % available moisture depletion level by adopting the irrigation schedule as presented in Table 4.17.

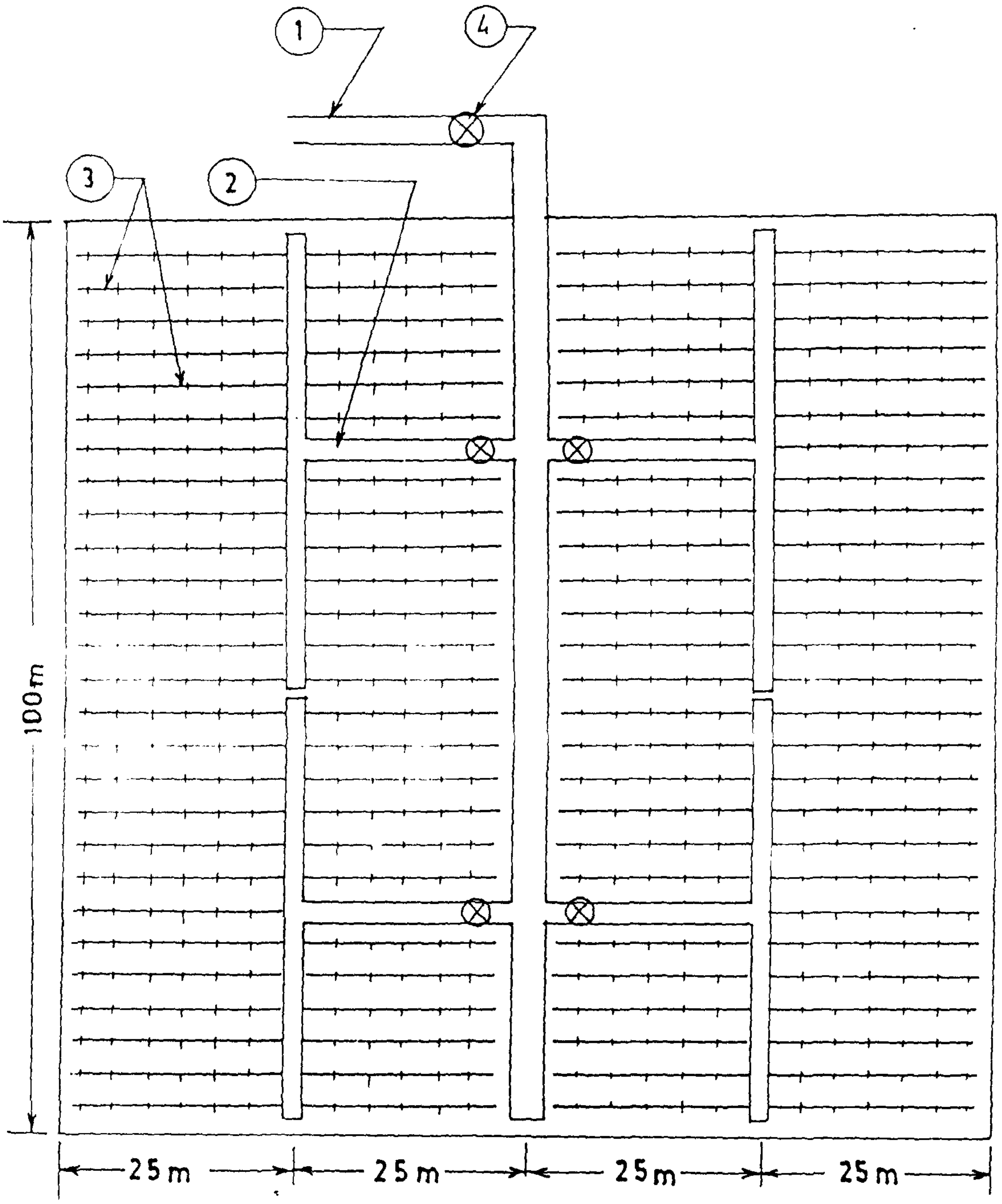
Table 4.17 Scheduling of irrigation for garlic

Method of irrigation	Growing stages of garlic crop	Average depth of irrigation at 20 % depletion level (mm)	Irrigation frequency (days)
Micro-sprinkler	Initial (0-20 DAS)	10	3
	Crop development (21-50 DAS)	25	6
	Mid season (51-85 DAS)	25	4
	Late season (85 DAS- upto harvest)	25	3

4.10 Economics of micro-sprinkler system

To determine the economics of micro-sprinkler irrigation system for garlic crop, the fixed cost, operating cost, total cost, total return, net return and benefit cost ratio were worked out as described in section3.9.

The system cost per unit area of micro-sprinkler was worked out from the layout of the system. The general layout of micro-sprinkler system is depicted in Fig. 4.7.



Micro-sprinkler spaced at 1.75m

1. Main 50 mm ø G.I.
2. Submain 25 mm ø G.I.
3. Lateral LDPE 16 mm ø spaced at 1·75 m
4. Valve

Fig. 4.7 General layout of micro-sprinkler irrigation for cost economics.

Different particulars regarding length and number of main, submain, laterals, and micro-sprinklers were worked out from the layout and are reported in Table 4.18.

Table 4.18 Particulars of micro-sprinkler system from general layout

Sr. No.	Particulars	Length (m)	Quantity	Total quantity
1	Main (50 mm GI)	120 m	1	120 m
2	Submain (25 mm GI)	300 m	1	300 m
3	Lateral (LDPE 16 m)	25 m	228	5700 m
4	Micro-sprinkler	-	3265	3265 Nos.

Fixed cost and operating cost of micro-sprinkler system with centrifugal pumping unit were worked out and reported in Appendices III and IV. Assuming that the system will be used for three seasons in a year, seasonal fixed cost was worked out.

Total cost in Rs/ha for all depletion level treatment were estimated by adding fixed cost to operating cost and are presented in Table 4.19. The crop yield, total return, net return and benefit-cost ratio were also worked out and are also reported in Table 4.19.

The seasonal fixed cost of micro-sprinkler system was found to be Rs. 15850.0 per ha and seasonal operating cost was found to be Rs. 47820.0 per ha which gives seasonal total cost of system Rs. 63670.00 per ha. From Table 4.19 it is observed that the net returns from treatment T_1 to

T_4 were 206602.0, 191170.0, 169130.0 and 107570.0 Rs/ha, respectively. Similarly benefit cost ratio for treatments T_1 to T_4 were 4.24, 4.00, 3.66 and 2.68, respectively. The highest net return and benefit cost ratio were obtained in treatment T_1 (20 per cent depletion level). However, the lowest net return and benefit cost ratio were obtained in treatment T_4 (50 per cent depletion level).

Table 4.19 Seasonal fixed cost, operating cost, total cost, garlic bulb yield, total returns, net returns and benefit cost ratios for different per cent moisture depletion level treatments under micro-sprinkler irrigation system

Treatment	Seasonal fixed cost (Rs/ha)	Seasonal operating cost (Rs/ha)	Seasonal total cost Rs/ha	Garlic bulb yield (q/ha)	Rates* fetched (Rs/q)	Total returns (Rs./ha)	Net returns (Rs/ha)	Benefit cost ratio = Total returns/total cost
T_1	15850.0	47820.0	63670.0	67.568	4000	270272.0	206602.0	4.240
T_2	15850.0	47820.0	63670.0	63.710	4000	254840.0	191170.0	4.000
T_3	15850.0	47820.0	63670.0	58.325	4000	233300.0	169630.0	3.660
T_4	15850.0	47820.0	63670.0	42.810	4000	171240.0	107570.0	2.689

* Garlic rate Rs. 40/kg (Source : Sakal, Pune, 27th May, 2002).

Summary and Conclusions

5. SUMMARY AND CONCLUSIONS

5.1 Summary

The field experiment entitled, "Effect of different irrigation frequencies on yield of Garlic (*Allium sativam* L) under micro-sprinkler irrigation system" was undertaken at the Instructional Farm of Department of Irrigation and Drainage Engineering, College of Agricultural Engineering, MPKV, Rahuri during December 2001 to April 2002.

The experiment was laid out statistically with Randomised Block Design (RBD) with five treatments replicated for four times. Four treatments were based on different irrigation frequencies calculated on the basis of percent moisture depletion levels *viz.,* 20, 30, 40 and 50 per cent. The water was applied conventionally to the control treatment. Sowing of garlic was undertaken on 22nd December, 2001. The basal dose of 50 kg N, 50 kg P_2O_5 and 50 kg K_2O was given at the time of sowing. The second dose of 50 kg N was given one month after sowing. The harvesting of garlic was done on 14th to 16th May, 2002.

5.1.1 Physical properties of soil

The soil of the experimental field was clayey type. The field capacity, permanent wilting point, bulk density and infiltration rate of the soil were 38.23 per cent, 19.80 per cent, 1.26 g/cm^3 and 0.42 cm/hr, respectively. The micro-sprinkler system was laid down and calibrated in the field before sowing of garlic.

5.1.2 Irrigation

Micro-sprinkler system was installed in the field for irrigating the garlic crop. The micro-sprinklers were spaced at 1.75 x 1.75 m. Average discharge of the micro-sprinkler was 37.83 lph at 1 kg/cm^2 operating pressure. Similarly, the average rate of precipitation was 12.34 mm/hr.

5.1.3 Uniformity Coefficient (UC)

In order to assess the non-uniformity UC for the system was worked out and an average UC value of 85.00 % was observed in the field.

5.1.4 Depth of water applied and time of irrigation

The depth of water applied to different treatments i.e. T_1 to T_4 was based on total available water in soil and percent moisture depletion level. Gross depth of irrigation was calculated by dividing net depth of irrigation by uniformity coefficient. There was little variation in total depth of water applied due to per cent depletion level, irrigation interval and crop coefficient at various growth stages. The times of irrigation for T_1 to T_4 treatment was different due to the scheduling of the treatments at different percent moisture depletion levels. For control treatment (T_5) 70 mm depth of water was applied at an interval of 10 days.

5.1.5 Soil moisture studies

The different soil moisture depletion levels were attained in field almost on par to that of adopted for scheduling. The soil moisture stress was increased as the percent moisture depletion level increased and this finally decreased the yield of garlic. In treatment T_1 (20% depletion level), the soil moisture status was observed closer to the field capacity before irrigation.

5.1.6 Biometric observations

The mean plant height of garlic was observed maximum (57.233 cm) in treatment T_1 (20 per cent depletion level) at all growth stages and was the lowest (45.686 cm) in treatment T_4 (50 per cent depletion level) at all growth stages.

5.1.7 Yield contributing characters

Yield contributing characters such as bulb size, number of cloves per bulb and average weight of garlic bulb were maximum (37.28 mm, 9.60 and 20.25 g) in T_1 treatment (20 per cent depletion level) and lowest (24.56 mm, 7.30 and 10.54 g) in treatment T_4 (50 per cent depletion level).

5.1.8 Yield

The yield of garlic was influenced significantly by treatments scheduled at different irrigation frequencies based on different depletion levels. The maximum yield of garlic was observed in treatment T_1 (20 per cent depletion level) at harvest and after drying i.e. 109.68 and 82.53 q/ha, respectively. The lowest yield at harvest and after drying was observed as 66.71 and 53.14 q/ha respective in treatment T_4 (50 per cent depletion level). The data pertaining to drying factor and percentage reduction in weight showed little difference between the treatments. Yield of garlic bulbs, yield of stalk and bulb to stalk ratio were also observed maximum in treatment T_1 (20 per cent depletion level) was 67.56 q/ha, 14.96 q/ha and 4.80 respectively and lowest in treatment T_4 (50 per cent depletion level) i.e. 42.81 q/ha, 10.33 q/ha and 4.14 respectively. The yield of garlic was observed higher in T_1, T_2 and T_3 than control (T_5). However, treatment T_4 recorded less yield than control.

5.1.9 Water requirement

Water requirements of garlic crop at 20, 30, 40 and 50 per cent depletion levels i.e. T_1, T_2, T_3 and T_4 treatments were worked as 802.40 mm, 776.07 mm, 754.60 mm and 707.00 mm, respectively. There was little variation in water requirement of T_1 to T_4 due to percent depletion level, irrigation interval and crop coefficient (Kc) for different crop growing stages. The water requirement of control (T_5) was more (940.00 mm) than any other micro-sprinkler treatment.

5.1.10 Water use efficiency (WUE)

The WUE was observed maximum (84.20 kg/ha-cm) in treatment T_1 (20 per cent depletion level) and it was found decreased with increase in per cent depletion levels. It was observed (59.32 kg/ha-cm) in control treatment (T_5). In treatment T_4, it was observed less (60.55) due to more depletion level (50%)

5.1.11 Appropriate scheduling criteria

The garlic crop found to be responded to light and frequent irrigation by giving maximum yield of bulbs (67.568 q/ha) at 20 per cent moisture depletion level (T_1). Therefore the irrigation for garlic should be scheduled at 20 per cent depletion level i.e. with less frequency level by micro-sprinkler method. In general the irrigation interval may be decided as 3 to 6 day.

5.1.12 Cost economics of micro-sprinkler system

The seasonal fixed cost of micro-sprinkler system was found to be Rs. 15850.00/ha and seasonal operating cost was found to be Rs. 47820.0/ha which gives seasonal total cost of system Rs. 63670.00/ha thereby the benefit cost ratio was found maximum (4.24) in T_1 treatment (20 per cent depletion level) and was the lowest (2.68) in T_4 treatment (50 per cent depletion level).

5.2 Conclusions

Based on the results of the present investigation following conclusions are drawn

1. Light and frequent irrigation resulted in increased garlic yield and water use efficiency. For maximum bulb yield and WUE, garlic crop be irrigated at 20 per cent depletion level of available soil moisture.

2. Micro-sprinkler method of irrigation was found satisfactory for applying desired depth of irrigation and most suitable for irrigating close growing, low height crops like garlic. The percentage increase in yield, water saving and water use efficiency of 20 per cent depletion treatment was observed to be 21.16, 17.14 and 41.92 over check basin method of irrigation for garlic crop.

3. In clayey type of soil, irrigations should be scheduled at an interval of 3 days with depth of 10 mm during initial stage, 6 days with depth of 25 mm during crop development stage, 4 days with depth of 25 mm during mid season stage and 3 days with depth of 25 mm during late season stage by micro-sprinkler method of irrigation.

4. Water requirement of garlic crop at 20 per cent depletion level was 800 mm.

5. Benefit-Cost ratio indicated the economical feasibility of micro-sprinkler irrigation system for garlic crop.

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Appendices

APPENDIX-I

Observations of amount of water collected (mm) for 30 minutes in catch cans at grid points for calculating uniformity coefficient and precipitation rate at stake height of 50 cm of micro-sprinkler and average discharge rate of micro-sprinkler (lph) at 1 kg/cm^2

For Treatment T_1

RI

5.30	6.19	7.07	6.72	4.86
5.13	7.51	7.96	7.25	5.30
5.75	6.72	8.40	7.25	5.75
4.86	5.83	7.07	6.19	5.48
4.42	5.30	6.19	6.72	4.86

RII

4.86	5.83	6.72	7.60	4.42
5.30	7.07	7.51	8.40	5.30
4.86	6.19	7.60	7.96	5.83
4.42	5.83	7.07	5.83	4.86
4.95	6.19	7.51	5.92	4.42

RIII

4.60	5.48	6.19	6.00	4.425
4.42	5.13	5.83	6.90	5.48
6.00	6.90	7.51	7.95	5.30
4.86	6.00	7.07	7.51	5.13
5.13	6.19	6.90	6.19	4.42

For Treatment T_2

RI

4.95	5.88	6.19	6.01	4.24
4.42	6.01	7.07	5.88	4.86
4.24	5.88	6.63	7.51	4.42
4.42	6.19	7.25	6.01	4.47
5.88	6.19	6.63	5.83	4.24

RII

5.30	5.83	6.72	7.51	4.86
4.86	6.19	7.51	8.84	5.83
5.30	6.72	7.25	7.95	4.86
5.83	6.19	7.78	7.51	5.83
4.86	6.72	5.83	7.25	5.30

RIII

4.86	5.30	7.51	6.72	5.30
5.12	6.10	6.72	8.84	5.83
5.74	6.72	7.70	7.95	6.72
4.86	6.10	7.95	7.25	5.65
5.92	5.83	6.72	7.95	6.10

For Treatment T_3

RI

4.86	5.13	7.07	6.19	5.30
5.30	6.19	7.78	8.84	6.19
4.86	7.07	7.69	7.95	5.30
6.19	6.72	7.95	7.78	4.86
5.03	5.30	7.07	6.19	5.13

RII

5.13	5.83	7.51	6.72	5.30
5.30	6.19	7.95	8.84	6.72
5.13	6.72	7.51	8.48	5.83
6.01	7.95	8.84	7.51	5.13
4.86	5.83	6.72	7.51	5.83

RIII

4.95	5.83	7.07	6.54	4.86
4.95	6.19	7.96	9.73	6.72
6.19	7.60	9.90	7.25	6.19
5.30	6.01	7.96	7.60	5.13
4.95	6.72	7.78	6.01	4.77

For Treatment T_4

RI

4.68	5.21	6.72	6.90	4.86
6.10	6.19	7.95	9.72	6.90
6.00	7.60	9.28	8.48	6.19
6.19	6.00	8.48	6.90	5.66
4.86	4.95	6.72	6.90	4.95

RII

4.33	5.12	6.01	5.66	4.42
4.60	5.30	6.36	7.07	5.12
4.24	5.66	6.72	7.51	4.77
4.42	6.19	7.96	8.66	6.01
5.48	6.72	6.19	5.48	4.24

RIII

4.77	5.66	6.36	7.07	5.13
4.95	6.19	7.25	7.42	6.01
5.30	6.10	7.78	6.36	4.86
4.77	6.01	6.90	5.30	5.13
4.42	5.66	6.36	6.19	5.48

Sample calculation for Uniformity coefficient (UC) and average precipitation rate, ppt. (mm/hr) observed in T_1R_1

Observation (m) mm	Frequency (n)	Frequency x obs. (mm)	Numerical deviation	Frequency x deviation
4.42	1	4.42	1.74	1.74
4.86	3	14.58	1.30	3.90
5.13	1	5.13	1.03	1.03
5.30	3	15.90	0.86	2.58
5.48	1	5.48	0.68	0.68
5.75	2	11.50	0.41	0.82
5.83	1	5.83	0.33	0.33
6.19	3	18.57	0.30	0.07
6.72	3	20.16	0.55	1.65
7.07	2	14.14	0.90	1.80
7.25	2	14.50	1.08	2.16
7.51	1	7.51	1.34	1.34
7.96	1	7.96	1.79	1.79
8.40	1	8.40	2.20	2.20
Σ	25	154.08		22.098

$$\text{Mean} = \frac{154.08}{25} = 6.16$$

$$UC = 100\left(1 - \frac{\Sigma x}{mn}\right)$$

$$= 100\left(1 - \frac{22.098}{154.08}\right) = 85.65\ \%$$

$$\text{Average precipitation rate (Pi)} = \frac{154.08 \times 2}{25} = 12.33 \text{ mm/hr}$$

Similarly, by adopting above procedure values of UC and ppt were calculated and found to be as,

Average Uniformity coefficient (UC) in per cent

Treatment	RI	R-II	R-III	Average
T_1	85.65	83.00	84.73	84.46
T_2	85.22	86.68	86.50	86.13
T_3	83.91	84.50	83.60	84.00
T_4	83.85	84.22	87.33	84.13
			Average UC =	85.00

Average precipitation rate (Pi) in mm/hr

Treatment	RI	R-II	R-III	Average
T_1	12.33	12.21	11.33	11.96
T_2	11.34	12.70	12.97	12.33
T_3	12.62	13.25	12.64	12.84
T_4	12.85	12.05	11.79	12.33
			Average ppt (mm/hr) =	12.34

Average discharge of micro-sprinkler in lph

Treatment	RI	R-II	R-III	Average
T_1	37.76	37.39	34.698	36.63
T_2	34.73	38.89	39.72	37.76
T_3	38.65	4058	38.71	39.32
T_4	39.35	36.90	36.10	37.45
			Average discharge (lph) =	37.83

APPENDIX – II

Sample calculation of irrigation scheduling for treatment T_1 (20 % depletion level

I) Depth of irrigation

1. Total available water (TAW) $= \dfrac{FC - PWP}{100} \times BD \times D$

a) For initial stage (0-20 DAS) considering depth of root zone D = 200 mm

$$TAW = \frac{38.23 - 19.80}{100} \times 1.26 \times 200 = 46.44 \text{ mm}$$

b) For further growth stages (21 DAS- upto harvest) considering depth of root zone D = 450 mm

$$TAW = \frac{38.23 - 19.80}{100} \times 1.26 \times 450 = 104.49 \text{ mm}$$

2. Net depth of irrigation (Di) = (TAW x Dp) /100

a) For initial stage (0-20 DAS)

$$Di = \frac{46.44 \times 20}{100} = 9.28 \text{ mm}$$

b) For further growth stages (21 DAS- upto harvest)

$$Di = \frac{104.49 \times 20}{100} = 20.89 \text{ mm}$$

3. Gross depth of irrigation (Dg) = Di /UC

a) For initial stage (0-20 DAS)

$$Dg = \frac{9.28}{0.85} = 10.91 \text{ mm}$$

b) For further growth stages (21 DAS- upto harvest)

$$Dg = \frac{20.89}{0.85} = 24.57 \text{ mm}$$

4. Time of operation (To) = $\mathbf{\frac{Dg}{Pi} \times 60}$

a) For initial stage (0-20 DAS)

$$To = \frac{10.91}{12.34} \times 60$$

$$= 0.884 \text{ hr}$$

$$= 53 \text{ min } 2 \text{ sec.}$$

b) For further growth stages (21 DAS- upto harvest)

$$To = \frac{24.57}{12.34} \times 60$$

$$= 1.99 \text{ hr} = 1\text{hr } 59 \text{ min } 27 \text{ sec.}$$

Monthly average pan evaporation in mm/day in crop growing period from last five years (1996-2000)

Month	Average pan evaporation (mm/day)
December	4.37
January	4.60
February	5.90
March	7.14
April	8.70

Potential evapotranspiration (PET), mm/day

Crop growing stage	Period	Average PE mm/day over the period	PET = PE x 0.8
a) Initial stage (0 - 20 DAS)	24th December to 12th January	4.52	3.616
b) Crop development (21-50 DAS)	13th January to 11th February	5.12	4.096
c) Mid season (51-85 DAS)	12th February to 18th March	6.57	5.256
d) Late season (86 DAS upto harvest)	19th March to 30th April	8.165	6.832

III) Irrigation frequency

1. Net depth of irrigation remaining after two days after irrigation in mm (Dir) = Di – (PET x 2)

a) Initial stage (0-20 DAS)

Dir = 9.28 – (3.616 x 2) = 2.048 mm

b) Crop development (21-50 DAS)

Dir = 20.89 – (4.096 x 2) = 12.698 mm

c) Mid season (51-85 DAS)

Dir = 20.89 – (5.256 x 2) = 10.378 mm

d) Late season (86 DAS upto harvest)

Dir = 20.89 – (6.832 x 2) = 7.226 mm

2. Crop Evapotranspiration (ETc) = PET x Kc

a) Initial stage (0-20 DAS) Kc = 0.50

ETc = 3.616 x 0.50 = 1.800 mm/day

b) Crop development (21-50 DAS) Kc = 0.75

ETc = 4.096 x 0.75 = 3.072 mm/day

c) Mid season (51-85 DAS) Kc = 1.025

ETc = 5.256 x 1.025 = 5.387 mm/day

d) Late season (86 DAS upto harvest) Kc = 0.875

ETc = 6.832 x 0.875 = 5.978 mm/day

3. Irrigation Frequency (IF) $= \dfrac{\textbf{Dir}}{\textbf{ETc}} + 2$

a) Initial stage (0-20 DAS)

$$IF = \frac{2.048}{1.8} + 2$$

= 3.13 days ≅ 3 days

b) Crop development (21-50 DAS)

$$IF = \frac{12.698}{3.072} + 2$$

= 6.13 days ≅ 6 days

c) Mid season (51-85 DAS)

$$IF = \frac{10.378}{5.387} + 2$$

= 3.92 days ≅ 4 days

d) Late season (86 DAS upto harvest)

$$IF = \frac{7.226}{5.978} + 2$$

= 3.20 days ≅ 3 days

Similarly, irrigation depth and irrigation intervals were worked out for each treatment.

The irrigation date, depth of irrigation (mm) and time of operation (min) for each treatment was as under :

For Treatment T_1

Date	Depth of irrigation (mm)	Time of operation (min)
22.12.2001	50.00	243'6"
24.12.2001	50.00	243'6"
27.12.2001	10.90	52'28"
30.12.2001	10.90	52'28"
2.1.2002	10.90	52'28"
5.1.02	10.90	52'28"
8.1.02	10.90	52'28"
11.1.02	10.90	52'28'
17.1.02	24.50	119'7"
23.1.02	24.50	119'7"
29.1.02	24.50	119'7"
4.2.02	24.50	119'7"
10.2.02	24.50	119'7"
14.2.02	24.50	119'7"
18.2.02	24.50	119'7"
22.2.02	24.50	119'7"
26.3.02	24.50	119'7"
2.3.02	24.50	119'7"
6.3.02	24.50	119'7"
10.3.02	24.50	119'7"
14.3.02	24.50	119'7"
18.3.02	24.50	119'7"
21.3.02	24.50	119'7"
24.3.02	24.50	119'7"
27.3.02	24.50	119'7"
30.3.02	24.50	119'7"
2.4.02	24.50	119'7"
5.4.02	24.50	119'7"
8.4.02	24.50	119'7"
11.4.02	24.50	119'7"
14.4.02	24.50	119'7"
17.4.02	24.50	119'7"
20.4.02	24.50	119'7"
23.4.02	24.50	119'7"

For treatment T_2

Date	Depth of irrigation (mm)	Time of operation (min)
22.12.2001	50.00	243'6"
24.12.2001	50.00	243'6"
30.12.2001	16.37	79'35"
5.1.2002	16.37	79'35"
11.1.02	16.37	79'35"
17.1.02	36.88	179'19"
26.1.02	36.88	179'19"
4.2.02	36.88	179'19"
13.2.02	36.88	179'19"
19.2.02	36.88	179'19"
25.2.02	36.88	179'19"
3.3.02	36.88	179'19"
9.3.02	36.88	179'19"
15.3.02	36.88	179'19"
21.3.02	36.88	179'19"
26.3.02	36.88	179'19"
31.3.02	36.88	179'19"
5.4.02	36.88	179'19"
10.4.02	36.88	179'19"
15.4.02	36.88	179'19"
20.4.02	36.88	179'19"
25.4.02	36.88	179'19"

For treatment T_3

Date	Depth of irrigation (mm)	Time of operation (min)
22.12.2001	50.00	243'6"
24.12.2001	50.00	243'6"
1.1.2002	21.80	85'52"
9.1.2002	21.80	85'52"
17.1.02	21.80	85'52"
30.1.02	49.10	238'44"
12.2.02	49.10	238'44"
20.2.02	49.10	238'44"
28.2.02	49.10	238'44"
8.3.02	49.10	238'44"
16.3.02	49.10	238'44"
23.3.02	49.10	238'44"
30.3.02	49.10	238'44"
6.4.02	49.10	238'44"
13.4.02	49.10	238'44"
20.4.02	49.10	238'44"
27.4.02	49.10	238'44"

For treatment T_4

Date	Depth of irrigation (mm)	Time of operation (min)
22.12.2001	50.00	243’6”
24.12.2001	50.00	243’6”
4.1.2002	27.20	132’15”
15.1.02	27.20	132’15”
31.1.02	61.40	298’32”
16.2.02	61.40	298’32”
26.2.02	61.40	298’32”
8.3.02	61.40	298’32”
18.3.02	61.40	298’32”
27.3.02	61.40	298’32”
5.4.02	61.40	298’32”
14.4.02	61.40	298’32”
23.4.02	61.40	298’32”

For treatment T_5

Date	Depth of irrigation (mm)
22.12.2001	50
24.12.2001	50
2.1.2002	70
12.1.02	70
22.1.02	70
1.2.02	70
11.2.02	70
21.2.02	70
3.3.02	70
13.3.02	70
23.3.02	70
2.4.02	70
12.4.02	70
22.4.02	70

APPENDIX – III

Fixed cost of micro-sprinkler system per ha

Sr. No.	Item and Rate	Quantity	Fixed cost Rs/ha
1	Centrifugal pump set (5 HP) and accessories @ Rs. 12,500/-	1 No.	12500.00
2	By pass assembly at control need @ Rs. 1000/-	1 No.	1000.00
3	Screen filter @ Rs. 1600/-	1 No.	1600.00
4	Pressure guage@ Rs. 500	1 No.	500.00
5	G. I. main, 50 mm @ Rs. 185/m	120 m	22200.00
6	GI. submain 25 mm @ Rs. 85/m	300 m	25500.00
7	Lateral, LDPE 16 mm @ Rs. 5/m	5700 m	28500.00
8	Micro-sprinkler @ 15/- each	3265 Nos.	48975.00
9 10	Flow control value, 50 mm @ Rs. 650/- Flow control value, 25mm @Rs. 325/-	2 Nos. 4Nos.	1300.00 1300.00
10	GI end cap (Plain) for submai, 25 mm @ Rs. 30/- each	8	240.00
11	GI tee, 50 mm @ Rs. 90/-	1	90.00
12	GI reducer, 50 mm x 25 mm @ 60/-	2 Nos	120.00
13	GTO, 16 mm @ Rs. 2/-	228 Nos	456.00
14	LDPE end cap, 16 mm @ Rs. 2.5/-	228 Nos	570.00
15	Cost of system installation @ 3 % cost of micro-sprinkler set excluding centrifugal pump, by-pass assembly, screen filter and pressure guage (i.e. @ 3 % costs 5 to 14)	-	3877.53
16	Cost of micro-sprinkler set, by pass assembly, screen filter and pressure guage	-	132351.00
17	Depreciation for centrifugal pump and accessory (life : 20 years)	-	562.50
18	Depreciation of micro-sprinkler system set by pass assembly etc. (life : 8 years)	-	14540.75
19	Total depreciation (17 + 18)	-	15103.25
20	Interest on fixed cost per annum @ 15 % per annum i) Micro-sprinklers set etc. ii) Pumping unit	 - -	 19852.65 1875.00
21	Repair and maintenance i) @ 5 % of fixed cost of micro-sprinkler set etc. ii) @ 1 % centrifugal pumping unit	 -	 6617.55 125.00
22	Electricity charges per annum for 5 HP	-	4000.00
23	Total fixed cost per annum (19 + 20 + 21 + 22)	-	47573.45
24	Seasonal fixed cost (considering three seasons per annum)	-	15857.81
	Rounded to		15850.00

APPENDIX – IV

Cost of cultivation (operating cost) (Rs./ha)

Sr. No.	Item and Rate	Quantity	Fixed cost Rs/ha
1	Labour charges @ Rs. 45 per day		
	i) Sowing – 100 labour days	100	4500.00
	ii) Weeding - @ 50 labour days/weeding (for 3 weeding)	150	6750.00
	iii) Plant protection – 20 labour days/spraying (for 2 spraying)	40	1800.00
	iv) Fertilizer application – 20 labour days/application (for 2 applications)	30	1350.00
2	Ploughing chares @ Rs. 1000/- per ha	1 ha	1000.00
3	Harrowing charges @ Rs. 500/- per ha	1 ha	500.00
4	Garlic seeds, Rs.500/- per kg.	500 kg	25000.00
5	Fertilizer		
	i) Urea Rs. 225/50 kg	460.0 kg	2070.00
	ii) Single super phosphate Rs. 140/50 kg	312.5 kg	875.00
	iii) Murate of potash Rs. 200/50 kg	83.5 kg	334.00
6	Insecticides and pesticides @ Rs. 1500/ha	1 ha	1500.00
7	Working capital (1 to 6)		45679.00
8	Interest on working capital @ 15 % /annum (for half crop period ie. @ 2.5.%		1141.975
9	Rental value Rs. 1000/ha	1 ha	1000.00
10	Total operating cost per season Rs/ha		47820.975
	Rounded to		47820.00