MULCH-CUM-DRIP IRRIGATION SYSTEM FOR OKRA (*Abelmoschus esculentus* L. Moench)

By

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THESIS

Submitted in partial fulfilment of the requirement for the degree

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Department of Agronomy

COLLEGE OF HORTICULTURE

VELLANIKKARA, THRISSUR

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1998

DECLARATION

I hereby declare that this thesis entitled **"MULCH-CUM-DRIP IRRIGATION SYSTEM FOR OKRA (*Abelmoschus esculentus* L. Moench)"** is a bonafide record of research work done by me during the course of research and that this thesis has not previously formed the basis for the award to me of any degree, diploma, associateship, fellowship or other similar title of any other University or Society.

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Certified that this thesis entitled **"MULCH-CUM-DRIP IRRIGATION SYSTEM FOR OKRA (*Abelmoschus esculentus* L.Moench)"** is a record of research work done by **Sri. CHANDUPATLA SUNILKUMAR** under my guidance and supervision and that it has not previously formed the basis for the award of any degree, fellowship or associateship to him.

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CHANDUPATLA SUNILKUMAR

Dedicated

To

My Parents

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Introduction

INTRODUCTION

Vegetables form an important component of the daily diet, because of its palatability and nutritive value. Kerala produces only 5.78 lakh tonnes of vegetables annually from an area of 85122 ha (FIB, 1998) whereas the requirement of the state is 14.35 lakh tonnes (KAD, 1998). The daily per capita consumption of vegetables in Kerala is 23 g which is far less than the recommended daily intake of 300 g (FIB, 1996). This necessitates augmentation of vegetable production in the state.

The major factors impeding vegetable production in the state are lack of quality seeds in required quantities, lack of adequate quantities of water for frequent irrigation, improper use of inputs like manures and fertilizers high incidence of pests and diseases etc. Irrigated area of vegetables is only less than 10 per cent of the total area under it (FIB, 1998).

Kerala receives a mean annual rainfall of 300 cm, which is about 2.78 times than national average. But the per capita water availability in Kerala is 12800 l d^{-1}, which is far behind the national average (Basak, 1998). This coupled with the ill-distribution of the rainfall entails the requirement for proper management of the available water resources.

Any technology that help reducing the loss and increase efficiency of available water resources can go a long way in making Indian agriculture more productive. New water conservation technologies such as mulching and drip irrigation may contribute to enhancing the water use efficiency.

Under drip irrigation water is supplied directly to the rhizosphere thus eliminating losses due to conveyance, distribution and evaporation. According to an estimate of the National Committee on use of Plastics in Agriculture (NCPA), this will help to effect more than 100 per cent water saving, which can be utilized to bring additional land area under irrigation, concomitantly offering higher productivity of the crop (Narayanamoorthy and Deshpande, 1998).

Bhindi (*Abelmoschus esculentus* Moench.) is an important warm season vegetable cultivated in the Kerala. Adaptability to a wide range of soil and climatic conditions, easiness in cultivation, suitability for year round production etc. makes bhindi a popular vegetable in Kerala. Augmenting production and productivity of bhindi using modern techniques is yet to be tested for large scale adoption. Green house technology is an emerging field in vegetable production. Effect of mulching combined with drip irrigation has not been studied so far in Kerala.

Any study in this line is also a stepping stone to close house technology in vegetable production. In this context an investigation was undertaken with the following objectives.

1. Development of mulch-cum-drip irrigation technique for bhindi
2. Its testing and working out of feasibility for large scale introduction in vegetable cropping.

Review of Literature

REVIEW OF LITERATURE

Drip irrigation is an efficient method of application of water directly to the plants uniformly and in required amounts, according to their demand with little contribution to losses. Drip irrigation along with mulching not only provides a good water economy but also provides opportunity for fertilizer economy, reduced weed growth, less energy for irrigation and better yields and productivity.

This chapter reviews the relevant literature available in India and abroad on various aspects related to the present study under the following heads.

i) Growth of vegetables as influenced by mulch and drip

ii) Yield attributes and yield of vegetables as influenced by mulch and drip

iii) Water use of vegetables as influenced by mulch and drip

   (a) Total water use/water use efficiency

   (b) Moisture distribution pattern

iv) Economics of vegetable production as influenced by mulch and drip

I Growth of vegetables as influenced by mulch and drip

Surface irrigation significantly enhanced petiole length and plant height of taro (*Colocasia antiquorum* Schott.) more than subsurface irrigation, when irrigation was given with 20 mm of water when the pF reached 2.5 at 10 cm depth (Kudo, 1987).

According to Singh (1987) sprinkler irrigation equal to 60 per cent of pan evaporation produced highest growth and yield of okra cv. Clemsonspineless.

Experiment carried out in South Western Indiana lyles on watermelon cv. Charleston Gray in fine sandy loam soil revealed that greatest stem growth, and early and total yields were obtained from plants grown under polyethylene mulch with trickle irrigation (Bhella, 1988a).

Bhella (1988b) observed that in tomato cv. Sunny grown in fine sandy loam soil near Vincennes, Indiana, trickle irrigation increased plant height whereas polyethylene mulching increased plant spread and dry matter production.

Subhan (1988) observed that mulching either using black or transparent plastic increased plant height and dry weight of Kidney bean (*Phaseolus vulgaris* L.) at 30 days after planting, compared to straw mulching.

According to Van, 1989 black plastic mulch enabled spring planting of peas under all conditions. It also helped better crop development and eliminated weed problems.

An experiment conducted at Erbel using onion cultivar Texas Yellow Grono and Texas Early Grano revealed that irrigation along with mulching combined with furrow cultivation gave the highest values for bulb length, bulb diameter and fresh weight yield. Mulched and unirrigated crop produced as much as that of unmulched irrigated crop (Abdel, 1990).

According to Madramootoo and Rigby (1991) plant height and canopy diameter increased significantly with decreasing emitter spacing from 1.62 to 0.45 cm in case of drip irrigation to bell pepper.

In green house studies, Salman *et al.* (1990) observed that vegetative growth ie., plant height, number of leaves and leaf area, was increased irrespective of mulch colour ie., black or transparent in case of cucumber, but by black polythene in case of water melon.

II Yield attributes and yield of vegetables as influenced by mulch and drip

Abreu *et al.* (1978) observed in San Francisco Valley that melon cv. Valenciano yielded the highest of 13817 kg ha^{-1} when it was drip irrigated with 2 emitters per planting hole at the schedule of 0.7 atm in comparison to furrow irrigation at 0.7 or 0.4 atm or drip irrigation at these schedules with 1 or 4 emitter/hole.

Berrocal and Vives (1978) observed that saw dust and rice husk mulching led to highest production in tomato cv. Tropic compared to black polythene mulch. Transparent plastic mulch caused weed growth, organic mulches like sawdust reduced soil temperature and black plastic mulch increased soil temperature.

Melon cv. Valenciano Amarelo produced highest yield when drip irrigated at 0.7 atm with 1 emitter per 4 plants as compared to furrow irrigation (Olitta *et al.*, 1978).

According to Muirhead (1979) *Phaseolus vulgaris* beans irrigated during post-flowering period using drip produced the highest yield of 16 t ha^{-1}.

A comparative study of black, silver, white or transparent plastic mulches on Kohlrabi (*Brassica oleracea* var. gongylodes L.) cv. Azur by Zengerle (1981) revealed that there was increase in yield, quality and earliness, due to mulching irrespective of mulch material.

Silvestri *et al.* (1985) observed higher yields of tomatoes when plastic soil mulching was adopted in both direct seeding and transplanting than with no mulch and black plastic was more effective than biodegradable transparent plastic.

Djigma and Diemkouma (1986) observed that egg plants cv. Longue violette yielded 33.48 t ha^{-1} with 100 μm black polyethylene mulch compared to 10.07 t ha^{-1} with no mulch. The corresponding yields in Heinz-1370 tomatoes were 110.9 t ha^{-1} and 47.6 t ha^{-1} respectively.

Gupta and Gupta (1987) reported that light and frequent irrigation (30 mm water at Eo30 mm) along with straw mulching increased water availability, thereby increased the yields of tomato by 100% and okra 400% in arid regions of India.

Total yield of tomato variety Sunny grown in fine sandy loam soil of Indiana was enhanced by 66, 70 and 123% over control plot when crop was grown under black polythene mulch, trickle irrigation and polythene mulch cum drip irrigation respectively (Bhella, 1988b).

Mulching studies conducted on egg plant using pine needle, black plastic, news paper or no mulch revealed that in an year of abundant rainfall, mulching did not influence growth and yield of crop. In years of limited rainfall black plastic mulching increased earliness and yield of cv. Black Beauty and this as well as pine needle mulching conserved moisture and controlled weeds more effectively than other mulches (Carter and Johnson, 1988).

Goyal (1988) conducted an experiment to study the response of tomato to furrow, micro sprinkler and drip irrigations scheduled at soil moisture tension of 15-45 centibar in humid and semi-arid regions of Puerto Rico. The study revealed that bi-wall drip, microsprinkler and furrow irrigation increased the yields of by 112, 82 and 37 per cent respectively compared with no irrigation.

According to Shukla and Prabhakar (1988) the tomato cultivar Arka vikas when mulched with plastic sheets along the rows yielded 36.06 t ha^{-1} whereas non mulched crop produced 35.18 t ha^{-1} in monsoon season.

Wan Derverken and Lee (1988) observed that capsicum cv. California wonder produced maximum yields with drip irrigation along with black polyethylene mulching. When the crop was mulched, trickle irrigation scheduled either at 0.025 or 0.075 MPa had no varying effect on yield. Yields obtained from mulched plots without irrigation were similar to that from sprinkler irrigated but non mulched crop.

Red pepper (*Capsicum annum* L.) cv. Shinhong peppers gave the highest yields of 900 kg ha^{-1} in Korea when mulched with black polyethylene sheet compared to transparent polythene film and white PVC film. This has been recommended as most suitable mulch in Korea (Kwon *et al.*, 1988).

Black plastic mulch increased early yields of grade I fruits by 0.5 lb $plant^{-1}$ and total yields were increased by 1.7 lb $plant^{-1}$ of bell pepper cv. Skipper capsicums (Call and Courter, 1989).

Madramootoo and Rigby (1989) observed highest yields of capsicum when trickle irrigation was applied at 90 per cent fractional soil volume. The authors, further in 1991, reported that marketable yield increased when emitter spacing was reduced from 1.62 to 0.45 m.

The irrigation cum plant density study conducted by Gupta (1990) at Bangalore indicated that the maximum yield of Okra, 14.71 t ha^{-1} was obtained when the crop was irrigated at 20 mm cumulative pan evaporation which was the shortest interval tested.

According to Gorantiwar *et al.* (1991) drip irrigated okra cv. Parabhani kranti gave an yield of 70.12 q ha^{-1} representing a 35.77 per cent increase over furrow irrigation.

Pitts *et al.* (1991) have seen that drip irrigation in fine sandy soil using biwall tubes at the rate of two lateral tubes per row located at 24 cm from the row led to higher yields and larger fruits in tomato cv. Sunny.

Tomato cvs. Sunny and Pine-Rite, grown under trickle irrigation yielded on an average 84 t ha^{-1} under black polyethylene mulching when compared to 43 t ha^{-1} produced under non-mulching (Abdul-Baki *et al.*, 1992).

Aranjo *et al.* (1992) observed that harvesting `Vista Alegre' cucumbers (*Cucumis sativus* L.) could be brought forward by 7 days by mulching either with red or black plastic mulch. The red plastic mulch treatment produced the best yield of 60.27 t ha^{-1} against 47.03 t ha^{-1} with black plastic mulch and 42.33 t ha^{-1} with no mulch.

According to Brown *et al.* (1992) tomato cv. Muntain Pride produced higher and early marketable yields of 4.7, 4.5 and 4.3 t ha^{-1} when it was grown over aluminium, red or black mulch than from those grown over white mulch which produced 2.3 t ha^{-1}. They further observed that total marketable yield was higher in plants grown over green or aluminium mulch (18.7 and 17.3 t ha^{-1} respectively) than that in plants grown over black or white mulch (8.7 and 8.0 t ha^{-1} respectively).

According to Cevik *et al.* (1992) cucumber cv. Maram produced maximum yield of 111.5 t ha^{-1} when clear plastic mulch was used and irrigation was scheduled at 30 centibars. Yields obtained by black or clear plastic mulch were higher than that with wheat straw mulch or no mulch. Irrigation schedules arranged between 20 to 50 centibars did not affect fruit characteristics.

Gutal *et al.* (1992) observed an increase in yield by 24 per cent over control in brinjal with alternate day drip irrigation along with black LDPE mulch. Vigorous root growth, resistance to ageing and weed suppression were also noticed in mulched crop.

According to Konys and Konys (1992) tomato cv. Najwczesniejszy (intermediate) and New Yorker (dwarfing) produced the highest total and commercial yields of 43.2 and 19.7 t ha^{-1} when mulched with black plastic sheeting.

A field trial conducted on large-fruited vigorous tomato cv. Mountain pride to evaluate the effects of a black plastic mulch, drip irrigation and different rates of NPK fertilizer on fruit yield and quality revealed that yields of grade I quality fruits increased significantly by the use of drip irrigation along with mulching compared with no irrigation and no mulching (Mullins *et al.*, 1992).

In a field experiment conducted at Abernethy, FiFe (Scotland) with broccoli cv. Covert and Shogun and brussels sprout cv. Golfer revealed that among the mulches such as smooth paper, crimped paper, bark straw or black polythene mulch, the latter resulted in good weed control (with 0-1% ground cover weeds) and yields. A clean ground was left following removal of black polythylene and weed germination remained low throughout the season (Davies *et al.*, 1993).

According to Saggu and Kaushal (1993) the maximum yield of 32.1 t ha^{-1} was produced by potato variety Kufri Chandramukhi when drip irrigation was given on alternate days in loamy sand soil at Ludhiana. The crop irrigated by furrow method at 7 days interval produced only 25.4 t ha^{-1}.

Farias *et al.* (1994) observed that cucumber cv. Fanci Pack on a clay soil in Colima, Mexico gave the yield of 63.37 t ha^{-1} with clear plastic mulching against 21.61 t ha^{-1} with no mulch; both white and black plastic mulches significantly increased yields.

III Water use of vegetables as influenced by drip and mulch

(a) Total water use/water use efficiency

Palevitch *et al.* (1980) observed that paprika plants yielded 2.65-4 t dry red fruits ha^{-1} when irrigated with 150-180 mm of water using drip. The yield increased to 3.3 to 4.5 t ha^{-1} when irrigation water was increased to 250 mm. Applying higher amounts of water did not produce a corresponding increase in yield.

Drip irrigation in paprika with 100 or 300 mm of water produced 2.5 and 3 t ha^{-2} of dry red fruits respectively in Bet Dagan and 2.5 and 3 t ha^{-1} respectively in Western Galilee. The yield in respective tracts when irrigation was given only at the establishment of the crop was only 1.5 t and 2 t ha^{-1} (Palevitch *et al.*, 1981).

According to Bhattikhi *et al.* (1985) the tomato cv. Claudia Rat grown in plastic green house in the Jordan valley under drip irrigation system consumed 859, 803 and 693 mm water respectively when irrigation was scheduled at soil moisture tension of 0.05, 0.06 and 0.07 MPa measured at 30 cm depth. The average daily water consumption ranged from less than 2 mm during January for all plots to 8.61, 8.21 and 6.6 mm for the three treatments respectively. Moreover water use efficiency did not differ significantly between the treatments.

Bangal *et al.* (1986) observed that tomato variety Pusa Ruby required only 218 mm of water by trickle irrigation compared to 393 mm by furrow irrigation while producing comparable yields. At this rate, the ratio of gross irrigation plus rain to pan evaporation were 0.45 in trickle and 0.76 in furrow. The water use efficiency was 787 kg ha^{-1} cm^{-1} in the trickle system whereas it was only 465 kg ha^{-1} cm^{-1} in the furrow system.

The squash (*Cucumis pepo* L.) cv. clarette grown in Jordan valley under drip irrigation system, either mulched with transparent or black plastic or non-mulched, consumed on an average 191, 179 and 206 mm water and produced an yield of 25.9, 18.0 and 11.8 t ha^{-1} respectively (Bhattikhi and Ghawi, 1987).

Goyal *et al.* (1987) conducted a study on the response of sweet pepper to drip, microsprinkler, furrow irrigation and no irrigation along with plastic mulching during winter and summer seasons. Crop received irrigation at soil moisture tension of 0.015 - 0.045 MPa at 30 cm depth. Seasonal net irrigation requirement was estimated to be 341 mm for winter and 352 mm for summer peppers. Overall irrigation efficiency was 37 per cent for furrow, 65 per cent for sprinkler and 84 per cent for drip irrigation based upon actual gross applications and net irrigation requirement.

Safadi (1987) observed in Jordan valley that squash when drip irrigated at soil moisture tensions of 0.03, 0.05 and 0.08 MPa consumed 127.9, 127.5 and 124.4 mm of water during winter season. Average fruit yields at respective irrigations was 19.4, 21.6 and 22.0 t ha^{-1}. During summer the water consumptions by the crop were 151.8, 139.8 and 149.7 mm and yields were 8.6, 7.4 and 7.6 t ha^{-1} under respective irrigation schedules.

Chartzoulakis and Michelakis (1988) observed that tomato cv. Dombito grown in an unheated green house and irrigated maintaining soil moisture tension above 0.02 MPa the crop needed its growth period from September to June by 460 mm of water by furrow, 360 mm by microtubes, 290 mm by drip and 260 mm by subsurface methods of irrigation. At this level yield of the crop was not significantly affected and the highest water use efficiency was of 47.7 kg m^3 of water applied with drip irrigation and lowest of 27.8 kg m^3 with furrow irrigation.

Investigations carried out on capsicums by Hegde (1988) showed that the crop put up maximum growth, yield and water use efficiency when irrigated at the soil matric potential of 0.065 MPa at 15 cm depth compared to the treatments at 0.025, 0.045 and 0.085 MPa tension.

Dysko and Kaniszewski (1989) observed that capsicum cv. Lamuyo grown in plastic tunnels produced the highest yield with trickle irrigation when the soil moisture potential reached 0.015 MPa compared to other soil moisture tension of 0.03, 0.045, 0.06 MPa. At this moisture potential, the water consumption by the plants was 2.76 mm/m^2.

Srinivas *et al.* (1989) observed that relative water content and osmotic potential of water melon increased and water use efficiency as well as canopy temperature decreased when irrigation level was increased by 25 or 50 or 75 to 100% of evaporation replenishment under drip irrigation. Similarly drip irrigation at the rate of one emitter per 2 plants enhanced relative water content, osmotic potential and yield as well as water use efficiency compared to furrow irrigation using 25 or 50 mm of water. Interaction effects revealed that for realising high yields 25% evaporation replenishment under drip irrigation and 50 or 75 per cent replenishment under furrow irrigation were sufficient.

According to Batra and Kalloo (1991) in carrot cv. Gurgaon selection, grown at IW/CPE ratios of 0.4, 0.8 or 1.2, soil moisture content was significantly higher at the IW/ CPE ratio of 1.2. Water consumption increased with irrigation rate. Leaf water potential was directly related to available soil moisture content and decreased with crop age.

Tomato cv. Pusa Ruby seedlings transplanted and mulched with sugarcane trash produced the highest yield of 142.56 q ha^{-1} and required lowest seasonal water requirement of 594 mm. This resulted in 98.14 per cent increase in yield and 44.34 per cent saving in irrigation water over no mulch control. Here the crop received irrigation at 10 days interval (Firake *et al.*, 1991).

Okra cv. Parbhani Kranti when drip irrigated on alternate days over 40 per cent of the area required the least water of 182 mm and gave the highest water use efficiency of 3.89 q ha^{-1} cm^{-1}. This schedule resulted in 56.67% saving over furrow irrigation that was scheduled at IW/CPE ratio of 0.8. The irrigation requirement of okra under trickle irrigation was 200 mm water (Gorantiwar *et al.*, 1991).

Gutal *et al.* (1992) while experimenting with polythene mulches observed that coloured polythene mulch films increased soil temperature by 5-7° C which facilitated faster germination and better root proliferation. At the same time weed growth was checked and soil moisture was retained preserving soil structure. It was further observed that Co_2 around the plant was increased. Results of three years experiments with 25 μ black LDPE film as mulch indicated that tomato yield could be increased by 55 per cent and weed growth was reduced by 90 per cent and soil moisutre conserved was 28 per cent more than with control without mulch.

(b) Moisture distribution pattern

Phadtare *et al.*, 1992 studied different emitter discharges viz., 2,3,4 and 5 l hr^{-1} in a field experiment in a vertisol. A radial spread of 31.0 cm and 26.25 cm were observed at the surface for the lowest (2 l hr^{-1}) and the highest (5 l hr^{-1}) discharges respectively. The vertical advances were 105.65 and 118.5 cm for 2 l hr^{-1} and 5 l hr^{-1} emitter discharges respectively indicating that the radial spread at the surface was greater for the lower discharge whereas vertical advance was greater for higher discharge. The maximum radial spread of 56.76 cm was observed at 59.61 cm below the soil surface for the 3 litre hr^{-1} emitter discharge.

According to Amir and Dag (1993) from a very low energy moving emitter study in heavy clay soil at Israel inferred that the instantaneous application rates increased the width and uniformity of wetting of soil, but it caused high lateral dispersion of soil and reduced the depth of soil irrigated.

The moisture distribution under drip irrigation at Karnal was more uniform within a 10 cm radius of the emitter with maximum uniformity at zero, while nonuniformity increased with distance from the emitters (Mishra and Pyasi, 1993).

Pelletier and Tan (1993) conducted an experiment on time domain reflectometry technique at Agriculture Canada Research Station and it revealed that a distinct cone shape of >50 per cent available soil water extending from the emitter down to a depth of >45 cm occurred in a drip irrigation whereas the 50 per cent available soil water zone in a microjet system was an elongated semicircle from the soil surface to a depth of 35 cm.

IV Economics of vegetable production as influenced by drip and mulch

According to Djigma and Diemkouma (1986), cost analysis in egg plant and tomatoes showed that saving in water use due to weed control and higher productivity with the use of black polythene mulching in these crops justified the investment in mulching during cool season.

The study conducted by Younis (1986) in Western Nobaria revealed that the highest yields of tomatoes, the highest net profits and the least amount of water applied resulted from trickle irrigation, when compared to furrow or sprinkle irrigation.

Experiment conducted at Margahayu Experimental Farm on capsicum cv. Barito revealed that the unmulched unshaded control crop produced only 1.25 t of fruits ha^{-1} and this was more profitable than the crop mulched with black polythene and shaded which yielded 5.0 t ha^{-1} (Basuki and Asandhi, 1987).

An experiment was conducted in Juana Diaz, Pueroto Rico revealed that the highest marketable yield (64.5 t ha^{-1}) of tomatoes and net income were obtained from plastic mulching in combination with handweeding. In case of sweet pepper highest yield of 29.5 t ha^{-1} was obtained with plastic mulching in combination with directed spray of paraquat (Liu *et al.*, 1987).

According to Boldrin, 1989, if biodegradable film such as `Ecopac' was used as a mulching material cost for recovery was not there. Soil temperature at surface remained 6-7°C lower than that under black polythene. However it did not have the flexibility as plastic film.

According to the study conducted by Jadhav *et al.* (1990) the benefit cost ratio for tomato cv. Pusa Ruby was 5.15 with drip irrigation and 2.96 with furrow irrigation.

Gutal *et al.* (1992) observed that a 20 per cent saving in weeding cost could be achieved by the use of black LDPE film mulching in brinjal.

Return-risk analysis of adopting drip irrigation conducted by Prevatt *et al.* (1992a) at Florida USA using Target MOTAD model showed that, adoption of drip irrigation in the single and double cropped production alternatives resulted in lower levels of expected returns and higher levels of risk when compared to semiclosed sub-irrigation system. Among the various production enterprises, the highest level of risk was associated with tomatoes.

Operating capital requirements were substantially higher for double-cropped production compared to the single-cropped alternative. However double cropped production alternative resulted in substantially larger expected return values, while risk values were more variable.

The semi-closed subirrigation system was evaluated to be the lowest cost irrigation system for tomato under present fuel cost and non-limiting water supply conditions of Florida in sandy soils. The investment cost of drip irrigation system was significantly greater for semiclosed subirrigation (seepage) and fully enclosed subirrigation (seepage) systems. The variable cost for semi-closed system was less than that for fully enclosed and drip irrigation systems (Prevatt *et al.*, 1992b).

According to Satpute and Pawade (1992) the two plant drip layout resulted in 35 to 41 per cent savings in the cost over individual plant drip layout. The length of lateral line could be reduced by 25 to 50 per cent and that of microtube by 33 to 55 per cent by two plant drip layout in tomatoes in sandy clay loam soils.

According to Beverly (1993) the ASTER design could be beneficial where vegetable production was limited by the cost of irrigating land and could be adopted according to local needs and conditions.

According to Minasian *et al.* (1994) results of an economic analysis of four drip irrigation systems in comparison with furrow irrigation in Iraq indicated that drip irrigation was economically attractive in arid or semi-arid regions. Drip systems with injected emitters were more economical than those with extruded emitters, especially when the systems were used for several seasons. For single season use, the bi-wall pipe system and spiral online emitter system were economically preferable.

Materials and Methods

MATERIALS AND METHODS

A field experiment on mulch-cum-drip irrigation system for okra (*Abelmoschus esculentus* Moench) was conducted during the summer season (February-June) of 1997 in the summer rice fallows of Agricultural Research Station, Mannuthy of Kerala Agricultural University. The materials used and methods adopted in the study are briefly described below:

3.1 Location

The experiment was conducted in the farm of Agricultural Research Station, Mannuthy, Trichur District. This station is situated at 12° 32'N latitude and 74° 20'E longitude and at an altitude of 22.5 M above mean sea level.

3.2 Soil

Texturally soil of the experimental site was sandy clay loam. Bulk density of the soil ranged from 1.50 to 1.52 gcm^{-3} and mean pH was 5.6 The soil was medium in organic carbon and available potassium and high in available phosphorus. The important physical and chemical properties of the soil are presented in Table 1.

Table 1 Physio-chemical properties of soil in the experimental field

Particulars	Value (percent)	Method employed
A. Mechanical composition		
Coarse sand	27.2	Robinson's International
Fine sand	23.8	Pipette method
Silt	22.6	(Piper, 1966)
Clay	26.4	
Textural class	Sandy clay loam	I.S.S.S. system

B. Physical composition of the soil

Constant	Value	Procedure adopted
Field capacity (0.3 bars)	23.69% W/W	Pressure plateapparatus (Richard, 1947)
Permanent wilting point (15 bars)	9.54% W/W	Pressure plate apparatus (Richard, 1947)
Bulk density	0-15 cm depth = 1.50 gcm^{-1} 15-30 cm depth = 1.52 gcm^{-3}	Core method (Black, 1965)

Contd.....

Table 1 contd....

C. Chemical composition		
Particulars	Value	Method employed
Organic C	0.579%	Walkley and Black method (Soil Survey Staff, 1992)
Total N	0.084%	Semi-microkjeldahl method (Soil Survey Staff, 1992)
Available N	279.30 kg ha^{-1}	Alkaline permanganate distillation (Subbiah and Asija, 1956)
Available P	79.79 kg ha^{-1}	Bray-1 extractant - Ascorbic acid reductant method (Soil Survey Staff, 1992)
Available K	112 kg ha^{-1}	Neutral normal ammonium acetate extractant - flame photometry (Jackson, 1973)
pH	5.6	1:2.5 Soil : Water suspension using pH meter (Jackson, 1973)
Electrical conductivity	1.25 dS m^{-1}	Supernatant of 1 : 2.5 Soil : Water suspension using EC bridge (Jackson, 1973)

3.3 Climate and weather conditions

The mean monthly weather data for last 13 years (1984-1996) are given in Appendix 1.

Climatically the area experiences a tropical monsoon climate. The highest temperature is always experienced during March and the coldest regime in January. Higher temperature prevails upto May and temperature lowers with the start of monsoon. Normally the total annual rainfall is 3000 mm of which 65 per cent is received during South West monsoon (June-September), 30 percent during, North East monsoon (October-December) and remaining in summer (January-May).

Evaporation remains high to the tune of 7 mm day^{-1} during January-March period. Wind blows at the highest velocity during January.

The weekly weather data for the cropping period obtained from the Department of Agricultural Meteorology, College of Horticulture, Vellanikkara are graphically presented in Figure 1, while absolute values are given in Table 2.

Appendix 2 gives the absolute values for daily evaporation and rainfall data for the cropping period.

Table 2 Mean weekly weather parameters for the crop growth period

Standard week No.	Month and date	Maximum temperature (°C)	Minimum temperature (°C)	Sunshine hours (h)	Relative humidity (%) 8.00 AM	Relative humidity (%) 2.00 PM	Wind speed (Kmh^{-1})	Total evaporation (mm)	Total rainfall (mm)
1	Jan 01 - Jan 07	31.2	21.7	9.6	75	46	7.3	77.9	
2	Jan 08 - Jan 14	32.0	23.2	9.1	77	50	8.8	41.8	
3	Jan 15 - Jan 21	32.4	22.2	9.6	79	42	6.0	37.3	
4	Jan 22 - Jan 28	32.7	21.4	9.7	79	44	5.7	37.0	
5	Jan 29 - Feb 04	32.5	21.0	10.1	80	43	5.7	42.1	
6	Feb 05 - Feb 11	33.5	21.7	9.2	90	45	2.7	35.1	
7	Feb 12 - Feb 18	33.9	21.7	9.2	76	33	4.7	40.6	
8	Feb 19 - Feb 25	34.4	22.7	8.5	85	42	3.1	37.8	
9	Feb 26 - Mar 04	35.8	22.5	10.2	76	21	5.9	54.1	
10	Mar 05 - Mar 11	36.1	22.9	10.1	80	22	4.2	49.9	
11	Mar 12 - Mar 18	34.7	24.3	9.1	91	46	3.3	39.8	
12	Mar 19 - Mar 25	35.2	24.9	8.7	84	51	3.3	41.5	
13	Mar 26 - Apr 01	36.4	24.8	9.2	76	39	4.7	48.8	
14	Apr 02 -Apr 08	35.3	24.1	9.8	86	52	3.2	44.8	8.2

Contd....

Table 2 contd...

Standard week No.	Month and date	Maximum tempe-rature (°C)	Minimum tempe-rature (°C)	Sunshine hours (h)	Relative humidity (%) 8.00 AM	2.00 PM	Wind speed (Kmh^{-1})	Total evapo-ration (mm)	Total rainfall (mm)
15	Apr 09 - Apr 15	34.7	24.3	10.3	89	48	3.9	42.4	-
16	Apr 16 - Apr 22	35.5	24.2	9.3	81	49	3.2	43.5	-
17	Apr 23 - Apr 29	35.4	25.3	8.9	83	53	3.2	41.7	-
18	Apr 30 - May 06	34.8	24.3	7.3	85	56	3.1	37.4	15.4
19	May 07 - May 13	34.6	24.8	6.1	90	61	2.8	33.4	19.6
20	May 14 - May 20	33.7	24.7	3.6	86	59	3.4	32.7	-
21	May 21 - May 27	34.7	23.8	8.1	87	52	3.7	38.1	28.0
22	May 28 - Jun 03	34.0	24.9	8.9	89	57	3.0	76.3	24.0
23	Jun 04 - Jun 10	33.7	23.2	8.6	88	60	3.3	34.2	109.4
24	Jun 11 - Jun 17	31.1	23.2	6.9	93	67	3.2	31.2	50.0

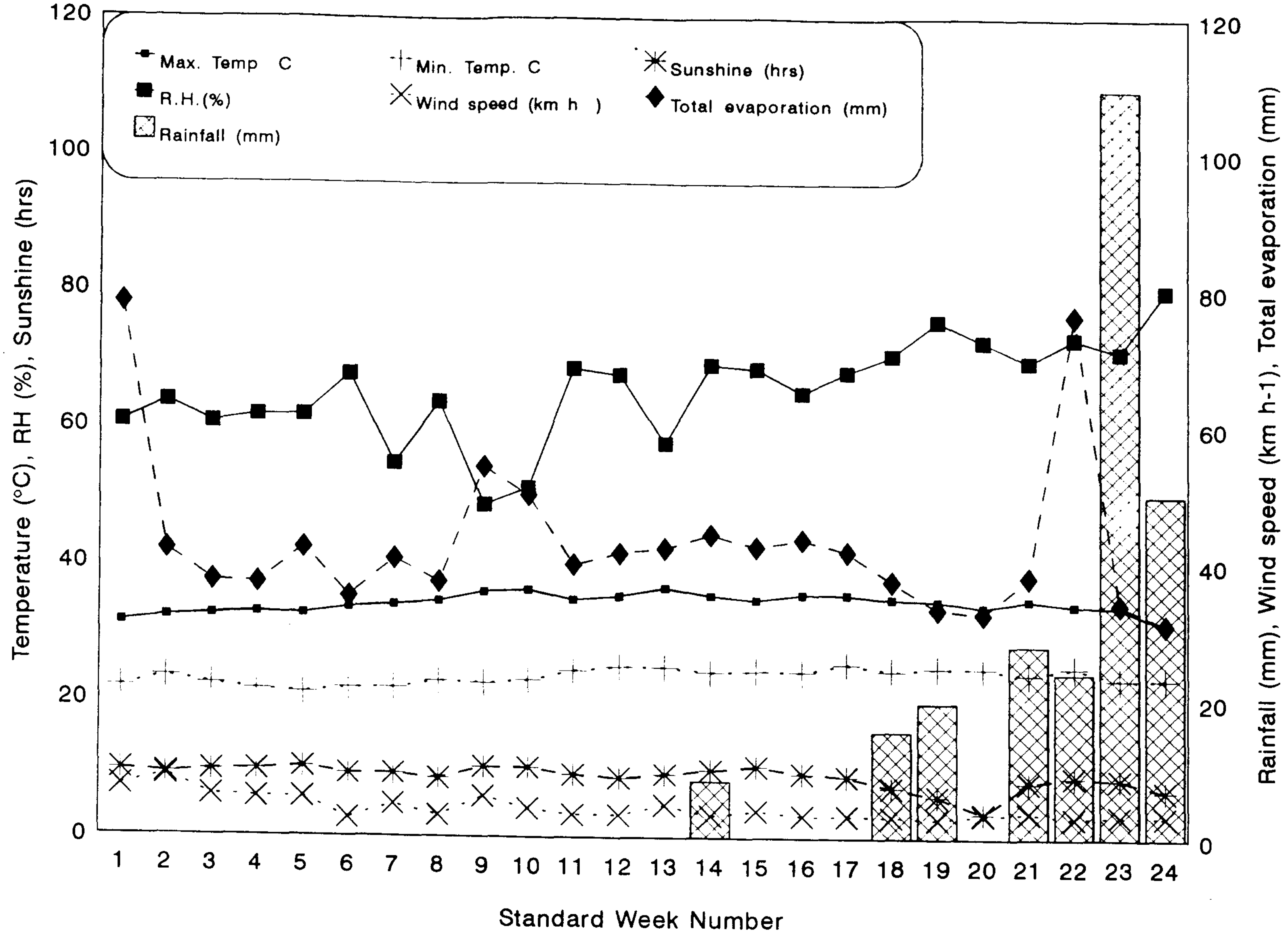

Fig.1 Meteorological data (weekly) during the crop period

(Temperature, sunshine hours, RH and wind speed data represent average for the week. Evaporation and rainfall data represent weekly total)

The weekly averages of maximum temperature ranged between 31.1°C and 36.4°C and the minimum between 21°C and 25.3°C. March remains the hottest month while minimum temperature was lowest in January.

The crop received 254.6 mm of rainfall during its growth period, scattered over the season into 7 days.

The relative humidity during the crop season ranged from 75 to 93 per cent at 8.00 AM and 21 to 67 per cent at 2.00 PM.

The wind velocity during the crop season ranged from 2.7 kmh^{-1} to 8.8 kmh^{-1}.

The mean weekly cumulative pan evaporation values varied from 31.2 mm to 54.1 mm.

3.4 Cropping history

The experimental site was a double crop paddy wet land. During the year of investigation a semidry crop of paddy was raised during April-May to August-September and field was kept fallow from October to January. There after field was ploughed to raise the crop under investigation. The cultivar Pusa Savani was used for the study. It is a high yielding variety, having a duration of four months. The variety is released from IARI, Pusa, New Delhi.

3.5 Details of experiment

The field experiment was conducted during summer season of 1997. The layout of the plan is given in Figure 2. The technical programme followed is as follows.

i) Design : Randomised Block Design

ii) Replication : Three

iii) Treatments

T_1 Drip irrigation at s.m.t. 0.04 MPa

T_2 Drip irrigation at s.m.t. 0.06 MPa

T_3 Drip irrigation at s.m.t. 0.08 MPa

T_4 Drip irrigation under LDPE mulch at s.m.t. 0.04 MPa

T_5 Drip irrigation under LDPE mulch at s.m.t. 0.06 MPa

T_6 Drip irrigation under LDPE mulch at s.m.t. 0.08 MPa

T_7 Furrow irrigation under LDPE mulch at s.m.t. 0.04 MPa

T_8 Furrow irrigation under LDPE mulch at s.m.t. 0.06 MPa

T_9 Furrow irrigation under LDPE mulch at s.m.t. 0.08 MPa

T_{10} Furrow irrigation without mulch (control) at s.m.t. 0.06 MPa

(s.m.t. - Soil moisture tension)

In case of drip irrigation system, the mains and submains was of PVC pipes of 30 mm diameter. The mains are connected to the submains through T-connectors. A valve was attached to each submain controlled the flow of water to each treatment line. From each submain three laterals of 12 mm HDPE pipes were run to cover the length of the

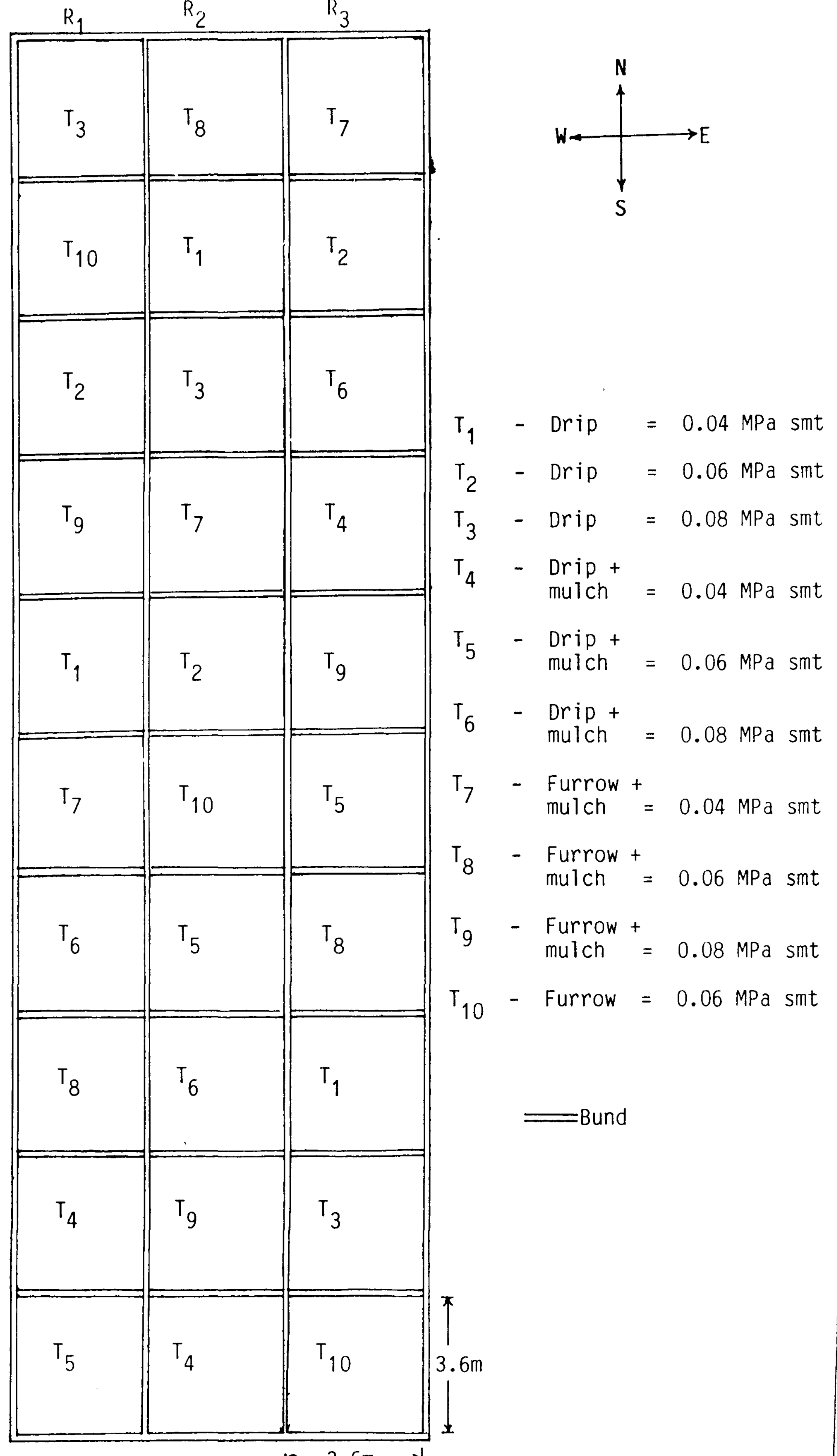

Fig. 2 Layout plan of the experiment

furrow. Micro tubes of 4 mm polytubes were connected to each lateral on either side at a spacing of 60 cm so that each micro tube can feed two plants in row. Drippers having discharge rate of 4 lph^{-1} were connected to the polytube end to regulate dripping. A schematic diagram of the layout of drip irrigation system is given in Figure 3. After formation of furrow before planting and layout of drip irrigation system in case of drip irrigation treatments, the plot was covered under 200 gauge black LDPE sheet before planting.

iv) Plot size : 3.6 x 3.6 m

v) Crop : Okra (*Abelmoschus esculentus* L. *Moench*)

3.6 Field culture

3.6.1 Preparation of main field

The experimental field was ploughed using tractor drawn disc plough and pulverised using rotovator. Then plots of size 3.6 m x 3.6 m were earmarked. In each plot six ridges were made at 60 cm apart. An intra row spacing of 30 cm was given to accommodate 12 plants in a row and altogether 72 plants in each plot. In case of drip irrigation one lateral ran between two ridges.

The field under mulch treatment was covered with black LDPE sheet before sowing. The tensiometer are installed at 15 cm depth and 7.5 cm away from the plant ie., at the middle of the plant and the dripper.

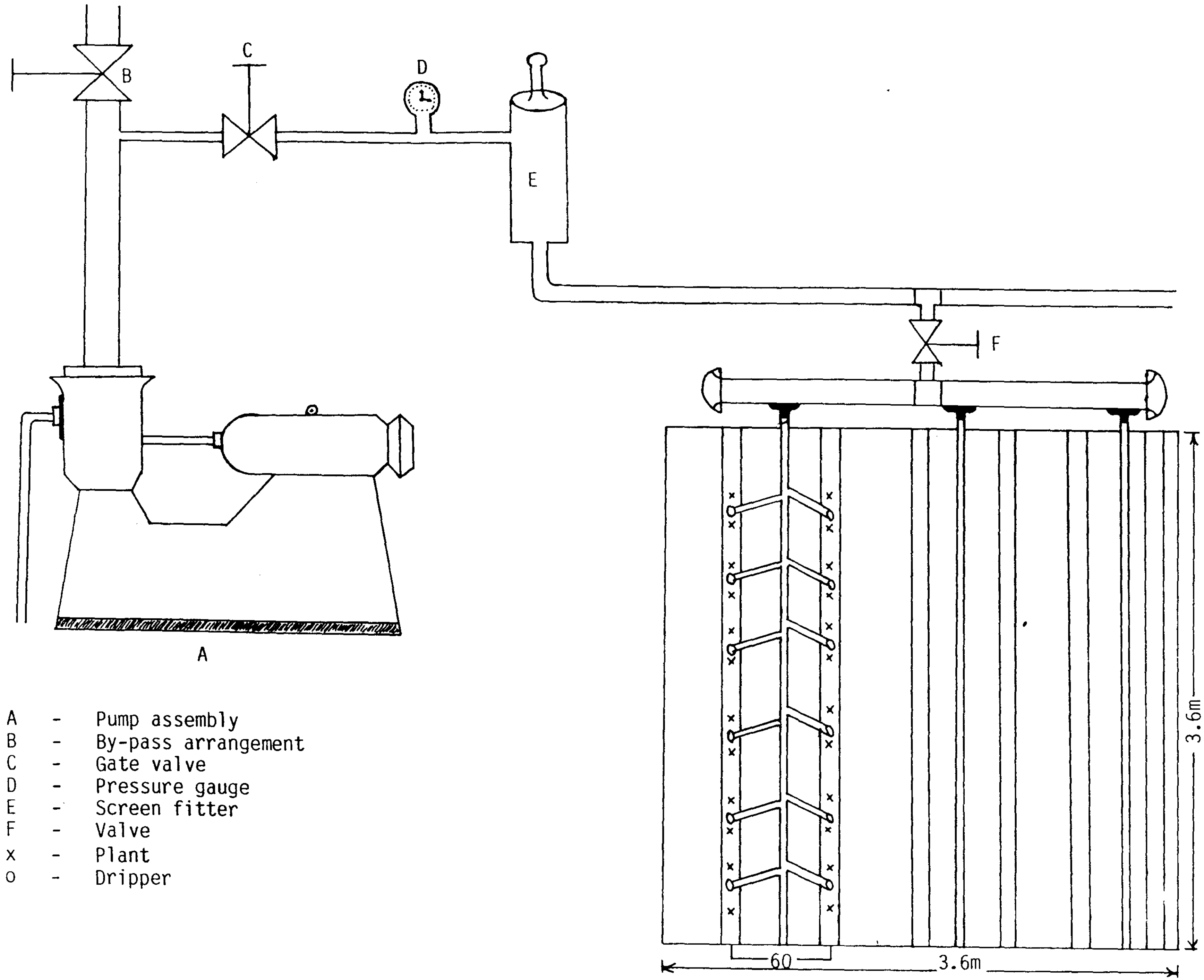

Fig. 3 Layout of drip irrigation system

3.6.2 Manures and fertilizer application

Well decomposed farm yard manure at the rate of 12 t ha^{-1} was applied uniformly to all plots as basal dose before forming the final ridge. A fertilizer dose of 50:8:25 kg ha^{-1} N, P_2O_5 and K_2O respectively was applied as per Pakcage of Practices Recommendations, Kerala Agricultural University (1993). Urea, Rajphos, Muriate of potash was the source of fertilizer materials used. Entire quantity of P_2O_5 was applied as basal dose. Half the dose of nitrogen and full potash was applied two weeks after sowing, remaining half of nitrogen was applied one month after the application of 1st dose.

3.6.3 Sowing

In case of mulched plots holes were made on the black polythene sheet uniformly at 30 cm spacing. Through these holes seeds were dibbled at the rate of two seeds per hole at a depth of 5 cm. In case of unmulched plots seeds were dibbled on the ridges at 30 cm apart. The seedlings were thinned to one per hole 15 days after sowing. Gap filling was also done to ensure a uniform stand of the crop.

3.6.4 Irrigation

One presowing irrigation was given uniformly to all plots. Thereafter three irrigations were given at three days interval to all the plots upto 10th day after sowing to ensure germination and survival of germinated plants.

Thereonwards irrigation was started according to the treatments.

Tensiometer was installed in each plot at a depth of 15 cm. The plots were irrigated according to tensiometer readings.

The quantity of water applied per irrigation was calculated by taking the depth or irrigation as 30 mm. Based on this, the volume of water to be applied per treatment was calculated to be 1166.4 litres. Considering the number of drippers per plot and pressure of flowing water observed through pressure gauge, the flow time was regulated so as to give the required quantity of water. In case of furrow irrigation measured quantity of water was given through partial flume. Last irrigation was given on 24.5.97, since thereafter rainfall is at regular intervals. The details of irrigation are given in Table 3.

3.6.5 After cultivation

The unmulched plots were kept weed free through out the crop growth period by hand weeding at monthly interval. The weeds were collected, fresh weight and dry weight were determined. In case of mulched crops, there was no weed growth.

Table 3 Details of irrigation

Treatment	No. of irrigations given	Dates of irrigation
T_1	11	24.02.97, 03.03.97, 07.03.97, 15.03.97, 19.03.97, 26.03.97, 01.04.97, 07.04.97, 21.04.97, 14.05.97, 24.05.97
T_2	6	09.03.97, 18.03.97, 25.03.97, 07.04,97, 14.05.97, 24.05.97
T_3	6	07.03.97, 17.03.97, 26.03.97, 08.04.97, 14.05.97, 24.05.97
T_4	7	07.03.97, 25.03.97, 31.03.97, 07.04.97, 21.04.97, 14.05.97, 24.05.97
T_5	5	15.03.97, 27.03.97, 07.04.97, 14.05.97, 24.05.97
T_6	3	24.03.97, 17.04.97, 15.05.97
T_7	7	09.03.97, 17.03.97, 27.03.97, 07.04.97, 12.04.97, 14.05.97, 24.05.97
T_8	5	07.03.97, 17.03.97, 27.03.97, 07.04.97, 15.05.97
T_9	4	19.03.97, 29.03.97, 08.04.97, 15.05.97
T_{10}	11	26.02.97, 07.03.97, 17.03.97, 20.03.97, 24.03.97, 31.03.97, 07.04.97, 12.04.97, 21.04.97, 14.05.97, 24.05.97

3.6.6 Plant protection

Carbaryl at the rate of 0.2 per cent was sprayed against jassids on 22.02.97 and 25.02.97. Monocrotophos at the rate of 4 ml/litre of water along with garlic extraction was sprayed against stem borer on 17-03-1997. Garlic extraction was prepared by fine grinding of 400 gm garlic with water and then fiber part is removed and this solution is made upto 8 L and used for spraying. On 25.03.97 acephate at the rate of 0.05 per cent was sprayed against stem and fruit borer. Kelthane at the rate of 5 ml/litre of water was sprayed to control red spider mite on 12.04.1997.

3.6.7 Harvesting

Fruits were harvested at tender stage as green fruits. The dates of sowing of seeds and harvesting are given in Appendix 3.

3.7 Biometric observations

The plants in the outer row were avoided as the border plants and were excluded from observations. From the remaining plants available, six plants from each plot were randomly selected, tagged and used as `sample plants' for recording observations.

3.7.1 Growth, yield attributes and yield

The following growth and yield characters were recorded during the course of investigation.

1. Height of plant
2. Number of leaves plant^{-1}
3. Leaf area plant^{-1} and leaf area index
4. Leaf water potential
5. Dry weight of weeds
6. Number of fruiting branches plant^{-1}
7. Number of flowers plant^{-1}
8. Number of fruits plant^{-1}
9. Percentage of fruit set
10. Weight of fruits plant^{-1}
11. Yield hectare^{-1}

3.7.1.1 Height of plant

The height of the six sample plants was recorded at 15 days interval. Height from the soil surface to the tip of the top most leaf was recorded. The mean height of six sample plants was computed.

3.7.1.2 Number of leaves plant^{-1}

The total number of green leaves on the six sample plants were counted at 15 days interval and the mean is reported.

3.7.1.3 Leaf area plant^{-1} and leaf area index

Leaf area index is calculated by graph paper method. The total number of leaves of a single plant per treatment taken at monthly interval. The leaf area per plant is calculated by tracing on graph. From the total leaf area average are was found out and is taken as area of the index leaf. The total number of leaves multiplied by the area of the index leaf gave the leaf area per plant. The leaf area index was calculated by the following formula.

$$LAI = \frac{\text{Leaf area plant}^{-1}}{\text{Land area plant}^{-1}}$$

3.7.1.4 Leaf water potential

Leaf water potential (ψ) was measured using scholander type pressure chamber (Soil Moisture Equipment Corporation, Ohio, USA). Measurements were made on mature leaves of three plants per treatment at 0600 hrs IST. The leaves were enclosed in a polybag before being detached (Turner, 1988). The pressure noted on the scale was taken as the leaf water potential.

3.7.1.5 Dry weight of weeds

Total weeds were collected at the time of weeding and dry weight of weeds was found and reported.

3.7.1.6 Number of fruiting branches plant^{-1}

The total number of fruiting branches on the six sample plants were recorded and the mean is reported.

3.7.1.7 Number of flowers plant^{-1}

The number of flowers formed on the six sample plants were recorded and the mean of the total is reported.

3.7.1.8 Number of fruits plant^{-1}

The total number of fruits on the six sample plants were recorded and mean is reported.

3.7.1.9 Percentage of fruit set

Based on total number of flowers formed per plant and number of fruits per plant, percentage of fruit set was computed.

3.7.1.10 Weight of fruits plant^{-1}

The weight of fruits of the six sample plants were recorded and the mean is reported.

3.7.1.11 Yield hectare^{-1}

Weight of fruits per plant, multiplied by number of plants ha^{-1} is reported as yield ha^{-1}.

3.8 Soil moisture studies

1. Bulk density
2. Field capacity
3. Permanent wilting point
4. Gravimetric estimation of soil moisture before cropping, at 15, 30 cm layer depth in case of drip and furrow irrigation.

5. Gravimetric estimation of radial soil moisture distribution at 30 cm segments upto 105 cm in radial distance along the ridge and upto 60 cm radial distance on either sides of the ridge and 15 and 30 cm vertical depth.

3.8.1 Bulk density of soil

The bulk density of the soil at 0-15 cm and 15-30 cm depth from surface was found out by using core sampler.

3.8.2 Field capacity

The field capacity of the soil was found out by using pressure-plate apparatus. The moisture content of the soil at 0.3 bar was found out gravimetrically and taken as field capacity.

3.8.3 Permanent wilting point

The permanent wilting point was found out by using pressure-plate apparatus. The moisture content of the soil at 15 bar was found out gravimetrically and taken as permanent wilting point.

3.8.4 Gravimetric estimation of soil moisture content

Soil moisture content of the soil at 15, 30 cm layer depth was found out gravimetrically before irrigation.

3.8.5 Gravimetric estimation of soil moisture distribution

Soil moisture content upto a radial distance of 105 cm along the ridge at 30 cm interval and upto a radial distance of 60 cm on either sides of ridge and 15 and 30 cm vertical depth was worked out gravimetrically to study soil moisture distribution.

3.9 Estimated parameters

1. Irrigation requirement
2. Consumptive use of water
3. Soil moisture distribution pattern
4. Crop water use efficiency and field water use efficiency

3.9.1 Irrigation requirement

Irrigation requirement was estimated by directly adding water used for irrigation in each treatment.

3.9.2 Consumptive use of water

Consumptive use of water was estimated based on water balance model as written as follows:

$$I + P + Si + Gi = E + So + Go + \Delta St$$

In which,

I = Irrigation water supplied

P = Precipitation

Si = Surface water inflow

Gi = Ground water inflow

E = Evapotranspiration

So = Surface water outflow

Go = Ground water outflow

Δst = Change in storage

Si, So, Gi and Go are neglected in the equation since there was no surface water flow and the ground water in the field was below 3 metres from the surface. Change in storage was worked out based on gravimetric method upto the rootzone depth of 30 cm. Only the part of the precipitation which is effective was considered to account for `P'. Irrigation water applied at a time was 30 mm. Finally the equation was reduced to:

$I + P = E + \Delta st$ (Bredero, 1991)

3.9.3 Soil moisture distribution pattern

The soil moisture extracted from each layer was estimated and converted into percent utilization over the total moisture used by the crop upto 30 cm depth to express soil moisture distribution pattern.

3.9.4 Crop water use efficiency (CWUE) and field water use efficiency (FWUE)

CWUE and FWUE were computed using the following formula and are expressed as kg fruit m^{-3} of water.

$$CWUE = \frac{\text{Fruit yield (kg)}}{\text{Consumptive water use } (m^3)}$$

$$\text{FWUE} = \frac{\text{Fruit yield (kg)}}{\text{Total water applied (m}^3\text{)}}$$

3.10 Economics of production

The total cost of production was worked out based on considering all the charges involved in the layout of irrigation system, its operational management, cost of cultivation of the crop and total yield actually got from the field based on per plant production and the value of produce in the prevailing market. For the cost of labour involved in the raising of crop as per treatment, the labour norms followed at the site of experiment at Agricultural Research Station, Mannuthy was considered. Cost sheet was prepared as per the procedure followed by Jadhav *et al.* (1990) and as discussed by Acharya (1997). Benefit-cost ratio was worked out after computing the additional net income received if the water saved is used for raising a crop in the proportionate area under the same treatment.

3.11 Statistical analysis

The data recorded were subjected to statistical analysis by applying `Analysis of variance' technique for `Randomised Block Design'. The variance ratio test was employed to identify the significance of treatment effects (Cochran and Cox, 1957). Standard error of means (S.Em$\pm$)

and critical difference (CD) at 5 per cent significance level were worked out for each character.

The estimated parameters such as soil moisture distribution pattern, irrigation requirement, consumptive use of water and crop water use efficiency are explained only based on comparative performance.

Results

RESULTS

The results obtained during the course of investigation on the growth and yield of bhindi, soil moisture distribution pattern, irrigation requirement, consumptive use of water and water use efficiency under both drip irrigation and furrow irrigation with or without mulch at different soil moisture tensions are presented in this chapter.

4.1 Studies on growth and yield of bhindi as influenced by mulch-cum-drip irrigation

4.1.1 Height

Mean height of bhindi plants recorded at different growth stages at 15 days interval at different levels of irrigations either as drip or furrow, with or without mulch are given in Table 4.

The data indicated that mulching under different levels of irrigation, irrespective of method significantly increased the height of plants. Drip irrigation at the tension of 0.04 MPa under mulch sustained maximum height throughout the growth period. This was comparable only to drip irrigated crop at the levels 0.06 or 0.08 MPa under mulching. This trend remained same throughout the growth period. However at final growth stage of 105 days after

Table 4 Mean height of bhindi plants (cm) at different growth stages as influenced by mulch-cum-drip irrigation

	Treatment	Days after sowing						
		15	30	45	60	75	90	105
T_1	Drip irrigation at s.m.t. 0.04 MP_a	7.44	13.50	20.89	32.30	42.10	53.55	66.66
T_2	Drip irrigation at s.m.t. 0.06 MP_a	8.61	16.00	22.16	30.32	40.11	51.44	75.16
T_3	Drip irrigation at s.m.t. 0.08 MP_a	6.07	11.52	17.44	26.38	33.66	40.99	54.88
T_4	Drip at s.m.t. 0.04 MP_a with mulch	11.10	19.72	32.66	52.22	70.05	82.05	96.16
T_5	Drip at s.m.t. 0.06 MP_a with mulch	9.28	18.28	31.22	51.47	60.61	69.05	77.72
T_6	Drip at s.m.t. 0.08 MP_a with mulch	8.83	18.44	32.61	51.61	62.89	74.11	85.50
T_7	Furrow irrigation at s.m.t. 0.04 MPa with mulch	8.38	14.72	24.61	43.03	54.05	66.78	91.16
T_8	Furrow irrigation at s.m.t. 0.06 MPa with mulch	7.27	13.97	24.05	42.22	52.55	63.65	79.61
T_9	Furrow irrigation at s.m.t. 0.08 MPa with mulch	5.78	12.25	23.08	45.55	55.05	64.78	78.28
T_{10}	Furrow irrigation at s.m.t. 0.06 MPa (Control)	7.11	12.96	20.33	30.52	39.88	52.44	73.10
	C.D. (0.05)	1.13	2.31	4.67	8.78	9.47	9.27	8.49

s.m.t. = soil moisture tension

planting maximum height achieved with drip irrigation at 0.04 MPa under mulching was comparable to furrow irrigation at soil moisture tension of 0.04 MPa under mulch. Throughout the growth period drip irrigation without mulching irrespective of tension levels, produced significantly lower stature than that with mulch. Similarly drip irrigation without mulching performed significantly badly in comparison to furrow irrigation with mulch. Conventional method of irrigation ie., furrow at soil moisture tension of 0.06 MPa performed equally likely as that of drip irrigation without mulch, without any significant difference between them.

When height was observed at 105 days after sowing plant irrigated using drip or furrow under mulch at soil moisture tension of 0.04 MPa produced 32 and 25 per cent more height, respectively than the crop irrigated under furrow method at soil moisture tension of 0.06 MPa.

4.1.2 Number of leaves plant^{-1}

The number of green leaves on the plants at different growth stages as influenced by the treatments is given in Table 5.

Throughout the growth period the crop mulched and irrigated using drip system irrespective of irrigation levels produced maximum green leaves. The irrigation

Table 5 Mean number of green leaves of bhindi plants at different growth stages as influenced by mulch-cum-drip irrigation

	Treatment	Days after sowing						
		15	30	45	60	75	90	105
T_1	Drip irrigation at s.m.t. 0.04 MP_a	2.00	5.66	10.49	20.72	27.94	27.28	20.22
T_2	Drip irrigation at s.m.t. 0.06 MP_a	2.00	8.39	12.94	18.83	27.00	35.27	29.50
T_3	Drip irrigation at s.m.t. 0.08 MP_a	1.89	7.44	10.72	15.05	23.50	29.39	17.66
T_4	Drip at s.m.t. 0.04 MP_a with mulch	2.21	9.88	16.32	31.94	46.16	59.60	51.35
T_5	Drip at s.m.t. 0.06 MP_a with mulch	2.88	9.66	18.44	41.33	54.38	57.77	33.49
T_6	Drip at s.m.t. 0.08 MP_a with mulch	2.44	8.66	17.22	41.72	54.60	62.88	45.05
T_7	Furrow irrigation at s.m.t. 0.04 MPa with mulch	2.05	4.94	7.76	23.77	37.05	52.72	45.33
T_8	Furrow irrigation at s.m.t. 0.06 MPa with mulch	2.17	7.44	14.28	28.39	42.05	53.55	34.00
T_9	Furrow irrigation at s.m.t. 0.08 MPa with mulch	2.00	9.88	15.72	30.99	45.05	55.44	30.55
T_{10}	Furrow irrigation at s.m.t. 0.06 MPa (Control)	2.00	7.22	10.94	17.61	30.77	40.28	19.05
	C.D. (0.05)	0.20	2.17	4.23	7.93	8.16	7.47	8.93

s.m.t. = soil moisture tension

levels under mulched condition did not affect the green leaf production both under drip and furrow irrigated system. Crop under drip-cum-mulch system produced more green leaves than that under furrow-cum-mulch. Drip alone at any of the three moisture levels was either inferior or on par with the control ie., furrow irrigation at soil moisture tension 0.06 MPa. This trend was persistent throughout growth period and was more conspicuous towards the final growth of the crop.

At the final growth stage, crop mulched and irrigated using drip at soil moisture tension of 0.04 MPa produced 169 per cent more leaves compared to the control crop (furrow irrigation at soil moisture tension 0.06 MPa) which retained only 19.06 leaves per plant. The crop mulched and irrigated either with drip at soil moisture tension of 0.08 MPa or furrow at soil moisture tension of 0.04 MPa produced statistically similar number of green leaves as that of the crop mulched and irrigated using drip at 0.04 MPa.

4.1.3 Leaf area per plant and leaf area index

The data on leaf area and leaf area index at different growth stages as influenced by drip-cum-mulch are given in Table 6.

Throughout the growth period drip-cum-mulch irrigation system irrespective of irrigation levels produced maximum

Table 6 Leaf area per plant (LA) and leaf area index (LAI) of bhindi plants at different growth stages as influenced by mulch-cum-drip irrigation

	Treatment	Days after sowing					
		30		60		90	
		LA	LAI	LA	LAI	LA	LAI
T_1	Drip irrigation at s.m.t. 0.04 MP_a	139.31	0.07	514.71	0.28	671.08	0.37
T_2	Drip irrigation at s.m.t. 0.06 MP_a	206.36	0.11	463.29	0.25	867.82	0.48
T_3	Drip irrigation at s.m.t. 0.08 MP_a	183.10	0.10	265.72	0.20	722.99	0.40
T_4	Drip at s.m.t. 0.04 MP_a with mulch	495.64	0.27	1601.78	0.89	2989.26	1.66
T_5	Drip at s.m.t. 0.06 MP_a with mulch	484.61	0.26	2078.69	1.15	2888.96	1.60
T_6	Drip at s.m.t. 0.08 MP_a with mulch	434.66	0.24	292.25	1.16	3153.59	1.75
T_7	Furrow irrigation at s.m.t. 0.04 MPa with mulch	204.98	0.11	985.30	0.54	2184.85	1.21
T_8	Furrow irrigation at s.m.t. 0.06 MPa with mulch	308.58	0.17	1176.48	0.65	2219.24	1.23
T_9	Furrow irrigation at s.m.t. 0.08 MPa with mulch	409.71	0.22	1284.49	0.71	2297.43	1.27
T_{10}	Furrow irrigation at s.m.t. 0.06 MPa (Control)	171.69	0.09	418.58	0.23	957.45	0.53
	C.D. (0.05)	103.18	0.05	380.24	0.21	348.37	0.19

s.m.t. = soil moisture tension

leaf area per plant as well as LAI. This was significantly superior to that of the crop under furrow-cum-mulch irrigation. Drip irrigation without mulching had a significantly lower leaf area and LAI which were comparable to the control crop receiving irrigation at soil moisture tension of 0.06 MPa under furrow system. At the later growth stages, as observed after 90 days after sowing, drip irrigated crop without mulch produced even lesser leaf area thereby lower LAI than the control plot.

When observed at 90 days after sowing the drip-cum-mulch irrigated crop on an average irrespective of irrigation levels produced 214 per cent more leaf area whereas furrow-cum-mulch irrigated crop produced 133 per cent more leaf area than the control crop that produced 957.45 cm^2 leaf area per plant. A similar trend is also seen in case of LAI.

4.1.4 Leaf water potential

The data on leaf water potential recorded at 6.00 AM at 46, 65 and 78 days after sowing are given in Table 7.

The soil moisture tension recorded simultaneously from the tensiometers are also given in the Table 7. The days elapsed since last irrigation in each treatment are also given as the value in parenthesis.

Table 7 Leaf water potential (ψL) and soil moisture tension (s.m.t.) as influenced by mulch-cum-drip irrigation

Treatment	46		65		78	
	ψL (MPa)	S.m.t. (MPa)	ψL (MPa)	S.m.t. (MPa)	ψL (MPa)	S.m.t. (MPa)
T_1	-0.14	0.017 (2)	-0.12	0.050(8)	-0.14	0.008 (1)
T_2	-0.15	0.035 (3)	-0.17	0.070 (15)	-0.17	0.021 (11)
T_3	-0.18	0.030 (4)	-0.17	0.080 (14)	-0.18	0.016 (11)
T_4	-0.15	0.018 (4)	-0.11	0.043 (8)	-0.13	0.012 (1)
T_5	-0.15	0.036 (6)	-0.11	0.016 (2)	-0.12	0.019 (11)
T_6	-0.18	0.065 (26)	-0.19	0.053 (17)	-0.19	0.043 (29)
T_7	-0.16	0.029 (4)	-0.20	0.015 (2)	-0.16	0.022 (11)
T_8	-0.13	0.028 (3)	-0.22	0.015 (2)	-0.16	0.024 (17)
T_9	-0.15	0.033 (2)	-0.27	0.080 (11)	-0.17	0.034 (11)
T_{10}	-0.12	0.023 (1)	-0.24	0.018 (2)	-0.14	0.014 (1)

* Figures in parentheses is the days after irrigation

Leaf water potential always remained on an average 5-10 times higher than that of soil moisture tension. As the days elapsed since last irrigation, in drip irrigated plot without mulching soil, moisture tension in general increased initially for a short period after irrigation thereafter decreased sharply. In drip irrigated mulched field a similar trend was observed, especially when irrigation was scheduled at higher tensions of 0.06 and 0.08 MPa. But in case of treatment T_4, ie. irrigation scheduled at soil moisture tension of 0.04 MPa, soil moisture tension gradually increased with the elapse of days since irrigation. Mulched and furrow irrigated field had a lower moisture content and maintained a higher soil moisture tension compared to mulched drip irrigated field. In case of furrow irrigation without mulching soil moisture tension observed at 15 cm depth increased initially and thereafter remained unchanged for longer time.

Leaf water potential in general remained static without considerable change temporally in case of drip irrigation without mulching. But in case of furrow irrigation without mulching leaf water potential increased sharply with time span. Similarly in case of drip irrigation with mulching leaf water potential did not show any remarkable spurt with respect to time. However leaf water potential was lower in case of higher frequency irrigation (0.04 MPa) and higher for lower frequency irrigation (0.08 MPa). In case of furrow irrigation with mulching leaf water potential though initially decreased gradually a small increase was noticed after few days.

Soil moisture tension vs. LWP relation is depicted. In case of drip irrigation without mulching, LWP was not severely altered by decline in soil moisture tension. But when mulching was undertaken there was a shift in the trend that LWP increased in proportion to increase in soil moisture tension. This relation was conspicuous for furrow mulching. In case of furrow irrigation without mulching a sharp increase in LWP with respect to increase in soil moisture tension was seen.

4.1.5 Dry weight of weeds

Three manual weedings at 19, 43 and 72 days after sowing were needed to remove the weeds grown in the unmulched plot. Dry weight of weeds recorded (Kg/m^2) are given in Table 8. There was no weed growth in the mulched crop. The control crop which was unmulched and receiving irrigation at 0.06 MPa as furrow method recorded maximum weed growth of 5.778 kg dry weight of weeds per m^2 compared to unmulched drip irrigated crop. There was 21, 40 and 43 per cent reduction in weed growth in unmulched drip irrigated plot irrigated at soil moisture tension of 0.04, 0.06 and 0.08 MPa respectively when compared to the control plot.

Table 8 Total dry weight of weeds kg m^{-2}

Treatment	Days after sowing			Total
	19	43	72	
T_1	0.3611	3	1.2222	4.5833
T_2	0.3055	2.305	0.8611	3.4722
T_3	0.2222	1.972	1.0833	3.2777
T_{10}	0.1111	3.25	2.4166	5.7777

4.1.6 Number of fruiting branches plant $^{-1}$

The data on number of fruiting branches of the bhindi crop as influenced by mulch-cum-drip is given in Table 9.

When the crop was mulched from the sowing onwards, methods of irrigation viz., drip or furrow and the irrigation levels tried at soil moisture tensions of 0.04, 0.06 or 0.08 MPa did not affect the number of fruiting branches formed in the plant.

When the crop was not mulched and drip irrigation was resorted to it did not benefit the crop even under higher levels of soil moisture tension and the crop produced statistically similar number of fruiting branches as that of the control plot receiving irrigation at soil moisture tension of 0.06 MPa by furrow method.

On an average drip-cum-mulch and furrow-cum-mulch irrigations led to 99 per cent and 78 per cent more number of fruiting branches respectively than that which produced by the control crop.

4.1.7 Number of flowers plant $^{-1}$

The data on total number of flowers per plant as influenced by drip and mulch are given in Table 9.

Drip irrigation at various soil moisture tensions without mulch did not enhance flower production significantly over that of the control crop. But when the crop was mulched, the crop produced on an average 46 per cent more number of flowers under the varying levels of drip irrigation than the control crop. Varying irrigation levels did not alter number of flowers produced when the crop was mulched. Furrow irrigation under mulched situation also led to a significant increase in flower production compared to control or drip irrigated crop without mulch. The mulched crop under furrow irrigation at soil moisture tension of 0.06 and 0.08 produced 34 and 57 per cent more flowers than the control crop and these remained statistically on par with the mulched crop under drip irrigation at the three levels of irrigation. However irrigation scheduled at 0.04 MPa under furrow irrigation with mulch did not induce as much number of flowers as that could under drip irrigation with mulch.

4.1.8 Number of fruits plant^{-1}

The data on number of fruits per plant as influenced by mulch-cum-drip are given in Table 9.

Drip irrigation alone though scheduled at different soil moisture tension did not improve fruit production significantly over the furrow irrigated crop at soil moisture tension of 0.06 MPa which served as the control. But when mulching was done from the seeding onwards either drip or furrow method of irrigation performed equally and significantly better than the control. Once mulching was adopted, irrigation scheduled at different moisture tensions did not cause variation in fruit production remarkably except in case of furrow irrigation at soil moisture tension of 0.04 MPa.

The mulched crop under drip irrigation at 0.04, 0.06 and 0.08 MPa produced 65, 76 and 51 per cent more number of fruits respectively than the control crop, which on an average produced 13.55 number of fruits per plant. The corresponding increase in number of fruits in furrow under mulching is 20, 56 and 70.

4.1.9 Percentage of fruit set

Data on fruit set may be seen in Table 9.

Mulched crop irrespective of irrigation levels and methods of irrigation, recorded significantly higher levels of fruit set. The fruit set on an average in these treatments was 88.1 per cent. Significantly lower fruit setting on an average 72.1 per cent, was noticed in unmulched drip irrigated plot, without any variation between the irrigation levels. Unmulched furrow irrigated crop recorded 78.8 per cent fruit set.

4.1.10 Weight of fresh fruits plant^{-1}

The fruit weight per plant as influenced by much-cum-drip irrigation is given in Table 9.

Table 9 Total number of fruiting branches, total number of flowers, total number of fruits, fruiting percentage and weight of fresh fruits per plant as influenced by mulch-cum-drip irrigation

Treatment	Number of fruiting branches per plant	Number of flowers per plant	Number of fruits per plant	Fruiting percentage	Weight of fresh fruits per plant (g)
T_1	7.38	15.38	11.50	74.10	160.45
T_2	7.27	15.55	10.55	67.13	159.22
T_3	5.83	13.83	10.33	75.16	156.86
T_4	11.16	25.44	22.39	87.53	427.67
T_5	11.77	25.66	23.83	92.83	430.37
T_6	12.94	23.55	20.50	86.63	370.68
T_7	9.77	18.44	16.33	87.96	352.75
T_8	11.44	23.38	21.11	85.83	330.97
T_9	10.83	26.11	23.00	88.03	447.76
T_{10}	5.99	16.99	13.55	78.80	231.42
C.D. (0.05)	2.645	5.364	5.394	7.411	131.45

Drip irrigations alone either at 0.04 or 0.06 or 0.08 MPa soil moisture tension could not significantly improve total fruit weight over the furrow irrigated crop at soil moisture tension of 0.06 MPa without mulch which served as the control. But when the crop was mulched from seeding onwards either drip or furrow method of irrigation significantly enhanced fruit yield in terms of total weight over that of the control crop. The respective increase in total fruit weight was 77 and 63 per cent. These were also significantly superior to drip irrigated crop without mulching. When mulching was adopted in drip irrigated crop at soil moisture tensions of 0.04, 0.06 and 0.08 MPa there were 165, 170 and 136 per cent more fruit yield, in terms of total weight of fruits per plant, than that produced from respective crops without mulch.

4.1.11 Yield ha^{-1}

Data on yield per hectare was given in Table 10.

Mulched and drip irrigated crop produced maximum fruit yield per hectare, which was significantly superior to all other treatments, except that of mulched furrow irrigated crop at 0.08 MPa tension. There was no significant effect due to varying levels of irrigation in these treatment. On an average, mulched and drip irrigated crop produced 22,698 kg fruits ha^{-1}, which was 77.5 per cent more than that of unmulched furrow irrigated crop at 0.06 MPa tension, which

Table 10 Total yield (t ha^{-1}) of Bhindi crop as influenced by mulch-cum-drip irrigation

Treatment	Yield (t ha^{-1})
T_1	8.91
T_2	8.85
T_3	8.71
T_4	23.59
T_5	23.91
T_6	20.59
T_7	19.60
T_8	18.39
T_9	24.88
T_{10}	12.86
C.D. (0.05)	7303.27

served as control crop. Furrow irrigated and mulched crop, on an average over irrigation levels, produced 20,954 kg fruit ha^{-1}, which was 63 per cent more that the control crop that produced 12,857 kg fruits ha^{-1}. Unmulched drip irrigated crop, on an average produced only 8,824 kg fruit hq^{-1}, which was lesser by 31.3 per cent over that of control crop.

4.2 Soil moisture studies

4.2.1 Consumptive use

The data showing the total water applied, consumptive use of water by the crop and the soil moisture extraction upto 30 cm depth by the crop under different methods of irrigation with or without mulch are given in Table 11.

The total quantity of water applied varied according to the methods and schedules of irrigation as well as mulching. The control plot ie., unmulched crop receiving irrigation at soil moisture tension of 0.06 MPa, received 11 irrigations which was similar to the crop receiving irrigation through drip at soil moisture tension of 0.04 MPa without mulching. When crop was mulched and irrigated at the schedule of 0.04 MPa crop received only 7 irrigations accounting to nearly 32 per cent reduction in consumptive use irrespective of surface or drip irrigation method. When crop was irrigated at soil moisture tension of 0.06 MPa in the mulch condition, there was 49 per cent reduction in the consumptive use without any variation between drip or surface method. But when the crop was irrigated at 0.08 MPa under mulch condition there was 66 per cent reduction in irrigation water in case of drip method and 58 per cent reduction in case of surface method.

4.2.2 Soil moisture extraction

In general, 30-50 per cent soil moisture was contributed from the surface 0.15 cm layer and 50-70 per cent from the 15-30 cm layer depending upon the method of irrigation scheduled and mulching (Table 11).

When frequency of irrigation was increased viz. as the soil moisture tension was decreased for scheduling irrigation, 15-30 cm layer contributed more towards soil moisture extraction by the crop. In case of drip irrigation at soil moisture tension of 0.06 and 0.08 MPa without mulching nearly 66 and 69 per cent of moisture was extracted respectively from 15-30 cm layer. However, in case of drip irrigation at soil moisture tension of 0.04 MPa without mulching, contribution from this layer was nearly 50 per cent. But when mulching was adopted surface 15 cm layer contributed more to consumptive use compared to that from unmulched crop. However, when the soil moisture tension was increased for scheduling irrigation, 15-30 cm layer made a major contribution for soil moisture extraction by the crop. At soil moisture tension

Table 11 Total water received, consumptive use of water and soil moisture extraction by the crop as influenced by mulch-cum-drip irrigation

Treatment	Total water received (mm)	No. of irrigati ons	Total CU (mm)	Moisture use (mm) at different soil depth		% moisture use at different soil depth		% decrease of CU over control (T_{10})
				0-15 cm	15-30 cm	0-15 cm	15-30 cm	
T_1	365	11	365.15	180.97	184.14	49.56	50.44	0.31
T_2	215	6	215.44	74.06	141.35	34.38	65.62	41.18
T_3	215	6	215.75	66.19	149.54	30.68	69.32	41.09
T_4	245	7	248.02	111.86	136.14	45.10	54.90	32.28
T_5	185	5	183.59	79.93	103.63	43.54	56.46	49.87
T_6	125	3	123.85	48.50	75.34	39.16	60.84	66.18
T_7	245	7	245.71	116.44	129.24	47.39	52.61	32.91
T_8	185	5	183.60	84.53	99.05	46.04	53.96	49.87
T_9	155	4	154.29	54.90	99.38	35.58	64.42	57.87
T_{10}	365	11	366.28	150.21	216.03	41.01	58.99	-

of 0.08 MPa, 15-30 cm layer supplied 61 and 64 per cent of the total soil moisture extracted by the crop in case of the mulched crop with drip and furrow irrigation respectively.

4.2.3 Radial distribution of soil moisture

Data regarding gravimetric soil moisture content observed at the point of dripper ie., 15 cm away from plant at 15 and 30 cm vertical depth before irrigation is given in Table 12.

Soil moisture content observed at 30 cm depth before irrigation was in general more than that at 15 cm depth. In case of both drip irrigation as well as surface irrigation soil moisture content was higher in mulched situation compared to unmulching situation. Average soil moisture content under drip irrigation without mulching was 8.34 whereas under mulched situation it was 11.17. Under furrow system with mulch soil mositure content before irrigation on an average was 11.20 per cent while under unmulched situation it was 7.51 per cent.

Soil moisture content along the row at different lateral distances from the plant observed at 30 cm depth before irrigation are given in Table 13.

Table 12 Mean value of soil moisture content (w/w) at 15 and 30 cm depth before irrigation at 15 cm away from plant

Treatment	Depth		Average irrigation interval (days)
	15 cm	30 cm	
T_1	9.35	9.91	9
T_2	8.60	9.39	17
T_3	6.78	6.19	17
T_4	10.56	13.10	14
T_5	9.45	10.23	20
T_6	10.68	12.99	31
T_7	11.81	12.82	14
T_8	10.29	11.44	18
T_9	9.14	10.61	23
T_{10}	7.65	7.37	9

Table 13 Mean soil moisture content (w/w) in per cent at 30 cm depth before irrigation at different lateral distances along the row from the plant

Treatment	Lateral distance (cm) from the plant			
	15 (A)	45 (B)	75 (A)	105 (B)
T_1	10.16	9.87	10.38	9.94
T_2	9.76	10.18	11.14	10.60
T_3	8.21	7.74	8.02	8.11
T_4	11.33	11.25	12.35	11.82
T_5	11.12	9.23	9.59	9.54
T_6	9.56	9.78	10.51	10.89
T_7	9.78	10.35	10.60	11.70
T_8	10.07	10.20	9.69	10.91
T_9	10.38	10.03	11.21	10.14
T_{10}	9.28	9.19	9.71	8.36

(A) at the point of dripper
(B) 30 cm away from dripper

Soil moisturte content along the row reduced gradually as the distance from dripper increased. The average soil moisture content at 30 cm depth before irrigation at the point of 30 cm away from the dripper (ie., the middle point between two plants in a row) is 9.3, 8.78, 10.42 and 10.55 in case if drip irrigation without mulch, surface irrigation without mulch, drip irrigation with mulching and surface irigation with mulching respectively. In general soil moisture content before irrigation was higher in case of irrigation at lower tensions compare to irrigation at higher tensions.

Soil moisture content observed at 30 cm depth before irrigation across the row prependicular to the line of dripper is given in Table 14. Soil moisture content at 30 cm radial distance perpendicular to the line of dripper was higher compared to that observed at the point of dripper. In general soil moisture content at this 30 cm radial distance was 1.4 to 1.8 per cent more than that at the point of dripper.

4.3 Water use efficiency

The mean data regarding crop water use efficiency and field water use efficiency are given in Table 15.

Water use efficiency was higher in case of mulched crop compared to unmulched crop at the same level of

Table 14 Mean soil moisture content (w/w) in per cent on either side of dripper across furrow at 30 and 60 cm distance at 30 cm depth before irrigation

Treatment	Lateral distance from the dripper across the row			
	Left		Right	
	30 cm	60 cm	30 cm	60 cm
T_1	10.69	10.14	11.21	10.78
T_2	11.60	9.52	10.61	9.77
T_3	9.39	8.08	9.41	8.94
T_4	13.38	10.87	13.37	11.98
T_5	10.81	9.82	10.92	9.83
T_6	12.63	10.62	11.93	10.76
T_7	13.13	10.81	14.01	11.33
T_8	12.75	8.94	15.96	11.66
T_9	12.30	8.66	12.38	10.99
T_{10}	10.01	9.42	10.13	9.12

Table 15 Crop WUE and field WUE (kg m^{-3}) of bhindi plants as influenced by mulch-cum-drip irrigation

Treatment	Crop WUE	Field WUE
T_1	2.44	2.44
T_2	4.10	4.11
T_3	4.04	4.05
T_4	9.51	9.62
T_5	13.02	12.92
T_6	16.62	16.47
T_7	7.97	7.99
T_8	10.01	9.94
T_9	16.12	16.04
T_{10}	3.51	3.52

irrigation. Under drip irrigation system crop water use efficiency enhanced by 289, 218 and 311 per cent when mulching was done to the crop at the irrigation schedules of 0.04, 0.06 and 0.08 MPa tension respectively. When furrow system was resorted to, mulching improved crop water use efficiency over that of unmulched crop irrigated at 0.06 MPa to the tune of 127, 185 and 359 per cent when irrigated at soil moisture tension of 0.04, 0.06 and 0.08 MPa.

4.4 Economics of production

The data regarding the economics of production of bhindi crop under different treatments are given in Table 16. The data relating to components of the seasonal and fixed costs are given in Appendices 4 to 10. The Benefit-Cost ratio was worked out considering the additional net income that might be received if the water saved through each system was used for raising crop in proportionate area (Table 16).

The data indicate that if drip system alone is adopted for raising bhindi crop, there is substantial loss, even though considerable saving in water can be achieved. In this case, eventhough there is nearly 70 per cent saving in water either under 0.06 or 0.08 MPa irrigation, the yield is poorer and leading to an average net loss of Rs. 0.94 lakh per ha^{-1}, from the total area of 1.70 hectare. This is

Table 16 Economics of production of Bhindi crop as influenced by mulch-cum-drip irrigation

Sl. No.	Item	T1	T2	T3	T4	T5	T6	T7	T8	T9	T10
1	Total variable cost	66428	65924	65814	62019	62106	59147	59417	57723	62833	71503
2	Yield of bhindi crop (t/ha)	8.914	8.845	8.714	23.592	23.909	20.593	19597	18.389	24.875	12857
3	Value of product @ 5000/t	44570	44225	43570	117960	119545	102965	97985	91945	124375	64285
4	One seasonal fixed cost (Rs/ha)	37972	37972	37972	53662	53662	53662	15690	15690	15690	-
5	Net seasonal income (Rs/ha)	-59830	-59671	-60216	2279	3777	-9844	22878	18532	45852	-7218
6	Additional net area that can be irrigated due to saving of water over flood irrigation method (ha)	-	0.70	0.69	0.47	0.99	1.95	0.49	0.99	1.37	-

Table 16 contd..

7	Additional income due to saving of water	-	30,957	30,063	55,441	118349	200781	48012	91025	170393	-
8	One seasonal fixed cost + cost of cultivation	-	72,727	71,612	54,370	114610	219977	35972	72678	107576	-
9	Additional net income due to increased area (Rs)	-	-41770	-41549	1,071	3739	-19196	12040	18347	62817	-
10	Net income due to irrigation system over flood irrigation	-59830	-94223	-94547	10,568	14734	-21822	42136	44097	115887	-
11	Benefit cost ratio	0.42	0.42	0.41	1.01	1.03	0.91	1.31	1.25	1.58	0.89

when compared to the crop raised under furrow method of irrigation at 0.06 MPa without mulch, which has the B.C. ratio only to the tune of 0.89. When mulching was adopted with the irrigation scheduled either at 0.04, 0.06 or 0.08 MPa, under drip irrigation system or surface method of irrigation the cropping became profitable and the B.C. ratio varied between 0.91 to 1.58. Maximum benefit of 1.58 (BC ratio) was derived when the crop was mulched and irrigated at soil moisture tension of 0.08 MPa. At this irrigation schedule nearly 137 per cent more area could be irrigated with the water saved through this irrigation method. However maximum total production of 60.749 tons was obtained when irrigation was scheduled at soil moisture tension of 0.08 MPa through drip. At this irrigation level 195 per cent more area could be covered under irrigation when compared to the furrow method of irrigation at 0.06 MPa without mulch. But at this schedule there was a net loss of Rs.7397 from one hectare and the B.C. ratio was 0.91.

Discussion

DISCUSSION

Augmentation of vegetable production is one of the priority areas of the state considering the pecuniary situations of a very wide gap between production and consumption. Manifold efforts are needed to increase production and productivity of the vegetables in the state to meet its demand. For solving all the physical constraints, modern technology like close house technology or tunnel farming is yet to receive attention. Controlled management of rhizosphere through mulching and drip irrigation is one of the modern techniques to improve productivity of vegetables through conservation of moisture as well as control of weeds, and to enhance net profitability. Conservation of moisture has got paramount importance considering the scenario of scarce water resource of the state. Production of vegetables in summer fallows is the main avenue for the horizontal expansion of vegetable cultivation of the state. Considering all these aspects this chapter explains the results obtained during the investigation and presented in the previous chapter.

Growth of bhindi as influenced by mulch-cum-drip irrigation

Growth of the plants as observed in terms of height, number of leaves and leaf area index was significantly improved when mulching was resorted to (Table 4, 5 and 6).

The effects of methods of irrigation and levels of irrigation were not pronounced under mulched situation even when the methods were principally different and levels were quantitatively varying. Drip irrigation alone or furrow method of irrigation alone could not significantly improve the growth of the plant under non-mulched situation in comparison to mulched situation. Mulching alone increased height by 25-32 per cent, leaf production by 169 per cent in case of drip irrigation at 0.04 MPa soil moisture tension, leaf area index improved by 214 per cent in drip-cum-mulch and 133 per cent in case of furrow cum mulch method of irrigation (Table 4, 5 and 6). In case of leaf area or leaf area index drip-cum-mulch fared better than furrow-cum-mulch.

Mulching has been very effective in conserving soil moisture, reducing evaporative losses and retaining a favourable soil moisture tension for effective utilisation of moisture (Bhella, 1988a; Bogle, *et al.*, 1989). Weed growth has also been severely checked due to mulching (Liu *et al.*, 1987; Van, 1989). The observations made in the present study on soil moisture distribution (Table 12) as well as weed growth (Table 8) fully subscribe to these observations. A better soil environment such as good soil moisture distribution, soil temperature as well as absence of any stress such as soil moisture stress, weed competition etc. have contributed towards a significantly better growth under mulched situation. Retention of available soil moisture for a longer period without subject to evaporative losses under mulching might be the reason for not having variable results under varying levels of irrigation (Fig.4). Wan Derverken and Lee (1988) have observed that when soil mulching was adopted in bell pepper at varying irrigation levels, the latter could not profoundly improve growth with respect to irrigation levels.

Leaf water potential measured at 46, 65 and 78 days after planting was 5 to 10 times higher than that of soil moisture tension (Table 7 and Fig.6). This is needed for the plant to absorb moisture from the soil to the leaf and other shoot parts based on the principle of potential gradient. Kramer (1983), and Van den Honert (1948), observed that leaf water potential always force a higher gradient so to enable absorption of water from the root zone.

Leaf water potential did not vary considerably in drip irrigated plot but increased with time lapse in furrow irrigated plot (Fig.5). This indicates that soil moisture stress is not felt in drip irrigated plot but in furrow irrigated plot. In mulch-cum-drip irrigation system leaf water potential remained almost static having a lower value under higher frequency irrigation. Under furrow-cum-mulch irrigation leaf water potential initially declined with irrigation and increased with lapse of time. This clearly indicated that when drip irrigation is provided in mulched situation plant is protected from soil moisture stress and soil moisture needs of the crop is adequately met with. The effect of this has been outwardly put up by the crop through increase in green leaf number as well as more photosynthetic area (Table 5). According to Bhella, 1988a, more leaf area and leaf number have been some of the prominent effects of drip-cum-mulch irrigation compared to other irrigation methods.

Results further indicate that leaf water potential remain static without much change with respect to soil moisture tension in case of drip irrigation without mulch whereas it increases with increase in soil moisture tension in case of mulching (Table 7, Fig.4 to 6). Probably plant is creating a larger gradient between leaf and soil under mulched situation, so as to absorb soil moisture conserved in the soil under this system. A sharp increase in leaf water potential with respect to furrow irrigation without mulch indicates that the plant is subject to severe water stress under this system. Turner and Jones (1980) observed that plant operates a osmoregulatory mechanism with respect to soil moisture tension and soil moisture temperature. A sharp increase in leaf water potential is an indicator for plant moisture stress.

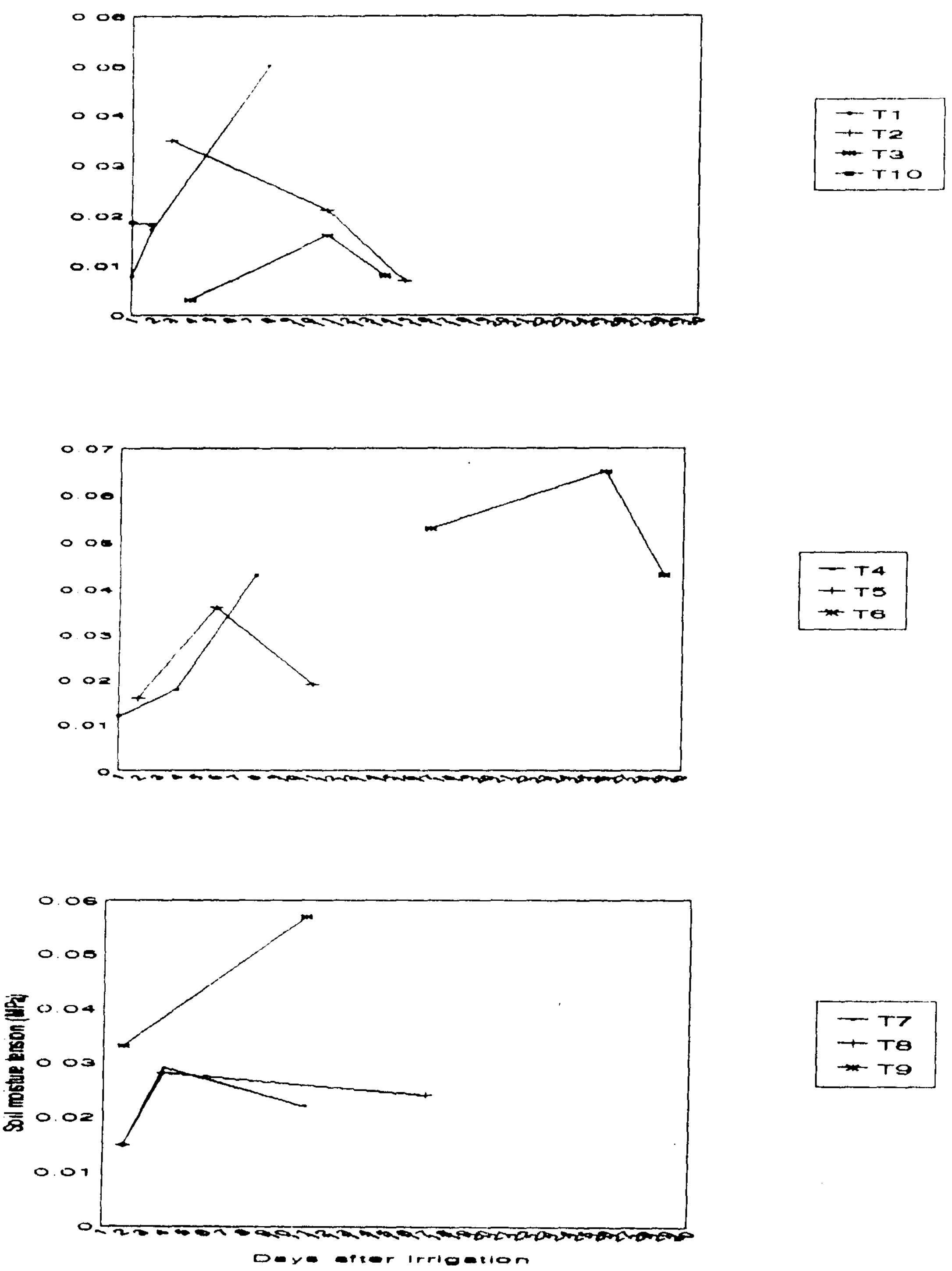

Fig.4 Variation in soil moisture tension (MPa) in different treatment with respect to days after irrigation

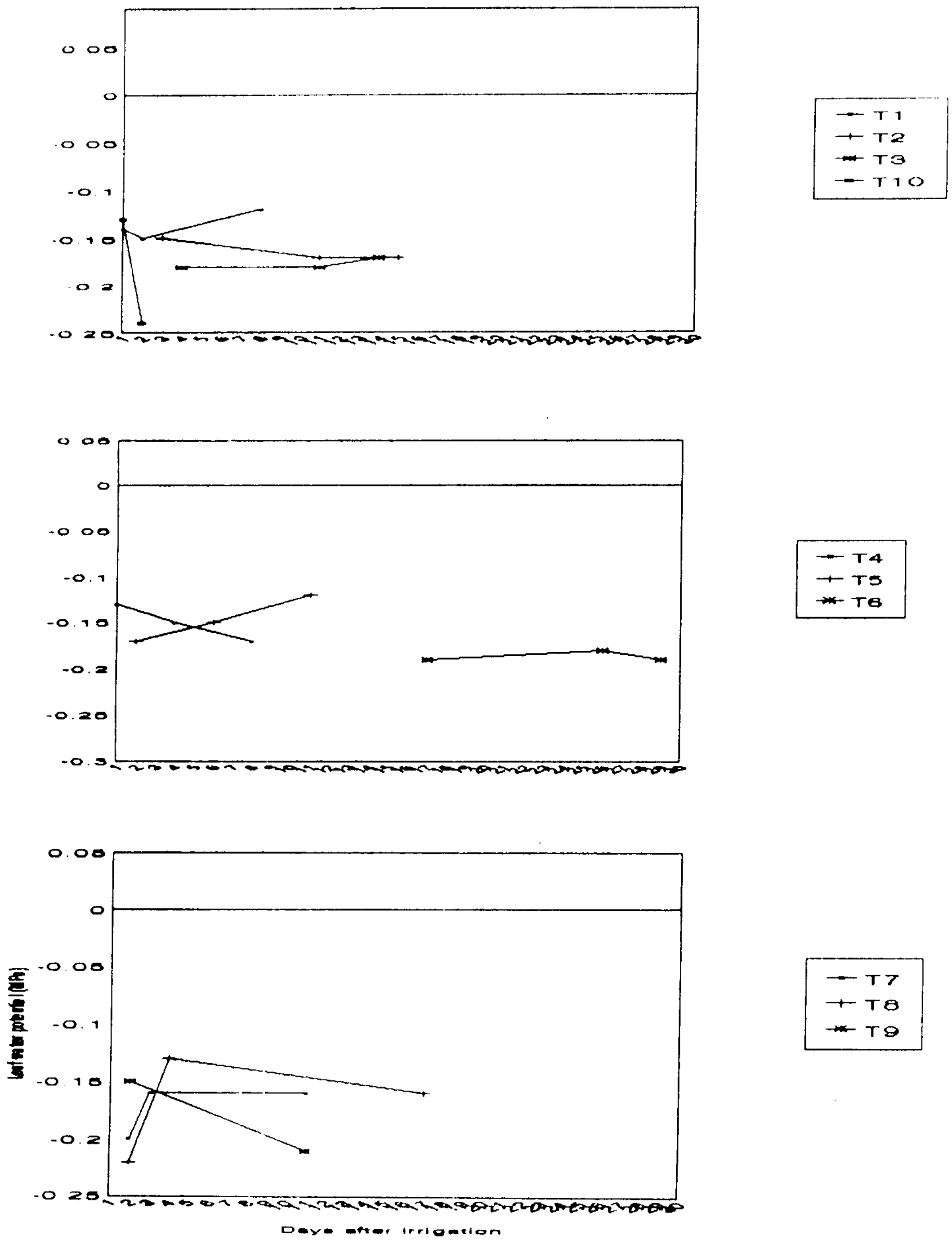

Fig.5 Variation in leaf water potential (MPa) in different treatments with respect to days after irrigation

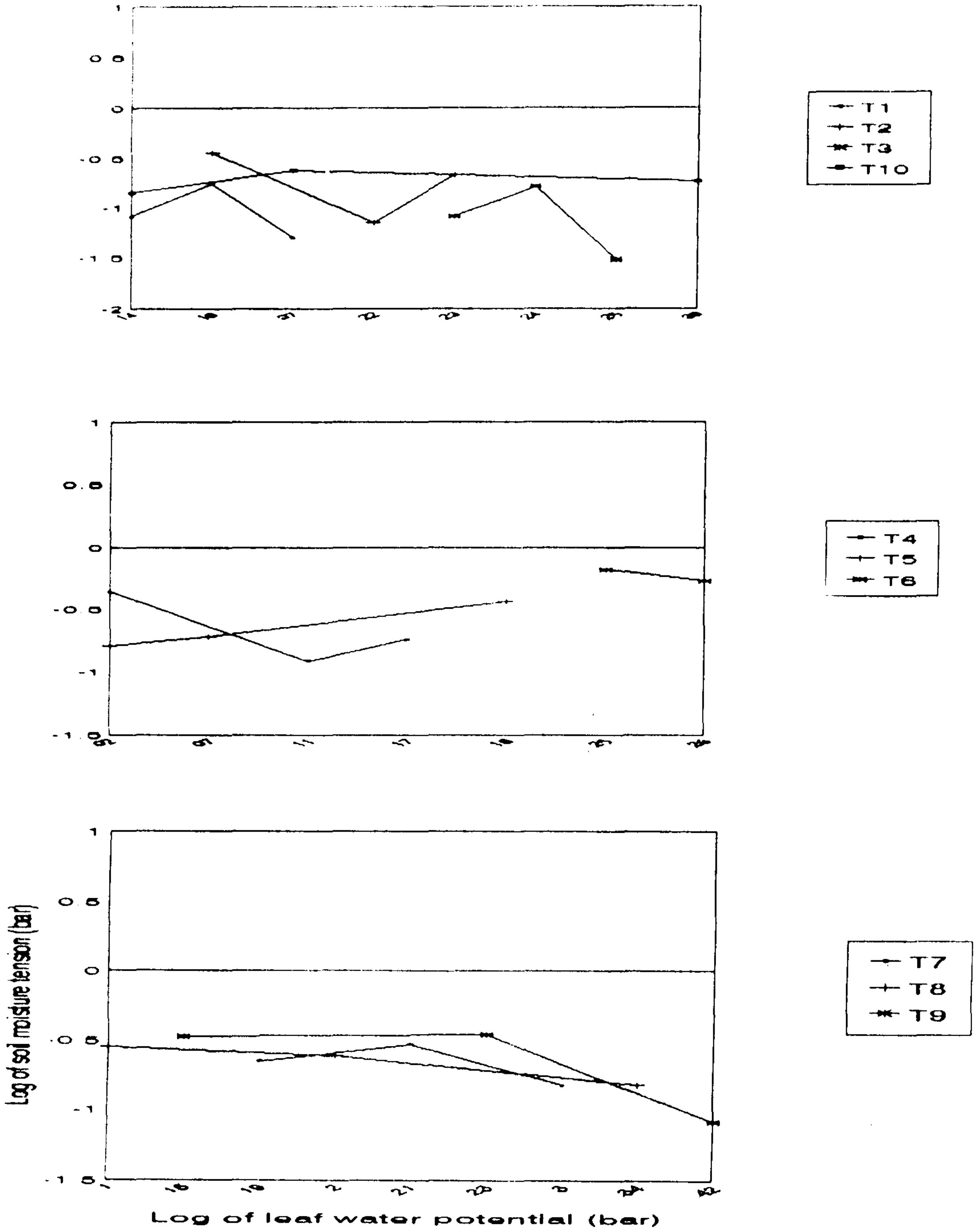

Fig 6 Variation in leaf water potential in relation to soil moisture tension in different treatments

The ancillary observation recorded on weed growth (Table 8 and Fig.7) indicates that weed growth is remarkably reduced due to mulching as well as with the decline in irrigation frequency. Lack of adequate sunlight and increase in soil temperature might have contributed for reduction in weed growth. According to Gutal *et al.* (1992), there is 90 per cent reduction in weed growth due to mulching alone in a crop of tomato.

Yield attributes and yield of bhindi as influenced by mulch-cum-drip irrigation

Bhindi (*Abelmoschus esculentus* Moench) is a crop with indeterminate growth habit in which both vegetative growth and reproductive growth occur simultaneously. An assured supply of factors of growth of production throughout the growth period, hence, is needed for higher productivity. In other words a growth habitat which ensures adequate and timely supply of moisture and nutrients and a good micro climate throughout the growth period ensure higher yield from this plant.

The ultimate yield of any plant is contributed through the components known as yield attributes. In case of bhindi also the yield is determined by the attributes such as number of fruiting branches, number of flowers, number of fruits, fruit set and weight of individual fruit.

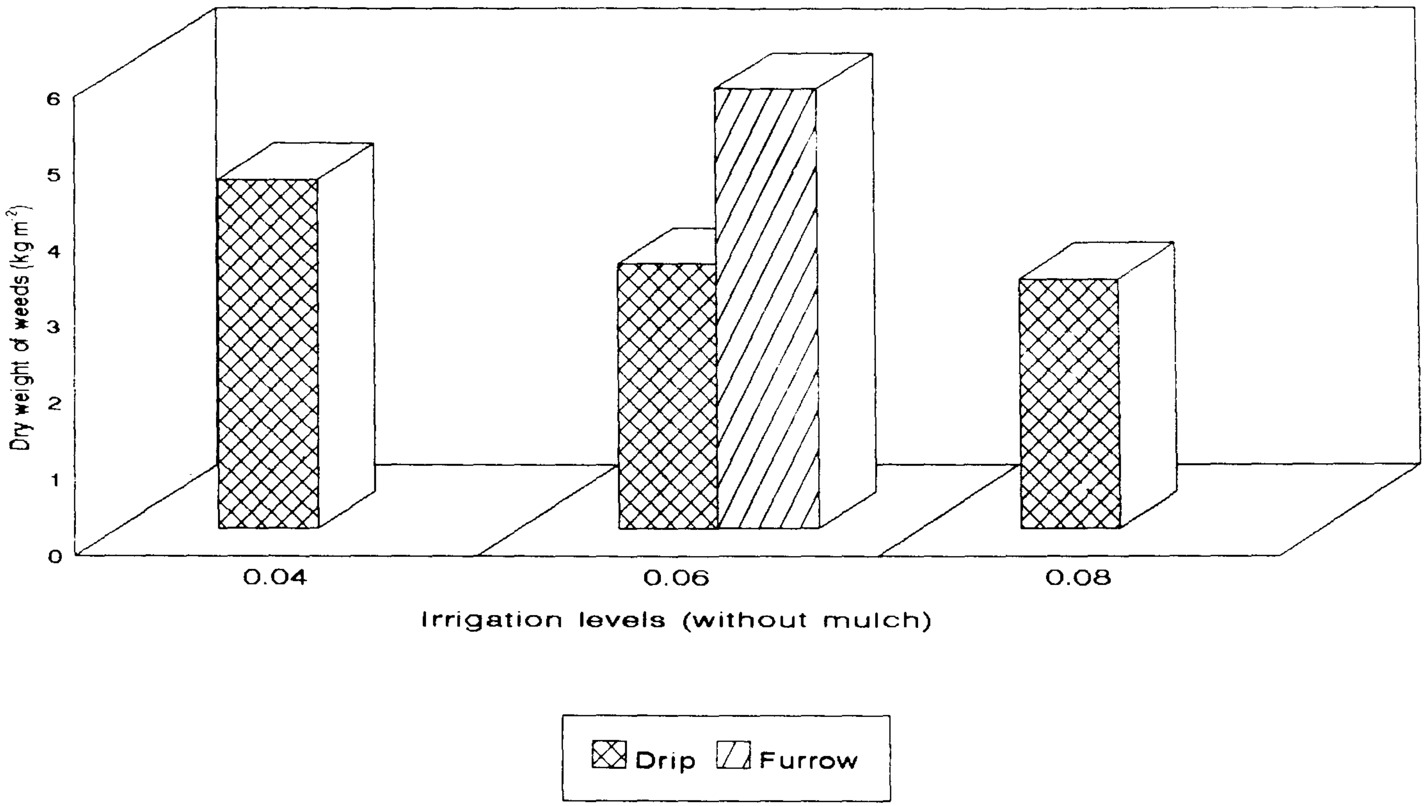

Fig. 7 Total dry weight of weeds (kg m^{-2}) as influenced by mulch-cum-drip irrigation

In the present investigation number of fruiting branches were increased when the crop was mulched. The methods of irrigation and irrigation levels did not further add to this effect (Table 9 and Fig.8). Drip-cum-mulch and furrow-cum-mulch irrigation enhanced production of fruiting branches by 99 and 78 per cent respectively compared to drip or furrow irrigation alone. Production of number of number of flowers also followed a same trend (Table 9 and Fig.9). In this case eventhough irrigation at 0.04 MPa under furrow method with mulch did not produce as much number of flowers as that of drip-cum-mulch irrigation at the same level, at 0.06 or 0.08 MPa irrigation level both methods were equally effective in enhancing flower production.

Similarly number of fruits produced plant^{-1} (Table 9 and Fig.10) was more ie., 66 to 76.5 per cent in drip method, 20 to 70 per cent under furrow method, both under mulched condition when compared to either drip or furrow alone. Furrow-cum-mulch and drip-cum-mulch in general were equally effective in the production of fruits, eventhough at 0.04 MPa irrigation level, furrow-cum-mulch could not produce as much as that of drip-cum-mulch.

Fruit set followed an identical trend. On an average furrow or drip-cum-mulch yielded 88.1 per cent fruit set while drip irrigation and furrow irrigation alone led to 72.1 per cent and 78.8 per cent fruit set respectively (Table 9, Fig.11).

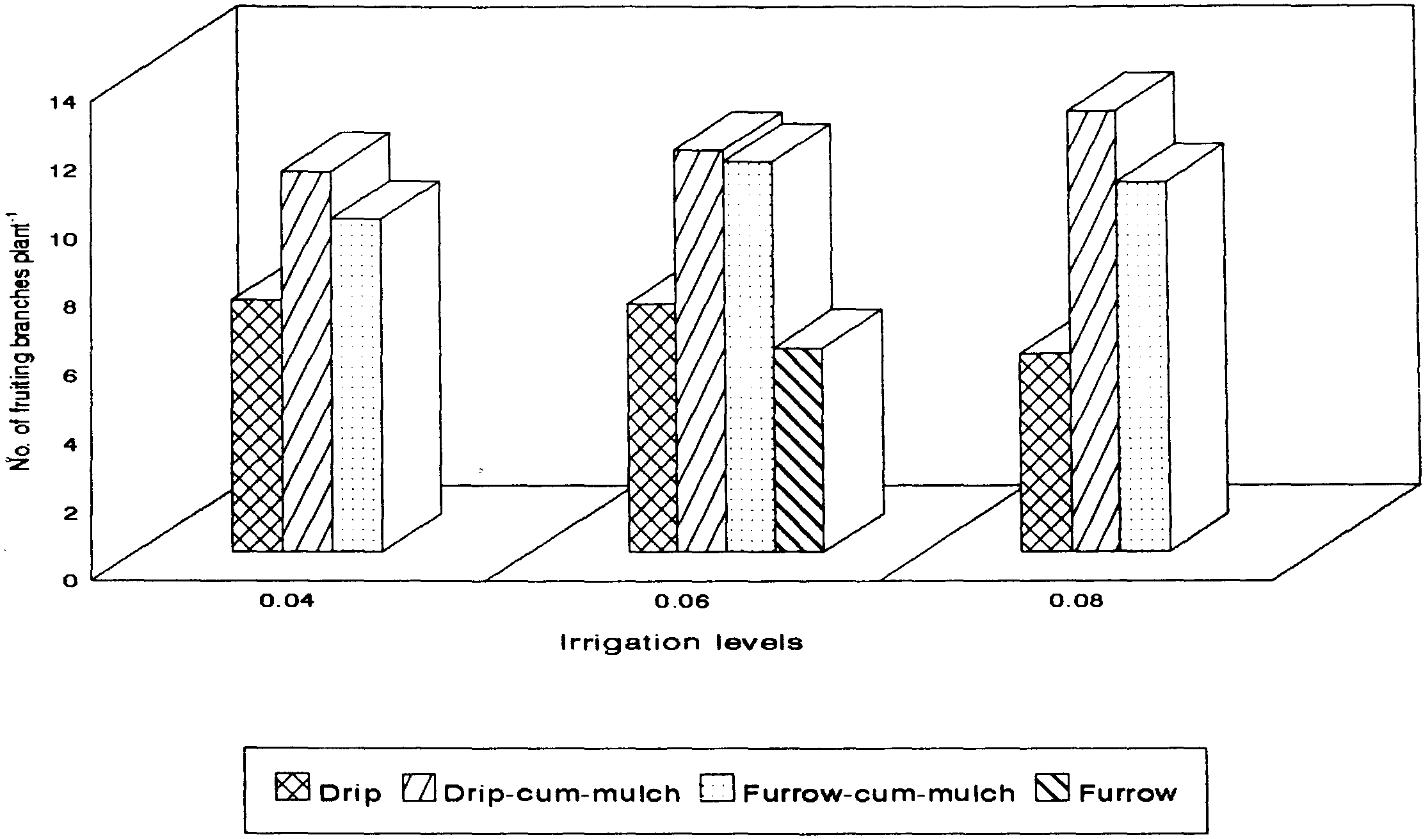

Fig. 8 Total number of fruiting branches plant^{-1} as influenced by mulch-cum-drip irrigation

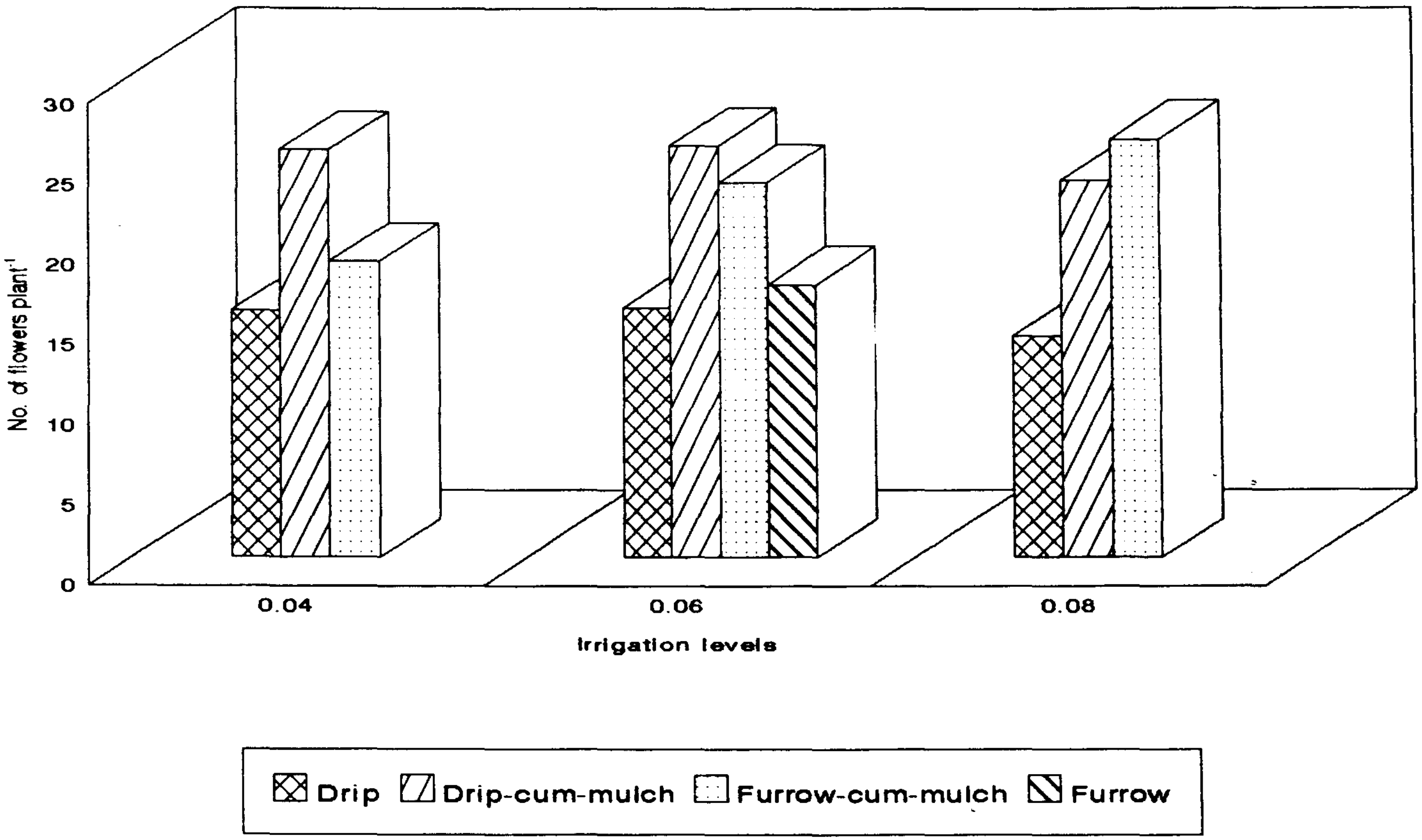

Fig. 9 Total number of flowers plant^{-1} as influenced by mulch-cum-drip irrigation

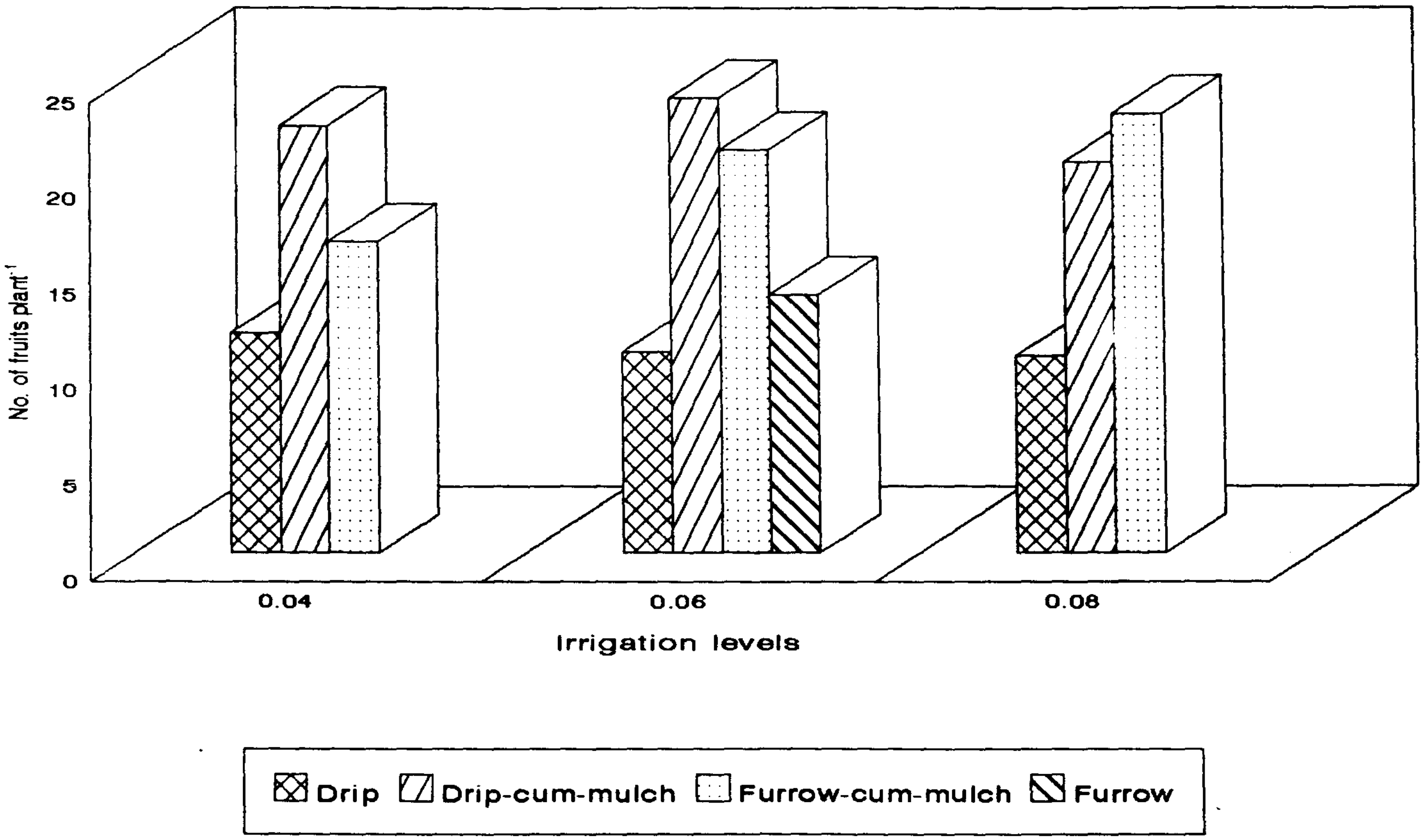

Fig. 10 Total number of fruits plant^{-1} as influenced by mulch-cum-drip irrigation

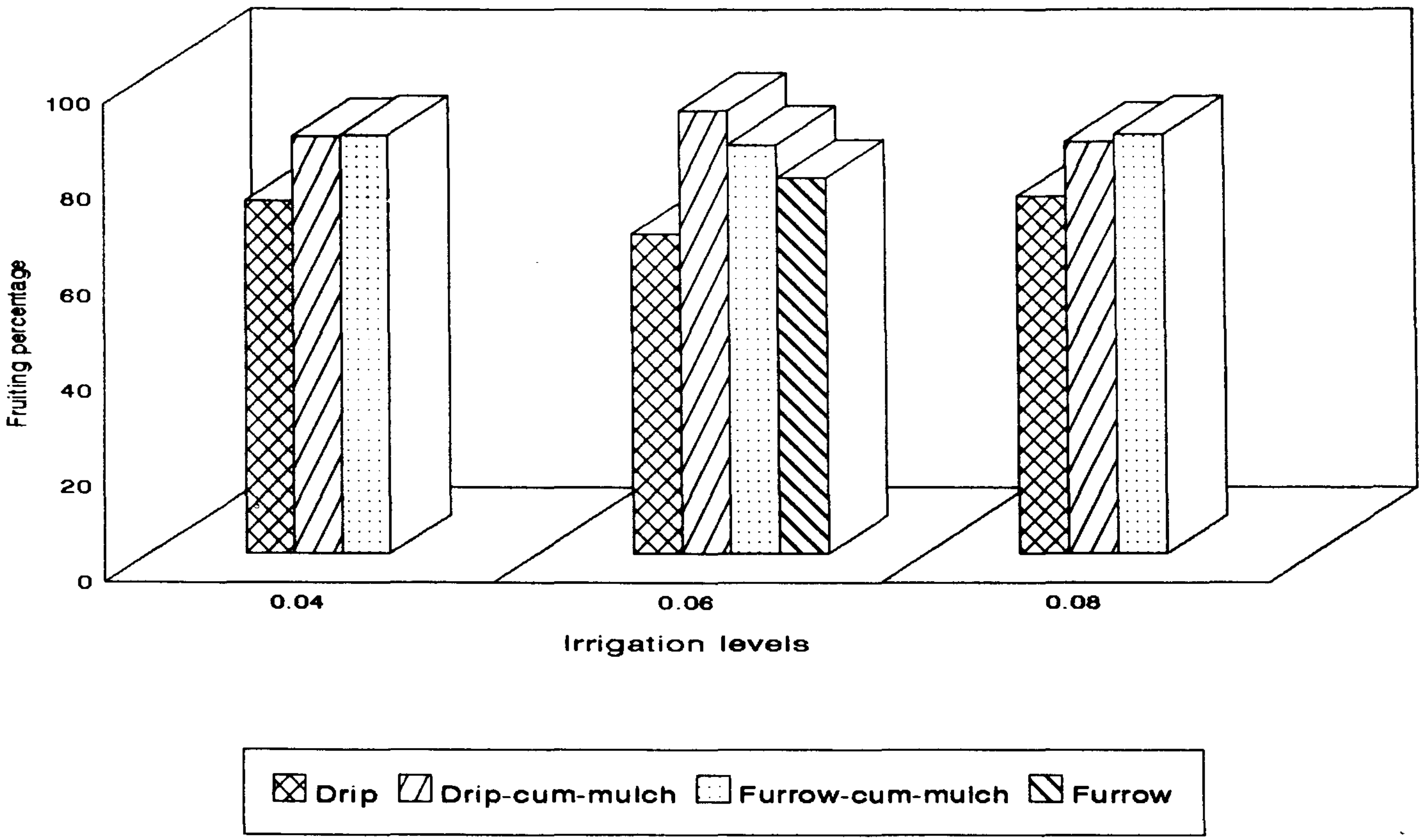

Fig. 11 Percentage of fruit set as influenced by mulch-cum-drip irrigation

Mulching had a remarkable effect on increasing the fresh weight plant^{-1} (Table 9, Fig.12 and 13). While drip-cum-mulch increased fresh weight plant^{-1} by 77 per cent, furrow-cum-mulch improved it by 63 per cent over the control crop. Nearly 136-166 per cent increase in fresh weight was observed in drip-cum-mulch crop compared to drip irrigation alone crop.

Hence there was an overall improvement in the yield attributes of bhindi crop when mulching was resorted to irrespective of method of irrigation. We have seen that better growth attributes such as height, green leaves, leaf area were always associated with mulching. Prolonged supply of moisture in mulched situation through drip has contributed to still more leaf area in drip-cum-mulch situation. Mulching has also insulated the plant from soil moisture stress and other physico-chemical competitive factors in the soil and helped in maintaining good internal water balance in the plant body (Table 7). These altogether contributed for higher yield attributes such as number of fruiting branches, number of flowers, number of fruits, fruit set and fruit weight ultimately the final fruit yield. Sustained moisture supply through drip compared to furrow method in mulched situation has provided a numerical advantage of drip system over furrow method in enhancing yield attributes and yield. Mulching provided

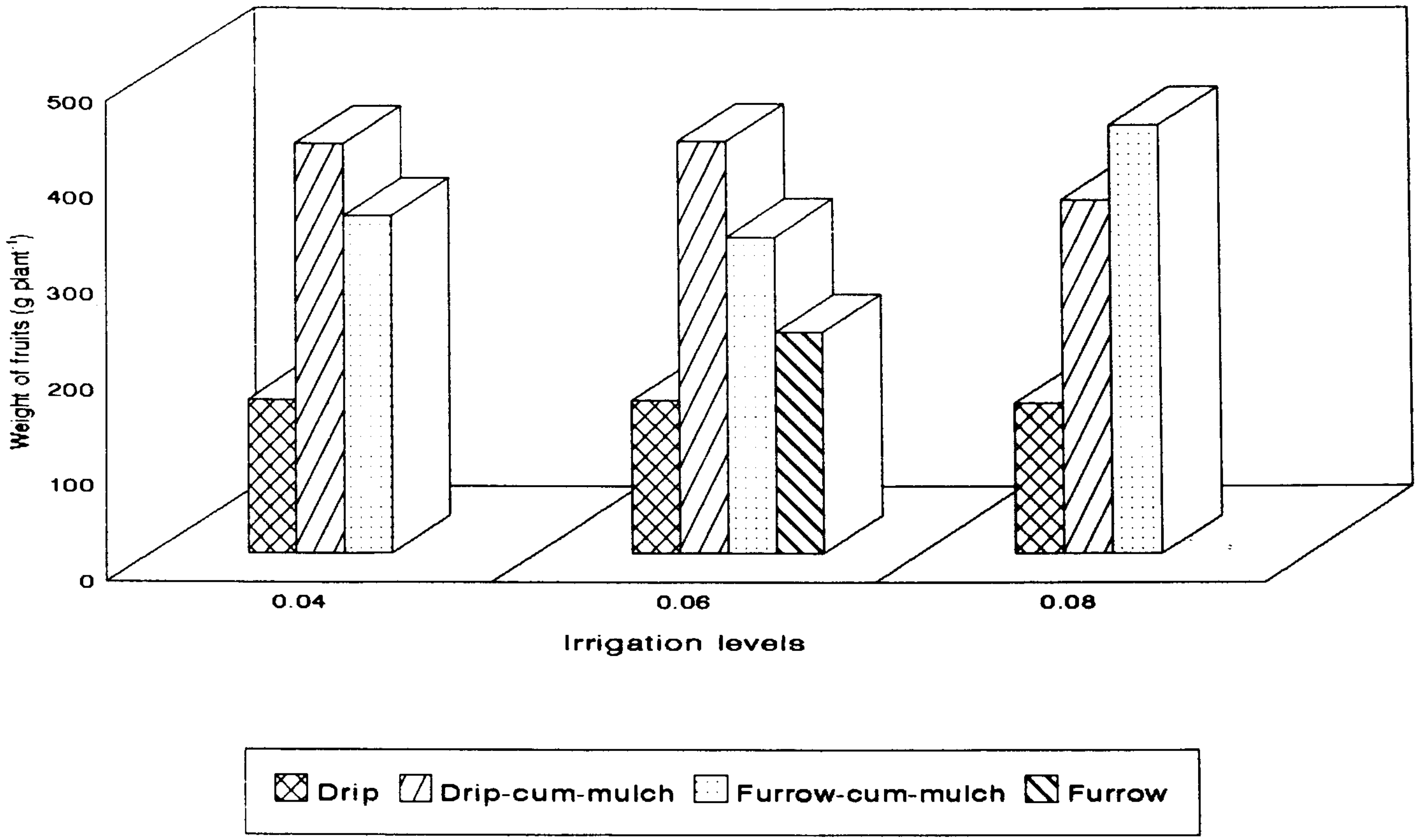

Fig. 12 Total weight of bhindi fruits per plant (gm) as influenced by mulch-cum-drip irrigation

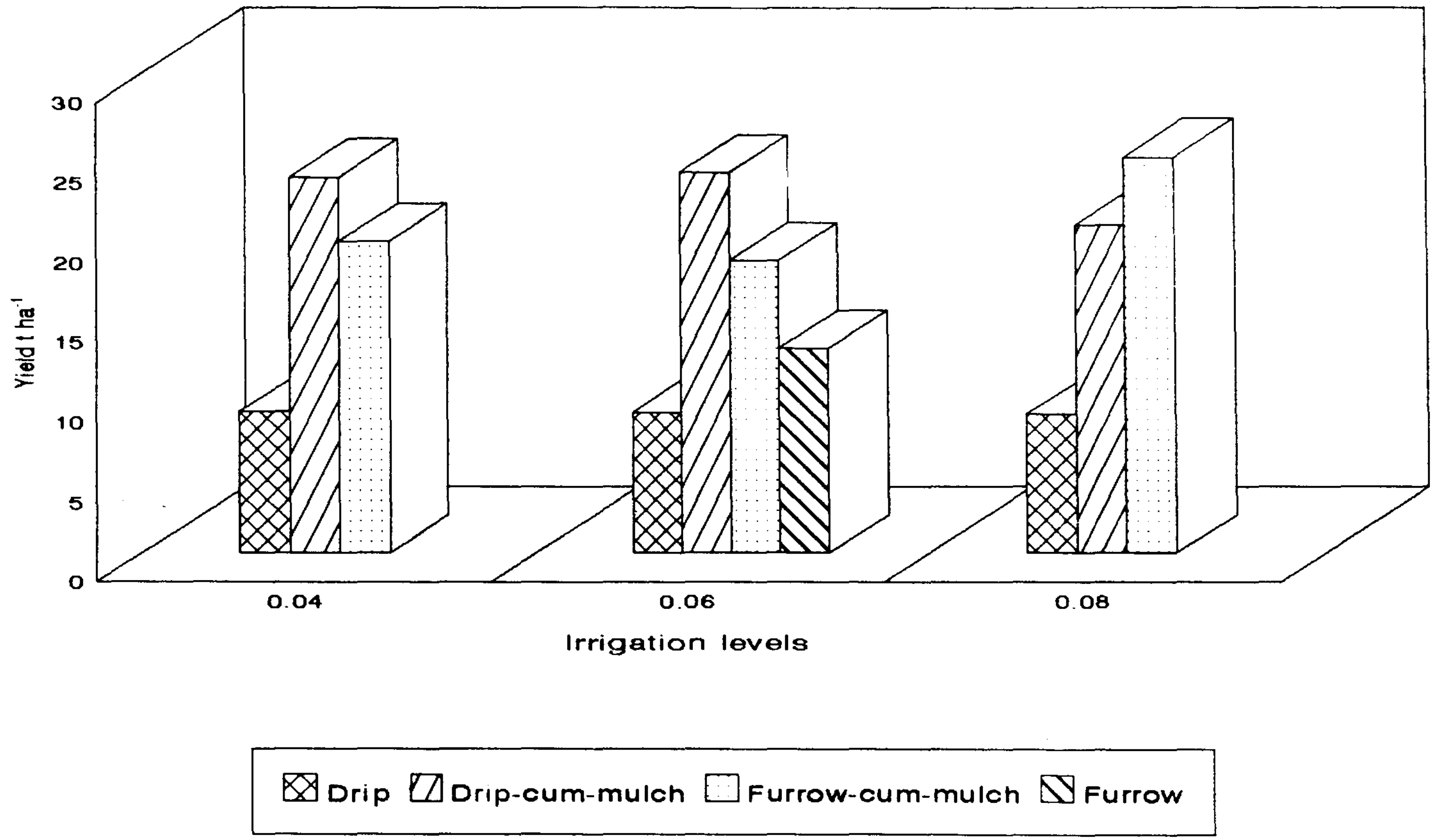

Fig. 13 Total yield of bhindi crop (t ha-1) as influenced by mulch-cum-drip irrigation

better yield in tomato (Bhella, 1988b), egg plant (Carter and Johnson, 1988), Sweet pepper (Goyal *et al.*, 1987), Squash (Battikhi and Ghawi, 1987) and in several other crops.

Water use efficiency

The above views are further supported by data provided on consumptive use in the Table 11 and Fig.14. Number of irrigation as well as consumptive use is substantially reduced in mulched situation both in furrow or drip system compared to non-mulched situation at any particular tension. It means that evaporative component in ET is cut off by mulching and soil moisture is conserved in the soil, paving a way for more of transpiration. Harrold *et al.* (1959) found that 56 per cent of ET was contributed by evaporation and 44 per cent by transpiration in Ohio, in USA, by lysimetric experiments. When transpiration component has been improved with in the same quantity of ET, then yield improved (Willis *et al.*, 1963). Yield is always positively correlated with ET (Sanders *et al.*, 1989). A better internal water balance in the plant and more of transpiration using the available water by plants under mulched situation have ultimately reflected as enhanced yield.

As observed in Table 11 higher amount of water has been used to maintain a particular irrigation

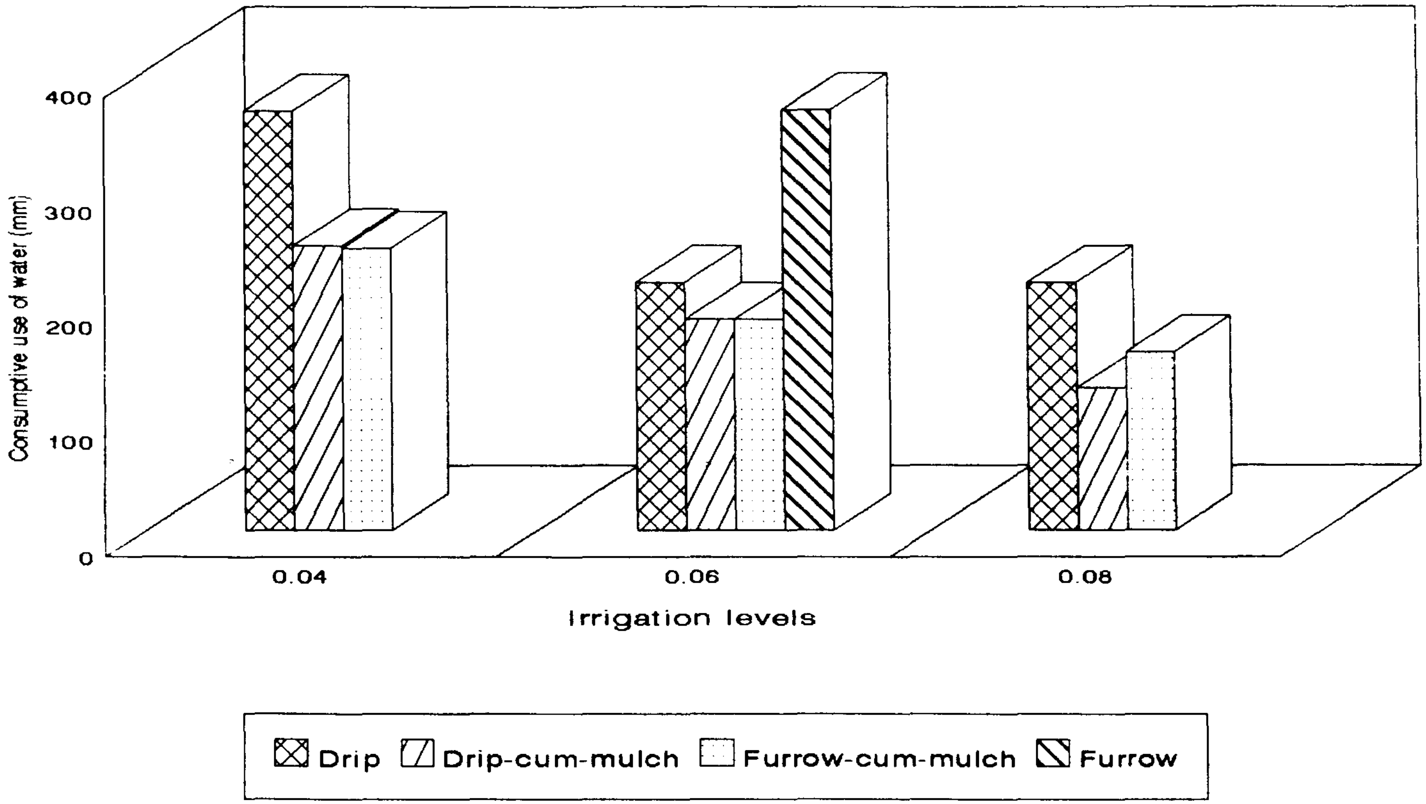

Fig.14 Total consumptive use of water (mm) as influenced by mulch-cum-drip irrigation

schedule in open situation compared to mulched condition. Nearly 32 per cent of the irrigation requirement could be cut off by mulching the crop under 0.04 MPa irrigation schedule. This benefit has been 49 and 66 per cent in case of the schedules 0.06 and 0.08 MPa respectively under drip method.

Mulching has prolonged the availability of soil moisture. This is evident from the soil moisture data and irrigation interval (Table 12 and Fig.15 to 17). This has cut off evaporative component as well as moisture use by weed growth. It is believed that surface mulching protected the soil surface from evaporative atmosphere and soil thermal gradient has been regulated to unfavour evaporation. According to Mc Calla and Army (1961) and Carter and Fanning (1964) mulching unfavour soil moisture loss through evaporation through regulation of soil energy gradient. A better soil moisture distribution is also seen in the mulched condition (Table 12). Hence a substantial reduction in irrigation requirement and consumptive use has been observed in the present study through mulching when compared to non-mulching at a particular irrigation schedule. Similar experiences have been reported by Goyal *et al.* (1987) in sweet pepper.

Surface layer conserved more moisture and contributed to consumptive use much more than sub-surface layer under

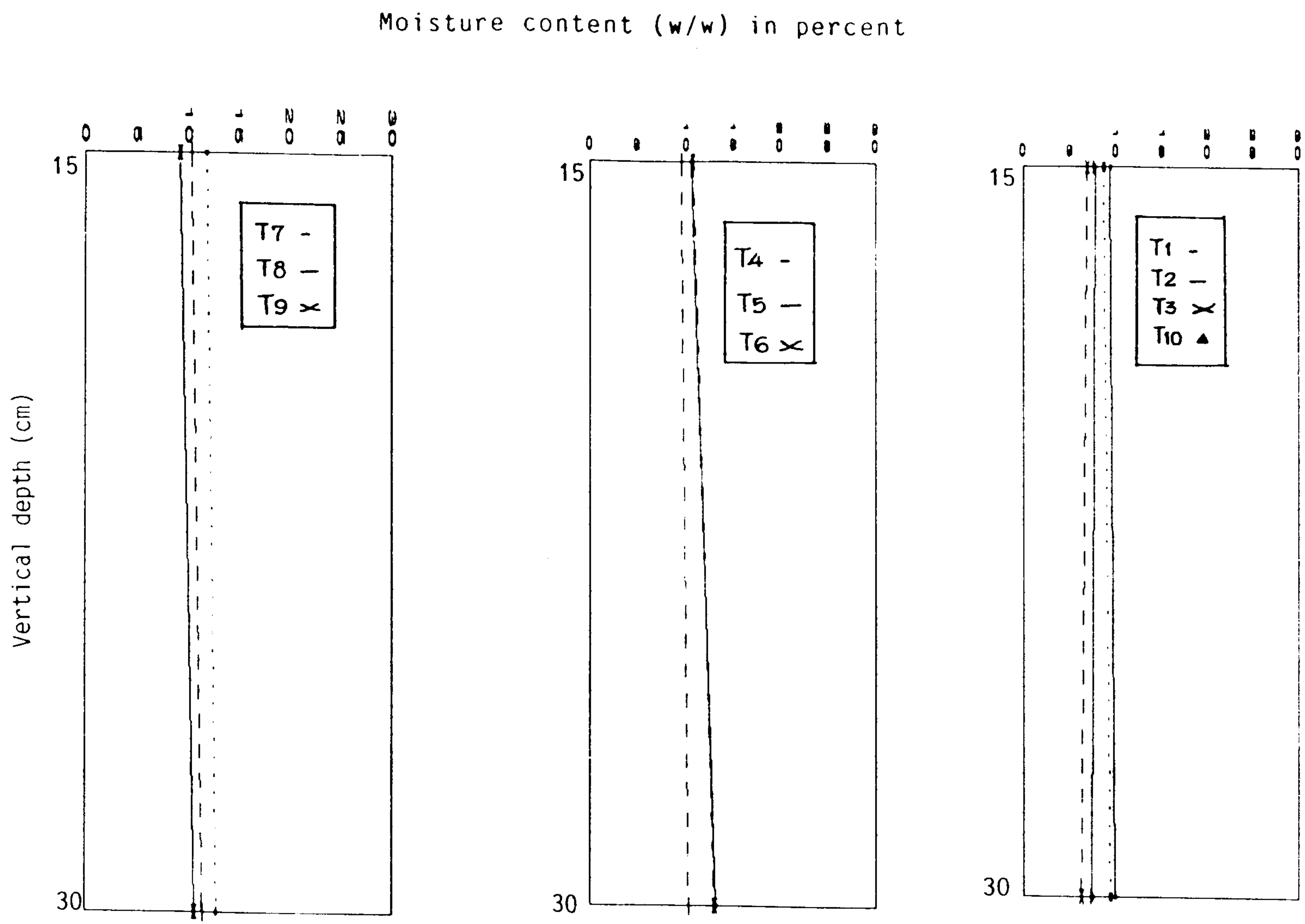

Fig. 15 Soil moisture content (w/w) in % before irrigation at the point of dripper

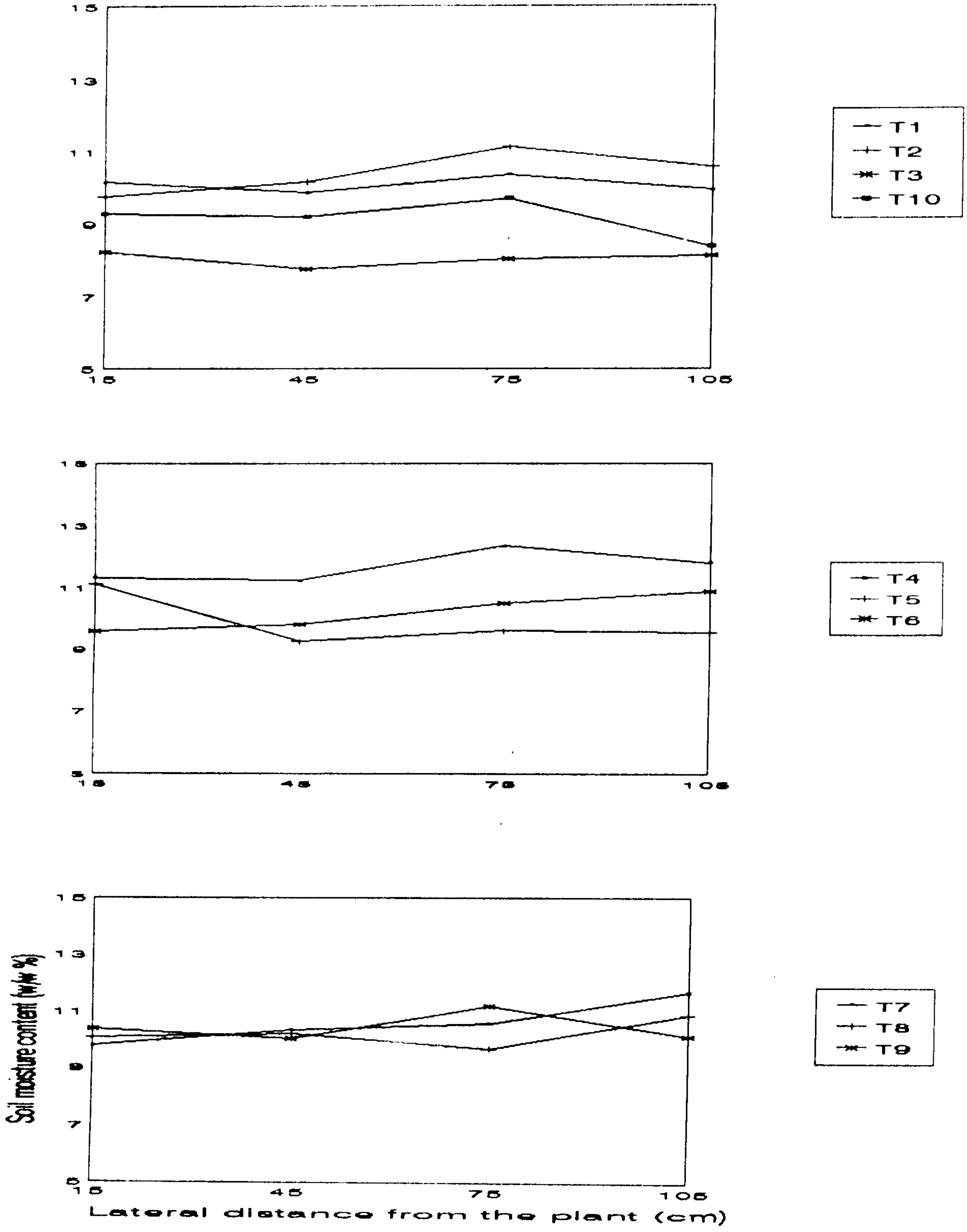

Fig.16 Soil moisture content (w/w %) before irrigation at 30cm depth in 30 cm intervals along the row

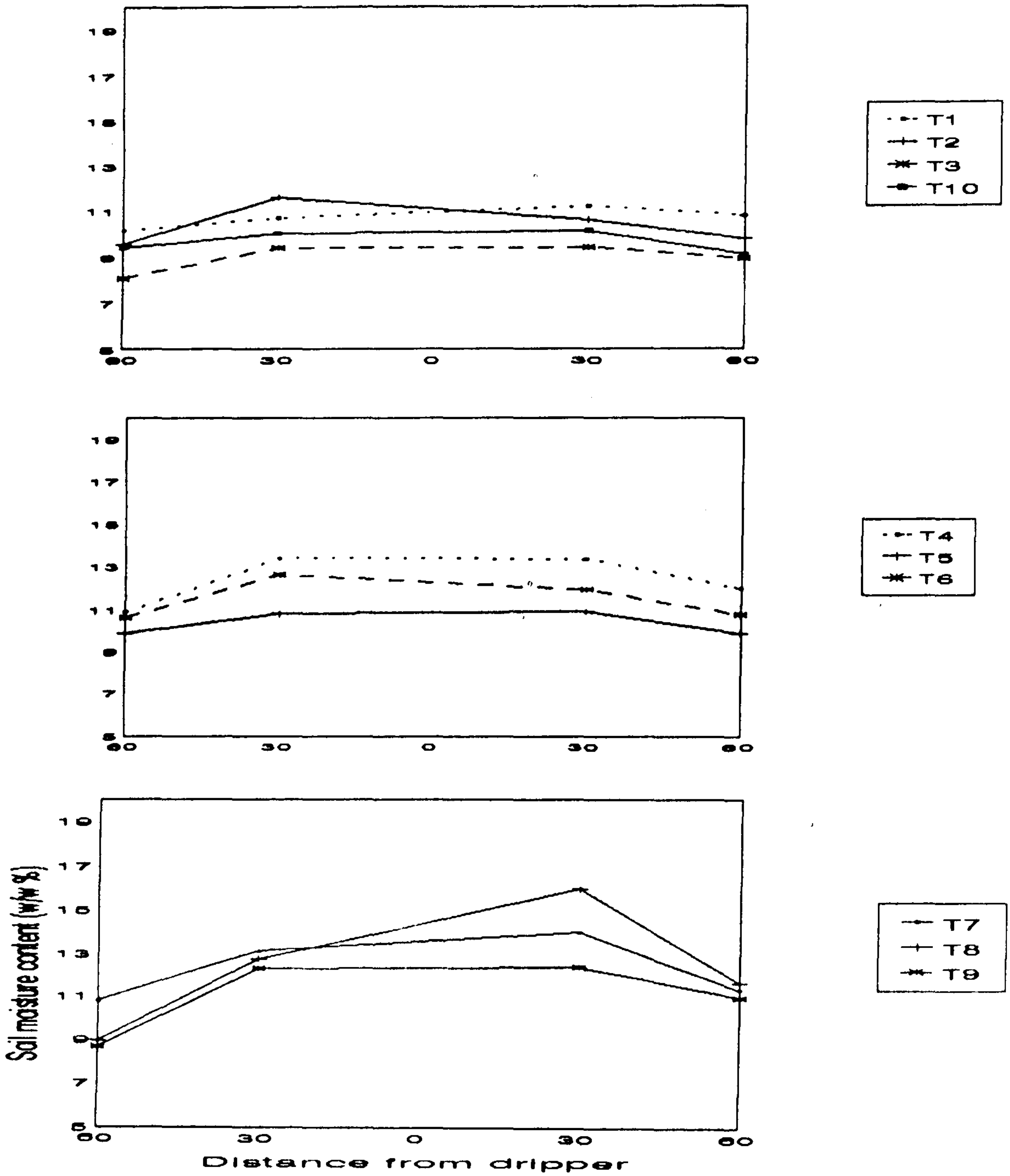

Fig. 17. Soil moisture content (w/w %) before irrigation at 30 cm depth in 30 cm interval across the row

mulched condition (Fig.18). As already explained, insulation from evaporation through mulching has led to this situation. A lower content of soil moisture at 30 cm depth and higher content of soil moisture at 15 cm have been observed in lower tension irrigation and vice versa in case of higher tension irrigation. Frequent irrigations required at lower tension makes soil profile to replenish its soil moisture loss through evapotranspiration frequently. According to Randall and Locascio (1988) higher water quantity resulted in higher soil moisture content, higher root density and improved plant water status than under lower quantity in cucumber and tomato. Due to prolonged supply of moisture in drip system a higher soil moisture content is always seen at surface layer around dripper in this system.

Soil moisture content gradually reduced as radial distance from dripper increased. Mulching due to its effect in reducing surface evaporation has helped in maintaining a high soil moisture content even at longer radial distance in case of drip irrigation (Table 13 and Fig.15 to 17).

According to Pelletier and Tan (1993) the soil moisture distribution assumed a shape of distinct cone of more than 50 per cent available water extending from the emitter down to a depth of more than 45 cm in drip system.

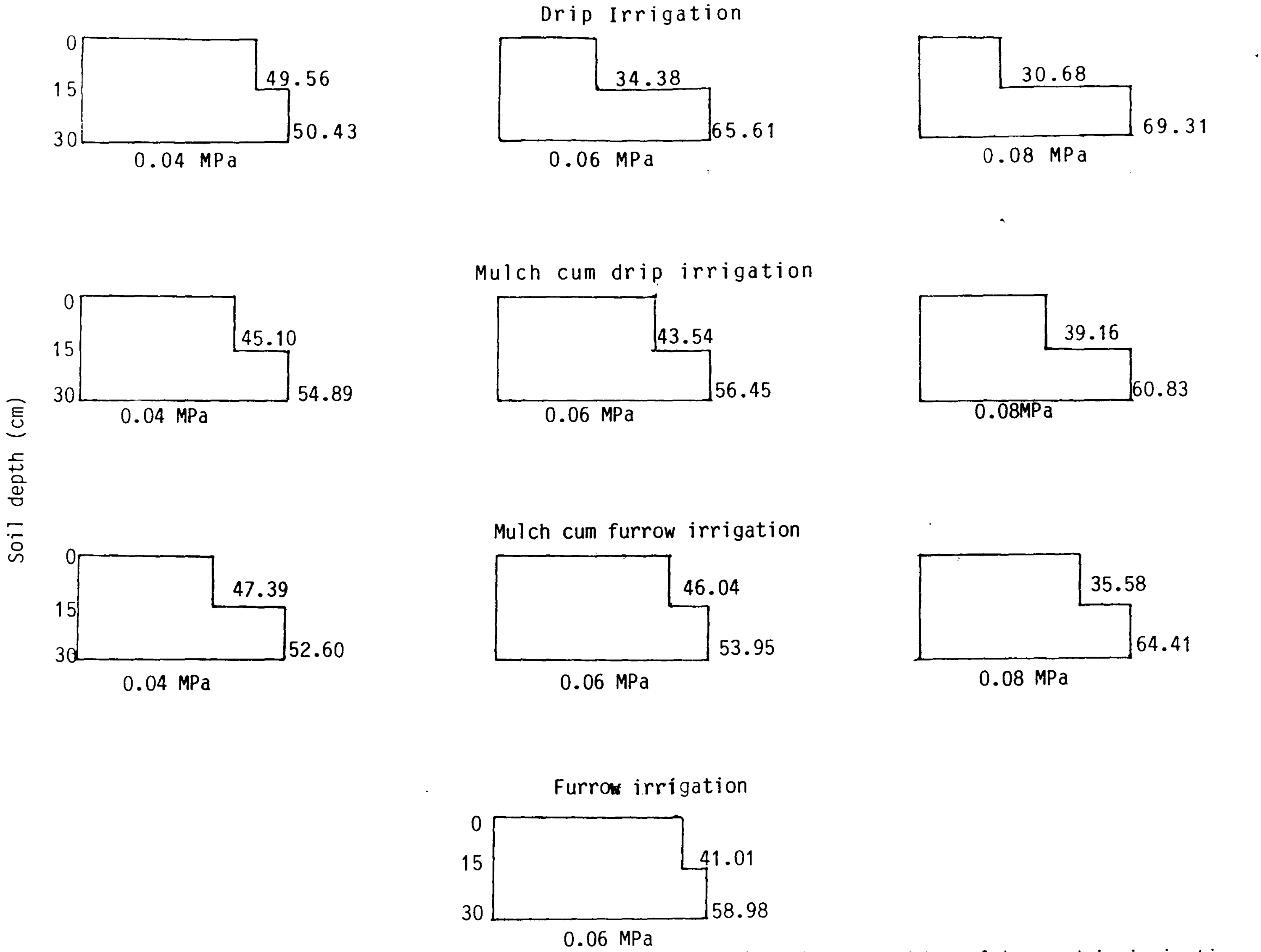

Fig. 18 Soil moisture extraction pattern (values in percent) as influenced by mulch-cum-drip irrigation

Whereas the 50 per cent available soil water zone in the microjet system was an elongated semicircle from the soil surface to a depth of 35 cm. They further observed that for the 30 cm soil profile, volumetric soil water content was more than 50 per cent of available soil water within a distance of approximately equal to 50 cm from the drip emitters but was only with 20 cm from the microjets.

Mulching always helped in keeping moisture to move more radially. It is observed that soil moisture content at the mid point between furrows is more, as this may be probably because that plant roots donot reach to extract moisture through this zone.

Water use efficiency is the ratio of economic yield to water consumed. An increase in yield or a reduction in water use, either way, brings out higher water use efficiency. But mulching has remarkably increased water use efficiency because of both ie., reduction in water use as well as enhanced yield obtained through effective utilisation of available and conserved moisture. Furrow-cum-mulch irrigation at 0.08 MPa has brought 359 per cent increase in water use efficiency whereas drip-cum-mulch irrigation at 0.08 MPa brought about 311 per cent increase in water use efficiency compared to furrow irrigation at 0.06 MPa without mulch (Table 15, Fig.19). It is to be noted that the furrow-cum-mulch irrigation at 0.08 MPa led

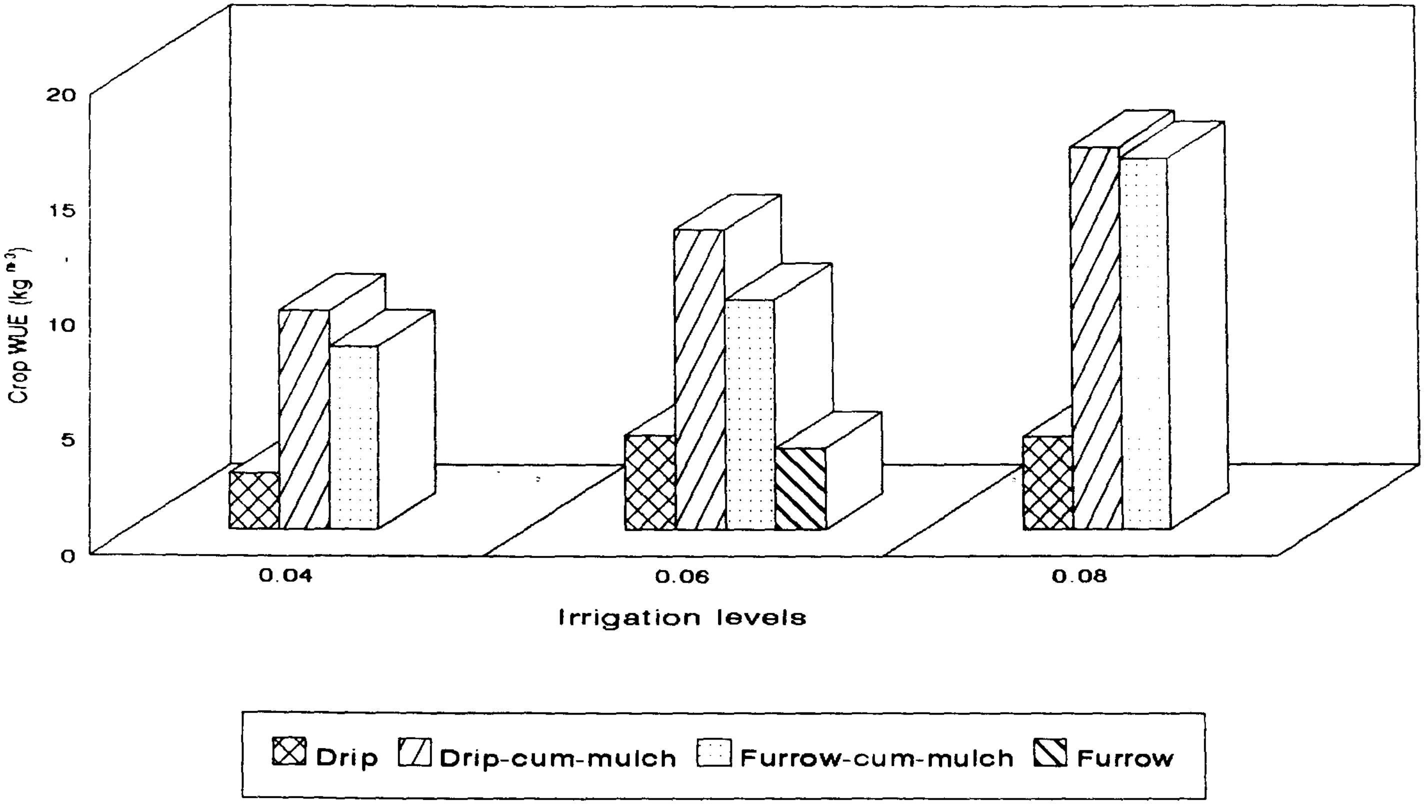

Fig.19 Crop WUE (kg m^{-3}) of bhindi plants as influenced by mulch-cum-drip irrigation

to highest yield of 24.875 tons ha^{-1} while the drip-cum-mulch irrigation at 0.08 MPa saved more moisture which enabled an 195 per cent more area to be brought under irrigation using the quantity of water that has been consumed by a crop requiring irrigation at 0.06 MPa under furrow method without mulch.

Higher water use efficiency is always an integral part in mulch-cum-drip irrigation (Bhattikhi and Ghawi, 1987).

Economics of bhindi crop as influenced by mulch-cum-drip irrigation

Economics of production (Table 16) attach much importance in the current scenario of vegetable production of the state. When the state is all its way for augmenting production of vegetables, any economic technology increasing productivity conserving the use of natural resource input has remarkable relevance.

While considering the B.C. ratio, only furrow-cum-mulch irrigation at 0.08 MPa has ratio above 1.5 and rest of the schedule and system have B.C. ratio less than 1.5. The said schedule brings about a net profit of 1.16 lakh from the gross cultivated area of 2.37 ha, considering the additional area that can be brought by adopting this irrigation, in equivalent to the water used (365 mm) by furrow method of irrigation. Total production by this method is 58.95 tons using 365 mm water. But if we consider the drip-cum-mulch irrigation at 0.08 MPa, the total production is 60.75 tons from an area of 2.95 ha, but using 365 mm water. This schedule, though leads to an economic loss of Rs.21,822 with B.C. ratio of 0.92 from the total area of 2.95 ha, enable to cultivate 1.95 ha of additional area. Hence for having effective use of natural resource like water, at the same time augmenting vegetable production, the concept of economics will have to be changed. Assigning priority to conservation and effective utilization of natural resource like water, but not at the expense of gross production, even a marginal loss would be considered productive and viable, while thinking in line with sustainable agriculture. A drip irrigation system with mulching scheduled at 0.08 MPa will be more fruitful to economic and sustainable use of water, where water is very scarce. But a furrow-cum-mulch irrigation scheduled at 0.08 MPa is rather more appropriate and economic where water resources are moderate (Jadhav *et al.*, 1990).

Summary and Conclusion

SUMMARY

A field experiment was conducted in the summer rice fallows of the Agricultural Research Station, Mannuthy during 1997 (February-June) to develop and test mulch cum drip irrigation system and compare it with drip without mulch or furrow irrigation system with or without mulch. The soil of the experiment field was sandy clay loam with the bulk density at 0-30 cm depth ranging from 1.50 to 1.52 gcm^{-3}, acidic in reaction, medium in organic carbon and available potassium content and high in available phosphorous. The technical programme comprised of ten treatments from the combinations of two irrigation systems (Drip irrigation and furrow irrigation) and three irrigation frequencies (soil moisture tension at 0.04, 0.06 and 0.08 MPa) either with or without mulch. Experiment was laid out in randomised block design with three replications. In case of drip irrigation system 4 lph emitters were placed 60 cm apart so that there will be one emitter in between 2 plants. In mulched plots, after the formation of ridges before sowing, the field was covered with black LDPE sheet. Holes were made on this sheet at a spacing of 30 cm and seeds were dibbled through these holes. The bindi variety Pusa Savani was tried as the crop. The weather conditions during the investigation was almost normal and the crop received nearly 35 mm rainfall.

The salient results obtained during the course of investigation are summarised below.

1. Mean plant height was higher under mulched situation than unmulched situation in both the irrigation systems irrespective of levels of irrigation. Plants were tallest when mulched and irrigated at soil moisture tension of 0.04 MPa using drip irrigation system. When compared to control crop ie., furrow irrigation at soil moisture tension of 0.06 MPa, without mulch, the increase in height under drip irrigation and furrow irrigation system respectively at soil moisture tension of 0.04 MPa was 21 and 24 per cent with mulch.

2. Throughout the growth period the crop mulched and irrigated using drip system, irrespective of irrigation levels, produced maximum green leaves than other irrigation systems. At the final growth stage crop mulched and irrigated using drip at soil moisture tension of 0.04 MPa produced 169 per cent more leaves compared to the control crop.

3. Maximum leaf area $plant^{-1}$ as well as leaf area index were observed in plants under drip cum mulch irrigation system without significant variation between irrigation levels.

4. Leaf water potential was on an average five to ten times more than of soil water potential. Leaf water potential remained static temporally without considerable change under mulched situation even with fall in soil moisture potential. The same observation was made in case of non-mulched situation, if method of irrigation was drip. Furrow irrigated field had a lower moisture content and maintained a higher soil moisture tension compared to drip irrigated field, both under mulched conditions.

5. The mulched crop was free from weed growth. In case of unmulched situation, there was 21, 40 and 43 per cent reduction in weed growth at soil moisture tensions of 0.04, 0.06 and 0.08 MPa respectively compared to the control plot, when drip irrigation was resorted to.

6. The plants under drip cum mulch and furrow cum mulch irrigation produced 99 and 78 per cent more number of fruiting branches respectively than that produced by the control crop.

7. The plants under drip cum mulch produced on an average 46 per cent more number of flowers than control crop. Crop under furrow-cum-mulch irrigation produced the same number of flowers as drip-cum-mulch when

irrigation was scheduled at 0.06 and 0.08 MPa soil moisture tension.

8. The mulched crop under drip irrigation at 0.04, 0.06 and 0.08 MPa respectively produced 65, 76 and 51 per cent more number of fruits than the control crop. The corresponding increase under furrow-cum-mulch irrigation was 20, 56 and 70 per cent.

9. Mulched crop, irrespective of irrigation levels and methods of irrigation, recorded significantly higher levels of fruit set.

10. Plants under drip cum mulch and furrow cum mulch irrigation respectively produced 77 and 63 per cent more total fruit weight $plant^{-1}$ compared to control.

11. Mulched and furrow irrigated crop at 0.08 MPa tension produced maximum fruit yield ha^{-1}, which was statistically comparable to that from mulched and drip irrigated crop irrespective of irrigation levels.

12. The crop irrigated at the schedules of 0.04 MPa and 0.06 MPa respectively under mulching showed 32 and 49 per cent reduction in consumptive use, irrespective of irrigation methods, when compared to that of control crop. When the crop was irrigated at 0.08

MPa under mulch condition there were 66 and 58 per cent reduction in irrigation water in cases of drip and surface method respectively.

13. Under mulched situation, the surface 15 cm layer contributed more to consumptive use, in case of irrigations at 0.04 and 0.06 MPa. But at 0.08 MPa, 15-30 cm layer supplied 61 and 64 per cent of the total soil moisture extracted by the crop in case of drip and furrow irrigations respectively.

14. In both drip as well as furrow irrigation soil moisture content at 15 or 30 cm depth was higher under mulched situation compared to unmulched situation.

15. Under drip irrigation system crop water use efficiency enhanced by 289, 218, 311 per cent at the irrigation schedules of 0.04, 0.06 and 0.08 MPa tension respectively, when mulching was done to the crop. When furrow system was resorted to, corresponding increase under mulched situation were 127, 185 and 359 per cent respectively, when compared to control crop.

16. Maximum B.C. ratio of 1.58 was derived when the crop was mulched and irrigated at soil moisture tension of 0.08 MPa. However, maximum area (195 per cent more)

could be irrigated with the same quantity of water (365 mm) when drip irrigation was adopted at the soil moisture tension of 0.08 MPa and crop was mulched.

CONCLUSION

The present investigation has proved the effect of mulch in conserving soil moisture and increasing the productivity of the vegetable crop bhindi. Considerable saving in water was resulted by the use of drip irrigation. This study exposes the possibility of increasing productivity with the conservation of natural resources like water. Furrow-cum-mulch irrigation and drip-cum-mulch irrigation, both at the soil moisture tension of 0.08 MPa, can be selected based on the need of the time, former more suited when assured water supply is there and latter more viable when water supply is constrained. Further studies may be required for confirmation of the results and extending this technology to other summer vegetables as well. The effect of fertigation under mulched situation may be studied in future. Micro climatic studies are also needed to refine this technology.

References

REFERENCES

Abdel, C.G. 1990. The influence of mulching on irrigated and non-irrigated onion cultivations. *Mesopotamia J. of. Agric.* 22(4): 25-33

Abdul-Baki, A., Spence, C., Hoover, R. 1992. Black polyethylene mulch doubled yield of fresh-market field tomatoes. *Hort. Sci.* **27**(7): 787-789

Abreu, T.A. De., Olitta, A.F.L. and Marchetti, D.A.B. 1978. Comparison of two irrigation methods (Furrow and Drip) on melons in Sao francisco Valley. *Pesquisa Agropecuaria Brasileira.* **13**(3): 35-45

Acharya, S.S. 1997. Agricultural price policy and development some facts and emerging issues. *56th annual conference of Indian Society of Agricultural Economics.* Kerala Agricultural University, Thrissur, Kerala

Amir, I. and Dag, J. 1993. Lateral and longitudinal wetting patterns of very low energy moving emitters. *Irrig. Sci.* **13**: 183-187

Aranjo De C.J.A., Çampos De Araujo, S.M., Castel lane, P.D., Siqueira, C.E.M. 1992. Analysis of cucumber (*Cucumis sativus* L.) production, "Vista Alegre" variety, using different coloured plastic soil mulch. *In XII Congreso internacional de plasticos en agricultura.* 108-113

Bangal, G.B., Londhe, R.B. and Kalbande, D.H. 1986. Evaluation of water saving in tomato by trickle method of irrigation. *Curr. Res. Reptr.* Mahatma Phule Agricultural University. **2**: 28-32

Bar-Yousef, B., Stammers, C. and Sagiv, B. 1989. Growth of trickle irrigated tomatoes as related to rooting volume and uptake of nitrogen and water. *Agron. J.* **72**(5): 815-822

Basak, P. 1998. Water Resources of Kerala - Myths and Realities. *Water Scenario of Kerala,* CWRDM : 1-6

Basuki, R.J. and Asandhi, A.A. 1987. Partial budget analysis: economic advantage of shade and mulch treatments on pepper (*Capsicum annum* L.) farm in the off-season. *Buletin Penelitian Horticultura* **15**(1): 152-160

Batra, B.R. and Kalloo. 1991. Effect of irrigation on moisture extraction patterns, consumptive use and plant water status in carrot. *Veg. Sci.* **18**(1): 1-10

Beverly, R.B. 1993. ASTER garden: a novel vegetable garden design for international development. *Hort. Sci.* **28**(7): 763

Berrocal, A.S.M. and Vives, L. 1978. The soil temperature under different mulches and its action on tomato production (*Lycopersicon esculentum*). *Boletin Tecnico, Facultad de Agronomia, Universidad de Costa Rica* **11**(5): 25

Bhella, H.S. 1988a. Effect of trickle irrigation and black mulch on growth, yield, and mineral composition of watermelon. *Hort. Sci.* **23**(1): 123-125

Bhella, H.S. 1988b. Tomato response to trickle irrigation and black polyethylene mulch. *J. Amer. Soc. for Hort. Sci.* **113**(4): 543-546

Black, G.R. 1965. Bulk density - core method. *Methods of Soil Analysis.* Part 1. American Society of Agronomy Madison, U.S.A. p. 375-376

Bhattikhi, A., Judah, O.M. and Suwwan, M.A. 1985. Irrigation scheduling of tomatoes grown under drip irrigation inside plastic greenhouses in the Jordan Valley. *Dirasat* **12**(6): 35-46

Bhattikhi, A. and Ghawi, I. 1987. Squash (*Cucurbita pepo* L.) production under mulch and trickle irrigation in the Jordhan valley. *Dirasat* **14**(11): 59-72

Bogle, C.R., Hartz, T.K. and Nunez, C. 1989. Comparison of subsurface trickle and furrow irrigation on plastic mulched and bare soil for tomato production. *J. Am. Soc. hort. Sci.* **114**(1): 40-43

Boldrin, L. 1989. Use of "Ecopac" mulch film. *Plasticulture* **54**(83) 51-52

Bredero, T.H.J. 1991. *Concepts and guidelines for crop water management research - A case study for India.* Oxford and IBH Publishing Co. Pvt. Ltd. pp.155

Brown, J.E., Goff, W.D., Dangler, J.M., Hogue, W., West, M.S. 1992. Plastic mulch color inconsistently affects yield and earliness of tomato. *Horti. Sci.***27**(10):1135

Call, R.E. and Courter, J.W. 1989. Response of bell pepper to raised beds, black plastic mulch, spunbounded row cover and trickle irrigation. *Transactions of the Illinois state Horticulture Society.* 122: 117-122

Carter, D.L. and Fanning, C.D. 1964. Combining surface mulches and periodic water applications for reclaiming saline soils. *Soil Sci. Soc. Amer. Proc.* **28**: 564-567

Carter, J. and Johnson, C. 1988. Influence of different types of mulches on egg plant production. *Hort. Sci.* **23**(1): 143-145

Cevik, B., Kanber, R., Koksal, H., Pakyurek, Y. 1992. Effect of different soil mulch materials and irrigation levels on yield, quality and evapotranspiration of cucumbers grown under glass house conditions. *Doga, Turk Tarim ve Ormancilik Bergisi.* **16**(3): 581-591

Chartzoulakis, K.S. and Michelakis, N.G. 1988. Influence of different irrigation systems on greenhouse tomatoes. *Acta Horticulturae* **228**: 97-104

Cochran, W.G. and Cox, G.M. 1957. *Experimental Design.* 2nd ed. Asia Publication House, Bombay. p. 613

Davies, D.H.K., Derysdale, A., Mc Kinlay, R.J., Dent. J.B. 1993. Novel approaches to mulches for weed control in vegetables. *Proceedlings of a conference on crop protection in Northern Britain, Dundee, UK* : 271-276

Djigma, A. and Diemkouma, D. 1986. Plastic mulch in dry tropical zones. Trials on vegetable crops in Burkina Faso. *Plasticulture* **69**(1): 19-24

Dysko, J. and Kaniszewski, S. 1989. The effect of soil moisture level on capsicum yield. *Biuletyn Warzywniczy* **2**(3): 189-194

Farias - Larios, J., Guzman, S., Michel, A.C. 1994. Effect of plastic mulches on the growth and yield of cucumber in a tropical region. *Biological Agriculture and Horticulture* **10**(4): 303-306

Farm Information Bureau. 1998. *Farm Guide.* Farm information Bureau, Govt. of Kerala, Trivandrum

Farm Information Bureau 1996. *Kerala Karshakan.* Farm Information Bureau, Govt. of Kerala, Trivandrum **41**(11): 3

Firake, N.N., Bangal, G.B. and Gutal, G.B. 1991. Soil moisture conservation efficiency of mulches in tomato. *Maharastra J. of Horticulture* 5(2): 83-87

Gorantiwar, S.D., Pingale, L.V., Pampattiwa, P.S., Pagar, V.W. and Saradesai, M.A. 1991. Evaluation of drip irrigation for ladies finger (*Abelmoschus esculentus* M.). *Maharastra J. Hort.* 5(2): 93-97

Goyal, M.L. 1988. Tomato response to furrow, microsprinkler, and drip irrigation. *Amer. Soc. agric. Engg.* (88): 13

Goyal, M.R., Gonzailez, E.A., Rivera, L.E., and Chaode Baez, C. 1987. Sweet pepper response to drip, microsprinkler and furrow irrigation. *Paper-American Society of Agricultural Engineers* **87**: 12

Gupta, A. 1990. Response of spring planted okra to varying levels of irrigation and plant spacing. *Veg. Sci.* **17**(1): 16-19

Gupta, J.P. and Gupta, J.N. 1987. Response of tomato and okra crops to irrigation and mulch in an arid region of India. *Agrochimica* **31**(3): 193-202

Gutal, G.B., Bhilare, R.M. and Takte, R.L. 1992. Mulching effect on yield of tomato crop. *In International agricultural engineering conference. Proceedings of a conference held in Bangkok, Thailand* **3**: 883-887

Gutal, G.B., Jadhav, S.S., Takte, R.C. 1992. Effective surface covered cultivation in fruit vegetable crop (Brinjal Manjari gota). *International agricultural engineering conference. Proceedings of a conference held in Bangkok, Thailand* **3**: 853-858

Harrold, L.L., Peters, D.B., Dreibelbis, F.R. and Mc. Guineess J.L. 1959. Transpiration evaluation of corn grown on a plastic-covered lysimeter. *Soil Sci. Soc. Amer. Proc.* **23**: 174-178

Hegde, D.M. 1988. Effect of irrigation regimes on growth, yield and water use of sweet pepper (*Capsicum annum* L.). *Ind. J. Hort.* **45**(3): 288-294

Jackson, M.L. 1973. *Soil Chemical Analysis*. Prentice Hall Inc. Engle Wood Cliffs, U.S.A.

Jadhav, S.S., Gutal, G.B. and Chougule, A.A. 1990. Cost economics of the drip irrigation system for tomato crop. *Proceedings of the 11th International Congress on the use of plastics in Agriculture*, New Delhi

KAD, 1998. Comprehensive project for increasing vegetable production to attain self sufficienciency in Kerala 1998. Project preparations and monitoring cell of Department of Agriculture, Kerala

KAU, 1993. *Package of Practices Recommendations `Crops'-93*. Directorate of Extension, Kerala Agricultural University, Vellanikkara, Thrissur, Kerala

Konys, E. and Konys, L. 1992. Multivariate statistical methods for analysing cropping in field tomatoes. *Roczniki Akademii Lolniczei to poznanius ogrodrictwo* (20): 39-50

Kramer, P.J. 1983. *Water Relations of Plants*. Academic Press. INC. Harcourt Brace Jovanovich Publishers, New York. pp.489

Kudo, K. 1987. The effect of the surface and subsurface irrigation on the yields of taro plants (*Colocasia antiquorum* Schott.). Bulletin of the Faculty of Agriculture, Meiji University. **76**: 29-43

Kwon, Y.S., Lee, Y.B., Park, S.K., Ko, K.D. 1988. Effect of different mulch materials on the soil environment, growth and yield of red pepper (*Capsicum annum* L.). *Research Reports of the Rural Development Administration, Horticulture, Korea Republic*. **30**(1): 9-17

Liu, L.C., Antoni-Padilla, M., Goyal, M.R., Gonzalez - Ibanez, J. 1987. Integrated weed management in transplanted tomatoes and peppers under drip irrigation. *J. Agriculture of the University of Puesto Rico.* **71**(4): 349-358

Madramootoo, C.A. and Rigby, M. 1989. Increasing vegetable production with trickle irrigation. *In Agricultural Engineering* **18**: 645-652

Madramootoo, C.A., Rigby, M. 1991. Effects of trickle irrigation on the growth and sunscald of bell peppers (*Capsicum annum* L.). In Southern Quebec. *Agril Water Management.* **19**(2): 181-189

Mc Calla, T.M., and T.J. Army. 1961. Stubble mulch farming. *In* A.G. Norman (ed.). *Advances in Agronomy* Academic Press, New York. **13**: 125-196

Minasian, A.N., Al-Karaghouli, A.A. and Habeeb, S.K. 1994. An economic analysis of drip irrigation systems - a choice among alternatives. *Plasticulture.* **101**: 23-27

Mishra, K.K. and Pyasi, S.K. 1993. Moisture distribution pattern in drip irrigation. *J. Research, Birsa Agricultural University.* **5**(1): 59-64

Muirhead, W.A. 1979. Snap beans. *Farmer's News Letter.* **144**: 24-25

Mullins, C.A., Straw, R.A. and Rutledge, A.D. 1992. Tomato production with fertigation and black plastic mulch. *Tennessee Farm and Home Science* (164): 23-28

Narayanamoorthy, A. and Despande, R.s. (1998). Micro-irrigation for sustainable agriculture. *The Hindu*. **121**(7): 28

Olitta, A.F.L., abreu, T.A. De. and Marchetti, D.A.B. 1978. Comparative study of irrigation by furrow and drip methods in melons. *Solo* **70**(2): 7-14

Palevitch, D., Gera, G., Shaked, M., Levy, A., Menagem, E., and Yehuda, M.B. 1980. Irrigation of paprika (*Capsicum annuum*) plants. *Hassadeh* **60**(8): 1535-1543

Palevitch, D., Menagem, E., Gera, G. and Barsilai, M. 1981. Irrigation of paprika plants with small amounts of water. *Hassadeh* **61**97): 1130-1132

Pelletier, G. and Tan, C.S. 1993. Determining irrigation wetting patterns using time domain reflectometry. *Hort. Sci*. **28**(4): 338-339

Phadtare, J.S., Pampattiwar, P.S. and Suryawanshi, S.N. 1992. Studies on moisture distribution pattern in trickle irrigation. *J. Maharashtra agric. Universities*. **17**(1): 106-109

Piper, C.S. 1966. *Soil and Plant Analysis*. Hans Publishers, Bombay. p. 368

Pitts, D.J. Obreza, T.A., Almedo, M.M. 1991. The effects of lateral tubing placement and number of drip irrigated tomatoes in Florida. *Applied Engg. Agric.* **7**(3): 338-342

Prevatt, J.W., Clark, G.A. and Stanley, C.D. 1992. A comparative cost analysis of vegetable irrigation systems. *Hort. Tech.* **2**(1): 91-94

Prevatt, J.W., Stanley, C.D., Gilreath, P.R. and Clark, G.A. 1992. Return-risk analysis of adopting drip irrigation. *Applied Engg. Agric.* **8**(1): 47-52

Randall C. Harold and Locascio J. Salvadore 1988. Root growth and water status of trickle irrigated cucumber and tomato. *J. Amer. Soc. Hort. Sci.* **113**(6): 830-835

Richard, L.A. 1947. Pressure membrane apparatus construction and use. *Agric. Engg.* **28**: 451-454

Safadi, A.S. 1987. Irrigation scheduling of squash under drip irrigation and black plastic mulch in the central Jordan valley. *Dirasat* **14**(2): 177

Saggu, S.S. and Kaushal, M.P. 1993. Drip irrigation is better than furrow irrigation for potato crop. *Indian Fmg.* **43**(9): 11-12

Salman, S.R., Bakry, M.O., Abou-hadid, A.f., El-Beltagy, A.S. 1990. The effect of plastic mulch on the microclimate of plastic house. *Acta Horticulturae*. **38**(287): 417-425

Sanders, D.C., Howell, T.A., Hile, M.M.S., Hodges, L., Meek, D. and Phene, C.J. 1989. Yield and quality of processing tomatoes in response to irrigation rate and schedule. *J. Amer. Soc. Hort. Sci.* **114**(6): 904-908

Satpute, G.V. and Pawade, M.N. 1992. Effect of drip layout and planting geometrics of tomato (*Lycopersicum esculentum* L.) on crop yield and cost of drip system. *In International agricultural engineering conference. Proceedings of a conference held in Bangkok, Thailand.* **3**: 773-781

Shukla, V. and Prabhakar, B.S. 1988. Role of plant spacing and polythene mulch during monsoon on tomato production. *Lal-Baugh*. **30**(2): 18-19

Singh, B.P. 1987. Effect of irrigation on the growth and yield of okra. *Hort. Sci.* **22**(5): 879-880

Silvestri, G.P., Siviero, P., Passeri, P. and Dadomo, M. 1985. New methods for extending the productive period of processing tomatoes. *Informatore Agrario* **41**(9): 75-81

Srinivas, K., Hegde, D.M., and Havangi, G.G. 1989. Plant water relations, canopy temperature, yield and water-use efficiency of watermelon *citrullus lunatus* (Thumb.) and drip and furrow irrigation. *J. Horti. Sci.* **64**(1): 115-124

Soil Survey Staff. 1992. *Soil Survey Laboratory Methods. Manual*. USDA - SCS - NSSC Soil Survey Investigation. Report No.42. US Govt. Print. Office, Washington DC, p. 400

Subbiah, B.V. and Asija, C.L. 1956. A rapid procedure for the estimation of available nitrogen in soils. *Curr. Sci*. **25**: 259-260

Subhan. 1988. The effect of rice straw and plastic mulches on the growth and yield of kidney bean (*Phaseolus vulgaris* L.) *Buletin Penelitian Horticultura*. **16**(3): 76-80

Turner, W.C. 1988. Measurement of plant water status by the pressure chamber technique. *Irrig. Sci*.,**9**:289-308

Turner, N.C., and Jones, M.M. 1980. Turgor maintenance by osmotic adjustment: A review and evaluation. *'Adaptation of plants to water and High Temperature Stress"* (N.C. Turner and P.J. Kramer, eds.), Wiley, New York: 87-103

Van, C.D. 1989. Black film in autumn; Problem free planting in spring. *Groenten en fruit*. 451(21): 67

Van den Honert, T.H. 1948. Water transport as a catenary process. *Discuss. Faraday Soc*. **3**: 146-153

Wan Derverken, J.E. and LEE D. Will cox. 1988. Influence of plastic mulch and type and frequency of irrigation on growth and yield of bell pepper. *Hort. Sci*. **23**(6): 985-988

Willis, W.O., Haas, H.J. and Robins, J.S. 1963. Moisture conservation by surface and subsurface barriers and soil configuration under semiarid conditions. *Soil Sci. Soc. Amer. Proc.* **27**: 577-580

Younis, S.M. 1986. Study of different irrigation methods in Western Nobaria to produce tomato. *Alexandra J. agric. Res.* **31**(3): 11-19

Zengerle, K.H. 1981. Effect of mulching and reflecting plastic on the earliness of kholrabi *Gemuse*. **17**(1): 11-22

Appendices

APPENDIX I

Thirteen years (1985-1997) mean monthsly weather data for the summer season

Month	Maximum temperature (°C)	Minimum temperature (°C)	Mean RH (%)	Bright sunshine hours (h day^{-1})	Wind speed (kmh^{-1})	Evaporation per day (mm)	Rainfall (mm)
January	32.9	21.5	56.3	8.9	10.5	7.1	8.5
February	34.9	22.1	56.3	9.4	7.3	6.9	7.5
March	36.2	23.4	61.7	9.1	5.7	6.8	14.3
April	35.4	24.4	69.1	8.4	4.9	5.8	77.1
May	33.9	24.3	73.9	7.1	4.7	5.1	175.3
June	29.8	23.1	86.1	3.4	5.1	2.9	748.5

APPENDIX 2

Daily evaporation and rainfall data for the cropping period (mm)

Date	Rainfall	Evaporation
03-02-1997	Nil	5.4
04-02-1997	Nil	4.2
05-02-1997	Nil	4.6
06-02-1997	Nil	5.9
07-02-1997	Nil	5.4
08-02-1997	Nil	3.8
09-02-1997	Nil	4.7
10-02-1997	Nil	5.5
11-02-1997	Nil	5.2
12-02-1997	Nil	4.3
13-02-1997	Nil	6.0
14-02-1997	Nil	7.0
15-02-1997	Nil	7.1
16-02-1997	Nil	6.2
17-02-1997	Nil	6.1
18-02-1997	Nil	4.9
19-02-1997	Nil	3.7
20-02-1997	Nil	4.9
21-02-1997	Nil	6.0
22-02-1997	Nil	5.8
23-02-1997	Nil	5.6
24-02-1997	Nil	4.8
25-02-1997	Nil	6.5
26-02-1997	Nil	7.4
27-02-1997	Nil	8.8
28-02-1997	Nil	7.5
01-03-1997	Nil	8.2
02-03-1997	Nil	6.5
03-03-1997	Nil	7.6

Appendix 2 contd...

04-03-1997	Nil	7.9
05-03-1997	Nil	7.2
06-03-1997	Nil	6.8
07-03-1997	Nil	7.7
08-03-1997	Nil	7.5
09-03-1997	Nil	7.4
10-03-1997	Nil	7.2
11-03-1997	Nil	6.1
12-03-1997	Nil	7.1
13-03-1997	Nil	5.6
14-03-1997	Nil	5.3
15-03-1997	Nil	5.3
16-03-1997	Nil	5.2
17-03-1997	Nil	6.0
18-03-1997	Nil	5.3
19-03-1997	Nil	7.0
20-03-1997	Nil	5.4
21-03-1997	Nil	5.5
22-03-1997	Nil	6.6
23-03-1997	Nil	5.8
24-03-1997	Nil	5.2
25-03-1997	Nil	6.0
26-03-1997	Nil	5.6
27-03-1997	Nil	8.0
28-03-1997	Nil	7.2
29-03-1997	Nil	8.4
30-03-1997	Nil	7.0
31-03-1997	Nil	5.8
01-04-1997	Nil	6.8
02-04-1997	8.2	6.6

Appendix 2 contd...

03-04-1997	Nil	5.8
04-04-1997	Nil	6.1
05-04-1997	Nil	6.1
06-04-1997	Nil	6.2
07-04-1997	Nil	6.6
08-04-1997	Nil	7.4
09-04-1997	Nil	6.9
10-04-1997	Nil	8.1
11-04-1997	Nil	6.4
12-04-1997	Nil	6.8
13-04-1997	Nil	7.0
14-04-1997	Nil	7.2
15-04-1997	Nil	6.8
16-04-1997	Nil	6.8
17-04-1997	Nil	6.0
18-04-1997	Nil	6.4
19-04-1997	Nil	5.8
20-04-1997	Nil	6.2
21-04-1997	Nil	6.4
22-04-1997	Nil	6.3
23-04-1997	Nil	5.8
24-04-1997	Nil	6.0
25-04-1997	Nil	6.0
26-04-1997	Nil	6.8
27-04-1997	Nil	5.9
28-04-1997	Nil	6.4
29-04-1997	Nil	4.8
30-04-1997	Nil	4.8
01-05-1997	Nil	5.4

Appendix 2 contd...

02-05-1997	15.4	5.7
03-05-1997	Nil	5.1
04-05-1997	Nil	5.3
05-05-1997	Nil	5.9
06-05-1997	Nil	5.2
07-05-1997	Nil	5.2
08-05-1997	17.2	3.8
09-05-1997	2.4	5.3
10-05-1997	Nil	4.0
11-05-1997	Nil	4.1
12-05-1997	Nil	5.2
13-05-1997	Nil	5.8
14-05-1997	Nil	5.7
15-05-1997	Nil	4.4
16-05-1997	Nil	4.2
17-05-1997	Nil	3.7
18-05-1997	Nil	3.5
19-05-1997	Nil	5.2
20-05-1997	Nil	6.0
21-05-1997	Nil	6.5
22-05-1997	Nil	6.2
23-05-1997	Nil	6.0
24-05-1997	Nil	4.6

APPENDIX 3

Dates of sowing and harvesting of the crop

Dates	Operation done
03.02.1997	Sowing of seeds
02.04.1997	1st harvesting
07.04.1997	2nd harvesting
12.04.1997	3rd harvesting
21.04.1997	4th harvesting
29.04.1997	5th harvesting
08.05.1997	6th harvesting
14.05.1997	7th harvesting
24.05.1997	8th harvesting

APPENDIX 4

Schedule of work

Sl. No.	Item of work	Labour requirement per ha	Rate per ha	Rupees per ha
1	Deep ploughing and levelling using tractor	9 hrs/ha	100	1,800
2	Formation of ridges	60 men	80	4,800
3	Application of cowdung	13 women	80	1,040
4	Basal does of fertilizer application and incorporating and earthing up	60 men	80	4,800
5	Installation of drip irrigation system	12 men	80	960
6	Covering the ridges with mulch (LDPE sheet) and making holes according to spacing	9 men	80	720
7	Sowing of weeds	78 women	80	6,240
8	Thinning and gap filling	15 women	80	1,200
9	Weeding (3 times)	204 women	80	16,320
10	Fertilizer application (2 splits) raking and earthing up	60 men (at a time)	80	9,600
11	Furrow irrigation	4 men (at a time)	80	320
12	Spraying (4 times)	4 men	80	1,280
13	Drip irrigation	1 man (at a time)	80	80
14	Harvesting	100 kg/women	80	...

APPENDIX 5

Total cost of labour ha^{-1}

Sl. No.	Item	T1	T2	T3	T4	T5	T6	T7	T8	T9	T10
1	Cost of labour exclduing mulch and drip	28,960	28,960	28,960	28,960	28,960	28,960	28,960	28,960	28,960	28,960
2	Labour cost for layout of drip	960	960	960	960	960	960	-	-	-	-
3	Labour cost for layout of mulch	-	-	-	720	720	720	720	720	720	-
4	Labour cost for furrow irrigation	-	-	-	-	-	-	2240	1600	1280	3520
5	Labour cost for drip irrigation	880	480	480	560	400	240	-	-	-	-
6	Cost of weeding	16,320	16,320	16,320	-	-	-	-	-	-	16,320
7	Cost of harvesting	7,129	7,074	6,969	18,870	19,123	16,475	15,672	14,709	19,895	10,285
Total cost of labour @ Rs.80/labour		54,249	53,794	53,689	50,070	50,163	47,355	47,592	45,989	50,855	59,083

APPENDIX 6

Total cost of inputs

Sl. No.	Item	Cost
1	Seed	450.00
2	FYM	4800.00
3	Fertilizers:	
	Urea	413.60
	Rajphos	88.00
	MOP	159.60
4	Chemicals	1200.00
5	Electricity	Rs.5/irrigation

APPENDIX 7

Schedule of items used in layout of drip-cum-mulch irrigation

Sl. No.	Item	Quantity	Rate	Cost (Rs)
1	PVC Pipe (30 mm)	2.4 m	16.45/m	39.48
2	Valve (30 mm)	1	50	50.00
3	T-connection (30 mm)	2	6.20	12.40
4	Take off	3	3.00	9.00
5	Lateral (12 mm PVC)	11.5 m	3.60	41.40
6	End cap	2	2.20	4.40
7	End lock	3	1.30	3.90
8	Micro tube (4 mm)	11	1.65	18.00
9	Emitters	36	2.40	86.40
10	Pin connector	36	1.10	39.60
11	Solvent cement	--	108/lit	3.00
				307.58
12	LDPE sheet	1 kg	68/kg	68.00
	Total			375.58

APPENDIX 8

Cost economics of mulch sheet

Life span = 2 years

2 seasons/year

A	Cost of sheet @ 68/kg 13m²/kg	52,300.00
B	Depreciation @ 25% per annum (Considerating life span of 2 years and 2 growing seasons a year)	13,075.00
C	Interest on capital @ 5% (considering 2 growing seasons a year)	2,615.00
		15,690.00

APPENDIX 9

Cost economics of drip

A	Cost of drip	2,37,330.00
b	Depreciation @ 10% per annum (considering life span of drip system 5 years and 2 growing seasons a year)	23,733.00
C	Interest on the capital @ 5% (considering 2 growing seasons a year)	11,866.00
D	Repairs, maintenance and replacement @ 1% of the initial cost	2,373.00
		37,972.00

APPENDIX 10

Cost of cultivation of bhindi ha^{-1}

Sl. No.	Item	T1	T2	T3	T4	T5	T6	T7	T8	T9	T10
1	Total tractor power	1,800	1,800	1,800	1,800	1,800	1,800	1,800	1,800	1,800	1,800
2	Total cost of labour	54,249	53,794	53,689	50,070	50,163	47,355	47,592	45,989	50,855	59,083
3	Cost of inputs	7,166	7,141	7,141	7,146	7,136	7,126	7,146	7,136	7,136	7,166
4	Land revenue and other taxes	50	50	50	50	50	50	50	50	50	50
5	Interest on working capital (@ 5%)	3,163	3,139	3,134	2,953	2,957	2,816	2,829	2,748	2,992	3,404

MULCH-CUM-DRIP IRRIGATION SYSTEM FOR OKRA *(Abelmoschus esculentus* L. Moench*)*

By

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ABSTRACT OF THE THESIS

Submitted in partial fulfilment of the requirement for the degree

Master of Science in Agriculture

Faculty of Agriculture
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ABSTRACT

An experiment was conducted in the summer rice fallows of the Agricultural Research Station, Mannuthy during 1997 to develop and test mulch-cum-drip irrigation system for okra (*Abelmoschus esculentus* Moench.) and compare this system with drip without mulch or furrow irrigation system either with or without mulch. The soil was sandy clay loam, medium in organic carbon and available potassium and high in available phosphorus. The ten treatments comprised of combinations of two irrigation systems (Drip irrigation and furrow irrigation) and three irrigation frequencies (soil moisture tension at 0.04, 0.06 and 0.08 MPa) either with or without mulch. The experiment was laid out in randomised block design with three replications. In case of drip irrigation system 4 lph emitters were placed 60 cm apart such that there was one emitter in between two plants. In mulched plots, after the formation of ridges, the field was covered with black LDPE sheet before sowing. Holes were made on this sheet at a spacing of 30 cm and seeds were dibbled through these holes.

The study proved the beneficial effects of mulching in the vegetable crop bhindi, irrespective of the levels and methods of irrigations. Biometric characters like plant height, number of leaves and leaf area index and the yield attributing characters like number of flowers, number of fruits and total weight of fruits $plant^{-1}$ were favourably influenced by mulching both under furrow and drip systems of irrigations, irrespective of levels of irrigation.

The maximum fruit yield of 24.88 t ha^{-1} was produced when the crop was mulched and furrow irrigated at soil moisture tension of 0.08 MPa. This accounted for 93.48 per cent increase in yield over the control crop that received irrigation by furrow method at 0.06 MPa without mulch.

The crop under mulched situation consumed lesser amount of water compared to without mulch situations at all the frequencies of irrigations. This decline of consumptive use of water, was to the tune of 49, 97 and 192 percent respectively at the soil moisture tension of 0.04, 0.06 and 0.08 MPa in case of drip irrigation and 49, 97 and 135 per cent in case of furrow irrigation. Under drip irrigation the total soil moisture extracted from 0-15 and 15-30 cm layers was 30.68 to 49.56 and 50.43 to 69.31 per cent respectively in open situation. The respective values under mulched situation were 39.16 to 45.1 and 54.89 to 60.83 per cent. In case of furrow irrigation system the respective values were 35.58 to 47.39 and 52.60 to 64.41 under mulched situation and 41.01 and 58.98 per cent in unmulched situation.

When mulching was adopted under drip irrigation or surface method of irrigation with the irrigation schedules at the soil moisture tensions of 0.04, 0.06 or 0.08 MPa, the cropping became profitable. Then, the B.C. ratios varied between 0.91 to 1.58. Maximum benefit cost ratio of 1.58 was derived when the crop was mulched and furrow irrigated at soil moisture tension of 0.08 MPa.