MICRO IRRIGATION AND POLYTHENE MULCHING IN ORIENTAL PICKLING MELON

(*Cucumis melo* var. *conomon* (L.) Makino)

By

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THESIS

Submitted in partial fulfillment of the
requirement for the degree of

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DECLARATION

I hereby declare that the thesis entitled "**Micro irrigation and polythene mulching in oriental pickling melon (*Cucumis melo* var. *conomon* (L.) Makino)**" is a bonafide record of the 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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CERTIFICATE

Certified that the thesis entitled "**Micro irrigation and polythene mulching in oriental pickling melon (*Cucumis melo* var. *conomon* (L.) Makino)**" is a record of research work done independently by Mr. Anoop N.C. 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.

Mannuthy
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Dr. P.A. Joseph
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CERTIFICATE

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ABBREVIATIONS

CU	:	Consumptive Use
CWRDM	:	Centre for Water Resources Development and Management
DAS	:	Days After Sowing
DMRT	:	Duncan's Multiple Range Testing
Ep	:	Pan Evaporation
ET	:	Evapotranspiration
ETm	:	Maximum Evapotranspiration
FIB	:	Farm Information Bureau
FTA	:	Female Threaded Adapter
FYM	:	Farm Yard Manure
IARI	:	Indian Agricultural Research Institute
ICAR	:	Indian Council of Agricultural Research
KAD	:	Kerala Department of Agriculture
KAU	:	Kerala Agricultural University
Kc	:	Crop Coefficient
LAI	:	Leaf Area Index
LDPE	:	Low Density Polyethylene
MOP	:	Muriate of Potash
MTA	:	Male Threaded Adapter
NS	:	Not significant
PET	:	Potential Evapotranspiration
PUC	:	Polyvinyl-Chloride
RBD	:	Randomized Block Design
Rs	:	Rupee(s)
Sig.	:	Significant
TNAU	:	Tamil Nadu Agricultural University
USWB	:	United State Weather Bureau
WUB	:	Water Use Efficiency
$	:	American Dollar

Introduction

INTRODUCTION

Vegetable growing is one of the most important branches of agriculture. Vegetables provide a good source of income to the growers and play an important part in human nutrition. They are quick growing and provide immediate returns to the growers. Since the yield from vegetables is three to four times more than that of cereals and pulses, their cultivation occupies an important place in the agricultural development and economy of the country.

In Kerala, vegetable production is estimated at 5.87 lakh tonnes annually from an area of 55,151 ha (Farm Information Bureau, 2007), whereas the requirement of the state is 24.11 lakh tonnes, as per ICMR norms. Because of this, the daily per capita consumption of vegetables in Kerala is 130 g only which is far below the recommended daily intake of 300 g (Farm Information Bureau, 1996). More over, the yield per hectare is also very low, as compared to that of the developed countries. The soil and climatic conditions in Kerala are quite suitable for getting maximum production per unit area. These necessitate extended research efforts to increase the productivity and to improve quality of the vegetable products. As far as Kerala is concerned, the extent of cultivable land is limited and hence vegetable production can be enhanced only through intensive multiple cropping practices. Therefore, vegetable cultivation in summer rice fallow has wider scope and is gaining popularity among the farmers of the state.

Cucurbits are the largest group of summer vegetable crops. They belong to the family Cucurbitaceae and they are good source of carbohydrates, vitamin-A, vitamin-C and minerals (Yawalker, 1980). Growing of cucurbitaceous vegetables in summer rice fallow is a common practice in Kerala. Out of these, cucumber is a very popular and a widely cultivated vegetable in Kerala. In India, it is eaten as raw with salt and pepper, or as salad with onion and tomato or else as cooked vegetable. The role of the crop in our diet needs no emphasis as it is regarded as protective food well equipped to combat malnutrition.

The main constraint of vegetable production during summer in the rice fallow is scarcity of water for irrigation. In order to bring more area under irrigated vegetable cultivation in summer, efficient irrigation system as well as schedule of irrigation and other water saving management practices are to be experimentally found out so that water saved can be utilized for growing vegetable in an additional area. Such efficient systems can save not only considerable irrigation water but also substantially improve the productivity of the crop.

Micro irrigation is one of the latest innovative methods of irrigation which enables slow and precise application of water and nutrients to plants, avoiding soil erosion and wastage of water by evaporation and deep percolation. Simca Blass, a water engineer, developed the modern technique of drip irrigation in Israel in 1959. Now it is very common in countries like America, Israel, Canada, Australia, South Africa and parts of Europe. In India, the area covered under micro irrigation is 1,70,000 ha only. Maharashtra is the leading state in the country with an area of 46,000 ha under micro irrigation followed by Karnataka and Tamil Nadu (Sivanappan, 1998). Major micro irrigation techniques adaptable in vegetables are drip, micro sprinkler, wick, microtube, microjet etc. There is the need to find out the most economic micro irrigation technique suitable for adoption in irrigated vegetables grown in the state.

Mulching of irrigated crops during summer improves moisture retention in soil, controls soil temperature, reduces weed growth, enhances nutrient uptake and promotes plant growth and yield. Different types of mulches have been found effective in various crops. Among the various mulches tried in vegetables, the superiority of polythene mulches has been well accepted. Polythene mulch and micro irrigation have shown improvement in early and total yields (Abdul-Baki *et al.*, 1992 and Maiero and Schales, 1987); increase water and nutrient use efficiency (Halsey, 1985); improve yield and quality (Vani *et al.*, 1989) and control weeds (Halsey, 1985 and Gebremedhin, 2001).

In recent times mulch-cum-micro irrigation has gained acceptance in many vegetable growing countries. In south eastern and mid-Atlantic United States about 44 per cent of vegetables are grown under micro irrigation system, out of which 97 per cent is combined with polythene mulch (George-Hochmuth, 1994). The increasing interest in applying micro irrigation and mulch in vegetable cultivation is not simply for water economy alone, but also for higher yield and quality fruits. The most important result of micro irrigation and polythene mulch studies in different crops is that the BC ratio is upto 13 and it goes upto 32 when water saving is also taken for calculation. That is, for every rupee of investment in micro irrigation, farmer may get an additional income of Rs. 13 to 32. This is substantially higher than the surface method of irrigation where BC ratio varies from 1.8 to 3.9 (Narayanamoorthy, 1997).

With these contexts, an investigation on the "Micro Irrigation and Mulching on Oriental Pickling Melon (*Cucumis melo* var. *conomon* (L.) Makino)" was initiated. The study was conducted at the Agricultural Research Station, Mannuthy during the summer seasons of 2004 -2005, with the following objectives:

(1) To find out the best micro irrigation technique based on daily pan evaporation value on growth and yield of oriental pickling melon.

(2) To examine the influence of extent of mulching with black LDPE on growth and yield of oriental pickling melon.

(3) To find out the best combination of mulch and micro irrigation schedule on growth and yield of oriental pickling melon

(4) To study the effect of mulching and micro irrigation on water and nutrient use efficiency of oriental pickling melon.

(5) To examine the soil moisture distribution and extraction pattern and consumptive use of oriental pickling melon.

(6) To work out the economics of irrigation methods and mulching on oriental pickling melon.

Review of Literature

REVIEW OF LITERATURE

Cucurbits are the largest group of summer vegetable crops grown in the state of Kerala. They belong to the family cucurbitaceae and are grown for their ripe and unripe fruits. Cucurbits are good sources of carbohydrates, vitamin-A, vitamin-C and minerals (Yawalker, 1980). Among the cucurbits grown in the state, oriental pickling melon is more popular.

Among the agronomic practices water management plays vital role in determining growth and yield of vegetables. As water is a scarce commodity during summer months, most efficient systems like drip irrigation and water saving practices such as mulching have been found to be highly efficient practices capable of substantially increasing yield and saving water 30-70 per cent in a variety of crops. Meagre specific research on micro irrigation techniques and a few specific researches on moisture conservation aspects have been reported in cucurbits. Attempts have therefore been made to review the works conducted in India and abroad on cucurbitaceous and other vegetables on water management and soil moisture conservation techniques are reviewed in this chapter.

2.1 Scheduling of irrigation using pan evaporation

The high relationship between water loss from an evaporimeter and potential evapotranspiration makes this approach more attractive for irrigation scheduling, as the evaporation is easy to monitor and necessary equipment is simple and easy to maintain (Doorenbos and Pruitt, 1977).

Vamadevan (1980) indicated that evaporation values measured from a standard USWB class A open pan evaporimeter are extensively used for scheduling of irrigation. An evaporimeter is an instrument which integrates the effect of all the different climatic elements furnishing them their natural weightage (Dastane, 1967). Musard and Yard (1990) found that vitreous flesh disorder in melons might be due to too much of water during fruit ripening and they also suggested that irrigation must be reduced to 40-50 per cent of evapotranspiration during the last week before harvest. Philips *et al.* (1996) in a field experiment on scheduling micro-irrigation found that watermelon yields were highest for treatments, which received the most irrigation water, this indicating that relatively high soil moisture contents based on the evapotranspiration instrument reading should be maintained.

Rekha *et al.* (2005) found that highest fruit yield and water use efficiency were noted when bhindi crop was drip irrigated at 1.0 Epan and fertilised with 120 kg N ha^{-1}.

Bahadur *et al.* (2006) studied the effect of fertigation on growth and yield of tomato in an irrigation experiment conducted at the Indian Institute of Vegetable Research, Varanasi. Results indicated that for maximum number of fruits per plant, fruit weight, and fruit yield, drip irrigation should be scheduled in tomato at 100 per cent ET_0. Similar studies conducted by Sharda *et al.* (2006) in onion also revealed that higher plant height, number of leaves and yield of onion were obtained when irrigation was scheduled at 1.0 X Epan.

2.2 Total and critical demand of water in cucurbits

Whitaker and Davis (1962) indicated that irrigation water required for watermelons and cucumber was 150 ha-mm each and that for pumpkins and summer and winter squashes were 180 ha-mm each. According to Dunkell (1966) optimal yields of cucumber could be obtained, when 600-750 mm of water was applied.

According to Neil and Zunio (1972) the water uptake increased during fruit enlargement. At harvest, water uptake was 85 per cent of potential evapotranspiration, which declined to 55 per cent by mid-day harvest. The water uptake at successive growth stage of melon crop was 560 m^3 ha^{-1} between germination and fruit set, 1008 m^3 ha^{-1} upto fruit enlargement, 882 m^3 ha^{-1} upto pre-maturity and 280 m^3 ha^{-1} to harvest.

Cselotel and Varga (1973) reported that during the period upto the beginning of flowering, the water uptake was small, amounting to five litres plant^{-1}. In a 30 days period following the beginning of flowering, the water uptake amounted to 30-31 litres plant^{-1}. In the subsequent 30 days period corresponding to full development of the fruits and the beginning of seed maturity, water uptake was 10-20 litres plant^{-1}.

Varga (1973) found that in cucumbers the period between flowering and fruit ripening was critical for fruit development. During this period, it was necessary to supply the crop with 40 mm of water. However excessive application of water was found to be deleterious. Hammett *et al*. (1974) observed that a constant supply of moisture is necessary during the growth of cucumbers especially during flowering and fruiting.

According to Loomis and Crandall (1977) the consumptive use of water in cucumber increased during flowering and early fruiting and then levelled of during late harvest. They also observed that the total amount of water used during the later two months period of crop growth ranged from 300-400 mm over each of the four years of experiment. The ratio of consumptive use to evaporation from a pan evaporimeter (Kc) increased to a maximum of 1.5 during the early harvest season. Thomas (1984) observed that the consumptive use increased with increase in the level of irrigation in the case of bittergourd. According to Pai and Hukkeri (1979) for good growth of vegetables the soil moisture should be maintained at or above 75 per cent of availability in the active root zone.

Safadi (1987) in Jordan valley observed that squash when drip irrigated at soil moisture tensions of 0.03, 0.05 and 0.08 MPa consumed 127.5, 127.5 and 124.4 mm of water during winter season. Average fruit yields at respective irrigations were 19.4, 21.6 and 22.0 t ha^{-1}. During summer the water consumption 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. According to Srinivas Rao and Bhatta (1988) photosynthetic and transpiration rates were decreased, when water stress was imposed at vegetative, flowering and fruit formation stages in capsicum. Riley (1990) reported that in gherkin cucumbers, there was a marked reduction in the total and saleable crop when water was not available during early flowering and particularly during fruiting stage.

According to Hegde (1993) irrigation from the start of flowering and at full bloom is particularly beneficial in vegetables. Fruit enlargement also requires large supply of water. Drought during flowering results in deformed, non viable pollen grains leading to poor yield. Lee-Kyeongbo *et al.*, (1995) in a study in oriental melon regarding the effect of irrigation on fruit weight and total yield indicated that plants irrigated from transplanted to 20 days after flowering
(88.8 mm) produced the highest yield (11.4 tonnes ha^{-1}) of good quality fruits.

Krishna Manohar *et al.,* (1996) indicated that water requirement of any crop is depended upon its season and stage of crop growth apart from other several factors. Plant water status has a marked effect on growth and reproductive characters. Moisture stress given at flowering, vegetative and fruit formation stages leads to reduction in vegetative growth, flower drop, reduction in fruit set and ultimately reduction in yield. Hence the three-stage *viz.*, vegetative, flowering and fruit formation are highly responsive to moisture (Vadivel *et al.*, 1990).

Veeraputhiran (1996) reported that, the peak consumptive use reached between 36-50 DAS for the irrigation intervals of IW/CPE ratio 1.2, 0.8 and 0.4, and it was 20-35 DAS for the irrigation at critical stage in cucumber. The highest yield of cucumber was obtained when the crop was supplied the total water requirement of 650 mm.

An ideal irrigation schedule must indicate when the irrigation water is to be applied and the quantity of water to be applied (Yellamanda Reddy and Shankara Reddy, 1997). It can thus be seen that the total and critical stage of water demand depends on the physiological stage of the crop, evaporative demand of the atmosphere and duration of the crop. Cucurbitaceous vegetable crops require about 500-600 mm of water. It is also found that a constant supply of moisture is necessary during the growth of cucumbers, especially during flowering and fruiting.

Gebremedhin (2001) studied the mean seasonal consumptive use of oriental pickling melon in a field experiment conducted at the Agricultural Research Station, Mannuthy, Kerala during summer season and found that mean seasonal consumptive use at the best yield obtained was 372 mm.

2.3 Influence of method, depth and frequency of irrigation on vegetables

Many studies have reported linear response in plant growth to increase in water application rate (Shmueli and Goldberg, 1972; Goldberg *et al.*, 1976b, Aleksicor, 1977 and Beese *et al.*, 1982) while, some studies indicated that only yield parameters are significantly affected by reduced irrigation levels rather than growth parameters (Bar-Yosef *et al.*, 1980; Bar-Yosef and Sagev, 1982).

Muthuvel and Krishnamoorthy (1980) found that among the multiple factors contributing to plant growth and yield, water is the most important and limiting one. Yadav and Bhupender Singh (1991) observed that plant growth and development like size, number and quality of fruits of solanaceous vegetables were very much influenced by soil moisture content. Since the plant integrates its soil and aerial environment, plant water status appears in many cases to reflect better response to growth of crop to environmental stress as induced by irrigation management (Plaut *et al.*, 1992).

2.3.1 Effect on plant growth

Vasanthakumar (1984) revealed that tomoto raised in red sandy soils of Karnataka under drip irrigation gave significantly higher yield (58 - 67 t ha^{-1}) compared to furrow irrigation (49-55 t ha^{-1}). This was attributed to higher LAI (0.65 with drip irrigation as against 0.55 with furrow irrigation) and total dry matter production (136.53 g plant^{-1} with drip as against 131.06 g plant^{-1} with furrow irrigation).

Ravindra Mulge *et al.* (1992) reported that vegetative growth parameters like number of branches, leaves and leaf area plant^{-1} were influenced by moisture stress. It was also reported that water stress decreased the number of flowers in brinjal (Prakash, 1990). Dhanabalan (1994) found that number of flowers has been increased at higher moisture regime (0.75 IW/CPE ratio) than that of lower moisture regime (0.6 and 0.4 IW/CPE ratio).

Singh *et al.,* (2001) studied the performance of microsprinkler, drip microtube, drip emitter and surface methods of irrigation on biometric yield of bottle gourd and indicated that increase in number of branches in different micro irrigated treatments over surface irrigation were 17.48, 6.63 and 2.74 per cent for drip microtube, drip emitter and micro sprinkler, respectively. The mean leaf area of bottle gourd were 267.25, 261.75, 261.50 and 248.80 cm^2 for drip microtube, drip emitter, surface and micro sprinkler methods of irrigation, respectively.

Manjunatha *et al.* (2001a) studied the effect of micro sprinkler and surface irrigation methods on potato and reported a net increase of 9.2 per cent in plant height, 22.6 per cent in average number of secondary branches, 18.7 per cent in average number of leaves and 19.4 per cent in mean leaf area with micro sprinkler irrigation as compared to furrow irrigation.

Agrawal *et al.* (2004) reported that there was significant increase in plant height, number of primary branches and number leaves in tomato due to drip irrigation over flood irrigation. Rekha *et al.* (2005) studied the influence of trickle irrigation and furrow irrigation on growth and yield of bhindi during summer seasons of 2003-2004 at the Directorate of Oil seeds Research, Hyderabad. Results indicated that growth and yield parameters and water use efficiency were best when the crop was drip irrigated.

2.3.2 Effect on root distribution and growth

Belik and Veselovskii (1975) reported that under surface irrigation, the main root mass in watermelons was in the 8.5-17 cm soil layer. Kudarimani (1977) reported that roots were found even to a depth of 45 cm in drip irrigation and 50 cm in furrow irrigation. In furrow irrigation roots were not significantly concentrated in any layers whereas, in drip irrigation, the root concentration was more around drip points which is due to availability of moisture at all times.

Zabara (1978) reported that in irrigated cucumbers the root distribution at bearing was 64.5 per cent at 0-10 cm depth, 28.5 per cent at 10-20 cm depth and 6 per cent at 20 to 30 cm depth. In the case of unirrigated cucumbers the figures were 53.7 per cent at 0-10 cm, 29 per cent at 10 to 20 cm and 14.9 per cent at 20 to 30 cm.

Abdullah (1981) reported that the distribution of roots were maximum at 5-10 cm depth in drip irrigation and 15-20 cm depth in furrow method. The lateral spread of roots was between 19-26 cm in drip and it was only 16-22 cm in furrow system of irrigation.

It was also reported that root growth and distribution of roots were maximum at 5-10 cm depth in drip and 15-20 cm depth in check-basin. The spread of roots were up to 40-55 cm within the wetted zone under drip and only 15 cm spread around the plant in check-basin method of irrigation (Naik, 1986).

Gebremedhin (2001) reported that in oriental pickling melon root depth was more in mulched plots than in control and that depth of root increased progressively from 50 to 100 per cent Ep with drip irrigation.

2.3.3 Effect on yield and yield factors

According to Abolina *et al.* (1963) the melon plants watered regularly produced greater number of female flowers. Chennappa (1976) observed that drip irrigation gave 27.8 per cent higher yield with better quality and size of tomato fruits compared to furrow irrigation. El-Gindy (1984) working on sweet pepper crop found that drip irrigation gave 64 per cent increased yield over furrow irrigation.

Kudarimani (1977) reported early maturity in cabbage and a yield of 70.75 t ha^{-1} with daily irrigation through drip system whereas with increase in irrigation interval in drip system, the yield reduced significantly.

According to Singh and Singh (1978) the yield increase by drip irrigation in crops like, bottle gourd, roundgourd and watermelon was associated with increased number of fruits $plant^{-1}$ and increased fruit weight. They recorded 20-25 per cent more yield in gourds under drip irrigation over furrow irrigation. It was also recorded that on loamy sand soils of hot arid regions, daily irrigation was advantageous in drip irrigation. Melon cv. *Valenciano amarelo* produced highest yield when drip irrigated at 0.7 atm. with one emitter per four plants as compared to furrow irrigation (Olitta *et al.*, 1978).

Reddy and Rao (1983) worked on the response of bitter gourd to pitcher and basin systems of irrigation. They found that the yield was highest in plots with pitcher filled every 4th day and lowest in plots with basin filled every 5th day. An experiment conducted at the Agricultural Research Station, Mannuthy in a sandy loam soil revealed that there was no significant difference in yield between irrigating at 25, 50 and 75 per cent depletion of available soil moisture for pumpkin, oriental pickling melon and ash gourd (Radha, 1985).

Srinivas (1986) working on water requirement of watermelon in the semi arid regions of South India reported that drip irrigation was far superior to furrow irrigation in realising higher yields to the tune of 24 per cent. Among different drip irrigation treatments *viz.*, with one emitter per two plants and one emitter per plant, the former one recorded slightly higher yields (34 t ha^{-1}) compared to latter treatment (33.15 t ha^{-1}), although the difference was not significant.

Goyal *et al.* (1987) reported that drip irrigation increased yields in sweet pepper significantly by 168 per cent compared to furrow irrigation (52%) and micro sprinkler (115%) over no irrigation during winter. While during summer season it was 186 per cent, 85 per cent and 119 per cent, respectively. Srinivas *et al.* (1989) observed that drip irrigation gave higher yield than furrow irrigation in water melon. Drip irrigation in cabbage recorded higher yields (218 q ha^{-1}) compared to surface irrigation (159 q ha^{-1}) as reported by (Singh *et al.*, 1990).

Kataria and Michael (1990) working on response of tomato to drip and furrow method of irrigation under Delhi conditions reported that drip irrigation gave higher yield by 47.4 per cent over furrow method of irrigation. The root spread at a depth of 30-40 cm below the ground surface was great in plants irrigated by furrows than those irrigated by the drip method. Drip method of irrigation in tomato recorded higher yield of 48 t ha^{-1} compared to 32 t ha^{-1} with flood irrigation (Jahdav *et al.*, 1990).

Nerson *et al.*, (1994) reported that increasing the water supply from a dry farm regime to weekly irrigation regime had only a small effect on fruit number. While, Yingjajaval and Markmoon (1993) found that in cucumber the yield increase by drip irrigation was due to fruit number rather than fruit size. Number of fruits $plant^{-1}$ in brinjal was significantly influenced by irrigation methods, the maximum number of fruits were recorded in drip irrigation (13.9) when compared to conventional furrow irrigation (10.7) (Kadam *et al.*, 1993). Khan *et al.* (1996) reported that the yield of cabbage increased from 15 t ha^{-1} under conventional system of furrow irrigation to 24.5 t ha^{-1} under microtube system of irrigation. Prabhakar & Hebbar (1996) reported that 25 per cent increase in yield of watermelon was observed with drip irrigation compared to furrow irrigation.

Kunzelmann and Paschold (1999) in their comparative study of drip and sprinkler irrigation for pickling cucumber in Germany revealed that, drip irrigation accelerated seedling development, thus leading to earlier yields and prolonged harvest periods; yields under drip and sprinkler irrigation were 547 and 400 t ha^{-1}, respectively. It was concluded that, micro irrigation is more suitable for cucumber cultivation than sprinkler irrigation.

Gebremedhin (2001) reported 27 per cent increase in oriental pickling melon yield with drip irrigation at 125 per cent Ep over basin method of irrigation. Rekha *et al.* (2005) conducted investigations on trickle and furrow irrigations in bhindi at the Directorate of Oil seeds Research, Hyderabad. They reported that higher yields (4188 and 4153 kg ha^{-1}) were noted when the crop was drip irrigated at 1.0 Epan. Furrow irrigated crop showed 54 and 57 per cent lower yield than drip method during 2003 and 2004, respectively.

Agrawal *et al.* (2004) studied the benefit of drip irrigation over flood irrigation in tomato in experiments conducted at the Horticultural Research Farm, Raipur during 1999-2000. There was significant increase in plant height, number of primary branches, number of leaves and marketable fruit yield in drip irrigated plot over flood irrigation.

Bahadur *et al.* (2006) reported from the field experiments conducted at Indian Institute of Vegetable Research, Varanasi that drip irrigation at 100 per cent ET_0 resulted in maximum number of fruits, fruit weight, total fruit yield and marketable fruit yield of tomato compared to other levels of ET_0 and surface irrigation. Drip irrigation scheduled at 100 and 80 per cent ET_0 saved 45.8 and 56.5 per cent water, respectively over surface irrigation.

Field experiments conducted at Punjab Agricultural University Campus by Sharda *et al.* (2006) revealed the benefit of drip irrigation over surface irrigation in onion. Drip irrigation at 1.3 X Epan resulted in the highest plant height, number of leaves and onion yield.

2.4 Effect of irrigation and moisture conservation system on growth and yield

Jayasree (1987) in a study conducted at the College of Agriculture, Vellayani revealed that there was a significant effect on yield by the interaction between irrigation and mulching. Dry leaf mulch with irrigation at 20 per cent depletion gave highest yield followed by sawdust mulch with irrigation at 40 per cent depletion. This was superior to paddy husk or paddy straw mulches with either 20 per cent or 40 per cent depletion.

Bhattikhi and Ghawi (1987) observed that 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 a yield of 25.9,18.0 and 11.8 t ha^{-1}, respectively.

In a field experiment conducted in fine sandy loam soil near Vincennes, Indiana, with tomato cv. *Sunny* revealed that trickle irrigation increased plant height whereas polythene mulching increased plant spread and dry matter production. In the same study yield 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, 1988)

Quadir (1992) conducted an experiment on watermelon using straw, clear polyethylene and black polyethylene mulches and unmulched control. Marketable fruit yield $plant^{-1}$ was highest with black polyethylene. Tomato cvs. *Sunny* and *Pine-Rite* grown under trickle irrigation and black polyethylene mulch yielded on an average 84 t ha^{-1} as compared to 43 t ha^{-1} produced under no-mulch plots (Abdul-Baki *et al.*, 1992).

In an experiment conducted at Erbel using onion cvs. *Texas yellaw Grono* and *Texas Early Grono* 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).

Field trials conducted at Regional Agricultural Research Station, Pilicode revealed that practice of daily irrigation along with paddy straw mulching gave more yield in cucumber than other treatments (Kerala Agricultural University, 1991).

Khalak and Kumaraswamy (1992) in an experiment conducted at Bangalore with potatoes cv. *Kufri jyothi* revealed that dry matter accumulation and tube yields were highest with plastic mulching followed by rice straw mulch.

Farias-Larios *et al.* (1994) revealed that the highest number of fruits and yield of cucumber were obtained with clear plastic mulch. White or black mulch also significantly increased yield. Similarly Larious *et al.* (1994) found that clear polyethylene gave more marketable yield in cucumber than white and black mulches.

Sunilkumar (1998) conducted studies on effect of mulch cum drip irrigation system in a sandy loam soil in okra and found that mean plant height was higher under mulch situation than unmulched in both furrow and drip irrigation system irrespective of levels of irrigation.

In field trials conducted by Mosler *et al*. (1998) to optimise drip irrigation and fertigation in pickling cucumbers in a former's field in Germany revealed that root density and distribution were varied markedly with different drip layouts and management.

Gebremedhin (2001) has observed that drip irrigation at 125 per cent Ep was the most efficient in registering increased growth, higher fruit yield, higher net income and net profit per rupee invested and this was closely followed by drip irrigation at 100 and 75 percent Ep in oriental pickling melon. The above schedules, when combined with black polythene mulch were superior to paddy waste mulch and unmulched control.

Singh (2005) studied the influence of mulch cum irrigation on the growth and yield of tomato in north Indian plains and found that polythene mulch was superior to rice straw or sugarcane trash on number of fruits per plant, fruit size and fruit yield. Black polythene mulch increased the fruit yield by 57.5 per cent and clear polythene by 40.7 per cent.

Aruna *et al.* (2007) in an experiment conducted in tomato at the Horticultural College and Research Institute, Periakulam reported that increased the plant height, early flowering, increased number of fruits per plant, fruit weight and fruit yield were observed when fertigated plots were mulched with black polythene. Paddy straw and sugarcane trash were inferior to black polythene mulch.

2.5 Influence of irrigation methods on soil moisture status

The size of root system and its depth in a given soil, plant growth and yield are determined to a greater extent, by soil moisture content, distribution and extraction and their interaction, with soil aeration and nutrient supply.

According to Bucks *et al*. (1984) in drip irrigation the soil water content in portion of plant root zone remains fairly constant because irrigation water can be applied slowly and frequently at a predetermined rate. Black (1976) reported that water content in drip irrigation is always nearer to field capacity in root zone but unsaturated, hence gravitational force is minimum. Slow and frequent watering eliminates wide fluctuation of soil moisture under drip irrigation resulting in better growth and yield (Sivanappan, 1998).

2.5.1 Soil moisture availability and movement in root zone

Chennappa (1976) has observed that water was available at all times around the root zone at very low moisture tension with no moisture stress in drip irrigation system, whereas in furrow method of irrigation, the plants were subjected to progressively greater moisture stress and it was also observed that drip irrigation established almost uniform moisture regime and distribution of water.

Kudarimani (1977) observed uniform moisture distribution in drip irrigation compared to furrow irrigation. It was also observed that as the distance from drip point increased, the moisture levels generally decreased. As the period of time increased the moisture levels near the drip points found decreased.

According to Gajare (1982) as the distance from the drip point increased the moisture content generally decreased with increase in the period of time. It was also noticed that middle layer of 15 to 30 cm of soil depth generally contain little higher moisture than top or bottom layers.

Gupta and Gupta (1987) reported that light and frequent irrigation (30 mm water at E_0 30 mm) along with straw mulching increased water availability, thereby increased the yields of tomato by 100 per cent and okra by 400 per cent in arid regions of India. Ramesh (1986) reported that availability of soil moisture was more constant with drip irrigation than with furrow irrigation. He obtained higher yield (7385 kg/ha) of green fruits in chilli crop with better quality fruits under drip irrigation scheduled at 0.6 Epan as compared to drip at 0.3 Epan as well as furrow irrigation at 0.3 and 0.6 Epan under Bangalore conditions.

Kataria and Michael (1990) reported that in drip irrigation, the surface soil layer upto 10 cm deep had the maximum soil moisture content. The soil moisture content decreased with depth. This coincided with the regions having the maximum number of effective roots, resulting in better environment for higher yield of tomato. But furrow resulted in higher soil moisture stress near the ground surface.

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.

Phadtare *et al*. (1992) studied different emitter discharges *viz*., 2, 3, 4 and 5 1 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 1 hr^{-1}) and the highest (5 l hr^{-1}) emitter discharges respectively. The vertical advances were 105.65 and
118.5 cm for 2 1 hr^{-1} and 5 1 hr^{-1} emitter discharges respectively. This 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 1 hr^{-1} emitter discharge.

According to Amir and Dag (1993) from a very low energy moving emitter study in heavy clay soil in 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.

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

Pelletier and Tan (1993) conducted an experiment on time domain reflectometry technique and it was 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 where as the 50 per cent available soil water zone in a microjet system was an elongated semicircle from the soil surface to depth of 35 cm.

According to Bell *et al*. (1998) subsurface drip irrigation and associated mandatory minimum tillage practices significantly reduced the incidence of lettuce crop (*Sclerotinia minor*) and the severity of corky root on lettuce compared with furrow irrigation and conventional tillage at the Hartnell East Campus in Salinas, California, USA. Three possible mechanisms for the drip irrigation-mediated disease suppression were examined. The soil moisture under subsurface drip irrigation was significantly lower at all depths and distances from the bed centre after an irrigation event than under furrow irrigation. The soil temperature in contrast, was significantly higher at both 5 and 15 cm depth under drip irrigation than under furrow irrigation. The suppression of lettuce drop under drip irrigation compared with furrow irrigation is attributed to differential moisture and temperature effects rather than to changes in the soil microflora or their inhibitory effects on *S. minor*.

Rajput and Patel (2002) studied the response of okra to drip irrigation and reported that the cyclic regulation and continuous wetting of soil associated with drip irrigation maintained optimum moisture in the crop root zone which in turn facilitated greater rates of water and nutrient absorption. Similar results of increased water use efficiency of drip system over furrow irrigation due to controlled water release near the crop root zone of okra was reported by Punamhoro *et al.* (2003)

Prabhakaran (2003) studied the influence of irrigation on water use in soybean in field experiments conducted at the Research Farm of Tamil Nadu Agricultural University, Coimbatore. He has reported that when soybean was irrigated at narrower irrigation frequency as dictated by IW/CPE ratio of 0.9, soil moisture content was higher at 17.2 and 19.2 per cent, respectively during summer and kharif in the surface 0-30 cm layer. It was also higher in the lower layer of 30-45 cm at 19.7 and 21.5 per cent, respectively during summer and kharif season. Application of composted coirpith at the rate of 12.5 t ha^{-1} increased soil moisture by five per cent in summer and eight per cent in kharif against control.

Awasthi *et al.* (2005) reported that irrigated brinjal when protected by black polythene sheet conserved 46-50 per cent moisture than unmulched control at 30 cm depth during September-November. During December-March, polythene mulching conserved 26-61 per cent more moisture at the same depth.

2.5.2 Soil moisture extraction pattern and consumptive use

Cucumbers extract 50 per cent of the amount of water consumed from the upper 30 cm of the soil profile, 30 per cent the next 30 cm and 10 per cent from the next 30 cm (Loomis and Crandall, 1977).

According to Choudhury (1983) pumpkin and squashes have a spreading but rather shallow root system while cucumbers are shallow rooted. This work revealed that, the root system of the cucurbits is extensive. The soil moisture extraction was also found to be highest from the top 30 cm of the soil profile. Such a high rate of moisture depletion from the surface may be attributed to the excessive evaporation losses besides loss of moisture by way of transpiration.

Thomas (1984) observed in bitter gourd the top 15 cm of the soil layer accounted for 42-48 per cent of the total moisture depleted. The moisture use from the 15 to 30 cm layer was as high as that from the next 30 cm soil layer below. The top 30 cm layer contributed about 66-71 per cent of total water use. Moisture depletion decreased rapidly with soil depth. He also observed that in comparison with wet regimes dry regimes extracted more soil water from the lower soil layer.

Thomas (1984) on trials conducted at the Agronomic Research Station, Chalakudy revealed that the consumptive use increased with increase in the level of irrigation in bitter gourd. Experiment conducted at the Agricultural Research Station, Mannuthy showed that the treatments which received frequent irrigation showed higher values of consumptive use throughout the crop growth period in cucurbits (Radha, 1985).

Eliades (1988) with cucumber in a heated greenhouse observed that the average water requirement during the whole growing period was equivalent to 0.7 x pan evaporation. It was also reported that, bitter gourd extracted major part of the water from upper layers of soil irrespective of the irrigation treatments (Ells *et al.*, 1989).

Komamura *et al*. (1990) in a drip and perforated pipe irrigation study in green house cucumber in Japan showed that the average consumptive use was (1.5-2.8 mm per days) nearly equal to the evaporation. In other study the seasonal consumptive use for cucumber and squash was 267.0, 242.4, and 226.0 mm under soil moisture tensions of 0.35, 0.45 and 0.55 bar, respectively. The calculated reference evapotranspiration values were 363.1, 325.9, 370.6 and 275.3 mm per season by Blanny-Criddle, radiation, modified Penman and pan evaporation methods, respectively (El-Gindy *et al*., 1991).

Veeraputhiran (1996) reported that in cucumber, grown in a sandy loam soils, the soil moisture depletion was about 50 per cent from the top 15 cm of the soil layer. The moisture depletion from the 15-30 cm and 30-45 cm layers ranged from 23 to 24.6 percent and 22 to 25.3 per cent, respectively among the mulching treatments. Moisture depletion changed between 23.6 to 25.4 per cent and 24.7 to 28.1 per cent, respectively among the levels of irrigation at 15-30 and 30-45 cm. There was relatively more depletion from the lower depths in drier regimes. Consumptive use increased when cucumber was mulched with coir pith, saw dust or paddy waste. The consumptive use increased with increase in frequency of irrigation. The highest value of 498.6 mm was recorded by frequent irrigation at IW/CPE ratio of 1.2, while that at the widest interval of irrigation at IW/CPE ratio of 0.4 amounted to 265.4 mm.

Gebremedhin (2001) observed higher depletion of soil moisture from the surface 0-15 cm soil layer by oriental pickling melon when it was mulched by black polythene and reduced depletion from 30-60 cm soil layer.

Prabhakaran (2003) studied the moisture extraction pattern of soybean crop in field experiments conducted at Coimbatore. He found that most of the moisture under all irrigation levels (IW/CPE 0.5, 0.7, 0.9) was extracted from surface 0-30 cm depth. Top 15 cm layer contributed the most when minimum number of irrigation was given (IW/CPE 0.5). Moisture extraction from lower profile (30-45 cm) was higher in less irrigation water applied treatment (IW/CPE 0.5) to the tune of 25.5 and 22.6 per cent respectively during summer and kharif seasons. The relative contribution of moisture in the upper layer for extraction was higher with composted coirpith application.

2.6 Effect of mulching and mulch-types

Water applied to crops is lost through evaporation from the soil surface and transpiration through foliage of crops and weeds. The essence of water conservation lies in minimizing evaporation rather than reducing the transpiration by the crop. Therefore moisture conservation and utilization are important in summer season to increase the efficiency of irrigation water by reducing soil temperature fluctuation, by improving soil moisture retention, by suppressing weed growth and by increasing yield.

2.6.1 Effect of mulch on moisture retention

According to Gutal *et al.* (1992) from a study conducted to find out the mulching effects on the yield tomato crop, polyethylene mulch films had significant effect on the growth of tomato by conserving 28 per cent more soil moisture compared to the control treatment. Channabasavanna *et al.* (1992) recorded an increase of soil moisture level of 10.4 per cent under straw mulch and 29.6 per cent in polyethylene mulch over control.

Patra *et al.* (1993) reported that mulched soils contained approximately 2 to 40 per cent more moisture at ploughing depth than unmulched soils. According to Uthaiah *et al.* (1993) both natural and synthetic mulches had helped in conserving soil moisture in the root zone of coconut and hence enhanced the growth.

Chakraborty and Sadhu (1994) reported greater soil moisture conservation with polyethylene mulches. The ability of rice straw mulch or water hyacinth mulch to conserve soil moisture was appreciably lower than that of the polyethylene mulch.

Srinivas and Hegde (1994) conducted a study to find out the effect of mulches and cover crops on 'Robusta' banana. Water use of banana was lowest under the polyethylene mulch followed by straw mulch, and was highest when banana was raised with cover crops. The evapotranspiration under polyethylene mulch decreased by 8 per cent and 14 per cent compared with that under straw mulch and no mulch. Water use efficiency was highest under polyethylene mulch, largely due to higher yield and reduced evapotranspiration.

Yoon *et al.* (1995) the effects of drip irrigation and mulching on capsicum were investigated in 4 areas in Korea Republic. Mulching increased soil water content and increased yields compared with controls. The highest yield (2778 kg ha^{-1}) was observed from the black polyethylene and rice hulls treatment. Adding (unspecified) compost to the soil also increased soil water content and increased yields compared with controls.

It was also reported that sowing and simultaneously covering the rows with perforated plastic strips increased soil moisture in the topsoil by upto
14.5 per cent and soil temperature by 0.5 to 1.6°C. This improved soil microclimate, accelerated days, and shortened the crop-growing period by 21 to 24 days compared with using transplants in head cabbage (Mikhov *et al.*, 1995). Gebremedhin (2001) reported 7.0 to 9.2 per cent increase in soil moisture in the top 60 cm soil depth with black polythene mulching and 2.2 to 4.2 per cent increase with paddy straw mulching.

Singh (2005) studied the influence of mulching on growth and yield of tomato in north Indian plains and reported that polyethylene mulch was superior to organic mulch. Polythene mulches retained more soil moisture than organic mulches. Among the mulches black polythene mulch was better than clear polythene mulch and the former increased fruit yield by 57.5 per cent and the latter by 40.7 per cent.

Studies by Awasthi *et al.* (2005) at the Central Institute for Arid Horticulture, Bikaneer on mulching studies in brinjal revealed that black polythene conserved 46-50 per cent more moisture than control at 30 cm depth during September-November. But during December-March, white polythene conserved more moisture to the extent of 21-61 per cent than control. The organic mulches did not follow any uniform pattern.

2.6.2 Effect of mulch on soil temperature

According to Franklin and Ravmond (1966) among the various types of mulches, plant growth was rapid; fruit set early and higher yields were obtained with plastic mulch because of rise in temperature below the plant canopy due to more light reflection by the plastic, and ultimately resulted in higher photosynthetic activity.

Decoteau *et al.* (1988) conducted a study to find out mulch colour effects on reflected light and tomato plant growth. Differences in the growth of tomato grown with white and black coloured polyethylene mulches were evaluated in a greenhouse. The surface colour of plastic mulch could change the quantity of light and the spectral balance reaching the plants, with resulting effects on growth and fruit production. The surface colour of the mulch affected root-zone temperature also. Soil temperature 2.5 cm below the black mulch surface averaged almost 1°C higher than soil temperatures below the white mulch surface.

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 moisture conserved was 28 percent more than the control.

Chakraborty and Sadhu (1994) reported that polyethylene mulches increased the soil temperature by 2 to 3°C above the control whereas plots mulched with natural materials such as straw or water hyacinth were not different from the control. Castilla *et al.* (1994) conducted a study to find out the effect of mulching with clear polyethylene film on garlic. Soil temperatures were significantly higher in the mulched treatments than in control.

Gupta and Acharya (1994) conducted an experiment on strawberry and reported that the use of black polyethylene much was superior to that of transparent polyethylene. The beneficial effects of transparent polyethylene due to rise in soil temperature during the initial growth stage was counteracted during the fruiting stage due to higher soil temperature. Whereas black polyethylene raised the soil temperature 2 to 3°C during night over unmulched soil and did not alter the day temperature.

Siwek *et al.* (1994) conducted an experiment to study the effect of white and black polyethylene mulches on sweet pepper. Temperature measurements taken at 8.00 hr. showed, the soil under black mulch was, on an average, 0.5°C warmer while that under white polythene was 0.5°C cooler than the bare soil.

Cebula (1995) investigated the effect of transparent or black plastic film on soil temperature for sweet pepper. The temperature of the soil was, on average, 2°C higher under transparent and black plastic mulch at depth of 4 and 12 cm compared with the unmulched control. The transparent film ensured higher soil temperatures during the day, while the loss of heat energy at night was to a greater degree prevented by the black mulch.

In an investigation by Ravinder *et al.* (1997) the effect of different plastic (black, blue or transparent polyethylene 200 gauge or black polyethylene

50 gauge) and organic (paddy straw, sugarcane trash or poplar leaves) mulches on soil temperature and moisture content was studied in a tomato field at Pantnagar, revealed that the soil temperature was significantly influenced by mulches almost in every week of observation from December to April. In general, plastic mulches increased the soil temperature during daytime, whereas organic mulches decreased it in comparison with the control. The soil moisture under mulched plots was significantly higher than the control.

Gebremedhin (2001) reported increase of soil temperature by 2^0C at 15 cm depth by polythene mulching in oriental pickling melon crop. However paddy waste mulch had no significant effect on soil temperature. Awasthi *et al.* (2005) reported lowering of soil temperature at 20 cm depth by 1.1-5.6 °C during summer months by organic mulching in brinjal. During winter, soil temperature increased by 0.6-3.2 °C under organic mulching. In winter, polythene mulching raised soil temperature by 2.7-5.1 °C.

2.6.3 Effect of mulch on weed control

Ashworth and Harrison (1983) conducted a study to determine the effect of organic and synthetic mulches on weed control, water conservation and soil temperature. They found that the opaque synthetic mulches like black polyethylene remained intact throughout the summer and thus provided the most effective weed control. The worst weed problems were associated with straw and clear polyethylene.

Davies *et al.* (1993) observed that among smooth paper, crimped paper, bark straw or black polythene mulches, the latter resulted in good weed control (with 0-1 per cent ground cover weeds). A clean ground was left following removal of black polyethylene and weed germination remained low throughout the season.

Chakraborthy and Sadhu (1994) reported that weeds did not grow at all in the plots mulched with black polyethylene. Clear polyethylene allowed considerable weed growth, and the fresh and dry weights of weeds under clear polyethylene much were as high as those obtained with rice-straw mulch.

According to Selders *et al.* (1994) shredded and chopped newspaper mulches can provide good weed control, help retain soil moisture, stabilise soil temperatures, reduce some disease problems and increase yields and quality of fruits. It is also reported that black polyethylene suppressed weed growth whereas transparent polyethylene cover encouraged excessive weed growth (Gupta and Acharya, 1994).

Shrivastava *et al.* (1994) conducted an experiment on tomato and found that a combination of drip with black plastic mulch could control the weeds as high as 98 per cent. In a similar study (Anonymous, 1989) it was reported that black plastic mulch and sugarcane trash mulch could reduce the weed growth to the tune of 91 and 87 per cent, respectively.

Monks *et al.* (1997) evaluated shredded newspaper (2.5, 7.6, 12.7, and 17.8 cm depth), chopped newspaper (2.5 and 7.6 cm), wheat straw (15.2 cm), black plastic and plastic landscape fabric during 1993 and 1994 in West Virginia for their effect on soil temperature, soil moisture, weed control, and yield in tomato. Results indicated that high newspaper mulching rates reduced soil temperature compared to black plastic and bare ground. Chopped newspaper controlled weeds more consistently than other treatments. At least 7.6 cm of chopped newspaper mulch was required to give 90 per cent control. Wheat straw was not as effective in controlling weeds. Generally mulches applied at 0, 2 or 4 weeks after transplanting resulted in weed control similar to the chemical treatment.

Gebremedhin (2001) reported 100 per cent weed control by black polythene mulching and 47 per cent weed control by paddy waste mulching in an experiment conducted in oriental pickling melon. Singh (2005) studied the effect of polythene and organic mulching in tomato and found that black polythene controlled weed growth completely, while clear polythene, rice straw and sugarcane trash mulches checked weed growth by 70.2, 79.1 and 84.2 per cent respectively, over control.

Verma *et al*. (2007) reported 81 per cent weed control under drip irrigation combined with polythene mulching in peach, whereas in the unmulched plot weeding was done 15 times during growing season.

2.6.4 Effect of mulch on growth and yield

According to Kapitany (1971) mulched capsicum gave increased yields by 9 to 14 per cent and raised average fruit size by 2 to 58 per cent over no-mulch treatment. Mulching had increased mean soil temperature by 3 to 5°C and maintained the soil moisture content at 60 to 70 per cent of field capacity compared to 40 to 50 per cent with no-mulch plot. Mulching with straw, transparent polythene or non-fermented manure improved the growth, yield and quality of tomatoes compared to no-mulch treatments (Voican *et al*., 1971)

Berrocal and Vives (1978) observed that sawdust 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.

According to Cerne (1984) in pickling cucumbers mulching with polythene increased the yield, vine length, leaf number and main root length by 149, 183, 163 and 128 per cent respectively. Iapichino and Gagliand (1984) observed the greater growth of watermelon and earlier appearance of first female flowers in polythene mulched plots.

Djigma and Diemkouma (1986) observed that egg plant 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.

Carter and Johnson (1988) conducted mulching studies on egg plant using pine needle, black plastic, newspaper or no mulch. They revealed that in a 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.

Vani *et al.* (1989) observed that use of yellow polythene, transparent polythene and straw mulch reduced the levels of mosaic disease incidence in muskmelon and increased the plant growth and yield by 36, 74 and 51 per cent respectively. In green house studies, Salman *et al.* (1990) observed that vegetative growth (plant height, number of leaves and leaf area), was increased irrespective of mulch colour that is, black or transparent in case of cucumber, but by black polythene in case of watermelon.

Aranjo *et al.* (1992) observed that harvesting ''Vista Alegre' cucumber (*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.

Channabasavanna *et al.* (1992) reported that mulching tomato with straw or black polythene conserved more moisture than no-mulch. This resulted in increased fruit yield of 118.58 q ha^{-1} and 158.94 q ha^{-1} with straw and black polythene mulch respectively, compared to 91.15 q ha^{-1} with no-mulch.

According to Brown *et al.* (1992) tomato cv. *mountain 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).

Albregts and Chandler (1993) investigated the effect of polyethylene mulch colour on the fruiting response of strawberry. The mulch colours used were black, white, blue, brown, green, orange, red and yellow. The early yield was increased in all three seasons by using yellow mulch, compared with black mulch. The soil temperature was the highest for the blue coloured mulch and lowest with the white and yellow mulches.

Davies *et al.* (1993) in a field experiment conducted at Abemethy, Fife (Scotland) with Broccls 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 per cent ground cover weeds) and plant growth.

Taber (1993) reported that plastic mulch and cover treatments increased total and early yields of muskmelon compared with bare soil. An experiment was conducted to study the effect of different mulch types and colours on the growth and yield of tomato. This study revealed that polyethylene mulches, irrespective of colour were superior to straw mulch in improving growth and yield (Chakraborty and Sadhu, 1994).

In field trials conducted by Farghale (1994) aubergine plants grown on a clay soil were mulched with black or white polyethylene sheets applied before planting. Comparing to unmulched controls, mulching resulted in earlier flowering and fruiting, increased plant height and greater number of branches. The white mulch resulted in slightly higher yields than the black one.

Saravanababu (1994) found that mean plant height, leaf area, number of flowers per plant, mean number of branches per plant, root length, dry matter production and yield of fruits of egg plant were all the highest in plants grown with banana trash mulch @ 15 t ha^{-1} compared to other mulches and with out mulch control.

Chakraborty and Sadhu (1994) conducted an experiment to study the effect of different mulch types and colours on the growth and yield of tomato, weed growth, soil temperature etc. Among the mulch colours, black and red polyethylene increased plant height by 23.8 and 30.9 per cent, respectively compared with the control. Black colour advanced the flowering period by 10 days and red colour by 11 days.

Siwek *et al.* (1994) studied the effect of mulching on changes in microclimate and on the growth and yield of sweet pepper grown in plastic tunnels. White or black polyethylene mulches were applied. The black polyethylene mulch resulted in a 10.3 per cent increase and the white polyethylene resulted in only a 6.1 per cent increase in the yield over the bare tunnel soil. Fruits were larger with either mulch than with no-mulch. Studies by Farias-Larios *et al.* (1994) on cucumber showed that fruit number and yield were higher for mulched plots. Mulching also reduced the number of days to flowering and first harvest.

Cebula (1995) investigated the effect of mulching with transparent or black plastic film on the vegetative growth of sweet pepper. The vegetative growth of plants was more intensive in mulched stands. The transparent film gave slightly better results than the black one. Yields were 38.6 and 19 per cent more for transparent and black mulches, respectively compared to control.

Rubeiz and Freiwal (1995) conducted a study to observe the effect of mulch on tomato production. Tomato plants were grown under floating raw covers, black polyethylene mulch, mulch plus row cover, and no protection (control). Early and total yields were highest with mulching and lowest with raw covers. The largest fruit were produced with black mulch. In other study, the yield of high bush blue berry was highest in bark mulched plots than peat and saw dust mulch (Mercick and Smolarz, 1995).

Lourduraj *et al.* (1996) conducted field experiments for four years on bhindi (Lady's Finger) and for two years on tomato at Tamil Nadu Agricultural University, Coimbatore. Results revealed the beneficial effects of mulching. In the case of tomato, mulching with black LDPE recorded yield of 12.74 kg ha^{-1}, thus registering 28.4 per cent yield enhancement over unmulched control. In okra, mulching with black LDPE resulted in 50 per cent yield increase compared with the control. In other study in cucumber among the bio-mulches tried the highest fruit yield ha^{-1} and per plant was produced by paddy waste incorporation and was at par with that of coirpith incorporation. It produced 27 and 17 per cent more yield respectively compared to control (Veeraputhiran, 1996).

Jain *et al.* (2001) conducted experiments to study the response of drip and surface irrigation methods with and without mulch on potato and found that the yield for treatments irrigated with drip system at 80 per cent irrigation moisture regime in combination with plastic mulch was found to be maximum as 30.45 t ha^{-1} and minimum as 18.44 t ha^{-1} for surface irrigation at 100 per cent moisture level with out mulch.

According to Sibin (2002) mulched tomato plants under green house conditions recorded a higher fruit setting percentage of 67.23 per cent as compared to 65.93 per cent under unmulched plots. Similarly mulched plots recorded a higher fruit weight of 72.18 g while unmulched plots recorded 69.4 g.

Natarajan *et al.* (2005) studied the effect of integrated nutrient management and mulching on yield and economics of tomato hybrids under polyhouse and found that soil + FYM + coirpith medium when protected by black polythene mulch produced the highest fruit yield and recorded the best BC ratios. Singh *et al.* (2005a) reported higher vegetative growth under mulch due to more water content under plastic mulch. Similarly Singh *et al.* (2005b) also recorded earlier flowering, better plant growth parameters and more fruit yield of winter tomato under plastic mulching.

Singh (2005) studied the effect of different types of mulches on the growth and yield of tomato on the north Indian plains. Polyethylene mulches were superior to organic mulches in improving growth and yield of tomato. Early flowering, greater number of fruits per plant and larger fruits were also observed with black and clear polyethylene mulches which resulted in 57.5 and 40.7 per cent higher fruit yield respectively over unmulched conditions.

Awasthi *et al.* (2005) studied the growth and yield of brinjal under different types of mulching in arid condition. Treatments which received black and clear polythene mulches produced more number of fruits per plant and significantly higher yield over control. In black polythene mulched plots, average fruit yield was 832 g per plant and the corresponding yield under clear polyethylene and unmulched control were in the order of 596 and 135 g, respectively. Under different organic mulches the yield per plant varied from 270-400 g.

Aruna *et al.* (2007) studied the effect of fertigation and mulching on the growth and yield of tomato at the Horticultural College and Research Institute, Periyakulam. They recorded higher plant height, early flowering, increased number of fruits per plant and higher fruit yield under black polythene mulching.

2.7 The comparative efficiency of micro irrigation in vegetables

In micro irrigation water is applied to the root zone of the crops through different kinds of emitters. Since the water is applied directly to the root zone, losses due to seepage, percolation and evaporation are greatly reduced. The water-saving ranges from 30 to 70 per cent. With the saving of available water, the irrigated area can be extended by 2 to 4 times. As, there is no need for constructing channels, labour for irrigation and weeding can be saved by 60 to 90 per cent. As plants are not exposed to any stress due to water scarcity at any stage of growth, there will be ideal moisture/oxygen relationship resulting in increased yields. Since only the root zone of the plants receive moisture, widespread of weed growth is inhibited. The reviews on the beneficial effects of micro irrigation in vegetables are given below.

Goldberg *et al.* (1976a) studied comparative effect of irrigating tomato on sandy dunes of northern Senai (Israel) under drip and sprinkler irrigation systems and found that the water use efficiency was high in drip system. Singh and Singh (1978) reported that drip irrigation gave highest water use efficiency (WUE) in round gourd (5.10 q ha-cm^{-1}) and watermelon (10.3 q ha-cm^{-1}) than furrow irrigation system (3.70 q ha-cm^{-1}) and (8.40 q ha-cm^{-1}), respectively.

Sivanappan and Padmakumari (1978) working on brinjal crop reported that only 24 cm of water was used under drip irrigation compared to 69 cm under furrow irrigation and yields (18,750 kgha^{-1}) were higher in drip irrigated plot due to more number of branches compared to furrow irrigation.

According to Srinivas (1986) in watermelon drip irrigation provide about 54 per cent increase in water use efficiency compared to furrow irrigation. Ramesh (1986) working on green chilli observed that irrigation at 0.6 Ep with drip method gave significantly higher water use efficiency (20.86 kg ha-cm^{-1}) compared to furrow irrigation (15.64 kg ha-cm^{-1}), which was due to higher yield under drip irrigation.

Goyal *et al.* (1987) conducted a study on the response of sweet pepper to drip, micro sprinkler, furrow irrigation and no irrigation along with plastic mulching during winter and summer seasons, crop received irrigation at soil moisture tension of 0.015 to 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 gross applications and net irrigation requirement.

According to Yadav *et al.* (1989) in watermelon, water use efficiency was higher with irrigation at 83 mm cumulative pan evaporation. Selvaraj and Ramamoorthy (1990) reported that, the consumptive use of water was higher at 1.0 IW/CPE ratio, but the water use efficiency was higher at 0.4 IW/CPE and 0.6 IW/CPE ratios, however the yield was highest at 1.0 IW/CPE as compared to 0.6 IW/CPE ratio.

Chartzoulakis and Michelakis (1990) conducted a study on the effect of furrow, microtube, drip, porous clay tube and porous plastic tube irrigation system on cucumber. Average fruit yield plant^{-1} (5.03 kg) and number of fruits plant^{-1} were higher in porous plastic tube irrigation system. Water use efficiency for harvested yield was highest with drip system and lowest with furrow (27.7 and 16.8 kg m^{-3} respectively).

Srinivas and Hegde (1990) reported higher WUE with drip irrigation (48.60 kg ha-cm^{-1}) compared to 43.10 kg ha-cm^{-1} with basin irrigation in banana crop. This was due to higher total dry matter, bunch weight and higher total nutrient uptake viz., nitrogen, phosphorus and potassium.

Hapase *et al.* (1990) studied response of sugarcane to different methods of irrigation *viz.*, furrow, drip and sub-surface drip with daily and alternate day irrigation, with paired row method of planting and conventional method of planting. They reported that micro irrigation systems recorded higher irrigation water saving to the extent of 50 to 55 per cent, increase in yields from 12 to 37 per cent and three fold increase in water use efficiency (160.10 kg ha-cm^{-1}) compared to furrow irrigation (64 kg ha-cm^{-1}).

According to Jahdav *et al.* (1990) in tomato, WUE was higher with drip irrigation (2.16 t ha-cm^{-1}) compared to 0.98 t ha-cm^{-1} with flood irrigation. This was due to higher tomato yield and lower water use (22.20 cm of water) when compared to high water use (32.40 cm of water) with flood irrigation. The yield under drip (48 t ha^{-1}) was 50 per cent more in comparison to flood irrigated crop (32 t ha^{-1}). Irrigation water saving was to the tune of 31.5 per cent with drip.

Prabhakar and Naik (1993) reported that, with the increase in the level of replenishment of pan evaporation from 60-120 per cent, the seasonal evapotranspiration of cucumber increased from 282 mm to 360 mm with corresponding increase in water use efficiency from 64 to 101 kg ha-mm^{-1}.

Gupta and Acharya (1994) reported that the use of black polyethylene mulch was superior to that of transparent polyethylene on strawberry. Water use efficiency in terms of fruit yield per centimetre of water used was maximum under the black polyethylene.

Pandey *et al.*, (1995) conducted studies to see the effect of micro sprinkler and furrow irrigation on yield and water requirement of potato and micro sprinkler method recorded highest yield and 22.82 per cent water saving over furrow irrigation. Sunilkumar (1998) reported that under drip irrigation system crop water use efficiency enhanced by 289, 218 and 311 per cent at the irrigation schedules of 0.04, 0.06 and 0.08 MPa, respectively in okra.

Prabhakar and Hebbar (1996) observed that 40 per cent saving of irrigation water with drip irrigation compared to furrow irrigation in watermelon. Aziz *et al.* (1998) on the study of the effect of soil conditioning and irrigation on chemical properties of sandy soils of Inshas, Egypt on cucumber production and water use efficiency, concluded that drip irrigation was the best method for water management, higher cucumber yield, water conservation and water use efficiency. Studies conducted on KAU micro sprinkler reveals that a large increase in yield of bitter gourd (4.31 t ha^{-1}) is possible with micro sprinkler irrigation as compared to drip irrigation (2.98 t ha^{-1}) (Kerala Agricultural University,1996).

According to Kunzelmann and Paschold (1999) pickling cucumber (*Cucumis sativus*) was grown under drip (1 l hr^{-1} and 30 cm distance controlled by tensiometers) and sprinkler irrigation (controlled by Geisenheim method) in

Germany. On a three year average, drip irrigation used 50 per cent less water than sprinklers. This study concluded that drip irrigation is the most efficient method for cucumber production.

Field experiments conducted to study the response of micro irrigation on various vegetables showed that maximum water use efficiency of 2.11 t $ha\text{-}cm^{-1}$ was achieved for tomato irrigated through drip microtube followed by drip emitter (1.89 t $ha\text{-}cm^{-1}$) and minimum for surface methods of irrigation (0.89 t/ha-cm). In potato, the higher water use efficiency of 2.26 t $ha\text{-}cm^{-1}$ was achieved for potato irrigated through drip emitters followed by drip microtube (1.74 t $ha\text{-}cm^{-1}$), micro sprinkler (1.20 t $ha\text{-}cm^{-1}$) and furrow methods of irrigation (0.96 t $ha\text{-}cm^{-1}$). Savings of water achieved for green chilli over surface irrigation was maximum (40.4%) in drip microtube followed by drip emitter (40.0%) and minimum in micro sprinkler irrigation (16.0%) (Manjunatha *et al.*, 2001b).

In an irrigation trial conducted at the research farm of the College of Agriculture, Raipur during 1999-2000, increased growth and yield parameters of tomato were observed under drip irrigation compared to flood irrigation (Agrawal *et al.*, 2004).

Rolbiecki (2004) studied the effects of drip and micro sprinkler irrigations on the growth and yield of cucumber on sandy soil in central Polland. He observed upto 85 per cent increase in fruit yield under drip and micro sprinkler irrigations compared to flood irrigation. Rekha *et al.* (2005) observed 21.25 per cent saving of irrigation water in bhindi crop as compared to furrow irrigation.

Bahadur *et al.* (2006) studied the effect of drip irrigation and surface irrigation in tomato in a study at the Indian Institute of Vegetable Research, Varanassi during 2003-2005. Results indicated that maximum number of fruits, fruit weight, total fruit yield and marketable fruit yield were in drip irrigation at 100 per cent ET_0 and it saved 45.8 per cent water compared to surface irrigation.

2.8 Nutrient uptake and its composition as influenced by mulch and irrigation

The N, P, and K contents of cucumber and tomato leaves during different phases of growth were determined by Grozdova (1970). He found that cucumber required higher N dose from the time of flower bud formation until the end of growth. The need for P increased during flower and bud formation, decreased slightly during flowering and rose again during cropping. Potassium was readily absorbed during early growth, declined during flower bud formation and then rose again.

The total uptake of N, P and K by pickling cucumbers was 90, 12 and 145 lb acre^{-1} respectively and the nutrients removed by the harvested fruits was 40, 6 and 55 lb per acre^{-1}, respectively (Mc-Collum and Miller, 1971). The percentages of N and P in the plant tissue were highest after maximum application of the respective nutrients irrespective of the irrigation frequency (Jassal *et al.*, 1972).

Wilcox (1973) determined the leaf N content and related it to yield. Optimum leaf total N composition in relation to yield was 4.5 per cent and the optimum petiole nitrate N composition was over 1500 ppm during plant growth and fruit formation stage in muskmelon.

According to Rauchkolb *et al.* (1978) a significantly higher P content was measured in trickle irrigated tomato over surface irrigation method. The highest P uptake recorded in most frequent drip irrigation with more quantity of water (Bar-Yosef *et al.*, 1980).

While studying the effects of irrigation, Gamayun (1980) observed that a moisture regime of 80 per cent of the field capacity was ideal for the maximum uptake of N, P and K by tomato than 60 and 70 per cent of field capacity.

Bar-Yosef and Sagev (1982) found that N uptake increased with increase in N application rate upto the optimum level. Other study showed that, the N application rate was having linear relationship with N uptake in drip irrigation system. Nitrogen uptake was markedly influenced by frequency as well as timing of irrigation (Stark *et al.,* 1983).

According to Panchalingam (1983) N, P and K content of leaves and uptake in brinjal became reduced as the soil water deficit increased. Goyal *et al.* (1984) found significant influence of trickle irrigation on K uptake in tomato. In other study irrigated pumpkins accumulated more N, P and K than dryland pumpkins (Swiader, 1985).

The studies conducted at Agronomic Research Station, Chalakudy, revealed that N and P content of bittergourd leaves and stems were not affected by water management practices during any of the growth stages. However, the leaves on the 55^{th} day recorded a significantly higher value which was not visible at the final harvest. N, P and K uptake followed the trend more or less similar to that of dry matter production at all the growth stages (Thomas, 1984).

Swiader (1985) found mat the concentration of N, P and K in foliage generally decreased as pumpkin age increased, similarly the concentration of all nutrients decline with fruit maturity in watermelon (Hedge, 1987a).

Hegde (1987b) showed that irrigating watermelon when the soil matric potential at 15 cm depth reached -25 KPa compared with -50 and -75 KPa resulted in the highest mineral uptake of 51.82, 9.67, 50.28, 30.67 and 8.17 kg of N, P, K, Ca and Mg per ha respectively. In watermelon, frequent irrigation with 100 per cent pan evaporation replenishment resulted in the highest N, P, K, Ca and Mg uptake (Srinivas *et al.,* 1989).

Hegde and Srinivas (1990) reported that the total N uptake and its distribution in to different parts was higher with irrigation at a soil matric potential of -40 KPa while it was the lowest with less frequent irrigation at -85 KPa.

The K concentration of summer grown cucumber leaves and the corresponding soil samples were lower than the optimum level (Choliaras and Mavromatis, 1991). Roppongi (1991) found that with the rapid growth of cucumbers, the optimum levels of nitrate N in petioles were 800-200 ppm at the mid harvest and 100-300 ppm during the late stage of the harvest, while with slower growth the optimum level was 1000-2000 ppm for all the stages.

In the studies conducted at northern territory, Australia using watermelon, Smith (1991) observed that the peak N uptake occurred around 46 days after planting coinciding with fruit-set and rapid increase in ground cover. According to Drews and Fisher (1992), the standard press sap composition of cucumber nitrate N was 1000-16000 mg I^{-1} and for K it was 4000-5500 mg I^{-1}.

Experiments conducted at the Agronomic Research Station, Chalakudy revealed that the consumptive use, and the ratio of evapotranspiration to the pan evaporation (Et/Eo) values of bitter gourd increased progressively with levels of nitrogen and irrigation. Where as, water use efficiency of the crop, maintained a positive relation with levels of nitrogen and negative relation with levels of irrigation (Thampatti *et al.*, 1993).

According to Bhargava and Raghupathi, (1993) if the values of nutrient concentration obtained from leaves of cucumber for N, P, K, Ca and Mg are 1.6-1.9, 0.15-0.17, 0.9-1, 0.10-0.19 and 0.08-0.09 per cent respectively it is low. If the above values are (2-2.6, 0.18-0.30, 1.10-1.80, 0.2-0.5 and 0.10-0.35) per cent respectively, it is sufficient (optimum). Whereas the values are greater than (2.6, 0.3, 1.8, 0.5 and 0.35) per cent respectively, it indicates higher level of concentration. The values of nutrient concentration obtained from the analysis indicate the composition and nutritional level of the plant at the time of sampling by comparison with such pre-established standard norms.

Bafna *et al.* (1993) reported that a significantly higher total N uptake by different parts of tomato plant was recorded under drip irrigation over conventional irrigation. The N concentration of petiole sap of cucumber increased with leafage (Schacht and Schenk, 1994).

Petsas and Lulakis (1995) conducted a nutrient uptake study in muskmelon cv. *Galia-71* in cold green house. They observed that for the production of approximately 5.2 kg fruit per plant, 10.97 g N, 2.67 g P, 21.20 g K, 15.08 g Ca and 4.68 g Mg plant^{-1} were taken up by the plant. They also found that N, P and K uptake was most intense between 10 and 12 weeks after planting, when fruit production was maximum but Ca and Mg uptake was most intense between four to six weeks after planting when vegetative growth was greatest. P and K uptake of greenhouse cucumbers were in a constant ratio to N uptake during the whole growing period and there was no constant relationship between water and N uptake (Schacht and Schenk, 1995).

Veeraputhiran (1996) in a field study of irrigation and sub-surface moisture conservation in cucumber revealed that N, P and K content of leaves were significantly higher in plants which received incorporation of paddy waste. Higher levels of irrigation also markedly increased the N and K content of leaves upto 45 DAS and P content upto 75 DAS. Decomposable mulch is effective in increasing the N, P, and K content of leaves. Similarly drip irrigation is also effective in raising the NPK content of leaves. A soil moisture regime of 80 per cent of field capacity is ideal for maximum uptake of nutrients by plants.

Gebremedhin (2001) reported significant increase in N, P, and K content of oriental pickling melon when mulched with paddy waste or black polythene. Similarly NPK contents increased in drip irrigation till 100 per cent Ep. Kaya *et al.* (2005) observed improved nutrient availability and uptake by cucumber when irrigation was combined with black polythene mulching.

2.9 Economic feasibility of mulch-cum-micro irrigation for vegetables

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.

Rajagopallan *et al.* (1989) in an experiment conducted in watermelon and cucumber grown in summer rice fallow at the Regional Agricultural Research Station, Pilicode revealed that irrigation at IW/CPE ratio 0.5 had the maximum BC ratio for both the crops.

Jahdav *et al.* (1990) studied the economic feasibility of the drip irrigation systems for tomato crop. The benefit cost ratio of drip system was found to be 5.15, while it was 2.96 for conventional flood method the yield under drip (48 t ha^{-1}) was 50 per cent more in comparison to flood irrigated crops (32 t ha^{-1}). Irrigation water saving was to the tune of 31.5 per cent with drip. It was also reported that, a 20 per cent saving in weeding cost could be achieved by the use of black LDPE film mulching in brinjal.

Water management and fertiliser studies conducted at the College of Agriculture, Vellayani showed that scheduling, irrigation (5 cm depth) when the CPE values reached 25 mm was the most economic management practice for cucumber raised in summer rice fallow (Kerala Agricultural University, 1991).

According to Satpute and Pawade (1992) the two plant drip layout resulted in 35-41 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.

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.

Results of the studies of Singh and Suraj Bhan (1993) revealed that maximum return of Rs. 7,501 ha^{-1} obtained by the use of plastic mulch in cotton was closely followed by maize stover mulch (Rs. 7,188 ha^{-1}).

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 was economically preferable.

Salvi *et al.* (1995) reported that, highest fruit yield (15.03 tonnes/ha) net monetary return (Rs. 46,772 ha^{-1}) and benefit: cost ratio (2.75) were obtained when irrigation was scheduled at 25 mm CPE in combination with 150 kg N ha^{-1} on latteritic soil of Konkon in bell pepper *(Capsicum annuum* L. var. grossum sendt).

Veeraputhiran (1996) reported that, incorporation of paddy waste, coirpith and saw dust in oriental pickling melon increased net profit by Rs. 27,697.99 (68%) for paddy waste, Rs. 13, 958.99 (34%), for coir pith and Rs. 4,254.74 (10%) ha^{-1} for saw dust over control.

Hugar (1996) noted that the BC ratio was much higher in tomato under drip irrigation when the water so saved was assumed to be utilized to cover additional area of the same crop than conventional irrigation.

Sunilkumar (1998) in an irrigation study in bhindi at Agricultural Research Station, Mannuthy, maximum BC ratio of 1.58 was derived when the crop was mulched and irrigated at soil moisture tension of 0.08 MPa. Asokaraja (1998) recorded higher discounted benefit cost ratio of 9.89 due to drip than surface irrigation (5.44) in tomato.

Wilks and Wolfe (1998) in an investigation of the problem of analysing a sequence of daily irrigation decisions utilising weather forecast information was formulated for lettuces grown in Central New York State, USA, and solved using a stochastic dynamic programming algorithm. The results suggested that irrigation was quite viable even in the relatively humid climate of New York. The annual economic value of irrigation verses no irrigation was estimated at ≈ \$ 4000-5000 ha^{-1} for lettuces. Optimal use of weather forecasts to schedule irrigation was estimated to increase annual value by \$1000 ha^{-1} year^{-1}.

Manjunatha *et al.* (2001c) reported that income generated from brinjal production was maximum for micro sprinkler irrigation followed by drip microtube, drip emitter and surface method in the descending order. The highest income achieved through micro sprinkler irrigation was due to production of more yield compared to other treatments.

Natarajan *et al.* (2005) reported highest fruit yield and BC ratio of tomato grown in polyhouse when water soluble fertilizer was applied at 250 kg NPK ha^{-1} through drip and mulched with black polythene. Results of studies of Aruna *et al.* (2007) revealed that mulching with black polythene and fertigation with recommended NPK recorded highest fruit yield and net return in tomato in a study conducted at Horticulture College and Research Station, Periyakulam.

Among the irrigation systems drip provides the highest benefit-cost ratio. Mulches alone or in combination with drip irrigation are capable of providing a favourable BC ratio to the cultivator.

Materials and Methods

MATERIALS AND METHODS

A field experiment on micro irrigation and mulching in oriental pickling melon (*Cucumis melo* var. *conomon* (L.) Makino) was conducted during the summer season (7th December to 8th March) of 2004-2005 in the summer rice fallow of Agricultural Research Station, Mannuthy. The details of the material used and the techniques adopted during the course of this investigation are presented below.

3.1 Location

The experiment site has a typical warm humid tropical climate. It is situated at 12°32' N latitude and 74°20'E longitude at an altitude of 22.5 m above mean sea level in the Agricultural Research Station Farm, Mannuthy, Thrissur district, Kerala.

3.2 Cropping history

The experimental site is a double crop paddy wetland in which a semi-dry crop (April to September) and a wet crop (September to December) are regularly cultivated. The land is usually left fallow during the summer season.

3.3 Soil characteristics

Composite soil samples from 0-60 cm depth were taken before the commencement of the experiment and used for the determination of the physio-chemical properties and the details are given in Table 1.

3.4 Climate and weather data

The experiment was conducted during the summer season of 2004-05. The daily data on different weather elements viz; maximum and minimum temperature (°C), sunshine hours, relative humidity (%), wind speed (km hr-1), mean evaporation (mm day-1) and rainfall (mm) were collected from the Principal

Table 1. Soil characteristics of the experimental field

Particulars	Value	Procedure adopted
1) Mechanical composition		
Coarse sand (%)	27.1	
Fine sand (%)	23.9	
Silt (%)	22.8	Robinson's International pipette method
Clay (%)	26.2	(Piper, 1950)
Textural class	Sandy clay loam	
		I.S.S.S. system (SSS, 1992)
2) Physical constants of the soil		
Field capacity (0.3 bars)	21.82	Pressure plate apparatus (Richard, 1947)
Permanent wilting point (15 bars)	9.34	Core method (Blake, 1965)
Bulk density (g cm^{-3})	1.34	
0-30 cm	1.36	
30-60 cm	2.16	Pycnometer method (Blake, 1965)
Particle density (g cm^{-3})		
3) Chemical properties		
Organic carbon (%)	0.43	Walkley and Black rapid titration method (Jackson, 1973)
Available nitrogen (kg ha^{-1})	233.4	Alkaline permanganate method (Subbiah and Asija, 1956)
Available phosphorus (kg ha^{-1})	15	Bray-1 extractant – Ascorbic acid reductant method (Soil survey staff, 1992)
Available potassium (kg ha^{-1})	55	Neutral normal ammonium acetate extractant – flame photometry (Jackson, 1973)
Soil reaction (pH)	5.4	1:2.5 soil : water suspension using pH meter (Jackson, 1973)
Electrical conductivity (dS m^{-1})	1.25	Supernatant of 1:25 soil : water suspension using EC bridge (Jackson, 1973)

Agro-meteorological Station of the College of Horticulture, Vellanikkara for the crop period from December, 2004 to March, 2005. The details are given in Table 2 and Fig. 1.

3.5 Crop and variety

The crop used for the investigation was oriental pickling melon (*Cucumis melo*), variety Mudicode (*conomon* (L.) Makino). The plants have green pubescent and angular stem. The leaves are orbicular with slightly serrated margin and blunt tip. The fruits are long and oval, golden yellow in colour.

3.6 Experimental details

3.6.1 Layout

The layout plan of the experiment is given in Fig. 2 and in Plate Ia. The details are presented below:

Design	: Randomised Block Design (RBD)
Replications	: 3
Number of treatments	: 15
Total number of plots	: 45
Plot size	: 4 x 3m
Spacing	: 2 x 1.5m
Number of plants per pit	: 4
Number of pits per plot	: 4
Systems of irrigation	: Micro irrigation and basin method
Effective root zone	: 60 cm depth and 75 cm radius
Date of Sowing	: 19th December 2004
Date of Harvest	: 7th March 2005

Table 2. Mean weekly weather parameters of the crop growth period (December 2004 – March 2005)

Standard week no.	Month and date	Surface air temperature (^{0}C)		Relative humidity (%)		Wind speed (km hr^{-1})	Sunshine (hrs day^{-1})	Evaporation (mm)	Rainfall (mm)	Soil temperature (15 cm depth)	
		Max.	Min.	Morning	Evening					Morning	Evening
	2004										
50	December 10-16	31.9	24.2	66	47	10.1	8.4	6.6	-	26.7	33.6
51	December 17-23	32.0	20.3	73	36	5.4	8.9	4.8	-	24.9	33.6
52	December 24-31	32.5	23.2	63	42	8.0	8.5	6.4	-	26.5	34.7
	2005										
1	January 1-7	32.8	23.1	69	41	7.1	8.4	5.6	-	26.9	34.8
2	January 8-14	32.8	21.2	64	32	5.6	8.4	5.4	-	25.4	34.1
3	January 15-21	33.5	22.3	75	38	7.2	9.6	5.6	-	26.6	35.0
4	January 22-28	34.3	23.2	74	41	5.4	8.6	5.3	-	27.7	36.8
5	Jan. 29- Feb. 4	33.2	23.2	81	48	5.2	7.8	4.7	-	27.0	35.8
6	February 5-11	34.5	20.4	64	27	8.4	10.2	7.8	-	26.9	37.0
7	February 12-18	34.9	21.1	60	41	4.9	10.1	6.0	-	26.2	37.3
8	February 19-25	35.4	23.0	80	36	4.3	10.0	5.7	-	29.1	39.5
9	Feb. 26- Mar. 4	37.0	22.2	78	26	4.6	10.2	6.7	-	28.4	39.7
10	March 5-11	35.4	24.5	83	46	4.1	8.4	5.7	-	30.6	41.4

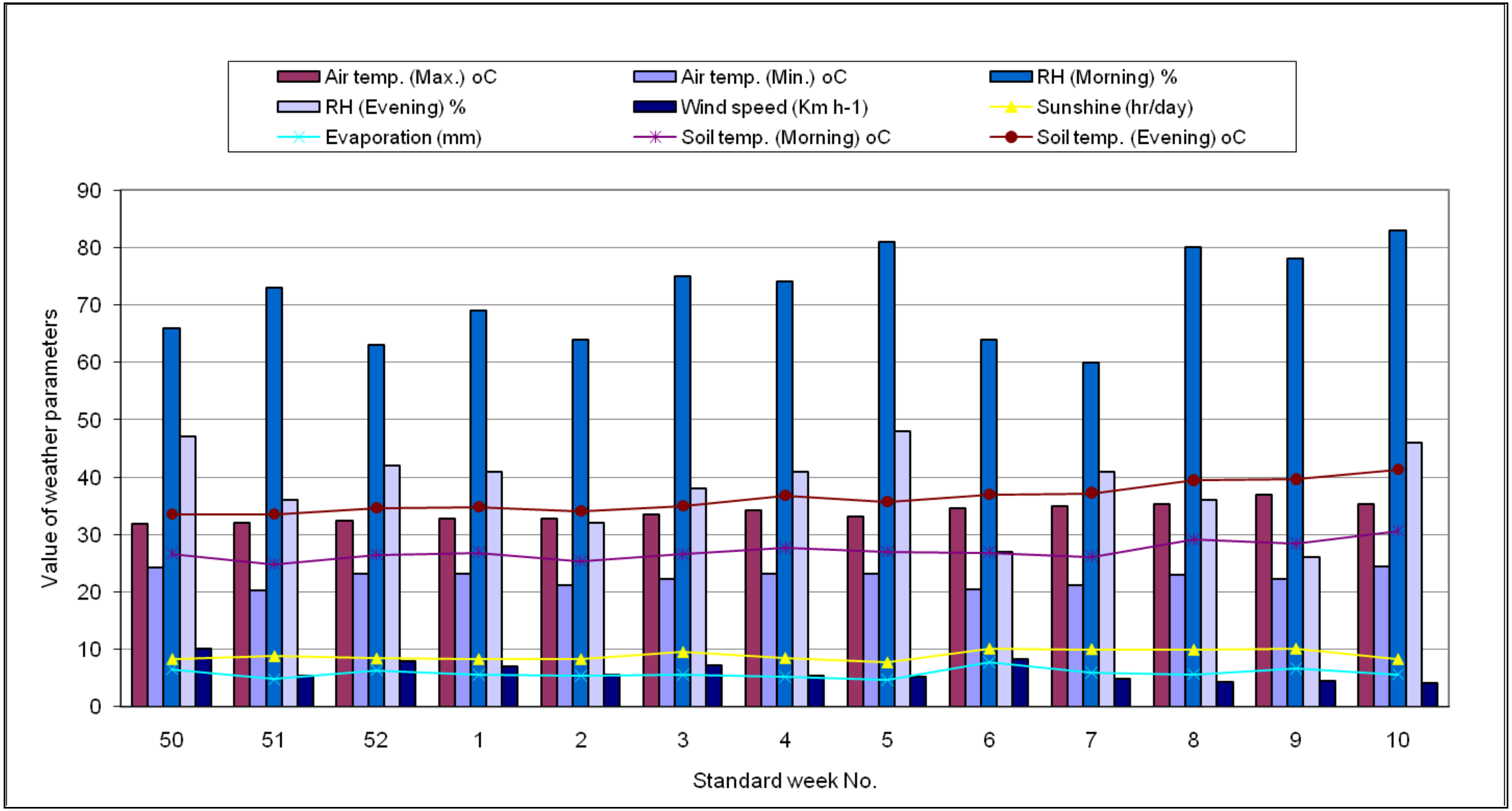


Fig. 1. Mean weekly weather parameters for the crop growth period (December, 2004 – March, 2005)

Fig. 2. Lay out plan of the experiment

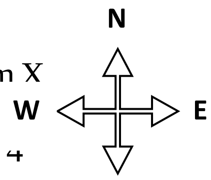
Distance between plots = 1.5m X 2m

Distance between Replications = 3m

Distance between micro irrigation and basin method = 6m

Plot size = 3m X 4m

Number of pits per plot = 4



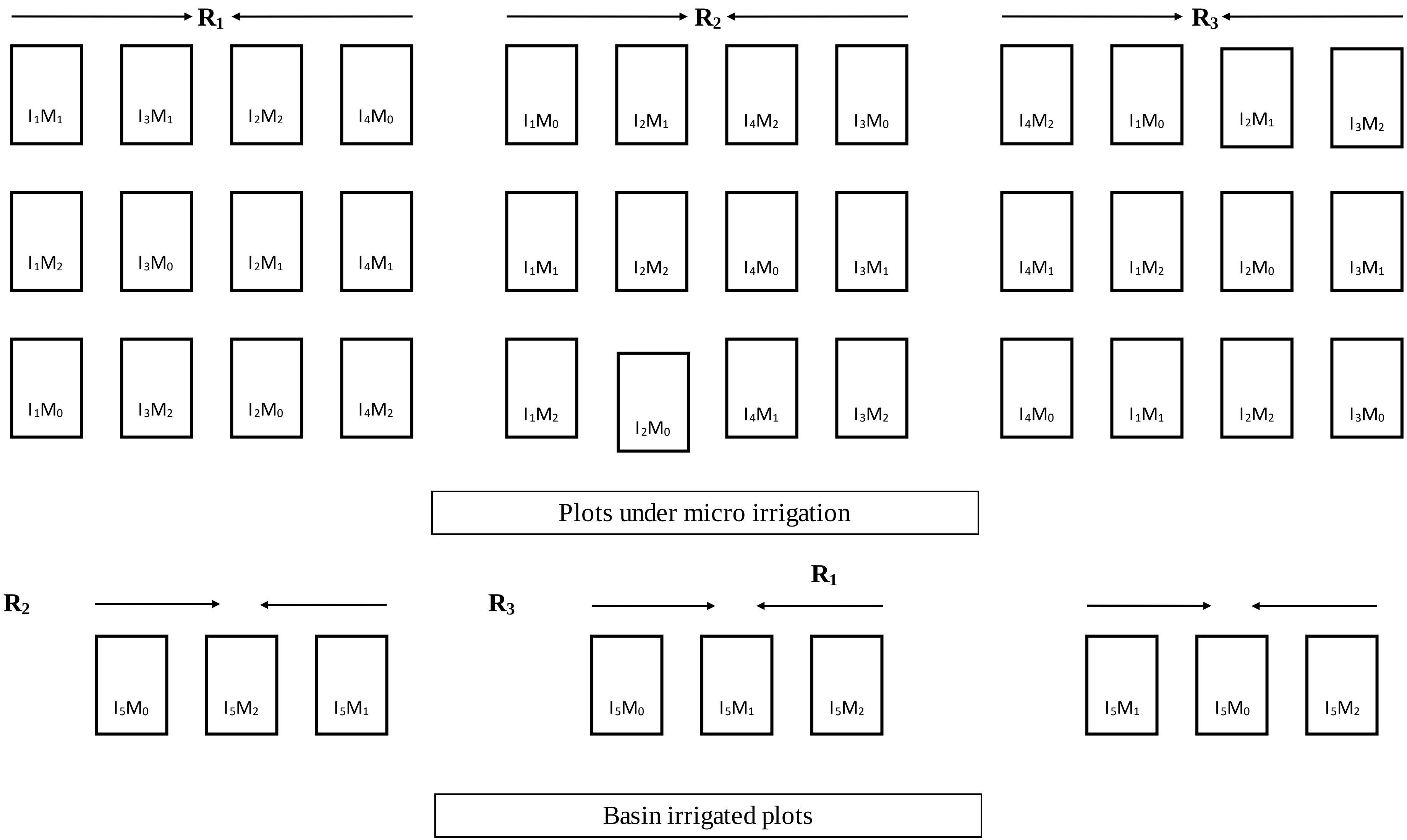


Plate Ia. Field layout preview

Plate Ib. Drainage channel preview

3.6.2 Treatments

The treatments consisted of combinations of five irrigation methods and three levels of black polythene mulching. The details are given below.

3.6.2.1 Irrigation methods

I_1: Drip irrigation

I_2: Irrigation through microtubes of drip system without drippers

I_3: Irrigation through bubblers instead of drippers (KAU micro sprinkler)

I_4: On-line wick irrigation through laterals of drip system

I_5: Basin irrigation @ 45 l pit^{-1} once in three days (Farmer's practice as control)

The quantity of water for daily irrigation for all treatments except I_5 is 50 per cent of pan evapo-transpiration (Ep).The Ep taken into account on any day will be the Ep recorded in the previous day.

3.6.2.2 Levels of black LDPE mulching

M_0: No mulching

M_1: Mulching the basins (to a radius of 60 cm)

M_2: Mulching in the entire area

3.6.2.3 Combination of treatments

I_1M_0	I_2M_0	I_3M_0	I_4M_0	I_5M_0
I_1M_I	I_2M_1	I_3M_1	I_4M_1	I_5M_1
I_1M_2	I_2M_2	I_3M_2	I_4M_2	I_5M_2

3.7 Crop husbandry

3.7.1 Land preparation

The experimental field was ploughed using tractor drawn disc plough to break the soil. Then cultivator was passed over to crush the clods and to bring soil to fine tilth. The plots were laid out as per the plan and pits of 60 cm depth and
60 cm diameter were taken manually at 2 x 1.5m spacing and soil was spread evenly within the plots. For controlling seepage of water from surrounding fields and keeping the ground water below the root zone depth, 45 cm wide and 75 cm deep drainage channels were dug around the experimental field (Plate Ib).

3.7.2 Manure and fertilizer application

Farmyard manure at the rate of 20 t ha^{-1} was applied uniformly in all the pits as basal dose. After thoroughly mixing with topsoil the pits were filled fully. Fertilisers were applied as per package of practices recommendations of Kerala Agricultural University (2002) at 70:25:25 kg N, P_2O_5 and K_2O ha^{-1} in the form of urea, Rajphos and Muriate of potash, respectively. Half of recommended nitrogen and entire dose of phosphorus and potassium were applied as basal dose at the time of sowing. The remaining 50 per cent nitrogen was applied in two equal split doses at the time of vining and at the time of full blooming.

3.7.3 Sowing

Sowing was done on 19th December 2004. Six seeds per pit were sown uniformly. Thinning was done on 20th day after sowing by retaining only four healthy plants per pit.

3.7.4 Irrigation

A pre-sowing irrigation was given uniformly to all the pits. After sowing, daily light irrigation with rose can was given at 5 litres pit^{-1} for 10 days. There after irrigation was done on alternate days at 10 litres pit^{-1} upto 19th day after sowing. Irrigation as per the treatments was started from the 20th day after sowing when the plants were well established. Micro irrigation was given every day based on the evaporation value of the previous day and 50 per cent of Ep was given for all the treatments except control.

The required amount of water was provided through single emitter pit^{-1}. There were 24 rows of cucumber pits, each of which containing six pits. One storage tank of 500 1 capacity was kept on platform of one metre height above ground. The tank was installed to provide water for irrigation through drippers, microtubes and online wicks. The tank was constantly kept filled with water by connecting to the pumping line. The inside end of the outlet of the tank was covered with wire mesh to filter out the impurities from entering into the pipe system. The tank was connected to a main line made of rigid PVC pipe having three inch diameter and 22 m length. To the main line 18 laterals made of LDPE having 12 mm internal diameter were connected at appropriate intervals. Each lateral was laid out to irrigate one row of plants having six pits. For each line of lateral a separate control valve was provided at the beginning. Everyday at 7 am all the 18 taps were opened. Once the required quantity of water was applied, the tap of that particular treatment was closed.

In case of irrigation through drippers and micro-tubes laterals were laid between two rows of pits and water was applied at the center of the pit by using 4 mm LDPE micro-tubes. The discharge rate of single dripper was two litres $hour^{-1}$ and the discharge through micro-tubes was maintained at a rate of 20 litres $hour^{-1}$ by using a regulator at the connecting point of micro-tubes to the laterals.

The bubblers were operated at pumping pressure by connecting the mainline directly to the pumping line. At this time all the connections to laterals of other treatments were kept closed. The discharge rate of bubblers was 60 litres $hour^{-1}$.

In case of online wick method, laterals were laid over each row of pits and cotton wicks were fixed into the small holes made on the laterals at the center of each pits. The discharge through wicks was four litres $hour^{-1}$.

In basin irrigated control, measured quantity of water @ 45 l pit^{-1} was constantly given once in three days. The details of irrigation schedule and quantity of water used are given in Table 3.

3.7.5 After cultivation

No hand weeding was done in the mulched plots and twice in the non-mulched plots.

3.7.6 Mulching

Mulching was done at the time of planting. Black LDPE polyethylene sheet of 100 μ thick was used as mulching material. In case of basin mulching, black polythene sheet was used to cover the basin to a radius of 60 cm. In the treatment M_2, the polythene sheets were covered in the entire area including the interspaces. During mulching small holes were made in the polythene sheets for passing through each plants and water emitters. When the plants started to vine, the inter-spaces between the plants were covered uniformly with dried coconut leaves.

3.7.7 Plant protection

Carbaryl 50 per cent WP were sprayed 10 and 20 DAS as prophylatic measure against the attack of red pumpkin beetle and termite. At fruit development stage attack of mites and fruit flies were brought under control by spraying Dicofol and Dimecron at 0.05 per cent.

Table 3. Total quantity of water used for the different irrigation treatments

Treatments	Irrigation interval	Quantity of water used			Total quantity of water applied (mm)
		Pre-treatment irrigation (mm)	Irrigation as per treatment (mm)	Effective rainfall (mm)	
$\mathbf{I_1}$	Daily	106.6	171.5	-	278.1
$\mathbf{I_2}$	Daily	106.6	171.5	-	278.1
$\mathbf{I_3}$	Daily	106.6	171.5	-	278.1
$\mathbf{I_4}$	Daily	106.6	171.5	-	278.1
$\mathbf{I_5}$	Once in 3 days	106.6	509.5	-	616.1

3.7.8 Harvesting

Fruits were harvested when they were fully mature (when they got dark golden yellow colour). This was judged by visual appearance. All fruits w harvested in a single stage at 78 DAS on 7th March 2005.

3.8 Soil moisture studies

3.8.1 Soil sampling

Soil samples were collected using a tube auger. Sampling was done at depths of 0-15, 15-30 and 30-60 cm at horizontal distances of 15, 30, 45 and 60 cm at weekly interval. Soil moisture content was determined gravimetrically after oven drying the samples at 105°C till constant weight was attained. After taking the weights of dry-soil, the loss of moisture was estimated and expressed as percentage of oven dry soil. The moisture percentage was found out for the entire layer 0-60 cm, by taking the mean of the soil moisture percentages of the layers and the same was used to find out the extend of depletion.

3.8.2 Consumptive use of water

Consumptive use of water was estimated based on water balance model is described below:

$$I + P + S_i + G_i = E + S_o + G_o + \Delta St$$

where,

I	:	Irrigation water supplied
P	:	Precipitation
S_i	:	Surface water inflow
G_i	:	Ground water inflow
E	:	Evapotranspiration
S_o	:	Surface water outflow
G_o	:	Ground water outflow
ΔSt	:	Change in storage

Since there was no surface water flow and the ground water in the field was below three meters from the surface S_i, S_o, G_i and G_o were neglected in the equation. Change in storage (ΔSt) was worked out based on the gravimetric content upto the root depth of 60 cm. Irrigation water was worked out by directly adding water applied in to the soil. Only the part of the precipitation, which was effective, was considered to account for P. During the experimental period, since there was no precipitation, the equation is reduced to:

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

The moisture percentage obtained from gravimetric method was converted into cm of water to a particular depth of soil by using the formula below:

$$\text{Depth of water (cm)} = \sum_{i=1}^{n} \frac{M_i}{100} \times BD_i \times D_i$$

where,

n = number of soil layer

M_i = Moisture per cent in the i^{th} layer

BD_i = Bulk density (g/cc) of the i^{th} layer

D_i = Depth (cm) of i^{th} layer

The total amount of water used from sowing upto 20^{th} DAS by multiplying pan evaporation value with crop factor (0.6) was taken into account for calculating the consumptive use. The seasonal consumptive use was calculated by summing up the consumptive values for each sampling interval.

3.8.3 Soil moisture depletion pattern

The average relative soil moisture extracted from each layer of 0-15, 15-30 and 30-60 cm depth for horizontal distance of 0-15, 15-30, 30-45 and

45-60 cm was estimated from gravimetric moisture content and converted into percent utilization from the total moisture used by the crop. Moisture distribution pattern was also worked out from these data.

3.8.4 Water use efficiency (WUE)

Field WUE and crop WUE were estimated by using the follow formulae and expressed as kg fruit m^{-3}.

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

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

3.8.5 Crop coefficient (Kc)

The Kc was worked out as the ratio of consumptive use to the pan evaporation during the crop growing period.

3.9 Biometric observation

For understanding the effect of the treatments on growth and development of the crop, growth and yield parameters were taken. This was done by randomly selecting and tagging four plants per plot. All growth observations were taken from the same plants. Biometric observations taken during the course of investigation were as follows.

3.9.1 Number of branches per vine

The number of branches per vine was counted from four plants per plot at harvest.

3.9.2 Length of vines

The length of vines was taken from each plot from two selected plants at 30 and 45 DAS and at harvest. The length of all the vines was measured from the base to the growth tip and the mean length of vines plant^{-1} was worked out.

3.9.3 Number of leaves per vine

The total number of leaves per vine was recorded from two plants per pit, at 30 and 45 DAS and at harvest of the crop. From this, the mean numb leaves per vine and per plant was worked out.

3.9.4 Leaf area

Number of leaves from four sample plants per plot was counted. The leaves were classified into 13 groups based on the leaf size. From each group, four leaves were taken and leaf area was determined by graph paper method. The average area leaf^{-1} was worked out and multiplied by the number of leaves in each group. Thus the total leaf area was found out by adding the leaf area of all categories and this divided by total number of leaves plant^{-1} to get the average leaf area. The average leaf area was worked out at 30 and 45 DAS and at harvest.

3.9.5 Leaf area index (LAI)

Leaf area index was found out by dividing the total leaf area by the land area occupied by the plant (Watson, 1947). It was worked out on 30 and 45 DAS and at harvest by the formula given below:

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

3.9.6 Days to first flowering

Number of days taken for first blooming of flower was recorded in all the four observational plants and average worked out.

3.9.7 Flower number and Female-Male ratio

The number of male and female flowers plant^{-1} was recorded upto 60 DAS and the ratio of female flowers to male flowers was calculated.

3.9.8 Number of fruits per plant

The fruits harvested from all the plants in a plot were counted and the average number of fruits per plant was worked out.

3.9.9 Mean length and girth of fruit

The total fruit-weight harvested from all the plants in a plot was taken and by dividing it by total number, mean weight was obtained. Randomly, four fruits having the mean weight were selected for fruit length and girth determination. The length and girth of sample fruits were recorded in centimetres and the means were worked out.

3.9.10 Mean weight of fruits

The mean weight of a fruit was calculated from total fruit yield and total number plot^{-1}.

3.9.11 Volume of fruit

Volume of fruits from each plot was found from the selected fruits having mean weight using water displacement method. The average of four fruits was worked out.

3.9.12 Fruit yield plant^{-1} and hectare^{-1}

Total weight of fruits harvested from each plot was recorded and the yield in kg plant^{-1} and yield in tonnes hectare^{-1} were worked out.

3.9.13 Plant dry matter production

The dry matter content of the plant was recorded at the time of harvest. Four plants per plot were randomly chosen and uprooted. This was then oven dried at 80 ± 5°C to a constant weight. The dry matter content was expressed as g plant^{-1}.

3.9.14 Weeds dry matter production

Weed samples were collected from one m^2 quadrat at the time of harvesting. The weed plants were removed from the soil by uprooting. After removing the adhering soil, it was oven dried at 80 ± 5°C to a constant weight. The dry matter content was expressed in g m^{-2}.

3.10 Plant analysis

Leaf samples were collected at two stages of crop viz, 35 days after sowing and at harvest. Samples were oven dried at 80 ± 5°C, ground and used for N, P and K analysis.

3.10.1 Nitrogen content

The total nitrogen content of leaf samples was determined by micro-kjeldahl method (Jackson, 1973).

3.10.2 Phosphorus content

The phosphorus content of the samples was determined using di-acid extract method (Jackson, 1973). A Klett Summerson photoelectric colorimeter was used for reading the colour intensity developed by Vanadomolybdo phosphoric yellow colour method.

3.10.3 Potassium content

The potassium content of samples was determined with di-acid extract, reading in an EEL flame photometer (Jackson, 1973).

3.11 Economics of production

The economics of production was worked out based on the input costs, labour charges and the price at which the local sellers accepted the fruits of cucumber at the time of harvest. Input costs were taken as the actual cost of the materials at the time of conduct of the experiment. Labour charges considered were the prevailing labour wages of the locality at the time of conduct of the experiment. Cost of micro irrigation systems used for the experiment was taken as one fifth of the total cost of the materials as it is assumed that they can be used at least for five consecutive crops. The cost of black LDPE was accounted only to one-third of the total cost of LDPE sheets as it is assumed that the same sheets can be used for three crops. Based on this the total cost and return was worked out. From this the net income and the net profit per rupee invested was calculated. In addition the area that can be irrigated from the saving of water was also quantified.

3.12 Statistical analysis

Analysis of variance was done separately for all the characters at different stages as per the statistical design of RBD with two factor combinations and significance was tested by ‘F’ test (Snedecor and Cochran, 1967). DMRT was used to identify homogenous group of treatments.

Results

RESULTS

The results obtained from the experiment on "Micro irrigation and polythene mulching in oriental pickling melon (*Cucumis melo* var. *conomon* (L.) Makino)" are furnished in this chapter.

4.1 Growth components

4.1.1 Number of branches per vine

The data on number of branches per vine at 60 DAS are given in Table 4 and the analysis of variance in Appendix I(a).

The results indicated that mulch and irrigation treatments had significant influence on number of branches per vine, where as their interaction was not significant [Appendix II(a)].

Application of polythene mulches (M_1 and M_2) recorded maximum number of branches per vine and was significantly superior to treatment with no mulch (M_0). Among mulching, full mulching (M_2) recorded highest number of branches (4.93) though it was at par with basin mulching (4.53).

Among irrigation treatments, highest number of branches per vine was recorded in I_5 (basin irrigation) and it was at par with all other treatments except I_1 (drip irrigation), which was significantly inferior to others.

In general, effect of polythene mulch was significant on number of branches per vine over unmulched control. Among irrigation treatments all treatments except I_1 had significantly higher number of branches per vine.

4.1.2 Average length of vines

The data on average length of vines plant-1 at growth stages of 30, 45 DAS and at the time of harvest are given in Table 5 and the analysis of

Table 4. Influence of mulch and irrigation on number of branches per vine at 60 DAS

Treatments	Number of branches
Mulch	
M_0	3.87 [b]
M_1	4.53 [a]
M_2	4.93 [a]
Irrigation	
I_1	3.78 [b]
I_2	4.33 [ab]
I_3	4.56 [a]
I_4	4.56 [a]
I_5	5.00 [a]
Interaction	NS

Figures with same alphabets in superscript do not differ significantly at 5 % level in DMRT

Table 5. Average length of vines (cm) as influenced by mulch and irrigation at different growth stages

Treatments	30 DAS	45 DAS	Harvest
Mulch			
M_0	42.1^c	127.3^c	171.2^c
M_1	45.3^b	132.9^b	177.9^b
M_2	49.0^a	138.1^a	183.1^a
Irrigation			
I_1	41.4^b	128.4^c	170.0^c
I_2	47.0^a	127.2^c	170.4^c
I_3	48.3^a	136.9^{ab}	184.3^a
I_4	41.2^b	131.6^{bc}	177.9^b
I_5	49.2^a	139.7^a	184.4^a
Interaction	NS	NS	NS

Figures with same alphabets in superscript do not differ significantly at 5 % level in DMRT

variance in Appendix I(b). The results indicated that mulches and irrigation types had significant effect on vine length plant^{-1} at all growth stages. But their interaction was not significant [Appendix II(a)].

At all stages of observation, vine length was significantly the higher under full mulching (M_2). Vine length under basin mulching (M_1) was significantly higher than control at all growth stages.

Among irrigation methods, highest vine length was observed with I_5 at all growth stages. At 30 DAS it was at par with I_2 and I_3, at 45 DAS and at harvest it was at par with I_3. Vine length was comparatively lesser in I_1 and I_2 at different growth stages.

In short, the results indicated the significant effect of full mulching of the interspaces on vine length. Among the irrigation methods, farmer's practice of basin irrigation (I_5) recorded the highest value and was at par with bubbler irrigation (I_3).

4.1.3 Number of leaves per vine

The data on number of leaves per vine taken at various stages of growth are given in Table 6 and the analysis of variance in Appendix I(c).

The result indicated that mulching had significant influence on number of leaves at all the growth stages taken and irrigation treatments had significant influence at growth stages of 30 and 45 DAS only. At harvest the influence was statistically not significant. Their interaction also was not significant at any of the growth stages [Appendix II(a)].

Application of full mulch (M_2) recorded maximum number of leaves per vine at all the growth stages taken and was significantly superior to others at 30 DAS and at harvest. At 45 DAS, it was at par with M_1 (basin mulching) and significantly superior to M_0 (control). At 30 and 45 DAS, lowest value was

Table 6. Effect of mulch and irrigation on number of leaves per vine at different growth stages.

Treatments	30 DAS	45 DAS	Harvest
Mulch			
M_0	7.1^{c}	17.5^{b}	19.4^{b}
M_1	8.1^{b}	18.8^{a}	20.1^{b}
M_2	9.3^{a}	19.3^{a}	21.0^{a}
Irrigation			
I_1	7.4^{b}	17.9^{b}	19.6^{a}
I_2	8.3^{ab}	18.3^{b}	20.6^{a}
I_3	8.4^{ab}	18.9^{ab}	20.6^{a}
I_4	7.8^{ab}	18.1^{b}	19.9^{a}
I_5	8.8^{a}	19.6^{a}	20.2^{a}
Interaction	NS	NS	NS

Figures with same alphabets in superscript do not differ significantly at 5 % level in DMRT

observed from M_0 and it was significantly inferior to M_1. At harvest M_0 and M_1 were at par with each other and significantly inferior to M_2.

Among the irrigation treatments, I_5 (basin irrigation) recorded the maximum number of leaves per vine at growth stages of 30 and 45 DAS. At 30 DAS, I_5 was significantly superior to drip method (I_1) and was at par with I_2, I_3 and I_4. At 45 DAS, I_5 was at par with bubbler method (I_3) and significantly superior to I_1, I_2 and I_4, where as I_3 was at par with I_1, I_2 and I_4.

At harvest, though the influence of irrigation treatments on number of leaves per vine was not significant, the highest value was recorded from I_2 and I_3.

In general, full mulching of interspace with black LDPE had significant effect on number of leaves per vine. Among the irrigation treatments basin irrigation (I_5), followed by bubbler (I_3) were superior to all other methods on number of leaves per vine.

4.1.4 Leaf area

The data on average leaf area (cm^2) at different growth stages; *viz.*, 30, 45 and at harvest are given in Table 7 and analysis of variance in Appendix I(d).

The results indicated that mulch and irrigation had significant influence on leaf area at all growth stages taken, whereas their interaction was not significant [Appendix II(b)].

At 30 DAS and at harvest, full mulching (M_2) was significantly superior to all other treatments and second highest value was obtained from M_1 (basin mulching) which was significantly higher than M_0 (control).

At 45 DAS, highest value was recorded from M_2, which was at par with M_1. The lowest value was recorded from M_0 and was significantly inferior to other treatments.

Table 7. Leaf area (cm^2) as influenced by mulch and irrigation at different growth stages

Treatments	30 DAS	45 DAS	Harvest
Mulch			
M_0	93.9^c	109.9^b	100.9^c
M_1	100.7^b	119.9^a	108.3^b
M_2	106.2^a	123.4^a	112.7^a
Irrigation			
I_1	92.8^c	109.4^b	98.4^c
I_2	98.1^b	113.1^b	105.9^b
I_3	106.4^a	124.1^a	115.7^a
I_4	96.1^{bc}	119.2^a	103.7^{bc}
I_5	107.9^a	122.8^a	112.9^a
Interaction	NS	NS	NS

Figures with same alphabets in superscript do not differ significantly at 5 % level in DMRT

Among irrigation treatments, at 30 DAS, I_5 recorded the highest leaf area and was at par with I_3 and both were significantly superior to all other treatments.

At 45 DAS, highest value was recorded from I_3, which was at par with I_4 and I_5. Lowest value was recorded from I_1 which was at par with I_2 and they were significantly inferior to all other treatments. At harvest also I_5 recorded the highest leaf area and was at par with I_3. Both these treatments were significantly superior to others.

Overall result indicated that M_2 was superior to other treatments at all growth stages. At all growth stages lowest values were recorded from M_0. In case of irrigation, in general I_3 and I_5 were superior to other treatments at all growth stages.

4.1.5 Leaf area index (LAI)

The data related to the leaf area index taken at various stages of growth are given in Table 8 and Plates II, III & IV shows leaf coverage of plants at different growth stages. The analysis of variance is given in Appendix I(e).

The result indicated that mulch and irrigation had significant influence on LAI at all the growth stages given. However their interaction was not significant [Appendix II(b)].

With respect to the leaf area index, full mulching (M_2) recorded maximum values in all growth stages and was significantly superior to all other treatments with an exception that it was at par with basin mulching (M_1) at 45 DAS. In all growth stages M_0 (control) recorded lowest value and was significantly inferior to all other treatments.

With respect to irrigation, at 30 and 45 DAS, basin irrigation (I_5) recorded highest value and at 30 DAS it was at par with I_2 (microtube irrigation) and I_3 (bubbler irrigation). I_1 (drip irrigation) and I_4 (wick irrigation) recorded

Table 8. Leaf area index (LAI) as influenced by mulch and irrigation at different growth stages

Treatments	30 DAS	45 DAS	Harvest
Mulch			
M_0	0.3549 ^{c}	1.030 ^{b}	1.044 ^{c}
M_1	0.4394 ^{b}	1.204 ^{a}	1.159 ^{b}
M_2	0.5265 ^{a}	1.275 ^{a}	1.264 ^{a}
Irrigation			
I_1	0.3721 ^{b}	1.048 ^{c}	1.029 ^{d}
I_2	0.4379 ^{ab}	1.110 ^{c}	1.164 ^{bc}
I_3	0.4842 ^{a}	1.253 ^{ab}	1.270 ^{a}
I_4	0.4006 ^{b}	1.154 ^{bc}	1.099 ^{cd}
I_5	0.5064 ^{a}	1.283 ^{a}	1.217 ^{ab}
Interaction	NS	NS	NS

Figures with same alphabets in superscript do not differ significantly at 5 % level in DMRT

Plate II. Plant leaf coverage as influenced by mulch and irrigation at 35 DAS

I_2M_2 – Microtube irrigation with full mulch

I_3M_0 – Bubbler irrigation with no mulch

I_1M_2 – Drip irrigation with full mulch

I_2M_0 – Microtube irrigation with no mulch

I_2M_1 – Microtube irrigation with basin mulch

Plate III. Plant leaf coverage as influenced by mulch and irrigation at 60 DAS

I_3M_0 – Bubbler irrigation with no mulch

I_3M_1 – Bubbler irrigation with basin

I_5M_2 – Basin irrigation with full mulching

I_3M_0 – Basin irrigation with no mulch

Plate IVa. View of different treatments at harvest stage

I_1M_2 – Drip irrigation with full mulching

I_1M_1 – Drip irrigation with basin mulching

I_1M_0 – Drip irrigation with no mulch

I_3M_2 – Bubbler irrigation with full mulching

Plate IVb. View of different treatments at harvest stage

I_3M_0 – Bubbler irrigation with no mulch

I_2M_0 – Microtube irrigation with no mulch

I_2M_1 – Microtube irrigation with basin mulching

I_2M_2 – Microtube irrigation with full mulching lowest values and significantly inferior to I_5. At 45 DAS, I_5 was at par with I_3 and significantly superior to other treatments. At harvest, highest value was recorded from I_3 and it was at par with I_5. The lowest value was observed from I_1 and it was at par with I_4 and significantly inferior to I_2, I_3 and I_5.

In short, the result revealed the significant influence of mulching on LAI. In general full mulching was found to increase the LAI compared to other treatments. In irrigation treatments, basin irrigation was found to increase the LAI at all growth stages and I_3 was found as second best treatment. At all the growth stages, drip irrigation had the least effect on LAI.

4.1.6 Dry matter production at harvest

The data on dry matter production at harvest (g plant^{-1}) is presented in Table 9 and analysis of variance in Appendix I(f).

The influence of mulch and irrigation was significant on dry matter production and their interaction also was statistically significant [Appendix II(b)].

Among mulches, full mulching (M_2) recorded maximum dry matter production and it was at par with M_1 (basin mulching). Control (no mulching) recorded very low dry matter production and it was significantly inferior to others.

Drip irrigation (I_1) recorded maximum dry matter production among irrigation treatments and it was at par with I_5 and I_4. The lowest dry matter production was recorded from microtube irrigation (I_2). It was significantly inferior to I_1, I_4 and I_5.

The Interaction between irrigation and mulch significantly influence dry matter production at harvest. Highest production of dry matter was observed in drip irrigation with full mulching (I_1M_2). It was at par with all other treatments except drip irrigation with no mulch (I_1M_0) which was significantly inferior to all other treatments. In drip irrigation (I_1), full mulching (M_2) recorded higher dry

Table 9. Dry matter production (g plant^{-1}) as influenced by mulch and irrigation at harvest

Treatments	Dry weight (g plant^{-1})
Mulch	
M_0	76.47^{b}
M_1	104.90^{a}
M_2	110.70^{a}
Irrigation	
I_1	112.00^{a}
I_2	75.89^{c}
I_3	80.78^{bc}
I_4	102.40^{ab}
I_5	105.70^{a}
Interaction	Sig.

Figures with same alphabets in superscript do not differ significantly at 5 % level in DMRT

Table 9b. Dry matter production (g plant^{-1}) as influenced by combination of mulch and irrigation at harvest

Treatment	**M_0**	**M_1**	**M_2**
I_1	55.33^{b}	144.00^{a}	166.70^{a}
I_2	67.67^{a}	78.67^{a}	81.33^{a}
I_3	62.67^{a}	92.67^{a}	87.00^{a}
I_4	83.33^{a}	104.70^{a}	119.30^{a}
I_5	113.30^{a}	104.30^{a}	99.33^{a}

Figures with same alphabets in superscript do not differ significantly at 5 % level in DMRT

matter production and it was at par with basin mulching (M_1). Lowest value was recorded in treatment with no mulch (M_0) and was significantly inferior to (M_1 and M_2).

In microtube method (I_2), highest value was recorded with M_2 and it was at par with all other treatments. The lowest value was observed in M_0. The trend was same in case of wick irrigation (I_4). In bubbler irrigation (I_3), highest value was recorded with M_1 and lowest with M_0 but both the treatments were at par. In basin irrigation (I_5), highest dry matter production was recorded with M_0 and it was at par with M_1 and M_2. M_2 recorded lowest dry matter production.

There was substantial increase of dry matter production due to mulching. Among irrigation methods, drip method (I_1) produced the highest dry matter followed by I_5.

4.2 Yield and yield attributes

4.2.1 Days taken to first flowering

The data on days taken to first flowering of cucumber var. *Mudicode* as influenced by mulch and irrigation are given in Table 10 and analysis of variance in Appendix I(g).

The effects of mulch and irrigation on days taken to first flowering were not significant. Their interaction also was not significant [Appendix II(c)]. It is worth to note that the differences between the treatments also were insignificant. Irrespective of treatments, days taken to first flowering remained constant at 30 days.

4.2.2 Number of female flowers per plant

The data on number female flowers taken at 60 DAS are presented in Table 10 and analysis of variance in Appendix I(g).

Table 10. Flower characteristics as influenced by mulch and irrigation

Treatments	Days taken for flowering	No. of female flowers plant $^{-1}$	No. of male flowers plant $^{-1}$	Female-male flower ratio (x 10 $^{-2}$)	Fruit set (%)
Mulch					
M_0	30.2^{a}	4.9^{b}	163.5^{c}	3.0^{a}	50.9 ^{a}
M_1	30.1^{a}	5.3^{ab}	173.4^{b}	3.1^{a}	55.0 ^{a}
M_2	30.5^{a}	5.9^{a}	181.3^{a}	3.2^{a}	52.6 ^{a}
Irrigation					
I_1	30.3^{a}	5.3^{a}	172.0^{ab}	3.1^{a}	47.1 ^{b}
I_2	30.2^{a}	5.4^{a}	171.8^{ab}	3.2^{a}	53.0 ^{ab}
I_3	30.6^{a}	5.4^{a}	176.6^{a}	3.1^{a}	47.0 ^{b}
I_4	30.0^{a}	4.9^{a}	163.8^{b}	3.0^{a}	59.6 ^{a}
I_5	30.2^{a}	5.7^{a}	179.6^{a}	3.2^{a}	57.5 ^{ab}
Interaction	NS	NS	NS	NS	NS

Figures with same alphabets in superscript do not differ significantly at 5 % level in DMRT

The influence of mulch on number of female flowers per plant was significant. But influence of irrigation and their interaction was not significant [Appendix II(c)].

Among mulching, the maximum number of female flowers (5.9) was observed under full mulching (M_2) closely followed by M_1 (5.3) and they were at par with each other. No mulch control (M_0) recorded 4.9 female flowers per plant and was significantly inferior to M_2 and was at par with M_1.

Number of female flowers per plant varied between 4. 9 and 5.7: among the irrigation treatments. But none of these was significantly different from each other.

4.2.3 Number of male flowers per plant

The data related to the number male flowers are presented in Table 10 and analysis of variance in Appendix I(g).

The main effects of both mulch and irrigation on male flower production were significant, but their interaction was not significant [Appendix II(c)].

The highest number of male flowers (181.3 plant^{-1}) was recorded from full mulching (M_2) and it was significantly superior to basin mulch and control.

This was followed by basin mulch (M_1), which recorded 173.4 male flowers plant^{1} and was significantly superior to no-mulch control, which recorded 163.5 male flowers plant^{-1}.

Among irrigation treatments, basin irrigation (I_5) recorded maximum number of male flowers per plant (179.6) and was closely followed by bubbler method (I_3) which recorded 176.6 numbers of male flowers. I_1, I_2, I_3 and I_5 were at par with each other. The lowest value (163.8) was recorded from wick irrigation (I_4) and was at par with I_1 and I_2.

4.2.4 Female-male flower ratio

The data on female to male flower ratio are presented in Table 10 and analysis of variance in Appendix I(g).

Mulch or irrigation in no way significantly influenced the ratio of female to male flower and their interaction also was not significant [Appendix II(c)]. Nevertheless, among the mulch treatments, M_2 recorded the highest female-male ratio and among the irrigation treatments I_5 recorded the highest ratio.

In short, among the flower characters, mulching influenced only number of male and female flowers. Full mulching (M_2) had significant effect on increasing both male and female flowers. Basin mulching (M_1) was significantly superior to no mulch control (M_0). Irrigation methods did not affect days to first flowering, number of female flowers per plant or female-male flower ratio. Only flower character affected by irrigation methods was number of male flowers per plant. Highest number of male flowers per plant was produced by I_5 followed by I_3.

4.2.5 Fruit setting

The data on fruit setting percentage of female flowers are presented in Table 10 and analysis of variance in Appendix I(g).

The data indicated that the fruit setting was influenced by irrigation and mulch had no effect on fruit setting. It was also found that their interaction was not significant.

Higher fruit setting percentage was recorded from mulched plots. The values recorded from basin and full mulching were 55.0 and 52.7 per cent, respectively and were at par with each other. The lowest value was recorded from the control without mulch (50.9 per cent) though it was at par with other treatments.

Among the irrigation treatments I_4 (wick irrigation) recorded the highest value of 59.6 and it was at par with I_2 (microtube) and I_5 (basin irrigation) which recorded 53.0 and 57.5 per cent of fruit setting, respectively. The lowest values were recorded with I_1 (drip irrigation) and I_3 (bubbler irrigation) which recorded 47.1 and 47.0 percent of fruit setting respectively and they were at par with I_2 and I_5 and significantly inferior to I_4.

The result in general indicated that fruit setting was higher for mulched plots compared to no mulch control. In the irrigation treatments, fruit setting was highest for wick irrigation (I_4) and it was significantly superior to I_1 and I_3 and was at par with I_2 and I_5.

4.2.6 Average weight of fruits

The data on mean single fruit weight in gram are presented in Table 11 and analysis of variance in Appendix I(h).

The effect of irrigation on mean fruit weight was significant, while the main effects of mulch and their interaction were not significant [Appendix II(c)].

The maximum mean weight of a fruit was recorded from wick irrigation (I_4) and this was at par with drip (I_1), microtube (I_2) and bubbler (I_3) irrigation methods. The value recorded from basin irrigation method (I_5) was significantly inferior to other treatments.

4.2.7 Mean fruit length

The data related to fruit length (cm) are given in Table 11. Plate V shows the maximum and average fruit length, while analysis of variance is given in Appendix I(h).

The result indicated significant influence of mulch and irrigation on fruit length. But their interaction was not significant [Appendix II(c)].

Table 11. Effects of mulch and irrigation on fruit characteristics

Treatments	Mean weight of fruits (g)	Fruit size		
		Length (cm)	Girth (cm)	Volume (cm^3)
Mulch				
M_0	1146.0 [a]	27.5 [b]	31.5 [a]	1607 [a]
M_1	1148.0 [a]	29.4 [a]	32.2 [a]	1781 [a]
M_2	1148.0 [a]	29.4 [a]	31.9 [a]	1707 [a]
Irrigation				
I_1	1205.0 [a]	28.2 [b]	31.9 [ab]	1651 [ab]
I_2	1146.0 [a]	29.1 [ab]	31.5 [ab]	1692 [ab]
I_3	1187.0 [a]	28.3 [b]	32.5 [a]	1809 [a]
I_4	1236.0 [a]	30.4 [a]	32.9 [a]	1888 [a]
I_5	963.5 [b]	27.9 [b]	30.7 [b]	1452 [b]
Interaction	NS	NS	NS	NS

Figures with same alphabets in superscript do not differ significantly at 5 % level in DMRT

Among the mulch treatments, basin mulching (M_1) recorded the longest fruits, which was at par with full mulching (M_2). Lowest value was recorded from no mulch control and it was significantly inferior to other treatments.

Among irrigation treatments, highest value on fruit length was recorded from wick irrigation (I_4) which was at par with microtube irrigation (I_2) and significantly superior to all other treatments. Lowest value was observed from basin irrigation (I_5) and it was at par with I_1, I_2 & I_3.

4.2.8 Mean fruit girth

The data on mean fruit girth (cm) are presented in Table 11 and analysis of variance in Appendix I(h).

The result indicated that the effect of irrigation on mean fruit girth was significant. Mulching had no significant influence on fruit girth. Similarly the interaction between mulch and irrigation was also not significant [Appendix II(c)].

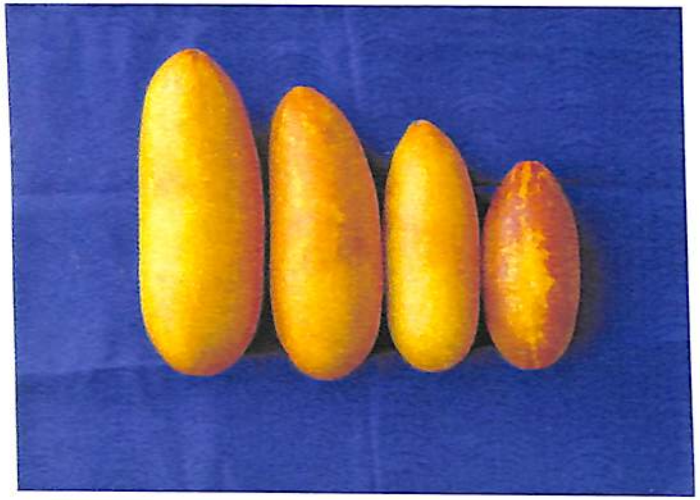
Among irrigation treatments, the highest value on average fruit girth was recorded from wick irrigation (I_4) and it was at par with all other treatments except basin irrigation (control). The control (I_5) recorded lowest value and it was at par with values recorded from I_1 & I_2.

4.2.9 Average fruit volume

The data on mean fruit volume in cm^3 are given in Table 11 and analysis of variance in Appendix I(h). Plate V shows the maximum and average fruit size.

The effect of irrigation on fruit volume was significant, while the influence of mulches and their interaction was not significant [Appendix II(c)].

Plate V. Fruit size under different treatments



I_1M_1 – drip with basin mulch

I_2M_1 – microtube with basin mulch

I_3M_2 – bubbler with full mulch

I_4M_0 – wick without mulch

I_4M_2 – wick with full mulch

I_5M_0 – basin without mulch

As in case of mean fruit girth, among irrigation treatments the highest value was recorded from wick irrigation (I_4) which was at par with all other treatments except I_5.

The effect of mulching and methods of irrigation on fruit characteristics are summarized as follows. Mulching had no significant effect on mean weight, girth and volume of fruits. But length of fruits were significantly higher in M_1 and M_2 over M_0. Methods of irrigation had significant effect on fruit characters. Mean weight, length, girth and volume of fruits were the highest in I_4 and significantly superior to I_5. Effect of I_4 was at par with I_1, I_2 and I_3 in the case of mean weight, length and volume of fruits. In the case of mean length of fruits I_4 was significantly superior to I_1, I_3 and I_5.

4.2.10 Number of fruits per plant

The data on number of fruits plant $^{-1}$ are presented in a Table 12 and the analysis of variance in Appendix I(i).

The results of number of fruits plant $^{-1}$ indicated that both mulch and irrigation methods had significant influence where are their interaction was not significant [Appendix II(c)].

Both the mulched treatments produced significantly more number of fruits per plant than unmulched control. However the number of fruits were maximum (3.1 plant^{-1}) from full mulching (M_2) and that under basin mulch (M_1) recorded 2.9 plant^{-1}. The difference was not statistically significant. The lowest value (2.4 fruits plant^{-1}) was observed from the control (M_0) and it was significantly inferior to the mulched treatments.

Among the irrigation treatments, the maximum number of fruits per plant (3.2) was recorded from basin irrigation (I_5). It was significantly superior to all other treatments. I_2, I_3 and I_4 were at par with each other. The lowest number

Table 12. Number of fruits and yield as influenced by mulch and irrigation

Treatments	No. of fruits plant^{-1}	Fruit yield	
		kg plant^{-1}	t ha^{-1}
Mulches			
M_0	2.4^{b}	2.7^{b}	36.0^{b}
M_1	2.9^{a}	3.2^{a}	43.2^{a}
M_2	3.0^{a}	3.5^{a}	46.0^{a}
Irrigation			
I_1	2.4^{c}	2.9^{b}	38.7^{b}
I_2	2.8^{b}	3.2^{ab}	42.8^{ab}
I_3	2.6^{bc}	3.0^{b}	39.9^{b}
I_4	2.9^{b}	3.5^{a}	46.3^{a}
I_5	3.2^{a}	3.1^{b}	41.0^{b}
Interaction	NS	NS	NS

Figures with same alphabets in superscript do not differ significantly at 5 % level in DMRT

of fruits (2.4 fruits plant^{-1}) was recorded from drip irrigation (I_1) and was at par with bubbler irrigation (I_3).

4.2.11 Fruit yield per plant

The data related to fruit yield (kg plant^{-1}) are presented in Table 12 and analysis of variance in Appendix I(i).

Fruit yield (kg plant^{-1}) was influenced by mulch and irrigation. But the interaction between them was not significant [Appendix II(c)].

Among mulches, full mulching (M_2) recorded maximum fruit yield (3.5 kg plant^{-1}) and it was at par with basin mulching (M_1) where the yield recorded was 3.2 kg plant^{-1}. Lowest value (2.7 kg plant^{-1}) was recorded from no mulch control treatment, and it was significantly inferior to other treatments.

Among irrigation treatments, wick irrigation (I_4) recorded maximum fruit yield (3.5 fruits plant^{-1}). It was at par with microtube irrigation (I_2) and significantly superior to I_1, I_3 and I_5. The lowest value was recorded from drip irrigation (I_1) and it was at par with I_2, I_3 and I_5.

4.2.12 Fruit yield per ha

The result on fruit yield (t ha^{-1}) is presented in Table 12 and analysis of variance in Appendix I(i).

The result showed that both mulch and irrigation had significant influences on fruit yield in t ha^{-1}. The interaction between mulch and irrigation was not significant [Appendix II(c)].

The result clearly indicated the beneficial effect of mulches on fruit yield. Both the mulched treatments recorded significantly higher yield than unmulched control treatment. The maximum yield of 46.0 t ha^{-1} was recorded from treatments with full mulching (M_2) and it was at par with basin mulching

(M_1) where the yield recorded was 43.15 t ha^{-1}. The lowest yield (35.98 t ha^{-1}) was recorded from control (M_0) and was significantly inferior to the mulched treatments.

Among irrigation treatments, I_4 (wick irrigation) recorded maximum yield of 46.3 t ha^{-1} followed by I_2 (microtube irrigation) with mean yield of 42.8 t ha^{-1}. Though I_4 was at par with I_2, it was significantly superior to I_1, I_3 and I_5. The lowest yield (38.7 t ha^{-1}) was recorded from drip (I_1), though it was at par with all other treatments except I_4.

As a conclusion of the effect of mulch and irrigation on fruit number $plant^{-1}$ and yield of fruits it may be pointed out that full mulching of the inter space was better that no mulch and basin mulching. When M_2 was significantly superior to M_0, the difference between M_2 and M_1 was not significant. The effect of I_5 was significantly superior to all other irrigation methods on number of fruits $plant^{-1}$. Highest fruit yield recorded in I_4 was significantly superior to all irrigation methods except I_2.

4.3 Effect of mulch and irrigation on weed growth

The data on weed growth as influenced by mulch and irrigation are presented in this portion.

4.3.1 Dry weight of weed

The data on weed growth in terms of dry matter (g m^{-2}) is presented in Table 13 and analysis of variance in Appendix I(j).

The result of dry weight of weeds indicated that both main effects of mulch and irrigation and their interaction were significant [Appendix II(b)]. Mulching effectively controlled the weed growth.

Weed dry matter production of 112.70 g m^{-2} was observed from the plots with no mulch (M_0), but it was significantly reduced by basin mulching. In the full

Table 13. Weed dry weight as influenced by mulch and irrigation

Treatments	Weed dry weight (g m^{-2})
Mulch	
M_0	112.70 [a]
M_1	22.27 [b]
M_2	0.00 [c]
Irrigation	
I_1	36.67 [b]
I_2	44.56 [ab]
I_3	50.56 [a]
I_4	45.22 [ab]
I_5	47.89 [a]
Interaction	Sig.

Figures with same alphabets in superscript do not differ significantly at 5 % level in DMRT

Table 13b. Weed dry weight as influenced by combination of mulch and irrigation

Treatment	**M_0**	**M_1**	**M_2**
I_1	87.00[a]	23.00[b]	0.00[c]
I_2	115.70[a]	18.00[b]	0.00[c]
I_3	118.00[a]	33.67[b]	0.00[c]
I_4	120.00[a]	15.67[b]	0.00[b]
I_5	122.70[a]	21.00[b]	0.00[c]

Figures with same alphabets in superscript do not differ significantly at 5 %level in DMRT mulched plots (M_2), weed growth was checked by 100 per cent. So it is not included in analysis of variance. The differences between each of these treatments were statistically significant.

Among the irrigation treatments, maximum weed dry matter production of 50.56 g m^2 was observed from bubbler irrigation (I_3) and followed by basin irrigation (I_5). I_2, I_3, I_4 and I_5 were at par with each other. Drip method (I_1) recorded the minimum weed growth (36.67 g m^{-2}) and it was at par with I_2 and I_4.

The interaction between irrigation and mulch significantly influence dry weight of weeds. Among the combinations, basin irrigation with no mulch recorded highest value of dry weight of weeds.

In drip irrigation (I_1), M_0 (no mulch control) recorded highest weed dry weight and it was significantly superior to basin mulching (M_1) and full mulching (M_2). M_2 recorded no weed dry weight and it was significantly inferior to other methods. The trend was same in microtube (I_2), bubbler (I_3) and basin method (I_5). In wick irrigation (I_4), though M_0 recorded higher weed dry weight and significantly superior other methods, the difference between M_1 and M_2 were not significant. Here also no weed dry weight was observed with M_2.

In short, full mulching of the interspace controlled weed growth completely. Even mulching in basin alone could significantly reduce weed growth. Among the irrigation methods drip irrigation was most effective in checking weed growth followed by microtube irrigation (I_2).

4.4 Nutrient composition in cucumber leaf

4.4.1 Nitrogen content of leaf

The data on total nitrogen content in leaf at 35 DAS and harvest are given in Table 14 and analysis of variance in Appendix I(k).

Table 14. Influence of mulch and irrigation on leaf nitrogen content (%) at different growth stages

Treatments	35 DAS	Harvest
Mulch		
M_0	4.21 ^{c}	2.37 ^{c}
M_1	4.53 ^{b}	2.67 ^{b}
M_2	4.82 ^{a}	2.99 ^{a}
Irrigation		
I_1	4.37 ^{c}	2.46 ^{b}
I_2	4.35 ^{c}	2.52 ^{bc}
I_3	4.81 ^{a}	2.81 ^{a}
I_4	4.45 ^{c}	2.73 ^{ab}
I_5	4.63 ^{b}	2.87 ^{a}
Interaction	NS	NS

Figures with same alphabets in superscript do not differ significantly at 5 % level in DMRT

The result showed that main effects of mulch and irrigation were significant on total leaf nitrogen content (%) at all the growth stages. But their interaction was not significant [Appendix II(d)].

At 35 DAS and at harvest, full mulching (M_2) recorded the maximum nitrogen content of 4.82 and 2.99 per cent, respectively. This was significantly superior to basin mulching (M_1) and control (M_0). The effect of M_1 was significantly superior to control. The lowest values of 4.21 and 2.37 per cent recorded at 35 DAS and at harvest respectively from control were significantly inferior to both the mulched treatments.

At 35 DAS, among the irrigation treatments, I_3 (bubbler irrigation) recorded the maximum total nitrogen content of 4.81 per cent and it was significantly superior to all other treatments. Basin irrigation (I_5) recorded 4.63 per cent leaf nitrogen and was significantly superior to I_1, I_2 and I_4. Microtube method (I_2) recorded the lowest value though it was at par with I_1 and I_4.

At harvest the maximum per cent of nitrogen (2.87) was observed from I_5 (basin irrigation), it was at par with I_3 and I_4 and significantly superior to I_1 and I_2. The lowest value (2.46 per cent) was observed from I_1 (drip method) and it was at par with I_2.

In short, full mulching of the interspace with black LDPE enhanced significantly higher content of nitrogen in leaves both at 35 DAS and at harvest. Basin mulching of LDPE also enhanced leaf nitrogen content over control, though it was significantly inferior to full mulching. At 35 DAS, highest leaf nitrogen content was observed in I_3 which was significantly superior to other treatments. But at harvest, leaf nitrogen content was the maximum in I_5 and was at par with I_3 and I_4 and significantly superior to I_1 and I_2.

4.4.2 Phosphorus content of leaf

The data on composition of phosphorus in leaf (%) as influenced by mulch and irrigation are presented in Table 15 and analysis of variance in Appendix I(l).

The result indicated that the effects of mulch and irrigation were statistically not significant at 35 DAS and at harvest. Their interaction also was not significant [Appendix II(d)].

Among mulches, full mulching (M_2) recorded the highest per cent of P in leaf at 35 DAS and at harvest, though do not vary significantly between mulch treatments.

Among irrigation treatments, I_2 (microtube method) recorded the lowest per cent of P and all other treatments recorded the same value. The trend was similar at 35 DAS and at harvest. The variation of P between I_2 and other methods was negligible.

Mulch and irrigation did not influence phosphorus content of leaves. It is also worth to note that the variation between treatments on leaf phosphorus content was very negligible.

4.4.3 Potassium content of leaf

The data on potassium content in leaf (%) at growth stage of 35 DAS and at harvest are presented in Table 16 and analysis of variance in Appendix I(m).

The result indicted that mulching had significant influence on K content in leaf at all the growth stages and influence of irrigation was significant only at harvest. Their interaction was not significant at any of the growth stages [Appendix II(d)].

Table 15. Influence of mulch and irrigation on phosphorus content of leaves (%) at different growth stages

Treatments	35 DAS	Harvest
Mulch		
M_0	0.47 [a]	0.26 [a]
M_1	0.48 [a]	0.27 [a]
M_2	0.49 [a]	0.27 [a]
Irrigation		
I_1	0.48 [a]	0.27 [a]
I_2	0.47 [a]	0.26 [a]
I_3	0.48 [a]	0.27 [a]
I_4	0.48 [a]	0.27 [a]
I_5	0.48 [a]	0.27 [a]
Interaction	NS	NS

Figures with same alphabets in superscript do not differ significantly at 5 % level in DMRT

Table 16. Influence of mulch and irrigation on potassium content of leaves (%) at different growth stages

Treatments	35 DAS	Harvest
Mulch		
M_0	2.74 [c]	1.72 [c]
M_1	2.83 [b]	1.85 [b]
M_2	2.93 [a]	1.92 [a]
Irrigation		
I_1	2.80 [a]	1.82 [ab]
I_2	2.87 [a]	1.84 [ab]
I_3	2.83 [a]	1.87 [a]
I_4	2.81 [a]	1.81 [ab]
I_5	2.84 [a]	1.80 [b]
Interaction	NS	NS

Figures with same alphabets in superscript do not differ significantly at 5 % level in DMRT

At 35 DAS and at harvest, full mulching (M_2) recorded the maximum P content of 2.93 and 1.92 per cent, respectively. This was significantly superior to basin mulching (M_1) and control. The effect of M_1 was significantly superior to control. The lowest values of 2.74 and 1.72 per cent recorded at 35 DAS and at harvest, respectively from control plots with no mulch were significantly inferior to both the mulched treatments.

At 35 DAS, among irrigation treatments the highest value was recorded from microtube irrigation (I_2), though it was at par with all other treatments.

At harvest, the maximum per cent of K (1.87) in leaf was observed from bubbler irrigation (I_3) and it was significantly superior to I_5 and was at par with I_1, I_2 and I_4. Basin irrigation (I_5) recorded the lowest value (1.80 per cent) of K content in leaf and was at par with I_1, I_2 and I_4.

In short, mulching with LDPE in the entire interspace significantly influenced the leaf K content both at 35 DAS and at harvest. Leaf K content was significantly higher in basin mulching over control. Methods of irrigation had no significant effect on leaf K content. Nevertheless, at harvest leaf K content in I_5 was significantly inferior to other irrigation methods.

4.5 Soil moisture studies

4.5.1 Vertical and radial distribution of soil moisture

The mean data showing the relative gravimetric soil moisture content (% w/w) for the depths of 0-15, 15-30 and 30-60 cm at the lateral distances of 0-15, 15-30, 30-45 and 45-60 cm taken before irrigation are given in Table 17 and 18. The periodical mean of soil moisture content (% w/w) for the crop growth period of 40, 60, and 78 DAS are given in Appendix III.

The results of the lateral moisture distribution indicated that, in all the irrigation treatments, soil moisture content was higher in mulched plots as

Table 17. Soil moisture content (% w/w) before irrigation at 0-60 cm depth on different distances as influenced by mulch and irrigation

Treatments	Lateral distance from the central point of irrigation			
	0-15 cm	15-30 cm	30-45 cm	45-60 cm
I_1M_0	11.6	9.8	8.1	6.6
I_1M_1	13.3	11.2	8.8	7.5
I_1M_2	12.7	11.0	10.0	10.8
I_2M_0	15.1	14.6	14.5	12.0
I_2M_1	15.6	14.7	13.3	12.4
I_2M_2	17.1	16.2	14.1	12.7
I_3M_0	15.4	14.7	11.6	9.6
I_3M_1	17.7	14.1	13.6	11.1
I_3M_2	16.4	15.0	13.8	11.5
I_4M_0	14.8	15.2	12.9	11.7
I_4M_1	15.5	13.9	13.0	12.5
I_4M_2	16.7	16.4	13.4	12.4
I_5M_0	15.2	14.9	14.2	14.6
I_5M_1	15.0	14.9	16.4	15.5
I_5M_2	15.6	16.3	18.0	16.1

Table 18. Soil moisture content (% w/w) before irrigation at 0-60 cm lateral distance in different depths as influenced by mulch and irrigation

Treatments	Depth from the surface		
	0-15 cm	15-30 cm	30-60 cm
I_1M_0	10.3	10.3	11.2
I_1M_1	10.6	10.8	11.3
I_1M_2	11.2	10.8	12.4
I_2M_0	12.1	13.8	13.9
I_2M_1	12.9	14.2	15.0
I_2M_2	14.6	14.7	15.7
I_3M_0	12.3	12.9	14.4
I_3M_1	14.9	13.9	15.1
I_3M_2	15.1	14.7	15.3
I_4M_0	12.2	12.8	15.1
I_4M_1	12.4	13.3	15.6
I_4M_2	13.9	14.5	15.7
I_5M_0	13.9	14.1	15.4
I_5M_1	14.4	15.6	17.7
I_5M_2	14.7	15.9	18.5

compared to unmulched plots. Full mulching with black polythene (M_2) retained more moisture in each lateral section compared to no-mulch and partial mulching with black polythene (M_1) in all irrigation treatments. Though M_1 retained less moisture than M_2, M_1 retained more moisture than unmulched situation.

Among the irrigation treatments, the maximum soil moisture content was observed with basin methods of irrigation (I_5). The lowest content of soil moisture among different methods of irrigation was observed in drip irrigation. Soil moisture content was the highest in the lateral distance of 0-15 cm from the centre of the pit in I_1 to I_4 irrespective of mulches. As the distance from the center of the pit increased, the moisture content in the soil decreased gradually in these irrigation treatments. In basin method of irrigation (I_5) soil moisture content remained almost constant from the centre of the pit to the lateral distance of 60 cm.

In the vertical distribution of soil moisture also mulched plots retained more moisture in all the three depths studied. Between basin mulching (M_1) and full mulching with black LDPE sheet, M_2 retained more moisture in the soil than M_1.

Among the irrigation treatments, basin method of irrigation (I_5) retained more moisture than others and the minimum by drip irrigation (I_1). In all irrigation treatments, highest content of soil moisture was observed in the lower most layer of 30-60 cm. Moisture content was the lowest in the surface layer of 0-15 cm depth.

In short, soil moisture content along the radial distance reduced gradually as the distance from the point of irrigation increased in all irrigation treatments except basin method. The moisture content for mulched treatments was higher for each radial distance as compared to control with out mulch. The maximum value was recorded from full mulching with black LDPE sheet. Among the irrigation treatments, highest soil moisture was recorded by basin method.

Depth wise also mulching helped to conserve more moisture. Full mulching with black LDPE sheet (M_2) was better than basin mulching with black LDPE sheet (M_1). Lower most layer of 30-60 cm retained the highest amount of water than the 15-30 and 0-15 cm layers in all the irrigation treatments.

4.5.2 Consumptive use (CU)

The date on mean seasonal consumptive use in mm for the total crop growth period is presented in Table 19.

Among the mulch treatments, maximum consumptive use (271.1 mm) was recorded in plots without mulch. The lowest value of CU (246.3 mm) was recorded from the fully mulched plot (M_2). Basin mulched plot (M_1) recorded 248.6 mm CU and it was higher than M_2, but lower than that of no-mulch plot.

From the irrigation treatments, the maximum seasonal CU of 279.9 mm was observed in drip irrigation. The lowest value of CU (224.9 mm) was recorded from basin irrigation.

4.5.3 Crop coefficient (Kc)

The data on mean daily CU and crop coefficient for different periods and overall average are presented in Table 20 and 21.

Mean daily CU is the mean seasonal consumptive use for a single day and hence the trend is exactly like that of seasonal consumptive use.

The average crop coefficient value was maximum (0.57) for plots with no-mulch and it was lowest (0.51) for M_2, but the difference among the mulched treatments was low. Among the irrigation treatments, maximum crop coefficient (0.59) was recorded from the drip irrigated plot. The lowest Kc value was observed from basin irrigated plots.

Table 19. Seasonal consumptive use (mm) as influenced by mulch and irrigation

Treatments	M_0	M_1	M_2	Mean
I_1	291.0	279.4	269.2	279.9
I_2	260.9	242.8	244.3	249.3
I_3	291.1	236.8	241.1	256.3
I_4	268.2	263.6	266.8	266.2
I_5	244.3	220.6	209.9	224.9
Mean	271.1	248.6	246.3	

Table 20. Daily consumptive use (CU), daily pan evaporation and crop coefficient as influenced by mulch and irrigation.

Treatments	Mean daily CU (mm)	Mean daily pan evaporation (mm)	Average crop coefficient
Mulch			
M_0	3.48	6.13	0.57
M_1	3.19	6.13	0.52
M_2	3.16	6.13	0.51
Irrigation			
I_1	3.59	6.13	0.59
I_2	3.20	6.13	0.52
I_3	3.29	6.13	0.54
I_4	3.41	6.13	0.56
I_5	2.88	6.13	0.47

Table 21. Daily consumptive use (CU) in mm day^{-1} and crop coefficient (Kc) at different periods of crop growth

Treatments	1-20 DAS		21-40 DAS		41-60 DAS		61-78 DAS		Average	
	CU	Kc	CU	Kc	CU	Kc	CU	Kc	CU	Kc
I_1	3.2	0.49	4.60	0.81	3.40	0.54	3.10	0.52	3.57	0.59
I_2	3.2	0.49	2.36	0.42	3.43	0.55	3.80	0.63	3.20	0.52
I_3	3.2	0.49	2.27	0.40	3.80	0.60	3.94	0.66	3.30	0.54
I_4	3.2	0.49	2.23	0.39	3.42	0.54	4.95	0.82	3.45	0.56
I_5	3.2	0.49	2.10	0.37	2.60	0.41	3.72	0.62	2.91	0.47

The periodical crop coefficient values also followed almost the same trend as the mean daily crop coefficient. But at 41-60 DAS, the highest Kc value was recorded by I_3 and minimum by I_5. At 61-78 DAS, highest Kc value was recoded by I_4 and the minimum by I_1. Counting the average value, it was observed that highest periodical Kc value was recorded by I_1 and the minimum by I_5. The CU and Kc values varied with crop age and growth. In general, both CU and Kc values increased gradually from early seedling stage to flowing and reached maximum at fruit enlargement and development stage.

4.5.4 Water use efficiency

The data on field water use efficiency (FWUE) and crop water use efficiency (CWUE) are given in Table 22.

Mulching increased field and crop water use efficiencies. Among the mulch treatments, full mulching by black LDPE sheet recorded the maximum FWUE (133.2 kg ha-mm^{-1}) and CWUE (186.9 kg ha-mm^{-1}). Partial mulching with black LDPE sheet also substantially increased FWUE and CWUE though not to that extent contributed by full mulching.

Among the irrigation treatments, maximum field water use efficiency (166.6 kg ha-mm^{-1}) was recorded by I_4. But minimum FWUE was recorded by basin irrigation (I_5). Crop water use efficiency was maximum with basin irrigation (182.1 kg ha-mm^{-1}) and minimum by drip method.

4.5.5 Soil moisture depletion pattern

The data on the relative soil moisture depletion pattern (%) for the effective root zone layers which was worked out based on periodical gravimetric soil moisture and consumptive use of the crop is presented in Table 23 and illustrated in Fig. 17.

Table 22. Effect of mulch and irrigation on field and crop water use efficiency

Treatments	FWUE (kg ha-mm^{-1})	CWUE (kg ha-mm^{-1})
Mulch		
M_0	104.0	132.7
M_1	124.8	173.6
M_2	133.2	186.9
Irrigation		
I_1	139.0	138.1
I_2	153.7	171.5
I_3	143.5	155.7
I_4	166.6	174.1
I_5	66.5	182.1

Table 23. Relative moisture depletion pattern at different soil layers (%) as influenced by mulch and irrigation

Treatments	Relative moisture depletion (%) from depth		
	0-15 cm	15-30 cm	30-60 cm
Mulch			
M_0	36.6	34.2	29.0
M_1	36.9	34.7	28.4
M_2	35.0	35.0	30.0
Irrigation			
I_1	34.2	34.7	31.1
I_2	37.3	32.7	30.0
I_3	32.2	37.1	30.7
I_4	38.6	34.3	27.1
I_5	40.1	35.4	24.5

In almost all treatments except M_2 and I_3 the upper most layer of 0-15 cm recorded the maximum moisture depletion ranging from 32.2 to 40.1 per cent. Moisture depletion was the lowest from the bottom most layer of 30-60 cm and it ranged from 27.1 to 31.1 per cent.

Among the mulched treatments, the variations in moisture depletion percentages were not much in the different layers studied. In the surface layer (0-15 cm) highest depletion was in M_1 (36.9%) and the lowest in M_2 (35.0%).

Among the irrigation treatments, depletion percentage varied in all the layers. In the surface layer of 0-15 cm, maximum percentage depletion was recorded by basin irrigation (40.1) and the lowest by I_3 (32.2). In the middle layer of 15-30 cm, highest percentage of moisture depletion was recorded by I_3 (37.1) and lowest by I_2 (32.7). In the bottom most layer of 30-60 cm, highest percentage depletion of moisture was recorded by I_1 (31.1) and lowest by I_5 (24.5).

4.6 Economics of production

The data pertaining to the economics of production of oriental pickling melon under different treatments in terms of total cost, total return, net profit and net return per rupee invested as influenced by individual and combinations of treatments are presented in Table 24 and 25. The details of investment and cost of production are given in Appendix IV.

Among the mulches, the highest net profit of Rs. 2,06,897 ha^{-1} was recorded by full mulching by LDPE followed by basin mulching by LDPE, which recorded a net profit of Rs. 1,95,846 ha^{-1}. The lowest net return of Rs. 1,55,059 ha^{-1} was recorded by no mulch treatment (M_0).

The highest net profit of Rs. 2, 13,306 ha^{-1} was recorded by online wick irrigation (I_4). This was followed by basin irrigation (I_5) and I_2 (microtube) which recorded net profits of Rs. 1,91,798 and 1,91,586 ha^{-1}, respectively. The lowest net profit of Rs. 1,63,946 ha^{-1} as recorded by drip irrigation (I_1).

Table 24. Economics of cucumber production per hectare as influenced by mulch and irrigation

Treatments	Total cost of production (Rs. ha^{-1})	Gross return (Rs. ha^{-1})	Net profit (Rs. ha^{-1})	Net income per rupee invested
Mulch				
M_0	60821	215880	155059	2.33
M_1	63055	258900	195846	2.85
M_2	69343	276240	206897	2.76
Irrigation				
I_1	68014	231960	163946	2.40
I_2	64914	256500	191586	2.95
I_3	70347	239460	169113	2.40
I_4	64734	278040	213306	3.29
I_5	54022	245820	191798	2.19

Table 25. Economics of cucumber production per hectare as influenced by combination of mulch and irrigation

Treatments	Total cost (Rs. ha^{-1})	Gross income ha^{-1}		Net profit (Rs. ha^{-1})	Net income per Rupees invested
		Yield (kg ha^{-1})	Value in Rupees		
I_1M_0	64429	31947	191682	127253.2	1.98
I_1M_1	66662	39307	235842	169179.9	2.54
I_1M_2	72951	44723	268338	195387.5	2.68
I_2M_0	61329	36307	212842	156512.9	2.55
I_2M_1	63562	45750	274500	210937.6	3.32
I_2M_2	69851	46193	277158	207307.2	2.97
I_3M_0	66868	33333	199998	133236.1	2.00
I_3M_1	68995	42500	255000	186004.8	2.70
I_3M_2	75284	43890	263340	188056.4	2.50
I_4M_0	61149	42500	255000	193850.9	3.17
I_4M_1	63382	46527	279162	215779.6	3.40
I_4M_2	69671	50000	300000	230329.2	3.31
I_5M_0	73319	35833	214998	141678.9	1.93
I_5M_1	75552	41667	250002	174449.6	2.31
I_5M_2	81841	45417	272502	190661.2	2.33

Among the mulches, the net income per rupee invested was highest in basin mulching with LDPE (2.85) followed by full mulching with LDPE (2.76). It was 2.33 in M_0.

Among the irrigation treatments, net income per rupee invested was maximum in online wick irrigation (3.29) followed by microtube irrigation (2.95). It was the lowest in basin irrigation (I_5).

Results of irrigation and mulching treatments combinations presented in Table 25 indicated that, in all irrigation treatments mulching tremendously increased net profit over M_0. Full mulching with LDPE (M_2) was better than partial mulching (M_1) in all cases except microtube irrigation where partial mulching was slightly superior to full mulching.

The increase in net profit in I_1, I_2, I_3, I_4 and I_5 with partial mulching of LDPE over M_0 was in the order of Rs. 41927, 54425, 52769, 21929 and 32771 ha^{-1} respectively. The corresponding increases in net profit in I_1, I_2, I_3, I_4 and I_5 with full mulching with LDPE over M_0 were in the order of Rs. 68134, 50794, 54820, 36478 and 48982 ha^{-1}, respectively.

Among the combinations I_4M_2 recorded the highest net profit of Rs. 2,30,329 ha^{-1} and was followed by I_4M_1 (Rs. 2,15,780 ha^{-1}). Third best combination was I_2M_1 (Rs. 2,10,938 ha^{-1}).

Polythene mulching either full or partial was highly effective in increasing the net income per rupee invested in all irrigation methods. Among the combinations, the highest net income per rupee invested was recorded by I_4M_1 (3.40) followed by I_2M_1 (3.32).

The results in general indicated the superiority of black LDPE mulching with all types of irrigation methods. Full mulching was better than partial mulching in all irrigation methods except microtube irrigation where partial mulching was slightly superior.

4.6.1 Additional benefits of different irrigation methods

The data related to the comparative benefits of different irrigation methods in relation to basin irrigation are presented in Table 26.

The data revealed that all the micro irrigation methods could save water to the extent of 121.5 per cent as compared to basin method. Nevertheless, drip and KAU micro sprinkler methods were not effective to increase yield over that of basin method. Over basin method, microtube irrigation increased yield by 4.3 per cent. By adopting online wick irrigation, there is a chance of extending irrigation to an additional area of 121.5 per cent by making use of the saved water in addition to the yield advantage of 13.1 per cent.

Table 26. Benefit of different irrigation methods on water saving, yield and extension of irrigated area as compared to basin method

Treatments	Quantity of water used (ha-cm)	Yield (t ha^{-1})	As compared to basin method		
			Water saving (%)	Yield advantage (%)	Percentage increase in irrigable area (ha)
Micro irrigation					
I_1	278.1	38.66	121.5	-5.64	121.5
I_2	278.1	42.75	121.5	4.34	121.5
I_3	278.1	39.91	121.5	-2.59	121.5
I_4	278.1	46.34	121.5	13.11	121.5
Basin method					
I_5	616.1	40.97	-	-	-

Discussion

DISCUSSION

The results of the investigation on "Micro irrigation and polythene mulching in oriental pickling melon (*Cucumis melo* var. *conomon* (L.) Makino)" are briefly discussed below.

5.1 Crop growth

The results of the study shows that application of polythene mulching and micro irrigation techniques increased growth attributes such as number of branches per vine, average length of vines, number of leaves per vine, leaf area and dry matter production (Table 4-9 and Fig. 3-6)

Polythene mulching had significant influence on both number of branches per vine and average length of vines. Full mulching recorded highest number of branches per vine though did not differ significantly from basin mulching. However, length of vines was significantly higher in full mulched plots than basin mulched plot at all stages of observation.

Number of leaves per vine and leaf area was also significantly influenced by polythene mulching. Full mulching recorded highest values of number of leaves per vine and leaf area at all stages of observation. At 30 DAS and harvest it was significantly superior to basin mulching and control and at 45 DAS it was at par with basin mulching.

Polythene mulching significantly influenced dry matter production. Full mulching increased dry matter production by 45 per cent and basin mulching by 37 per cent over control. Effects of both the mulched treatments were at par.

The higher vegetative growth under full polythene mulching might be due to availability of better conditions favouring growth. There was 100 per cent suppression of weed growth under full mulching. The soil remained under good tilth below the full mulching as it was at the time of sowing. Similarly at lateral

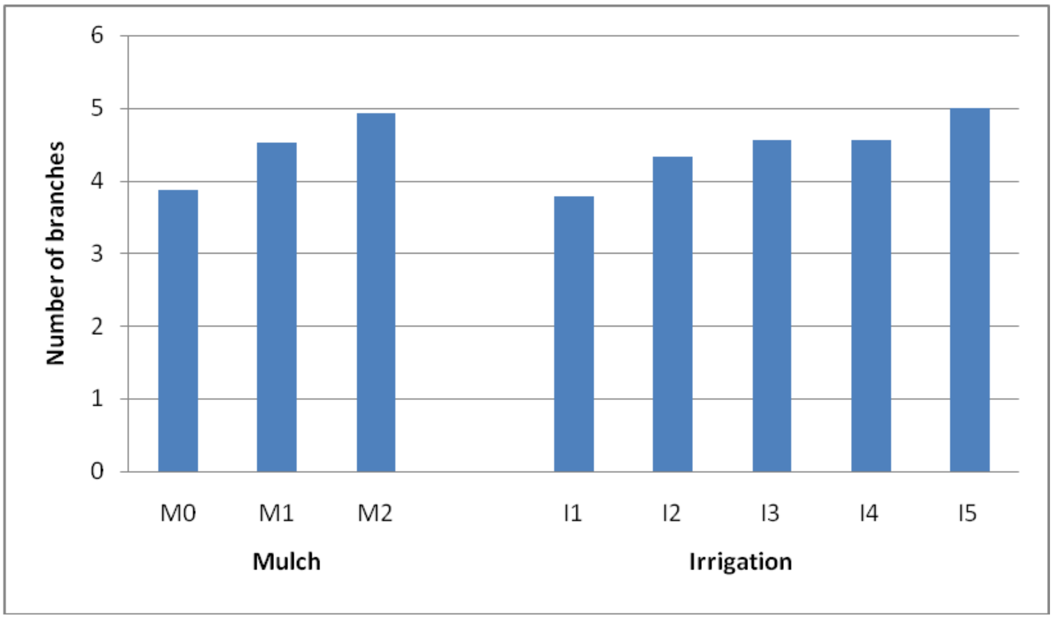


Fig. 3. Effect of mulch and irrigation on number of branches per vine at different growth stages

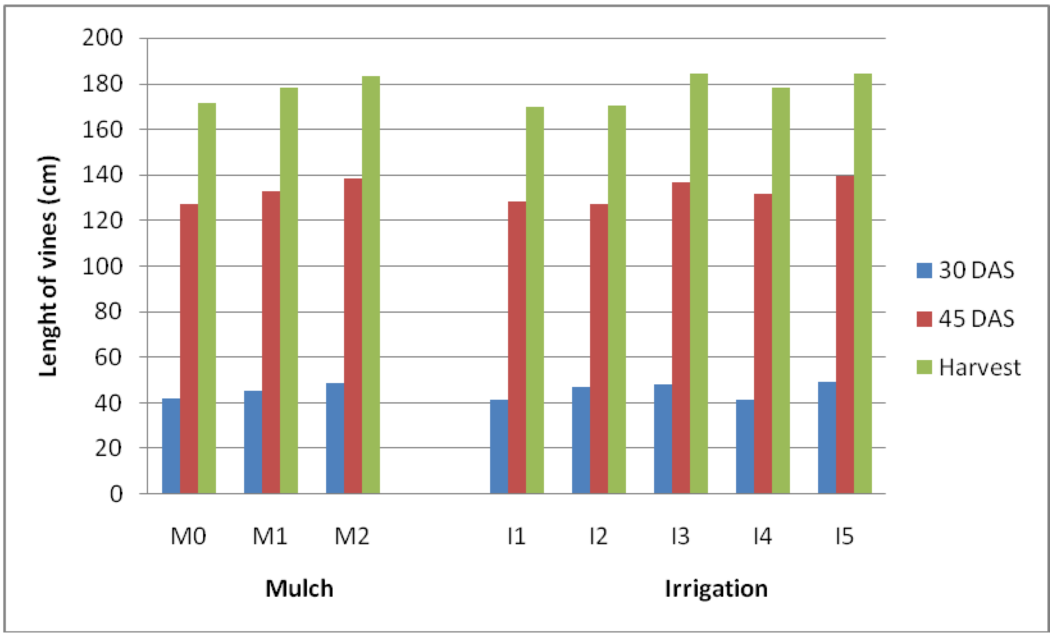


Fig. 4. Effect of mulch and irrigation on length of vines at different growth stages

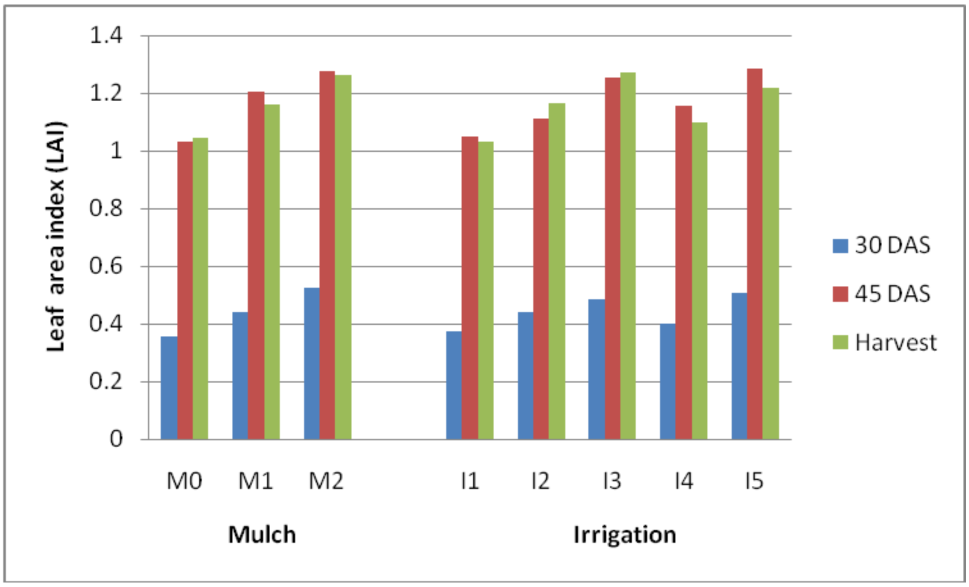


Fig. 5. Leaf area index (LAI) as influenced by mulch and irrigation at different growth stages

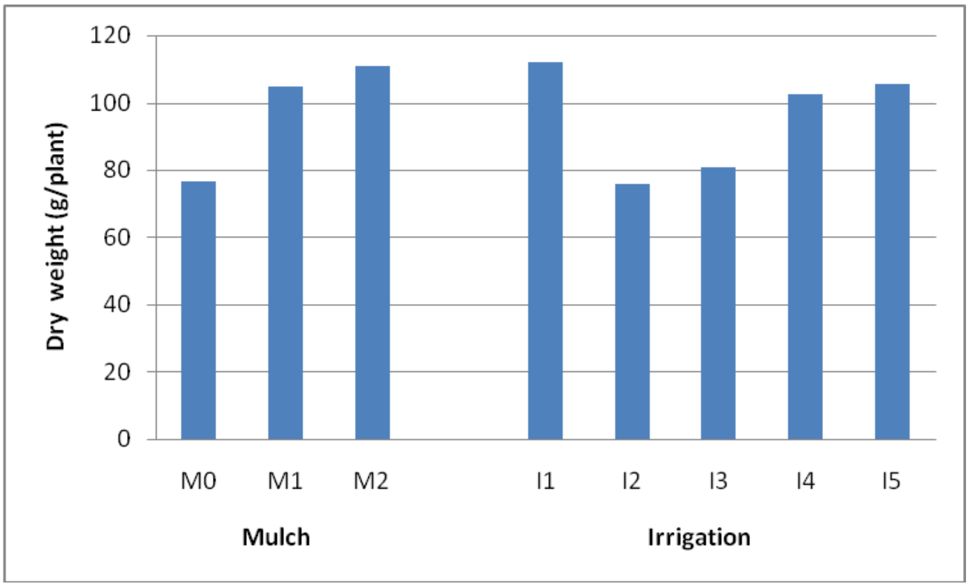


Fig. 6. Dry matter production (g plant^{-1}) as influenced by mulch and irrigation

distances of 0-15, 15-30, 30-45 and 45-60 cm soil moisture in the root zone depth increased by 7.9, 8.3, 13.0, 16.8 per cent, respectively under full mulching over control. Under basin mulching the corresponding increases over control were in the order of 7.0, 0.0, 6.2 and 7.4 per cent, respectively. The better physical conditions, weed free situation and higher soil moisture status under full polythene mulching favoured an ideal condition for growth, there by resulting in better growth. This growth was supported by better absorption of N, P, and K as evidenced by the highest content of these nutrients in the leaf samples analysed at different stages. Favourable growth conditions observed under polythene mulching produced more dry matter which favoured more number of branches per vine, average length of vines, number of leaves per vine, and leaf area. The result obtained in this study are in conformity with the results of Halsey(1985), Gutal *et al.* (1992), Chakraborty and Sadhu (1994), Ravinder *et al.* (1977), Shrivastava *et al.* (1994), Taber (1993) and Cebula (1995) in different vegetable crops.

In the case of basin mulching, its effect on weed control, checking evaporation loss, increasing soil moisture content, uptake of nutrients were not as effective as under full polythene mulching, but it was significantly better than control. Therefore its effect was better than that of control and lesser than that of full polythene mulching.

Growth characters varied significantly among irrigation treatments. Among irrigation treatments, in general, basin method recorded higher values of branches per vine (at par with all methods except drip), average length of vine (at par with microtube and bubbler at 30 DAS, bubbler at 45 DAS and at harvest), number of leaves per vine (at par with all methods except drip at 30 DAS, bubbler at 45 DAS and all methods at harvest), leaf area (at par with bubbler at 30 DAS, bubbler and wick at 45 DAS and bubbler at harvest. Leaf area index (LAI) was highest in bubbler methods (1.27) and was at par with wick method (1.22). Though dry matter production at harvest was maximum in drip irrigation, it was at par with basin method.

A higher moisture status in soil favoured better vegetative growth. Many studies have reported linear response to plant growth due to increase in water application rate (Beese *et al*., 1982, Hegde, 1987a and Singh *et al*., 1990). As melons require higher soil moisture, its growth was found greatly enhanced by an adequate supply of soil moisture @ 45 liters once in three days.

5.2 Flower production and setting

Among the flowering characteristics studied, mulching had no effect on days taken to first flowering and male-female flower ratio. But mulch had significant influence on number of female and male flowers produced per plant (Table 10 and Fig. 7).

Full mulching produced 10 per cent more female flowers than basin mulching, through the difference was not significant. Compared to control, the percentage increase in female flower production was 20.5 in full mulching in the polythene. In the case of male flower production M_2 produced 10.9 and 4.6 per cent more male flowers per plant than control and M_1, respectively and M_2 was significantly superior to M_0 and M_1. Basin mulching (M_1) produced 6.0 per cent more male flowers than control.

Application of polythene mulch had positive influence on number of flowers. This might be due to the conditioning effect of mulching on the rhizosphere through maintaining the soil moisture, temperature, aeration and suppressed weed growth supporting the better vegetative growth conducive for more flower production. Among the extent of polythene mulching, full mulching of the interspace was better than basin mulching. Generally, when cucurbitaceous crops are over irrigated, there is a tendency for higher vegetative growth and lower fruit yield. In this case also this trend could be visible very well.

Irrigation techniques had no significant influence on days taken to first flowering, Number of female flowers plant^{-1} and male to female flower ratio.

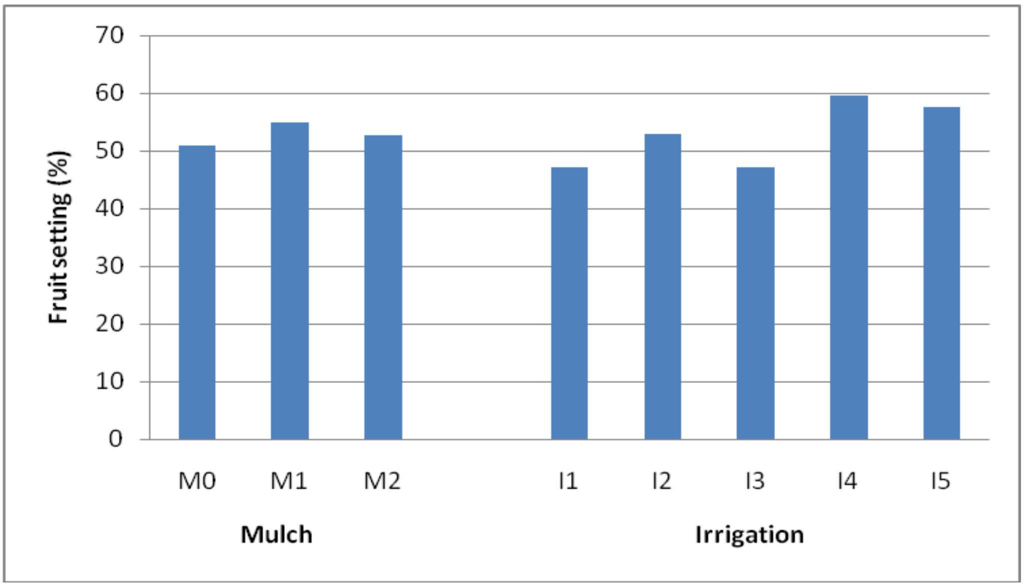


Fig. 7. Fruit setting (%) as influenced by mulch and irrigation

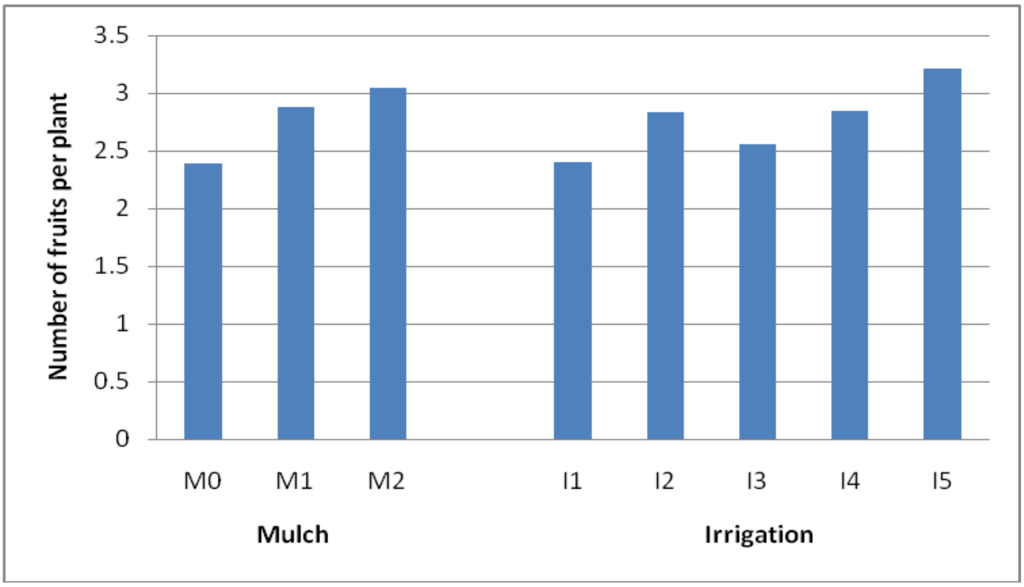


Fig. 8. Number of fruits plant^{-1} as influenced by mulch and irrigation

Influence of irrigation techniques was observed only in the case of number of male flowers

Among the irrigation treatments variation in number of days taken to first flowering was 30.00 to 30.56 days and this variation was negligible. Similarly the variation in female flower production plant^{-1} was 4.89 to 5.67. Significant influence of irrigation techniques on male flower production was observed. The value varied from 163.8 to 179.6 among the treatments. Highest male flower production was observed in basin irrigation and the lowest in I_4. The percentage increase in male flower production in I_5 over I_4 amounted to 9.6 per cent. I_5 was at par with all other irrigation methods except I_4. The general trend is that when the crop is over irrigated, the plant put forth more vegetative growth and less fruit production. It may be assumed that production of more male flowers is associated with more and vigorous vegetative growth.

Since all the irrigation methods contributed sufficient soil moisture ideal for crop growth, flower production did not vary much among them.

Among mulch treatments basin mulching in the polythene increased setting percentage by 7.9 and full mulching by 3.3 over control. In the case of irrigation, wick method recorded 3.7 per cent increase in setting over basin irrigation. In other micro irrigation techniques setting percentage was lesser by -11.5 to -18.2 than basin irrigation method. Poor fruit set observed in drip, microtube and bubbler irrigations may be due to insufficiency of moisture distribution in the root zone of the crop.

5.3 Yield attributes

Mulching had no significant effect on mean weight, girth and volume of fruits. Only length of fruits was significantly influenced by mulching (Table 11). However irrigation methods significantly influenced yield attributes.

Among the mulch treatments, the mean weight of fruits varied from 1146 to 1148 g, girth from 31.52 to 32.21 cm and volume from 1607 to 1781 cm^3 only. Fruit length varied from 27.51 to 29.39cm. Effects of basin mulching and full mulching were significantly superior control.

Wick irrigation recorded the highest values of mean fruit weight, length, girth and volume of fruit and the lowest values of the above parameters were recorded in basin irrigation (Table 11). I_4 was at par with I_1, I_2 and I_3 in the case of mean weight, girth and volume of fruits. In the case of mean length of fruits I_4 was superior to I_1, I_3 and I_5.

Slight advantage of wick irrigation over other methods of irrigation on parameters like mean fruit weight, length, girth and volume of fruit contributed to the better fruit yield in that treatment. It may also be noted that the higher moisture content provided by basin irrigation in no way influenced the yield attributes and in all the cases, it had negative influences.

5.4 Fruit yield

Mulch as well as methods of irrigation significantly influenced fruit yield (Table 12 and Fig. 8-9). Polythene mulching was superior to unmulched control. Though full mulching was at par with basin mulching, the former increased yield by 6.7 per cent over basin mulching. There was 28 per cent increase in fruit yield in full mulching over control, while that of basin mulching over control amounted to 20 per cent. Since fruit characteristics did not vary much among the mulch treatments, the increase in yield in mulched treatments was in direct proportion to the corresponding increase in mean number of fruits produced per plant over control.

More Moisture retention, good soil physical condition, weed free situation and better nutrient uptake associated with polythene mulching (black LDPE) promoted higher fruit set and fruit number $plant^{-1}$. This result is in conformity with the findings of Mavrodii (1979), Singh *et al.*(1990),

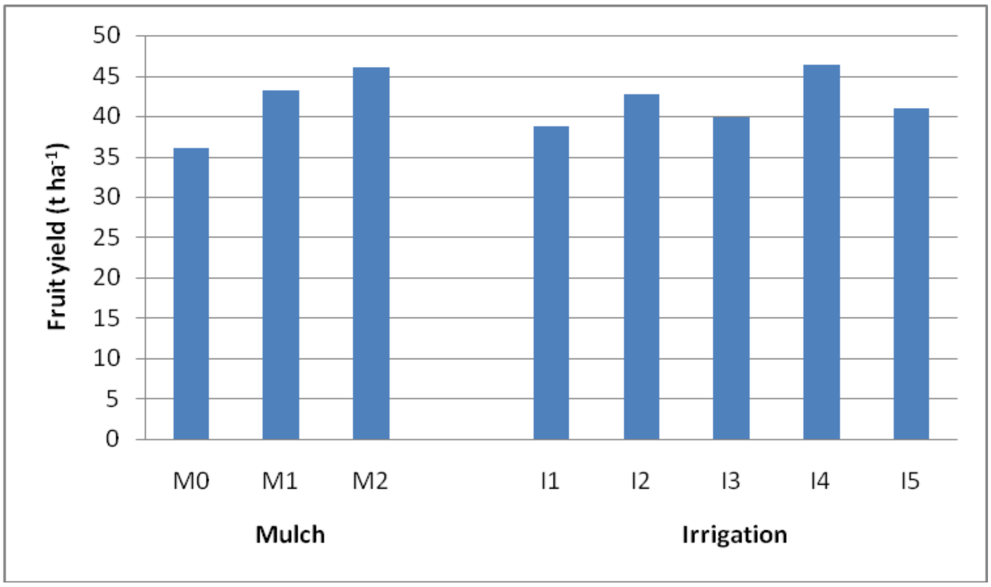


Fig. 9. Fruit yield (t ha^{-1}) as influenced by mulch and irrigation

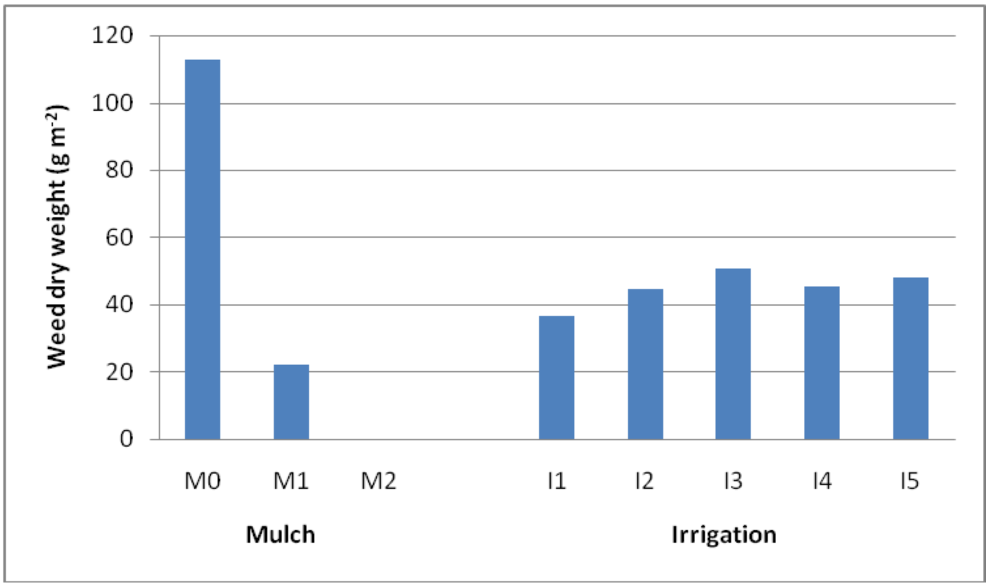


Fig. 10. Weed dry weight (g m^{-2}) as influenced by mulch and irrigation at harvest

Anabayan (1988), Veerabadran (1991), Clark and Moore (1991), Saravanababu (1994) and Gebremedhin (2001).

Among irrigation treatments highest yield was recorded in wick irrigation. It was 13 per cent more than that of basin method, 19.9 per cent over drip method, 8.4 per cent over microtube method and 16.1 per cent over bubbler method. Second best fruit yield was observed in microtube irrigation and the percentage increase overdrip, microtube, bubbler and basin methods were in the order of 10.6, 7.1 and 4.3, respectively.

Fruit yield per hectare was influenced by the number of fruits produced per plant and the mean weight of fruits. Though highest number of fruits produced per plant was the highest in basin irrigation, total yield was lesser than that of wick and microtube irrigations due to lowest mean fruit weight recorded in basin method. Wick irrigation, though recorded the second highest fruit number per plant; it recorded the highest yield due to the highest mean fruit weight observed in that treatment. Total yield of fruits was lesser in drip and microtube methods due to lesser number of fruits produced per plant in these treatments.

5.5 Mulching and irrigation methods on weed dry weight

The result on weed growth in terms of dry matter produced (Table 13 and Fig. 10) indicates that weed growth was significantly reduced with application of polythene mulch. Among irrigation methods drip and microtube irrigation were most effective in checking weed growth.

Weed Growth was checked by polythene mulching. Basin mulching alone reduced weed growth by 80 per cent and full mulching by 100 per cent. Complete absence of sunlight under black polythene mulch completely checked growth of weeds under it. Solarization effect under black polythene mulch also would have contributed to weed control.

Under irrigation methods bubbler and basin methods which received full wetting of basins recorded the highest weed growth. In methods like drip, microtube and wick irrigations, where water was applied at specific points, weed growth was much reduced due to limited wetted zone. Compared to basin method, weed dry matter production reduced by 23.4 per cent in drip, 7 per cent in microtube and 5.6 per cent in wick methods of irrigation. In bubbler method, weed dry matter increased by 5.6 per cent compared to basin method.

5.6 Chemical composition of leaves

Application of polythene mulch significantly increased N and K content in leaves at 35 DAS and harvest and in no way influenced leaf phosphorus content at the above stages of observation (Table 14-16 and Fig. 11-13).

Full mulching with black LDPE significantly enhanced nitrogen content in leaves both at 35 DAS and harvest over basin mulch and control. At 35 DAS, the leaf nitrogen content in full mulching was 4.82 percent and 4.21 per cent in control. The corresponding leaf nitrogen contents at harvest were 2.99 and 2.37 per cent respectively. Leaf potassium content in full mulching at 35 DAS was 2.93 per cent and 2.74 per cent in control. The corresponding leaf potassium contents at harvest were 1.92 and 1.72 per cent respectively. Leaf N and K contents both at 35 Das and harvest were significantly higher with basin mulching than control. Leaf phosphorus content was not significantly influenced by mulch treatments. But full mulching recorded, slightly higher values than the others.

The superior effect of full mulching with black LDPE on N and K concentration in leaves might be due to the favorable influence on soil moisture regimes created in the root zone of the crop, 100 per cent weed suppression reduced competition for nutrients and good tilth of the soil under polythene mulch. Even under basin mulching with black LDPE, a moderate effect of the above parameters could be observed on leaf N and K contents. The leaf

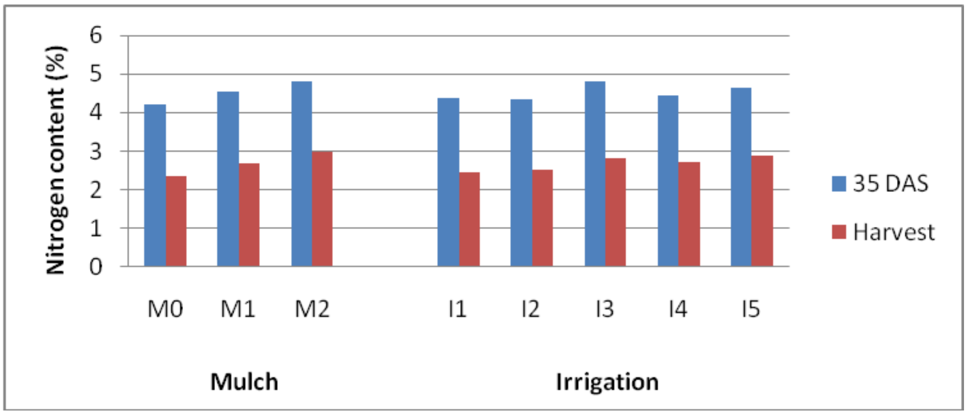


Fig. 11. Leaf nitrogen content (%) as influenced by mulch and irrigation at different growth stages

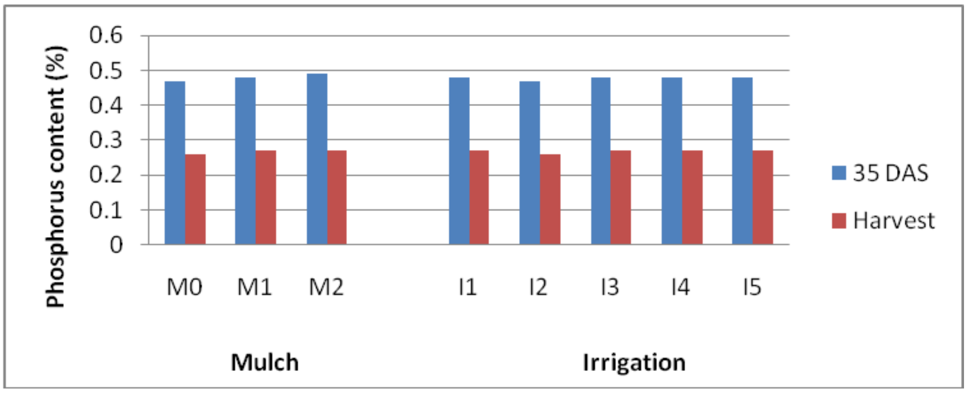


Fig. 12. Leaf phosphorus content (%) as influenced by mulch and irrigation at different growth stages

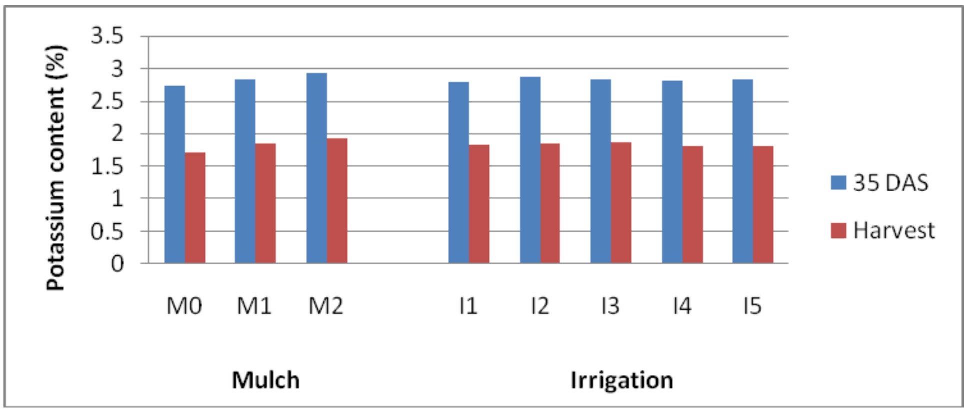


Fig. 13. Leaf potassium content (%) as influenced by mulch and irrigation at different growth stages

phosphorus content was very small compared to N and K and the variation in P content was negligible among the mulch treatments.

Among irrigation treatments, bubbler method recorded higher N and K contents. At 35 DAS, leaf N content was significantly higher in bubbler method and at harvest it was at par with basin method and wick irrigation and these treatments was superior to other methods. Potassium content at 35 DAS though did not vary significantly among irrigation methods, at harvest bubbler method recorded the highest value and was significantly superior to basin method. Leaf phosphorus content did not vary significantly among irrigation methods.

In the active growth stage of 35 DAS, among irrigation treatments significant variation in leaf nutrient concentration was recorded only in the case of nitrogen. There was 4 per cent increase in leaf N content in bubbler method over basin method and the corresponding increase in leaf N content in bubbler method over drip, microtube and wick methods were in the order of 10, 10.6 and 8 percent respectively. However, the higher leaf N content under bubbler method had not influenced fruit yield. It may be assumed that surface wetting as provided by bubbler method enhanced nitrogen content at the active growth stage of 35 DAS. But a heavy wetting as available with basin method did not enhance nitrogen content.

At harvest both nitrogen and potassium recorded moderate variation in their contents in leaves. In the case of leaf nitrogen, maximum content of 2.87 per cent was recorded in basin irrigation which was higher by 16.7, 13.9, 2.1 and 5.1 per cent respectively over drip, microtube, bubbler and wick methods of irrigation, respectively. When leaf potassium content was analysed, maximum content of 1.87 per cent was observed in bubbler method which was higher by 2.7, 1.6, 3.3 and 3.9 per cent respectively over drip microtube, wick and basin methods irrigation.

5.7 Soil moisture studies

5.7.1 Soil moisture distribution

Soil moisture content gradually decreased as radial distance from the dripper increased. Mulching due to its effect on reducing surface evaporation and increasing retention has helped in maintaining higher soil moisture content even at longer radial distance in all the irrigation methods. Full mulching with black LDPE increased soil moisture by 8.8, 8.3, 13.0 and 16.7 per cent over control at lateral distances of 0-15, 15-30, 30-45 and 45-60 cm, respectively, while the corresponding increase of soil moisture by basin mulching with black LDPE was in the order of 7.0, 0.0, 6.3 and 7.4 per cent, respectively. The moisture distribution at longer radial distance was higher under full mulching with black LDPE compared to basin mulching alone.

Under irrigation methods also, soil moisture content decreased over radial distance from the center of the pit where irrigation was applied except in basin irrigation. The result can be best understood from the Table 17 which depicts the mean soil moisture content at various radial distances as influenced by methods of irrigation.

Drip irrigation maintained lesser amount of water at all the radial distances from the central point of irrigation. At 0-15 and 15-30 cm radial distance, there was not much variation in soil moisture content between microtube, bubbler, wick and basin irrigation methods. But 30-45 and 45-60 cm radial distance basin flood irrigation maintained higher moisture than other methods. At 30-45 cm radial distance, basin flood irrigation maintained 81.7, 16.4, 24.8 and 24.0 per cent more soil moisture than I_1, I_2, I_3 and I_4 respectively. At 45-60 cm radial distance also, basin flood irrigation maintained 85.4, 24.7, 43.4, and 27.7 percent more soil moisture over I_1, I_2, I_3 and I_4. Microtube, bubbler and wick irrigation maintained more moisture around the plant to a radial distance of 30 cm while basin flood irrigation maintained more moisture to a radial distance of 60 cm. Mean soil moisture content (% w/w) before irrigation at different distance from the point of irrigation and different depths as influenced by irrigation methods are given in Table 27 and 28.

In the case of vertical moisture distribution also mulching with black LDPE retained more soil moisture than control. The increase in soil moisture at 0-15, 15-30 and 30-60 cm in basin mulched plots over control was in the order of 7.3, 6.0 and 7.6 per cent, respectively. In fully mulched plots, the corresponding increase in soil moisture over control was in the order of 14.2, 10.6 and 10.9 per cent, respectively.

Depth wise, soil moisture content increased gradually from the surface 0-15 cm to the bottom 30-60 cm layer in all the irrigation treatments. In all the layers, drip irrigation maintained the lowest amount of water as is evident from the Table 18.

Highest soil moisture level was maintained by basin flood irrigations in all the depths. The variation in soil moisture content among microtube, bubbler and wick irrigation was negligible in all the three layers studied.

The reason for higher soil moisture content at the bottom layer of 30-60 cm than 0-15 and 15-30 cm layers might be due to the fact that, the root mass is more concentrated at the depth of 5-30 cm and the removal of moisture by the crop and evaporation losses are mostly from the upper layers. This result is in conformity with the findings of Gebremedhin (2001).

5.7.2 Soil moisture depletion

Maximum depletion of soil moisture was observed from top 15 cm layer irrespective of moisture conservation and irrigation treatments except drip and bubbler methods, where maximum depletion occurred from 15-30 cm layer (Table 23 and Fig. 14).

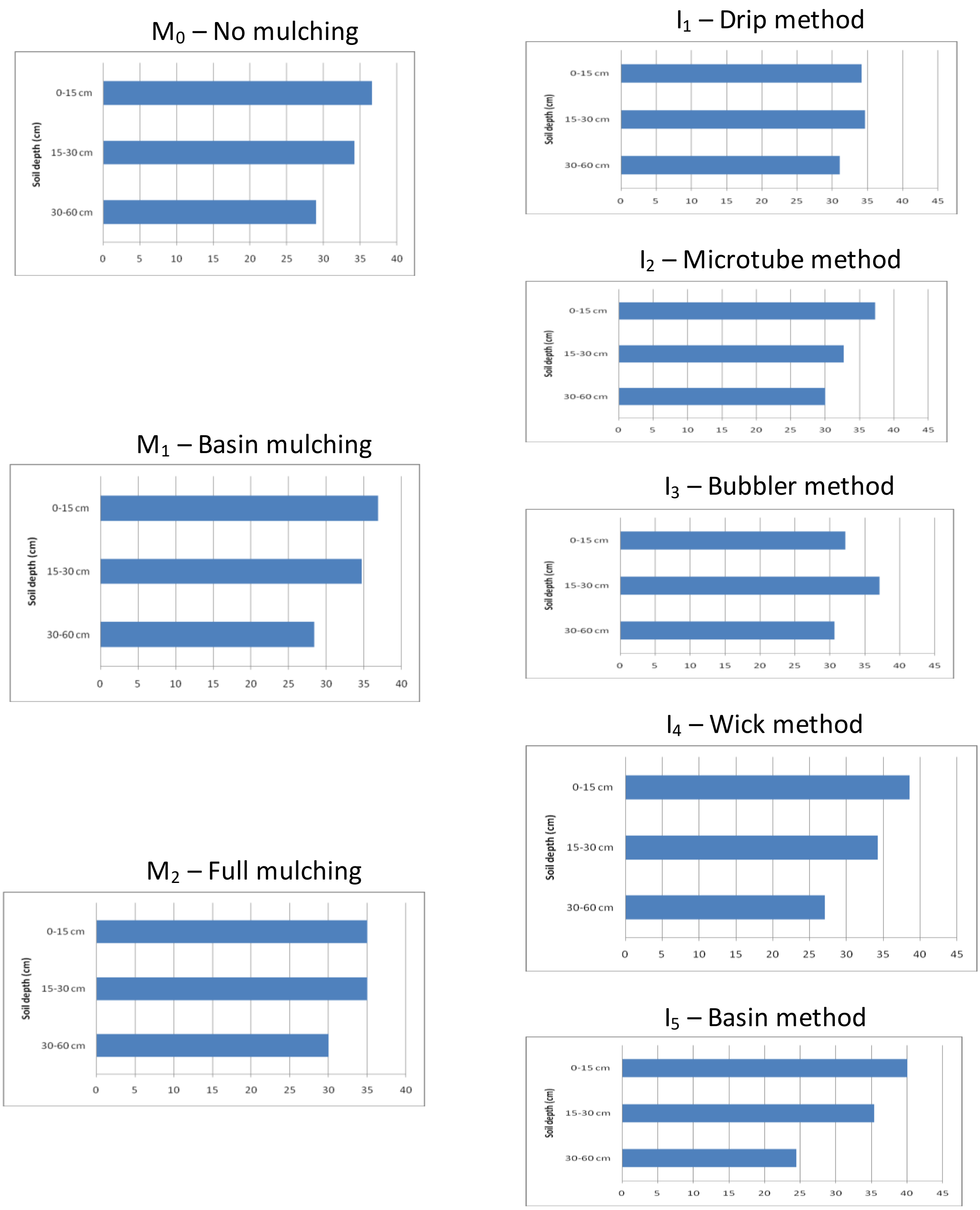
Table 27. Mean soil moisture content (% w/w) before irrigation at different distance from the point of irrigation as influenced by methods of irrigation.

Irrigation methods	Lateral distance from point of irrigation			
	0-15 cm	15-30 cm	30-45 cm	45-60 cm
I_1	12.53	10.64	8.93	8.30
I_2	15.93	15.16	13.94	12.34
I_3	16.51	14.55	13.00	10.73
I_4	15.66	15.18	13.09	12.05
I_5	15.24	15.37	16.23	15.39

Table 28. Soil moisture content (% w/w) before irrigation at different depths as influenced by irrigation methods.

Irrigation treatments	Depth from surface		
	0-15 cm	15-30 cm	30-60 cm
I_1	10.68	10.65	11.80
I_2	13.19	14.24	14.87
I_3	14.12	13.83	14.93
I_4	12.83	13.54	15.48
I_5	14.33	15.18	17.21

Fig. 14. Soil moisture depletion pattern (%) as influenced by mulch and irrigation



Among mulch treatments M_0 depleted 36.6 per cent from 0-15 cm layer, 34.2 per cent from 15-30 cm layer and 29.0 per cent from bottom 30-60 cm layer. This trend was almost identical under basin mulching with black LDPE (M_1). However, under full mulching moisture depletion was 35 per cent each from 0-15 and 15-30 cm layers and 30 per cent from 30-60 cm layers. Under full mulching depletion was slightly lowered in the top layer and slightly increased from bottom layers.

In the irrigation treatments, Soil moisture depletion varied much in all layers. For drip and bubbler methods, maximum depletion occurred from 15-30 cm layer. For microtube, wick and basin irrigation, maximum depletion occurred from surface 0-15 cm layer. In the surface layer of 0-15 cm, maximumdepletion of soil moisture occurred under basin irrigation and minimum under bubbler irrigation. In the 15-30 cm layer, maximum depletion occurred under bubbler method and minimum under microtube. In the 30-60 cm layer, maximum depletion occurred under drip method and minimum under basin irrigation.

Overall, the maximum depletion was observed from top 15cm layer except in drip and bubbler methods where maximum depletion occurred from 15-30 cm layer and depletion decreased with soil depth. This might be due to the fact that, besides transpiration, losses from the soil surface were considerable and also the roots of the crop were mostly confined to the top surface layers. Compared to basin flood irrigation, the extraction of more water from the lower layer of 30-60 cm under micro irrigation techniques (I_1 to I_4) may be due to proliferation of root system to utilize soil moisture from the deeper layers under micro irrigation systems with less amount of water. This finding is in conformity with the findings of Gebremedhin (2001).

5.8 Consumptive use and crop coefficient

The total consumptive use as indicated in Table 19 and Fig. 15 was lowest with full mulching with black LDPE (246.3 ha-mm) and basin mulching

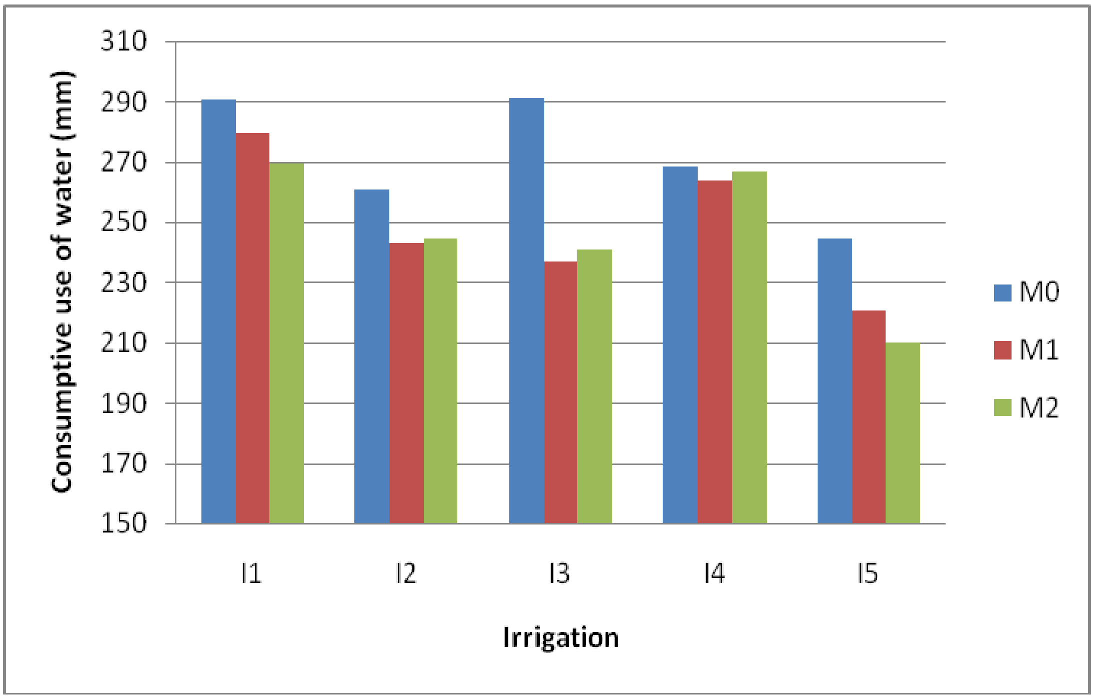


Fig. 15. Mean consumptive use of water as influenced by combination of mulch and irrigation

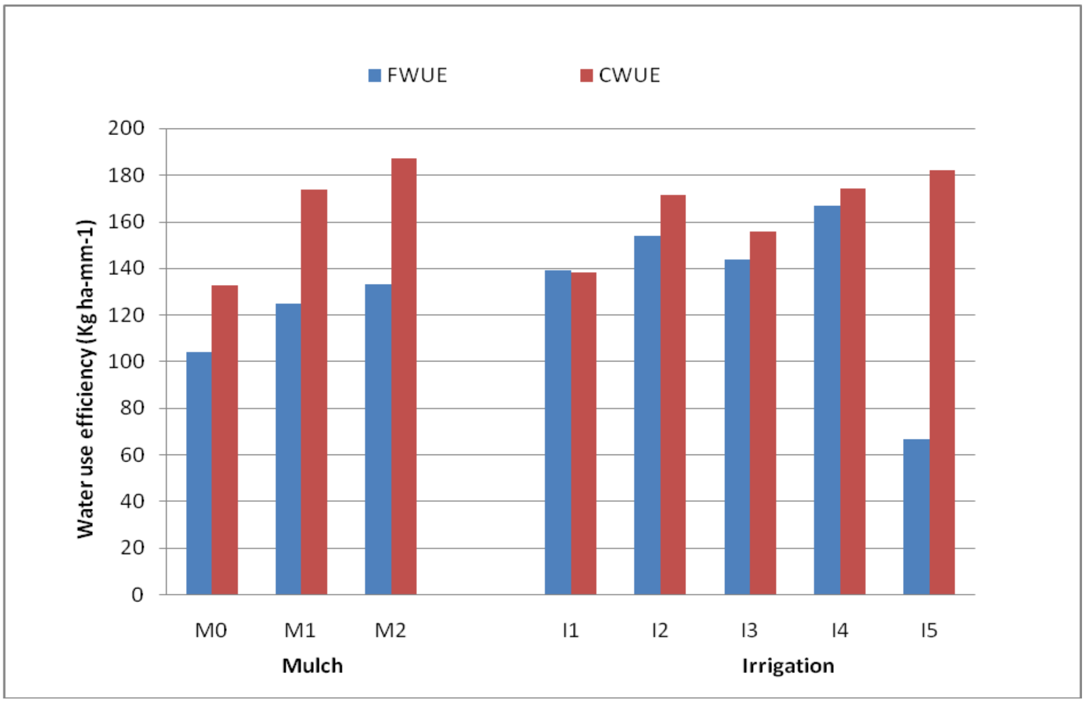


Fig. 16. Effect of mulching and level of irrigation on water use efficiency

(248.6 ha-mm) as compared to control (271.1 ha-mm). Consumptive use was reduced by 8.3 percent under basin mulching and by 9.1 per cent under full mulching compared to control. The black LDPE mulched treatments recorded lower consumptive use as they conserved more moisture in soil, while bare soil lost moisture quickly as evaporation loss and there was higher evapo-transpiration due to the highest weed growth (112.7 g m^{-2}). Reduced moisture loss and consumptive use under mulch has been pointed by Veeraputhiran (1996) and Gebremethin (2001) in oriental pickling melon.

Among the irrigation treatments highest mean seasonal consumptive use was recorded by drip method (279.9 ha-mm) and the lowest by basin flooding (224.9 ha-mm). Drip, microtube, bubbler and wick methods increased consumptive use by24.4, 10.8, 14.0 and 18.4 per cent over basin method. The higher consumptive use under micro irrigation techniques may be due to high evaporation loss from soil surface as water is applied daily at low pressure (2 l h^{-1}).

The average daily crop coefficient was maximum (0.57) with no mulch and minimum (0.51) under full mulching with black LDPE (Table 20). With respect to irrigation treatments, daily crop coefficient was the highest under drip irrigation and lowest under basin flooding. The trend was similar to what was observed for consumptive use.

5.9 The periodical mean consumptive use and crop coefficient values.

The periodical mean consumptive use and crop coefficient values varied with crop age and growth in irrigation methods (Table 21). The periodical CU and Kc values increased gradually from early seedling stage (1-20 DAS) to fruit maturity stage (61-78 DAS) is all irrigation methods except drip method where the highest CU and Kc values were observed at the active growth stage of 21-40 DAS. The peak periodical mean CU at 61-78 DAS may be associated with full fruit enlargement and development. Moreover, the meteorological parameters like high temperature and low humidity etc. towards the maturity stage of the crop also would have contributed to it.

5.10 Water use efficiency

Mulched crops recorded higher field and crop water use efficiencies (Table 22 and Fig. 16). Between mulched treatments full mulching with black LDPE was superior to basin mulching with black LDPE. The increase in FWUE due to full mulching and basin mulching were 28.0 and 20.0 per cent respectively and the corresponding figures for CWUE were 40.8 and 30.8 per cent respectively over control. Increase in WUE by application of black LDPE mulch was observed by Gupta and Acharya (1994) and Gebremedhin (2001). The higher field and crop WUE with application of mulch is due to lower consumptive use and higher fruit yield.

There was mulch variation in field and crop water use efficiencies among irrigation methods. Field WUE was maximum in wick irrigation and minimum in basin flooding. Compared to basin flooding, FWUE increased by 109, 131, 116 and 151 per cent in drip, microtube, bubbler and wick irrigation methods. High FWUE observed in wick irrigation was due to high yield observed in it and low FWUE observed in basin flooding was due to less water use compared to the high volume of water applied in it.

Highest CWUE was observed in basin irrigation and lowest in drip method. Between basin and wick methods, there was not mulch difference in mean seasonal consumptive use. Lowest consumptive use and comparatively higher yield recorded in basin irrigation contributed to higher CWUE.

5.11 Economics of irrigation methods and mulching in oriental pickling melon

The economic analysis of irrigation and mulching oriental pickling melon clearly indicated the superiority of mulching with black LDPE on gross return and net profit (Table 24-25 and Fig. 17).

The highest net profit was recorded from fully mulched plot with black LDPE. The increases in net profit due to full mulching with black LDPE and basin mulching with black LDPE over control without mulch were Rs. 51,838.30 and 40,786.70 per hectare respectively. Hence use of black LDPE as mulch in entire space or in the basin only has increased net profit by 33.4 and 26.3 per cent respectively compared to the control. The increase in net income per rupee invested was in the order of 2.76 and 2.85 respectively. The increase in cost of cultivation due to full mulching with black LDPE over basin mulching alone amounts to Rs. 6,288.40 and the increase in net profit due to full mulching over the latter amounted to Rs. 11,051.60. Therefore additional spending of Rs. 6,288.40 ha^{-1} is full mulching with black LDPE over basin mulching alone gave a benefit of Rs. 11,051.60 ha^{-1}. Therefore depending on convenience and money available with the farmer he can choose either one of the mulching schedules.

The net profit and net returns per rupee invested was the maximum in wick irrigation. Lowest net profit of Rs. 63,946.20 ha^{-1} per hectare was observed in drip irrigated plot and the lowest income per rupee invested (2.19) in basin flood irrigated plots. Net profit per hectare under wick irrigation was higher by Rs. 21,508 ha^{-1} over basin flooding method, Rs. 49,359.70 ha^{-1} over drip, Rs. 21,720 ha^{-1} over microtube and Rs. 44,192.80 ha^{-1} over bubbler method. The study has thus clearly indicated the benefit of wick irrigation on net profit and net income per rupee invested.

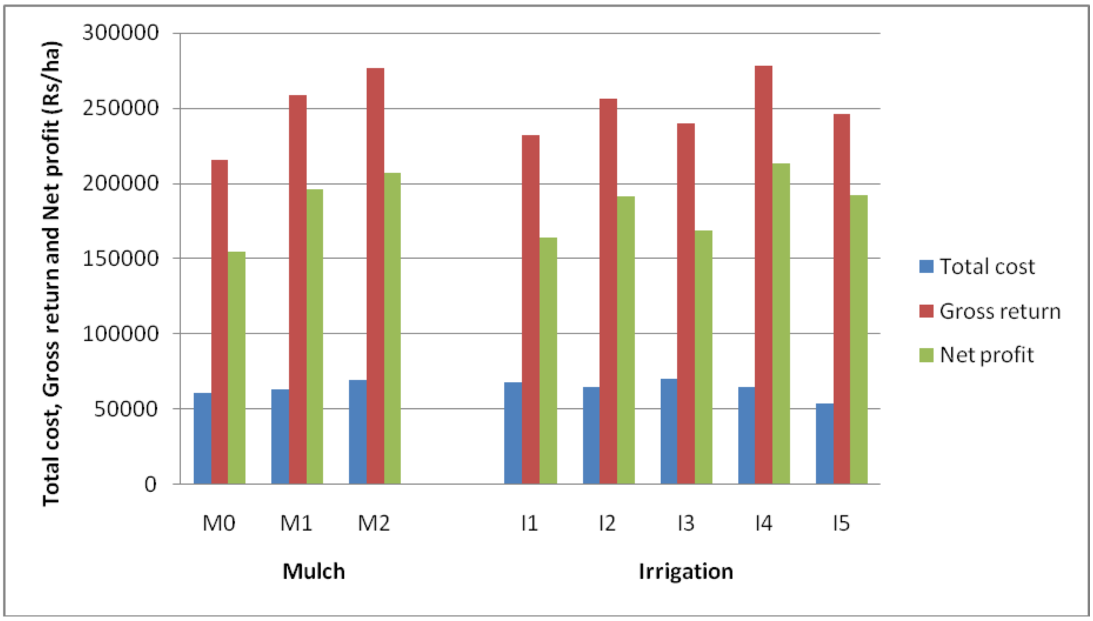


Fig. 17. Economics of cucumber production per hectare as influenced by mulch and irrigation

The result of economic analysis of treatment combinations also indicated that the highest net profit in each irrigation level was obtained from the combination with full mulching with black LDPE followed by combination with basin mulching. Among the combinations, highest net profit was recorded by I_4M_2 which amounted to Rs. 2,30,329.20 ha^{-1} followed by I_4M_1 with a net profit of Rs. 2,15,779.60 ha^{-1}. Among the treatment combinations, highest net income per rupee invested (3.40) was observed with I_4M_1 followed by I_2M_1.

Micro irrigation techniques saved water to an extent of 121.5 per cent (Table 26). However yield advantage was observed only in microtube and wick irrigations. Microtube irrigations in addition to saving water by 121.5 per cent increased fruit yield by 1.78 tonnes per hectare. On the other hand wick irrigation also saved irrigation water by 121.5 per cent and fruit yield by 5.37 tonnes per hectare over basin irrigation.

The final recommendation is that for the more profitable production of oriental pickling melon during summer months, daily wick irrigating at the rate of 50 per cent Ep should be combined with full mulching of the interspaces with black polythene.

SUMMARY

A field experiment was conducted at the Agricultural Research Station, Mannuthy, Thrissur during the summer season of December 2004 to March 2005 to study the effect of "Micro irrigation and polythene mulching in oriental pickling melon (*Cucumis melo* var. *conomon* (L.) Makino)" grown in summer rice fallows.

The soil of the experimental field was sandy clay loam with bulk density of 1.34 g cm^{-3}. It was acidic in reaction, medium in organic carbon, available nitrogen and potassium and low in available phosphorus. The weather during the period was almost normal with an average daily pan evaporation (5.9 mm), relative humidity (38.5 - 71.5 %) and wind speed (6.2 km hr^{-1}). During the cropping period no rainfall was received.

The experiment was laid out in ramdomised block design (RBD) with three replications. The treatments consisted of combinations of five irrigation techniques (drip, microtube, bubbler, online wick and basin irrigation) and mulch treatments (control, basin mulching and full mulching with black LDPE). Hence totally it consisted of 15 treatment combinations. Oriental pickling melon variety *Mudicode* was used for the study.

Important results obtained and conclusions drawn out from the investigations are summurised here under.

1. Mulching with black polythene significantly increased the number of branches per vine. Full mulching recorded the highest number of branches per vine though it was at par with basin mulching. Among irrigation methods, basin irrigation recorded the highest number of branches per vine which was at par with other irrigation techniques except drip method.
2. Full mulching with black LDPE significantly increased average length of vine at 30 DAS, 45 DAS and at harvest over basin mulching and control. At all the above growth stages, average length of vines was maximum under basin

irrigation, though it was at par with I_2 and I_3 at 30 DAS and with I_3 at 45 DAS and at harvest.

3. Application of LDPE in the entire interspace significantly increased the number of leaves per vine over basin mulching and control at 30 DAS and harvest. At 45 DAS, it was at par with basin mulching and significantly superior to control. At 30 and 45 DAS, basin irrigation recorded the maximum number of leaves per vine. At 30 DAS it was significantly superior to drip method and at par with other methods. At 45 DAS, it was at par with bubbler method and significantly superior to other methods. At harvest irrigation treatments were at par.
4. Leaf area was significantly increased by full mulching with black LDPE. At 30 DAS and harvest, full mulching was significantly superior to control and basin mulching. At 45 DAS, full mulching was at par with basin mulching and both these treatments were significantly superior to control. At 30 DAS and harvest, highest leaf area was produced by basin method and was at par with bubbler method and these two treatments were significantly superior to other methods. At 45 DAS, bubbler method recorded the highest leaf area, though it was at par with wick and basin irrigation methods. Full mulching of the interspace with black LDPE greatly increased LAI over basin mulching and control. Among irrigation methods, LAI was highest in basin irrigation followed by bubbler method.
5. Dry matter production at harvest was maximum in full mulching though it was at par with basin mulching. Both these treatments were superior to control. Drip irrigation recorded the maximum dry matter at harvest and was at par with online wick and basin irrigations. Highest production of dry matter was observed in drip irrigation with full mulching (I_1M_2). It was at par with all other treatments except drip irrigation with no mulch (I_1M_0) which was significantly inferior to all other treatments.
6. Neither mulch nor irrigation methods significantly influenced days taken to first flowering. It was almost 30 days in all the treatments.

7. Both the mulched treatments significantly increased number of female flowers per plant over control and M_1 and M_2 were at par. Irrigation methods had no significant influence on female flower production.
8. Full mulching with black LDPE significantly increased the number of male flowers per plant over basin mulching and control. Maximum number of male flowers per plant was produced by basin method and minimum by online wick method and the former was significantly superior to the latter and at par with other methods.
9. Mulch or irrigation treatments did not significantly influence female-male flower ratio. It varied from 2.97 to 3.24 among the treatments.
10. While basin mulching with black LDPE increased setting percentage by 10 per cent over control, full mulching increased it by five per cent only. Wick irrigation increased setting percentage by three per cent over basin method. Compared to basin irrigation setting percentage was lesser by eight to 22.7 per cent in other irrigation methods like drip, microtube and bubbler.
11. Mulch did not significantly influence average fruit weight. It was significantly lower in basin irrigation compared to all the other irrigation methods. It was highest in wick irrigation and registered 28 per cent higher mean fruit weight over basin method.
12. Mulching significantly increased mean fruit length over control and the difference between M_1 and M_2 was not significant. Among irrigation treatments, longest fruits were produced in online wick irrigation and was at par with microtube and significantly superior to other methods.
13. Mean fruit girth was not affected by mulches. Among irrigation treatments, highest average fruit girth was recorded in wick irrigation which was at par with all other methods except basin irrigation.
14. In the case fruit volume also mulch had no significant influence. Here also online wick irrigation recorded the highest fruit volume which was at par with other irrigation methods except basin irrigation. Wick irrigation recorded 30 per cent increase in fruit volume over basin method.

15. Basin and full mulched treatments produced significantly more fruits per plant than control and the difference between them was not significant. Over control, basin mulching and full mulching increased fruit number per plant by 20.5 and 27 per cent respectively. Among irrigation treatments maximum number of fruits per plant was produced by basin method and was significantly superior to all other methods. It produced 3.21 fruits per plant and this was more by 33.8, 13.4, 25.4 and 12.6 per cent over drip, microtube, bubbler and wick methods.
16. Mulching exhibited significant influence on fruit yield. Full mulching with black LDPE produced 46.04 tonnes fruits ha^{-1}, while basin mulching produced 43.15 t ha^{-1}. The increase in fruit yield in full mulching over control amounted to 28 per cent and that of basin mulching over control was 20 per cent. Both M_2 and M_1 were at par. Though basin irrigation produced the highest number of fruit per plant, fruit yield was maximum in wick irrigation followed by microtube irrigation due to higher average fruit weight. While wick irrigation was significantly superior to basin method, microtube irrigation was at par with basin method. The yield increase in wick irrigation over basin method was 13 per cent and that of microtube method over basin method amounted to 4.3 per cent.
17. While control plots produced 112.7 g weed dry matter per square meter, basin mulching significantly reduced it to 22.27 g. In full mulched plots weed growth was checked by 100 per cent. Among irrigation methods only drip method reduced yield growth (36.67 g m^{-2}) significantly. Highest weed growth was recorded in bubbler method (50.56 g m^{-2}) followed by basin method (47.89 g m^{-2}). Among the combinations, basin irrigation with no mulch recorded highest value of dry weight of weeds.
18. Both at 35 DAS and harvest, polythene mulches significantly increased N and K contents in leaves. Maximum contents of N and K were recorded under full mulching at both the above stages and full mulching was superior to basin mulching and control. Basin mulching also was significantly superior to control. Phosphorus content of leaf was not influenced by mulches. Among

irrigation methods bubbler method recorded higher N and K contents in general. At the active growth stage of 35 DAS, leaf N content (4.81 per cent) under bubbler method was significantly higher than other methods and at harvest it was at par with basin and wick methods. Potassium content did not vary significantly among irrigation methods at 35 DAS, but at harvest it was highest under bubbler method and significantly superior only to basin method. Leaf phosphorus content did not vary significantly among irrigation methods.

19. Mulching due to its effect in reducing evaporation and increase in retention has helped to maintain higher soil moisture content even at longer lateral distance. Full mulching with black LDPE retained more moisture than basin mulching. Full mulching retained 8.8, 8.3, 13.0 and 16.7 per cent more moisture than control at 0-15, 15-30, 30-45 and 45-60 cm lateral distance, respectively. Among irrigation methods, in general basin irrigation retained more moisture than other methods at lateral distances of 15 to 60 cm. As distance increased from the central point (0-15 cm.) to the outer boundary (45-60 cm.) of the pit, soil moisture content decreased gradually in all irrigation methods except basin irrigation were the moisture remained almost unchanged (15.24 to 15.39 per cent)
20. Due to mulching with black LDPE, soil moisture increased depth wise also. The increase in soil moisture content at 0-15, 15-30 and 30-60 cm layers under basin mulching over control were in the order of 7.3, 6.0 and 7.6 per cent respectively, while the corresponding increases under full mulching amounted to 14.2, 10.6 and 10.9 per cent respectively. Depth wise also, soil moisture content increased gradually from surface 0-15 cm layer to bottom 30-60 cm layer. At each of these layers, basin irrigation retained 2.0 to 46.0 per cent more moisture than other methods of irrigation.
21. Maximum depletion of soil moisture was observed from top 0-15 cm layers irrespective of mulch or irrigations methods except in drip and bubbler methods where maximum depletion occurred from 15-30 cm layer. On an average, the percentage depletion of moisture from 0-15, 15-30 and 30-60 cm layers accounted to 36.5, 35.0 and 28.5, respectively.

22. Mean seasonal consumptive use was less under full mulching with black LDPE (246.3 ha-mm) and basin mulching (248.6 ha-mm) compared to control (271.1 ha-mm). Among irrigation methods mean seasonal consumptive use was minimum with basin irrigation (224.9 ha-mm) and maximum with drip method (279.9 ha-mm).
23. The average daily crop coefficient value was maximum (0.57) for plots with no mulch and was reduced to 0.51 under full mulching and 0.52 under basin mulching. Among irrigation methods average daily crop coefficient value was the minimum for basin method (0.47) and maximum for drip method (0.59). The periodical mean consumptive use and crop coefficient values varied with crop age and reached the peak at fruit maturity stage (61-78 DAS) in irrigation methods except in drip method where the peak was reached at the active growth stage of 21-40 DAS
24. Full mulching and basin mulching with black LDPE substantially increased field water use efficiency (FWUE) by 28.0 and 20.0 and crop water use efficiency (CWUE) by 40.8 and 30.8 per cent respectively over control. Among irrigation methods FWUE was maximum under wick irrigation and minimum under basin irrigation. Drip, microtube, bubbler and wick irrigations recorded 109, 131, 116 and 151 per cent more FWUE over basin irrigation. In the case of CWUE also basin irrigation recorded the highest value and the least by drip method.
25. The total cost production of cucumber in a hectare under full mulching with black LDPE was Rs. 69,342.90 ha^{-1} and that for basin mulched treatment amounted to Rs. 63,054.50 ha^{-1}. The increases over control amounted to 14.0 and 3.7 per cent, respectively. The increases in net profit due to full mulching and basin mulching with black LDPE were Rs. 51,838.30 ha^{-1} (33.4 per cent) and Rs. 40,786.70 ha^{-1} (26.3 per cent) over control respectively. However, net income per rupee invested was slightly higher with basin mulching (2.85) than full mulching (2.76). Among irrigation treatments highest cost of cultivation per hectare was recorded by bubbler irrigation (Rs. 70,346.90 ha^{-1}) and the lowest by basin method (Rs. 54,022.10ha^{-1}).Thehighest net return

(Rs. 2,13,305.90 ha^{-1}) and net income per rupee invested (3.29) was recorded by wick irrigation and these values were higher by Rs. 21,508 ha^{-1} (11.2

per cent) and 1.1 (50.2 per cent) over basin method respectively. In each irrigation method, there has been reasonable increase in net profit due to mulching with black LDPE. Full mulching with black LDPE emerged better than basin mulching in all irrigation methods except microtube where full mulching was not superior to basin mulching. The highest net return of Rs. 2,30,329.20 ha^{-1} was recorded by the combination of wick irrigation and full mulching with black LDPE (I_4M_2) and the second by (I_4M_1) wick irrigation and basin mulching with black LDPE (Rs 2,15,779.60 ha^{-1}). The differences amounted to Rs. 14,549.60 ha^{-1} and the additional cost of cultivation of the former over the latter was Rs. 6,288.40 ha^{-1}. Therefore I_4M_2 is advantageous over I_4M_1 by Rs. 8,261.20 ha^{-1}.

26. Wick irrigation in addition to saving water by 121.5 per cent increased yield by 13 per cent and net income by 11 per cent over basin irrigation.

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*Originals not seen.

APPENDIX I

a) ANOVA table for number branches per vine

Source	Degree of freedom	Mean square
Replication	2	0.289
Irrigation (I)	4	1.778*
Mulch (M)	2	4.356**
I X M	8	0.244
Error	28	0.527

** significant at 1 per cent level
* significant at 5 per cent level

b) ANOVA table for vine length

Source	Degree of freedom	Mean square		
		30 DAS	45 DAS	Harvest
Replication	2	0.289	28.956	134.756
Irrigation (I)	4	132.444**	259.856**	452.411**
Mulch (M)	2	180.622**	442.956**	536.956**
I X M	8	3.678	9.122	36.844
Error	28	6.789	35.289	35.184

** significant at 1 per cent level
* significant at 5 per cent level

c) ANOVA table for number of leaves per vine

Source	Degree of freedom	Mean square		
		30 DAS	45 DAS	Harvest
Replication	2	0.422	2.756	3.822
Irrigation (I)	4	2.589	4.056*	1.700
Mulch (M)	2	18.156**	12.822**	9.689*
I X M	8	0.239	0.989	0.467
Error	28	1.446	1.351	1.513

** significant at 1 per cent level
* significant at 5 per cent level

d) ANOVA table for leaf area

Source	Degree of freedom	Mean square		
		30 DAS	45 DAS	Harvest
Replication	2	49.400	56.267	59.356
Irrigation (I)	4	392.089**	356.422**	438.411**
Mulch (M)	2	572.867**	731.267**	539.822**
I X M	8	22.006	18.739	12.378
Error	28	24.638	37.433	30.879

** significant at 1 per cent level
* significant at 5 per cent level

e) ANOVA table for leaf area index

Source	Degree of freedom	Mean square		
		30 DAS	45 DAS	Harvest
Replication	2	0.002	0.016	0.012
Irrigation (I)	4	0.028**	0.086**	0.081**
Mulch (M)	2	0.110**	0.240**	0.181**
I X M	8	0.001	0.006	0.003
Error	28	0.005	0.012	0.007

** significant at 1 per cent level
* significant at 5 per cent level

f) ANOVA table for dry matter production

Source	Degree of freedom	Mean square
Replication	2	689.356
Irrigation (I)	4	3235.411**
Mulch (M)	2	5037.956**
I X M	8	1850.261**
Error	28	573.356

** significant at 1 per cent level
* significant at 5 per cent level

g) ANOVA table for flower characteristics

Source	Degree of freedom	Mean square				
		Days to first flowering	Number of female flowers	Number of male flowers	Female-Male flower ratio	Fruit set (%)
Replication	2	0.067	4.289	120.200	1.091	414.431
Irrigation (I)	4	0.367	0.744	321.311**	0.049	301.991*
Mulch (M)	2	0.467	3.756**	1184.267**	0.267	61.062
I X M	8	0.883	0.061	11.294	0.011	82.785
Error	28	0.900	0.598	78.724	0.230	110.837

** significant at 1 per cent level
* significant at 5 per cent level

h) ANOVA table for fruit characteristics

Source	Degree of freedom	Mean square			
		Mean fruit weight	Fruit length	Fruit girth	Fruit volume
Replication	2	6629.335	2.355	1.504	9.306
Irrigation (I)	4	104709.860**	9.005*	6.755*	250530.069**
Mulch (M)	2	17.970**	17.512**	1.781	114109.306
I X M	8	28744.340	3.280	2.280	85470.590
Error	28	14074.265	2.781	2.162	58541.746

** significant at 1 per cent level
* significant at 5 per cent level

i) ANOVA table for yield characters

Source	Degree of freedom	Mean square		
		Fruit number per plant	Yield (kg/plant)	Yield (t/ha)
Replication	2	0.097	0.024	4.294
Irrigation (I)	4	0.859**	0.451**	80.189**
Mulch (M)	2	1.727**	2.260**	402.369**
I X M	8	0.144	0.036	6.374
Error	28	0.119	0.103	18.347

** significant at 1 per cent level
* significant at 5 per cent level

j) ANOVA table for weed dry weight

Source	Degree of freedom	Mean square
Replication	2	410.822
Irrigation (I)	4	245.022
Mulch (M)	2	53404.356**
I X M	8	268.939*
Error	28	97.257

** significant at 1 per cent level
* significant at 5 per cent level

k) ANOVA table for nitrogen

Source	Degree of freedom	Mean square	
		35 DAS	Harvest
Replication	2	0.063	0.150
Irrigation (I)	4	0.347**	0.292**
Mulch (M)	2	1.387**	1.473**
I X M	8	0.061	0.034
Error	28	0.031	0.051

** significant at 1 per cent level
* significant at 5 per cent level

l) ANOVA table for phosphorus

Source	Degree of freedom	Mean square	
		35 DAS	Harvest
Replication	2	0.000	0.001
Irrigation (I)	4	0.000	0.000
Mulch (M)	2	0.001**	0.001**
I X M	8	0.000	0.000
Error	28	0.000	0.000

** significant at 1 per cent level
* significant at 5 per cent level

m) ANOVA table for potassium

Source	Degree of freedom	Mean square	
		35 DAS	Harvest
Replication	2	0.021	0.005
Irrigation (I)	4	0.008	0.006
Mulch (M)	2	0.138**	0.156**
I X M	8	0.002	0.005
Error	28	0.007	0.003

** significant at 1 per cent level
* significant at 5 per cent level

APPENDIX II

a) Mean effect of mulch and irrigation levels on number of branches per vine, length of vines and number of leaves per vine

Treatment	Number of branches	Length of vines			Number of leaves per vine		
		30 DAS	45 DAS	Harvest	30 DAS	45 DAS	Harvest
I_1M_0	3.667^{c}	41.667^{bc}	127.333^{bc}	169.333^{d}	7.667^{ab}	17.667^{ab}	19.667^{a}
I_1M_1	3.667^{c}	44.000^{abc}	131.000^{abc}	171.667^{cd}	6.333^{b}	18.333^{ab}	20.000^{a}
I_1M_2	4.000^{bc}	44.333^{abc}	132.000^{abc}	174.000^{cd}	8.000^{ab}	18.333^{ab}	19.667^{a}
I_2M_0	3.667^{c}	47.000^{ab}	125.333^{c}	170.333^{d}	8.000^{ab}	18.000^{ab}	19.333^{a}
I_2M_1	4.667^{abc}	48.667^{a}	131.000^{abc}	172.000^{cd}	8.333^{ab}	18.667^{ab}	20.333^{a}
I_2M_2	4.667^{abc}	48.333^{ab}	134.000^{abc}	173.000^{cd}	9.000^{ab}	19.000^{ab}	21.000^{a}
I_3M_0	3.667^{c}	48.000^{ab}	133.667^{abc}	177.000^{bcd}	7.667^{ab}	19.667^{a}	20.333^{a}
I_3M_1	4.667^{abc}	50.000^{a}	140.333^{ab}	188.667^{ab}	8.667^{ab}	19.667^{a}	20.333^{a}
I_3M_2	5.333^{ab}	49.667^{a}	142.667^{a}	192.000^{ab}	9.333^{ab}	20.333^{a}	21.000^{a}
I_4M_0	4.000^{bc}	39.333^{c}	128.667^{bc}	172.667^{cd}	7.333^{ab}	18.000^{ab}	19.333^{a}
I_4M_1	4.667^{abc}	44.667^{abc}	133.000^{abc}	181.333^{abcd}	8.333^{ab}	19.667^{a}	19.667^{a}
I_4M_2	5.000^{abc}	45.667^{abc}	136.333^{abc}	183.000^{abcd}	9.667^{a}	16.333^{b}	20.667^{a}
I_5M_0	4.333^{abc}	45.333^{abc}	134.000^{abc}	176.333^{cd}	7.667^{ab}	18.333^{ab}	20.000^{a}
I_5M_1	5.000^{abc}	48.000^{ab}	138.333^{abc}	182.667^{abcd}	8.667^{ab}	19.000^{ab}	19.667^{a}
I_5M_2	5.667^{a}	50.000^{a}	140.000^{ab}	191.000^{a}	9.000^{ab}	20.000^{a}	20.667^{a}

b) Mean effect of mulch and irrigation levels on leaf area, leaf area index, plant dry matter production and weed dry weight

Treatment	Leaf area			Leaf area index			Plant dry matter production	Weed dry weight
	30 DAS	45 DAS	Harvest	30 DAS	45 DAS	Harvest		
I_1M_0	84.333^{f}	99.333^{e}	90.667e	0.285^{e}	0.882^{a}	0.887^{f}	55.33^{b}	87.00^{a}
I_1M_1	96.000^{de}	111.667^{cd}	98.000^{de}	0.372^{cde}	1.092^{a}	1.043^{de}	144.00^{a}	23.00^{b}
I_1M_2	101.000^{cde}	117.333^{abc}	106.667^{bcd}	0.459^{abc}	1.169^{a}	1.158^{bcde}	166.70^{a}	0.00^{c}
I_2M_0	94.667^{de}	102.667^{de}	99.667^{cde}	0.370^{cde}	0.950^{a}	1.046^{de}	67.67^{a}	115.70^{a}
I_2M_1	99.333^{cde}	116.000^{abc}	107.333^{bcd}	0.440^{bcd}	1.156^{a}	1.166^{bcde}	78.67^{a}	18.00^{b}
I_2M_2	100.667^{cde}	120.667^{abc}	110.667^{bc}	0.504^{abc}	1.224^{a}	1.278^{abc}	81.33^{a}	0.00^{c}
I_3M_0	98.667^{cde}	119.333^{abc}	109.000^{bcd}	0.381^{cde}	1.100^{a}	1.142^{bcde}	62.67^{a}	118.00^{a}
I_3M_1	104.667^{bcd}	125.000^{ab}	115.667^{ab}	0.484^{abc}	1.267^{a}	1.254^{bc}	92.67^{a}	33.67^{b}
I_3M_2	117.000^{a}	128.000^{a}	122.667^{a}	0.588^{a}	1.391^{a}	1.413^{a}	87.00^{a}	0.00^{c}
I_4M_0	93.333^{ef}	114.000^{bc}	97.667^{de}	0.320^{de}	1.097^{a}	1.006^{ef}	83.33^{a}	120.00^{a}
I_4M_1	97.333^{cde}	120.000^{abc}	107.333^{bcd}	0.380^{cde}	1.176^{a}	1.122^{cde}	104.70^{a}	15.67^{b}
I_4M_2	98.000^{cde}	123.667^{abc}	106.000^{bcd}	0.502^{abc}	1.187^{a}	1.168^{bcd}	119.30^{a}	0.00^{b}
I_5M_0	102.667^{bcde}	114.333^{bc}	107.333^{bcd}	0.419^{bcde}	1.118^{a}	1.141^{bcde}	113.30^{a}	122.70^{a}
I_5M_1	108.000^{abc}	123.333^{abc}	112.667^{ab}	0.521^{ab}	1.328^{a}	1.210^{bc}	104.30^{a}	21.00^{b}
I_5M_2	113.000^{ab}	126.000^{ab}	117.000^{ab}	0.580^{a}	1.404^{a}	1.300^{ab}	99.33^{a}	0.00^{c}

c) Mean effect of mulch and irrigation levels on flower and fruit characteristics

Treatment	Days to first flowering	Number of female flowers plant^{-1}	Number of male flowers plant^{-1}	Female-male flower ratio (x10^{-2})	Fruit set (%)	Mean fruit weight	Fruit size			Fruit number	Fruit yield (kg plant^{-1})	Fruit yield (t/ha)
							Length (cm)	Girth (cm)	Volume (cm^3)			
I_1M_0	30.33^{a}	4.67^{ab}	160.33^{de}	2.91^{a}	52.03^{a}	1079.0^{abcde}	26.04^{d}	31.35^{abc}	1460.00^{cd}	2.23^{fg}	2.396^{d}	31.94^{d}
I_1M_1	30.00^{a}	5.33^{ab}	174.67^{abcd}	3.05^{a}	44.60^{a}	1257.0^{abc}	28.33^{abcd}	32.13^{abc}	1701.67^{abcd}	2.35^{defg}	2.948^{bcd}	39.31^{bcd}
I_1M_2	30.67^{a}	6.00^{a}	181.00^{abc}	3.31^{a}	44.60^{a}	1278.0^{ab}	30.21^{abc}	32.13^{abc}	1792.50^{abcd}	2.63^{bcdefg}	3.354^{ab}	44.72^{ab}
I_2M_0	29.33^{a}	5.00^{ab}	161.67^{de}	3.09^{a}	48.33^{a}	1167.0^{abcde}	28.88^{abcd}	31.05^{bc}	1624.17^{bcd}	2.33^{efg}	2.723^{cd}	36.31^{cd}
I_2M_1	31.00^{a}	5.33^{ab}	171.33^{abcde}	3.12^{a}	62.23^{a}	1075.0^{bcde}	29.88^{abc}	32.55^{abc}	1912.50^{abc}	3.25^{ab}	3.431^{ab}	45.75^{ab}
I_2M_2	30.33^{a}	6.00^{a}	182.33^{ab}	3.29^{a}	48.30^{a}	1197.0^{abcd}	28.46^{abcd}	30.88^{bc}	1540.00^{bcd}	2.90^{abcde}	3.465^{ab}	46.19^{ab}
I_3M_0	31.00^{a}	2.00^{ab}	168.00^{bcde}	2.97^{a}	41.57^{a}	1224.0^{abc}	26.45^{d}	31.72^{abc}	1638.33^{bcd}	2.04^{g}	2.500^{d}	33.33^{d}
I_3M_1	30.33^{a}	5.33^{ab}	176.33^{abcd}	3.03^{a}	46.50^{a}	1295.0^{ab}	29.96^{abc}	34.04^{a}	2108.33^{a}	2.48^{cdefg}	3.188^{abc}	42.50^{abc}
I_3M_2	30.33^{a}	6.00^{a}	185.33^{a}	3.24^{a}	53.07^{a}	1044.0^{cde}	28.42^{abcd}	31.75^{abc}	1679.17^{abcd}	3.15^{ab}	3.292^{abc}	43.89^{abc}
I_4M_0	30.00^{a}	4.33^{b}	154.67^{e}	2.81^{a}	58.80^{a}	1310.0^{a}	28.75^{abcd}	32.88^{ab}	1844.17^{abc}	2.48^{cdefg}	3.188^{abc}	42.50^{abc}
I_4M_1	29.67^{a}	5.00^{ab}	165.00^{cde}	3.04^{a}	62.07^{a}	1166.0^{abcde}	31.00^{ab}	32.42^{abc}	1840.00^{abc}	3.00^{abcd}	3.490^{ab}	46.53^{ab}
I_4M_2	30.33^{a}	5.33^{ab}	171.67^{abcd}	3.11^{a}	57.93^{a}	1232.0^{abc}	31.33^{a}	33.34^{ab}	1980.83^{ab}	3.06^{abc}	3.750^{a}	50.00^{a}
I_5M_0	30.33^{a}	5.33^{ab}	173.00^{abcd}	3.08^{a}	53.90^{a}	952.2^{e}	27.42^{cd}	30.63^{bc}	1470.00^{cd}	2.85^{abcdef}	2.688^{cd}	35.83^{cd}
I_5M_1	29.67^{a}	5.67^{ab}	179.67^{abc}	3.16^{a}	59.33^{a}	948.9^{e}	27.79^{bcd}	29.92^{c}	1343.33^{d}	3.31^{a}	3.125^{abc}	41.67^{abc}
I_5M_2	30.67^{a}	6.00^{a}	186.00^{a}	3.24^{a}	59.27^{a}	989.4^{de}	28.42^{abcd}	31.46^{abc}	1541.67^{bcd}	3.46^{a}	3.406^{ab}	45.42^{ab}

APPENDIX III

Mean moisture distribution (% w/w) at different depths 21 – 40 DAS

Treatments	Depth (cm)		
	0-15	15-30	30-60
I_1M_0	9.15	9.88	11.45
I_1M_1	10.09	12.48	13.68
I_1M_2	13.78	10.86	13.56
I_2M_0	11.22	14.55	15.56
I_2M_1	11.19	14.32	15.02
I_2M_2	16.22	18.06	18.74
I_3M_0	15.06	16.30	15.45
I_3M_1	15.19	12.34	17.99
I_3M_2	13.31	14.22	16.16
I_4M_0	11.39	14.69	16.33
I_4M_1	11.93	14.97	19.80
I_4M_2	12.91	16.01	18.67
I_5M_0	15.46	12.18	17.00
I_5M_1	13.93	13.75	16.37
I_5M_2	14.72	17.04	17.67

Mean moisture distribution (% w/w) at different depths 41 – 60 DAS

Treatments	Depth (cm)		
	0-15	15-30	30-60
I_1M_0	11.33	10.77	11.75
I_1M_1	9.98	9.94	9.98
I_1M_2	11.65	12.32	13.53
I_2M_0	13.95	13.55	13.57
I_2M_1	13.63	15.08	15.17
I_2M_2	18.83	13.40	13.65
I_3M_0	10.61	11.33	13.50
I_3M_1	16.63	14.26	12.27
I_3M_2	15.49	16.28	16.97
I_4M_0	13.31	13.12	15.70
I_4M_1	12.55	14.77	14.95
I_4M_2	16.27	16.25	16.06
I_5M_0	14.23	15.44	14.50
I_5M_1	16.71	16.97	18.96
I_5M_2	14.65	15.26	18.85

Mean moisture distribution (% w/w) at different depths 61 – 75 DAS

Treatments	Depth (cm)		
	0-15	15-30	30-60
I_1M_0	10.33	10.30	10.33
I_1M_1	11.81	9.88	11.81
I_1M_2	10.81	12.81	12.14
I_2M_0	11.26	13.54	12.86
I_2M_1	13.74	13.23	14.72
I_2M_2	13.67	12.74	14.80
I_3M_0	8.44	11.14	11.25
I_3M_1	13.00	14.98	15.05
I_3M_2	15.83	13.51	12.63
I_4M_0	11.90	10.61	13.53
I_4M_1	12.73	12.13	12.18
I_4M_2	12.49	11.29	12.33
I_5M_0	11.96	14.55	14.63
I_5M_1	12.72	16.04	17.88
I_5M_2	14.82	15.21	18.95

Mean moisture distribution (% w/w) at different lateral distances 21 – 40 DAS

Treatments	Lateral distance (cm) from the plant			
	0-15	15-30	30-45	45-60
I_1M_0	12.56	8.93	8.87	8.27
I_1M_1	13.33	12.57	11.01	8.08
I_1M_2	12.05	11.07	10.89	11.60
I_2M_0	15.17	14.30	14.44	11.18
I_2M_1	14.54	12.62	12.04	14.84
I_2M_2	19.57	18.94	18.01	14.18
I_3M_0	18.94	18.37	16.03	11.97
I_3M_1	19.02	16.90	11.28	9.49
I_3M_2	14.63	12.11	13.36	12.48
I_4M_0	16.87	15.63	14.10	12.62
I_4M_1	16.30	16.35	13.57	14.04
I_4M_2	18.41	19.81	13.84	11.39
I_5M_0	14.73	13.56	10.95	11.27
I_5M_1	15.96	13.44	15.87	15.47
I_5M_2	14.32	17.90	21.30	18.40

Mean moisture distribution (% w/w) at different lateral distances 41 – 60 DAS

Treatments	Lateral distance (cm) from the plant			
	0-15	15-30	30-45	45-60
I_1M_0	12.15	12.31	9.17	8.51
I_1M_1	13.51	10.10	7.58	6.98
I_1M_2	14.56	11.42	9.63	11.72
I_2M_0	14.31	15.74	15.03	14.35
I_2M_1	16.32	16.45	14.62	11.11
I_2M_2	15.58	14.81	12.14	11.98
I_3M_0	16.46	15.55	8.04	7.21
I_3M_1	18.15	10.28	15.57	11.58
I_3M_2	20.74	17.76	14.60	11.88
I_4M_0	15.94	15.71	13.66	11.53
I_4M_1	17.58	14.80	13.29	10.67
I_4M_2	16.28	15.09	12.51	12.89
I_5M_0	15.80	16.46	16.04	14.60
I_5M_1	13.12	16.81	18.36	15.23
I_5M_2	16.89	17.10	16.97	14.05

Mean moisture distribution (% w/w) at different lateral distances 61 – 75 DAS

Treatments	Lateral distance (cm) from the plant			
	0-15	15-30	30-45	45-60
I_1M_0	10.19	8.04	6.78	5.97
I_1M_1	13.00	10.88	7.66	7.40
I_1M_2	11.46	10.44	9.41	9.08
I_2M_0	15.71	13.73	14.07	10.36
I_2M_1	16.00	15.31	13.13	11.14
I_2M_2	16.08	14.90	11.99	11.97
I_3M_0	10.80	10.05	10.75	9.50
I_3M_1	16.07	15.04	13.99	12.25
I_3M_2	13.84	15.00	13.54	10.23
I_4M_0	11.64	14.33	10.88	11.21
I_4M_1	12.52	10.66	12.08	11.47
I_4M_2	15.45	14.41	13.84	12.78
I_5M_0	14.98	14.60	15.65	14.95
I_5M_1	15.78	15.47	15.24	15.70
I_5M_2	15.47	14.00	15.87	15.95

APPENDIX IV

a) Cost of drip system per hectare

Sl no.	Materials required	Quantity	Unit cost (Rs)	Total cost (Rs)
1	water tank (1000 l capacity)	7	3000	21,000
2	2’’ PVC pipe	100 m	35	3,500
3	12 mm lateral	3350 m	3.96	13,266
4	4 mm extension tube	3333 m	1.65	5,499.45
5	dripper (2 l h^{-1})	3333	4.5	14,998.5
6	belt wash	134	13	1,742
7	pin connector	3333	1.1	3,666.3
8	2’’ PVC end cap	2	8	16
9	2’’ MTA	7	9.75	68.25
10	2’’ FTA	7	14.5	101.5
11	2’’ bend	7	12	84
12	2’’ coupling	7	9.5	66.5
13	2’’ valve	7	350	2,450
14	installation cost			3,500
	TOTAL			69,958.50

b) Cost of microtube system per hectare

Sl no.	Materials required	Quantity	Unit cost (Rs)	Total cost (Rs)
1	water tank (1000 l capacity)	7	3000	21,000
2	2’’ PVC pipe	100 m	35	3,500
3	12 mm lateral	3350 m	3.96	13,266
4	4 mm extension tube	3333 m	1.65	5,499.45
5	belt wash	134	13	1,742
6	pin connector	3333	1.1	3,666.3
7	2’’ PVC end cap	2	8	16
8	2’’ MTA	7	9.75	68.25
9	2’’ FTA	7	14.5	101.5
10	2’’ bend	7	12	84
11	2’’ coupling	7	9.5	66.5
12	2’’ valve	7	350	2,450
13	installation cost			3,000
	TOTAL			54,460

c) Cost of bubbler system per hectare

Sl no.	Materials required	Quantity	Unit cost (Rs)	Total cost (Rs)
1	water tank (1000 l capacity)	7	3000	21,000
2	2’’ PVC pipe	100 m	35	3,500
3	12 mm lateral	3350 m	3.96	13,266
4	4 mm extension tube	3333 m	1.65	5,499.45
5	Bubbler	3333	8	26,664
6	belt wash	134	13	1,742
7	pin connector	3333	1.1	3,666.3
8	2’’ PVC end cap	2	8	16
9	2’’ MTA	7	9.75	68.25
10	2’’ FTA	7	14.5	101.5
11	2’’ bend	7	12	84
12	2’’ coupling	7	9.5	66.5
13	2’’ valve	7	350	2,450
14	installation cost			3,500
	TOTAL			81,624

d) Cost of wick system per hectare

Sl no.	Materials required	Quantity	Unit cost (Rs)	Total cost (Rs)
1	water tank (1000 l capacity)	7	3000	21,000
2	2’’ PVC pipe	100 m	35	3,500
3	12 mm lateral	3350 m	3.96	13,266
4	4 mm extension tube	3333 m	1.65	5,499.45
5	Wick	3333		100
6	belt wash	134	13	1,742
7	pin connector	3333	1.1	3,666.3
8	2’’ PVC end cap	2	8	16
9	2’’ MTA	7	9.75	68.25
10	2’’ FTA	7	14.5	101.5
11	2’’ bend	7	12	84
12	2’’ coupling	7	9.5	66.5
13	2’’ valve	7	350	2,450
14	installation cost			2,000
	TOTAL			53,560

e) Cost of mulch and its application per treatment per hectare

Sl no.	Treatments	Quantity	Unit cost (Rs)	Total cost (Rs)
1	M_1 (polythene mulching – basin) - cost of mulching material - cost of spreading	 490 kg 15 men	 55 150	 26950 2250 **29,200**
2	M_2 (polythene mulching – full) - cost of mulching material - cost of spreading	 833 kg 15 men	 55 150	 45815 2250 **48,065**

f) Cost of inputs per hectare

Sl no.	Input	Quantity	Unit cost (Rs)	Total cost (Rs)
1	Seed	0.75 kg	700	525
2	FYM	20 t	400	8000
3	Urea	152 kg	4.8	729.6
4	Rock phosphate	125 kg	2.4	300
5	MOP	42 kg	54.44	186.48
6	Acephate	1.5 kg	752	1128
7	Dicofol	0.75 l	400	300
	TOTAL			11,169.08

g) Cost of weeding per hectare

Sl.no.	Treatments	Quantity	Unit cost (Rs)	Total cost (Rs)
1	M_0 (un mulched) 1st weeding 2nd weeding **Total**	 50 women 50 women 100 women	 90 90 90	 4500 4500 9000
2	M_1 (polythene mulch - basin) 1st weeding 2nd weeding **Total**	 - - -	 - - -	 - - -
3	M_2 (polythene mulch – full)) 1st weeding 2nd weeding **Total**	 - - -	 - - -	 - - -

h) Labour cost for irrigation and cost of electricity

Sl. no.	Treatments	Quantity	Unit cost (Rs)	Total cost (Rs)
1	I_1 (Drip irrigation @50% of Ep) - labour cost - electricity cost	27 men 108 units	150 0.63	4050 68.04 **4,118.04**
2	I_2 (Microtube irrigation @50% of Ep) - labour cost - electricity cost	27 men 108 units	150 0.63	4050 68.04 **4,118.04**
3	I_3 (Bubbler irrigation @50% of Ep) - labour cost - electricity cost	27 men 108 units	150 0.63	4050 68.04 **4118.04**
4	I_4 (Wick irrigation @50% of Ep) - labour cost - electricity cost	27 men 108 units	150 0.63	4050 68.04 **4,118.04**
5	I_5 (Basin irrigation @45 l per pit)	180 men	150	**27,000**

i) Cost of cultivation

Sl. no.	Particulars	Quantity	Unit cost (Rs)	Total cost (Rs)
1	Ploughing by tractor	8 h + 1 man		910
2	Digging of corners and trimming of bunds	3 men	150	450
3	Pit preparation by tractor	32 h + 8 men		4240
4	Application of FYM and filling	8 women	90	720
5	Incorporation of FYM and filling	20 men	150	3000
6	Sowing of seeds	3 woman	90	270
7	Pot watering upto 19 DAS	72 woman	90	6480
8	Basal fertilizer application	8 women	90	720
9	Thinning and gap filling	6 women	90	540
10	Top dressing of fertilizer	8 women	90	720
11	Collection and spreading of coconut leaves	25 women	90	2250
12	Chemical spraying (3 times)	9 men	150	1350
13	Harvesting and transportation	50 women	90	4500
	TOTAL			26,150

j) Summary of cost economics per hectare in Rupees for each of the treatments

Treatments	Cost of irrigation system and installation	Cost of inputs	Cultivation cost	Weeding cost	Irrigation and electricity expenses	Cost of mulch and its application	Total cost	Total Return	Net Profit
I_1M_0	13991.7	11169.1	26150.0	9000.0	4118.0	-	64428.8	191682	127253.2
I_1M_1	13991.7	11169.1	26150.0	-	4118.0	11233.3	66662.1	235842	169179.9
I_1M_2	13991.7	11169.1	26150.0	-	4118.0	17521.7	72950.5	268338	195387.5
I_2M_0	10892.0	11169.1	26150.0	9000.0	4118.0	-	61329.1	217842	156512.9
I_2M_1	10892.0	11169.1	26150.0	-	4118.0	11233.3	63562.4	274500	210937.6
I_2M_2	10892.0	11169.1	26150.0	-	4118.0	17521.7	69850.8	277158	207307.2
I_3M_0	16324.8	11169.1	26150.0	9000.0	4118.0	-	66761.9	199998	133236.1
I_3M_1	16324.8	11169.1	26150.0	-	4118.0	11233.3	68995.2	255000	186004.8
I_3M_2	16324.8	11169.1	26150.0	-	4118.0	17521.7	75283.6	263340	188056.4
I_4M_0	10712.0	11169.1	26150.0	9000.0	4118.0	-	61149.1	255000	193850.9
I_4M_1	10712.0	11169.1	26150.0	-	4118.0	11233.3	63382.4	279162	215779.6
I_4M_2	10712.0	11169.1	26150.0	-	4118.0	17521.7	69670.8	300000	230329.2
I_5M_0	-	11169.1	26150.0	9000.0	27000.0	-	73319.1	214998	141678.9
I_5M_1	-	11169.1	26150.0	-	27000.0	11233.3	75552.4	250002	174449.6
I_5M_2	-	11169.1	26150.0	-	27000.0	17521.7	81840.8	272502	190661.2

MICRO IRRIGATION AND POLYTHENE MULCHING IN ORIENTAL PICKLING MELON

(*Cucumis melo* var. *conomon* (L.) Makino)

By

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ABSTRACT OF THE THESIS

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ABSTRACT

A field experiment on micro irrigation and polythene mulching in oriental pickling melon (*Cucumis melo* var. *conomon* (L.) Makino) was conducted during the summer season of December 2004 to March 2005 in the summer rice fallows of Agricultural Research Station, Mannuthy, Thrissur. The experiment was laid out in Randomized Block Design (RBD) with three replications. The treatments consisted of combinations of five irrigation methods (drip, microtube, bubbler, wick and basin irrigations) and three mulch treatments (control, black LDPE mulching in the basin and in the entire interspace). The variety used in the study was Mudicode.

The study revealed that mulching with black LDPE enhanced soil moisture retention in soil, growth, yield, water use efficiency and economic parameters than control. Mulching in the entire interspace with black LDPE was superior to basin mulching alone. Number of branches per vine, length of vines, number of leaves per vine, leaf area and dry matter production at harvest were highest in full mulching. Similarly, full mulching with black LDPE recorded the highest male and female flowers per plant and female to male flower ratio. In the setting percentage, basin mulching recorded 10 per cent more setting over control, while full mulching increased it by five per cent. Mulch had no significant influence on fruit characteristics like mean fruit weight, girth and volume. Full mulching enhanced number of fruits per plant by 27 per cent and basin mulching by 20.5 per cent over control. While full mulching increased fruit yield per hectare by 28 per cent over control, basin mulching increased it over control by 20 percent. Full mulching checks weed growth by 100 percent and enhanced leaf contents of N and K. Due to checking of evaporation from soil, soil moisture content was higher by 8.3 to 16.7 per cent laterally to a distance of 60 cm from the centre of the pit and higher by 10.6 to 14.2 per cent depth wise to a depth of 60 cm over control. Mean seasonal consumptive use and crop coefficient values were the least in full mulched plots. Full mulching and basin mulching increased field water use efficiency by 28.0 and 20.0 and crop water use efficiency by 40.8 and 30.8 per cent, respectively over control. Economic analysis revealed that net profit

increased by Rs. 51,838 (33.4 per cent) and Rs. 40,787 (26.3 per cent) by full mulching and basin mulching, respectively over control.

Among the irrigation methods, oriental pickling melon responded best to wick method. Though basin irrigation promoted better vegetative characters, its favourable influence on yield characters were not visible. Wick irrigation recorded higher fruit setting percentage than other methods. Though basin irrigation recorded 12.6 to 33.8 per cent more fruits per plant than other methods, average fruit weight was significantly the lowest in basin method. Wick irrigation recorded the highest mean fruit weight of 1236 g while basin irrigation recorded the lowest weight of 963.5 g. Highest fruit yield was recorded in wick irrigation (46.34 t ha^{-1}) followed by microtube method (42.75 t ha^{-1}) and basin irrigation (40.97 t ha^{-1}). Though basin irrigation retained higher moisture in soil, radially as well depth wise compared to other methods it was not reflected in fruit yield. Though basin irrigation recorded the lowest mean seasonal consumptive use, it recorded the lowest FWUE. Wick irrigation recorded the highest net return (Rs. 2,13,306 ha^{-1}) and net income per rupee invested (3.29).

The combination of mulching with black LDPE and irrigation methods increased fruit yield, water use efficiency, net profit and net return per rupee invested over the individual effects of irrigation. Best fruit yield and net profit were obtained when wick irrigation was combined with mulching with entire interspace with black LDPE.