DRIP IRRIGATION AND MULCHING IN ORIENTAL PICKLING MELON

(*Cucumis melo* var. *Conomon* (L.) makino)

By

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THESIS

Submitted in partial fulfilment of the requirement for the degree of

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DECLARATION

I hereby declare that the thesis entitled "**Drip irrigation and 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 Socieity.

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Certified that the thesis entitled "**Drip irrigation and mulching in oriental pickling melon (*Cucumis melo* var. *Conomon* (L.) makino)**" is a record of research work done independently by Mr. Alemayehu Ambaye Gebremedhin under my guidance and supervision and that it has not previously formed the basis for the award of any degree, fellowship or associateship to him.

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Alemayehu Ambaye Gebremedhin

Dedicated

To

"GOD"

"The people of Abyssinia"

and

"My mother Ms. Maledech Zeriay"

CONTENTS

ABBREVIATIONS

CU	:	Consumptive Use
CWRDM	:	Centre for Water Resources Development and Management
DAS	:	Days After Sowing
DMRT	:	Duncan's Multiple Range Testing
DMP	:	Dry Matter Production
Ep	:	Pan Evaporation
ET	:	Evapotranspiration
ETm	:	Maximum Evapotranspiration
FIB	:	Form Information Bureau
FTA	:	Female Threaded Adapter
FYM	:	Farm Yard Manure
IARI	:	Indian Agricultural Research Institute
ICAR	:	Indian Council of Agricultural Research
IW/CPE	:	Irrigation Water / Cumulative Pan Evaporation
KAD	:	Kerala Department of Agriculture
Kc	:	Crop coefficient
KAU	:	Kerala Agricultural University
LAI	:	Leaf Area Index
LDPE	:	Low Density Polyethylene
MOP	:	Murate 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 States Weather Bureau
WUE	:	Water Use Efficiency
$	:	American Dollar

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Introduction

INTRODUCTION

Vegetable growing is one of the most important branches of agriculture. They 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 their food yield is three to four times more as compared to that obtained from cereals and pulses, their cultivation as such occupies an important place in the agricultural development and economy of the country.

In Kerala, vegetable production is estimated at 5.78 lakh tonnes annually from an area of 85122 ha (FIB, 1998) and the requirement of the state is 14.35 lakh tonnes (KAD, 1998). Because of this the daily per capita consumption of vegetables in Kerala is 130 g which is far less than the recommended daily intake of 300 g (FIB, 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 improve the quality of the vegetable products. As far as Kerala is concerned, the extent of cultivable land is limited and hence the 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 (Yowalker, 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 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 fallow, efficient 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.

Drip 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 drip irrigation followed by Karnataka and Tamil Nadu (Sivanappan, 1998).

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 varying crops. Among the various mulches tried in vegetables the superiority of polythene mulches has been well accepted. Polythene mulch and drip has been shown to improve early and total yields (Abdul-Baki *et al.*, 1992 and Maiero *et al.*, 1987); increase water and nutrient use efficiency (Halsey, 1985); improve yield and quality (Vani *et al.*, 1989) and control weeds (Halsey, 1985).

In recent times mulch-cum-drip 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 drip system, out of which 97 per cent is combined with polythene mulch (George-Hochmuth, 1994). The increasing interest in applying drip 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 drip 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 drip 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).

Evaporation values measured from a standard USWB class A open pan evaporimeter are extensively used for scheduling of irrigation. Since an evaporimeter is an instrument, which integrates the effect of all the different meteorological parameters, it helps in generating precise information. Moreover it is easy to monitor and necessary equipment is simple and easy to maintain. Hence a method of scheduling irrigation based on the available evaporation data is highly desirable.

With these contexts, an investigation on the "Drip 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 1999-2000, with the following objectives:

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

(2) To examine the influence of types of mulch on growth and yield of oriental pickling melon.

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

(4) To study the effect of mulching and drip 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 cost economics of irrigation methods and mulching on oriental pickling melon.

Review of Literature

REVIEW OF LITERATURE

Vegetable growing is one of the most important branches of agriculture. Cucurbits are the largest group of summer vegetable crops. 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 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 few specific researches on moisture conservation aspects have been reported in the case of 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 under the sections given below:

2.1 Scheduling of irrigation using pan-evaporation

2.2 Total and critical demand of water in cucurbits

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

2.3.1 Effect on plant growth

2.3.2 Effect on root growth and distribution

2.3.3 Effect on yield and yield factors

2.1 Scheduling of irrigation using pan evaporation

Consumptive use of water, which is the main component of water requirement of a crop, is governed primarily by meteorological parameters. The high relationship between water loss from an evaporimeter and potential evapotranspiration makes this approach attractive for irrigation scheduling, as the evaporation is easy to monitor and necessary equipment is simple and easy to maintain (Doorenbos and Pruitt, 1977).

Singh and Singh (1978) reported high total yields with drip irrigation, at 65 per cent of the evaporation from a class A pan in crops like bottlegourd, roundgourd and watermelon in loamy sandy soils of hot arid regions. Similar studies in ashgourd recorded the highest yield at IW/CPE ratio of 1.0, which was on par with the IW/CPE ratio of 0.7. Both these were significantly superior to the IW/CPE ratio of 0.4 (ICAR, 1982). Thomas (1984) reported that for bittergourd, irrigation at the IW/CPE ratio of 1.2 recorded the maximum net profit and followed by IW/CPE ratio of 0.8.

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).

In melons, Musard and Yard (1990) found that vitreous flesh disorder 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.

According to Yingjajaval and Markmoon (1993) increasing the irrigation rate from 100 to 150 or 200 per cent of PET increased the total yield of cucumber by 12 and 13 per cent respectively. In other study the irrigation scheduled to replenish 120 per cent of pan evaporation recorded the highest yield in cucumber. This treatment also resulted in 25 per cent more of early harvestable yield (Prabhakar and Naik, 1993).

Khade *et al.* (1995) in an experiment on water melon variety *sugar baby* reported that, the highest fruit yield was obtained with the combination of irrigation scheduling at 20 mm CPE and 120 kg N + 100 kg K_2O ha^{-1}.

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.

2.2 Total and critical demand of water in cucurbits

According to Whitaker and Davis (1962) 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. Dunkell (1966) showed that optimal yields of cucumber could be obtained, when 600-750 mm of water was applied.

Neil and Zunio (1972) reported that 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.

In a trial to find out the relationship between development and water utilisation in cucumber, Cselotel and Varga (1973) reported that during the period upto the beginning of flowering, the water uptake was small, amounting to five litres per plant. In a 30 days period following the beginning of flowering, the water uptake amounted to 30-31 litres per plant. In the subsequent 30 days period corresponding to full development of the fruits and the beginning of seed maturity, water uptake was 10-20 litre per plant. Varga (1973) observed 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) found that a constant supply of moisture is necessary during the growth of cucumbers especially during flowering and fruiting.

The consumptive use of cucumber increased during flowering and early fruiting and then levelled of during late harvest (Loamis and Crandall, 1977). They also found 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) found that the consumptive use increased with increase in the level of irrigation in the case of bittergourd. It can thus be seen that consumptive use depends on the physiological stages of the crop, evaporative demand of the atmosphere and duration of the crop. Pai and Hukkeri (1979) observed that 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 tha^{-1} under respective irrigation schedules.

Srinivas Rao and Bhatta (1988) reported that, photosynthetic and transpiration rates were decreased, when water stress was imposed at vegetative, flowering and fruit formation stages in capsicum.

According to Riley (1990) 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.

Hegde (1993) reported that 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, nonviable 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.

According to Krishna Manohar *et al.* (1996) water requirement of any crop is depended up on 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 days after sowing for the irrigation intervals of IW/CPE ratio 1.2, 0.8 and 0.4, and it was 20-35 days after sowing 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.

Yellamanda Reddy and Shankara Reddy (1997) indicated that an ideal irrigation schedule must indicate when the irrigation water is to be applied and the quantity of water to be applied. 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.

The review indicates the water requirement of cucumber is 600-750 mm; the period of one month from flowering to fruit enlargement stage has the peak requirement of consumptive use.

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-Yesef and Sagev, 1982).

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). Muthuvel and Krishnamoorthy (1980) reported 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.

2.3.1 Effect on plant growth

Locascio *et al.* (1981) indicated that the stem diameter of tomato plants irrigated at 1.0 E_P was higher than irrigation given at 0.5 E_P. Beese *et al.* (1982) working on sweet pepper under drip irrigation found linear response to water application rates at 0.8, 1.0, 1.2 and 1.4 times the control with regard to leaf area and dry matter production and also resulting in higher yields at higher regime.

Vasanthakumar (1984) working on tomato crop in the red sandy soils of Karnataka reported that drip irrigation gave significantly higher yield (58 - 67 t/ha) compared to furrow irrigation (49 - 55 t/ha). This was attributed to higher LAI (0.65 with drip irrigation as against 0.55 with furrow irrigation) and total DMP (136.53 g/plant with drip as against 131.06 g/plant with furrow irrigation).

Prakash (1990) reported that water stress decreased the number of flowers in brinjal. Dhanabalan (1994) reported 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). It was also reported by Ravindra Mulge *et al.* (1992) that vegetative growth parameters like number of branches, leaves and leaf area per plant were influenced by moisture stress.

In experiments conducted during the summer season of 1991 at Bangalore, Prabhakar and Naik (1993) found that 60, 90 and 120 per cent pan evaporation replenishment had significant effect on vine length and number of branches while it had no marked effect on number of leaves.

Maria *et al.* (1996) reported that in drip irrigation fruit yield and fruit size were decreased with reduction in amount of water applied. Asokaraja (1998) indicated that plant height was higher in 100 per cent and 75 per cent of CPE under drip irrigation than 50 per cent of CPE and conventional irrigation in tomato.

2.3.2 Effect on root distribution and growth

Belik and Veselovskii (1975) reported that under irrigation, the main root mass in watermelons was found in the 8.5-17 cm soil layer. Kudarimoni (1977) observed 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) observed 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 and 15-20 cm depth in furrow method. The lateral spread of roots was between 19-26 cm in drip and it was only between 16-22 cm in furrow system of irrigation.

Naik (1986) 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 upto 40-55 cm within the wetted zone under drip and only 15 cm spread around the plant in check-basin method of irrigation.

Dhanabalan (1994) registered higher shoot-root ratio at 0.75 IW/CPE ratio as compared to 0.4 and 0.6 IW/CPE ratio in brinjal. Harold *et al.* (1988) reported that higher water application rate resulted in higher soil water content, higher root density and improved plant water status than with lower water application rate.

From the review it can be summarised that the maximum growth and distribution of roots of cucurbitaceous vegetables is in the 0-10 cm depth, whereas in check basin between 15-20 cm and no specific pattern was observed in furrow system. In drip irrigation, the lateral spread amounted to 19-55 cm while in furrow system it ranged between 19-26 cm and in check basin between about 15 cm.

2.3.3 Effect on yield and yield factors

Abolina *et al.* (1963) observed that the melon plants watered regularly produced greater number of female flowers. Chennappa (1976) reported 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 tonnes per hectare with daily irrigation through drip system whereas with increase in irrigation interval in drip system, the yield reduced significantly.

Singh and Singh (1978) reported that the yield increase by irrigation in crops like bottlegourd, roundgourd and watermelon was associated with increased number of fruits per plant 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 1 emitter per 4 plants as compared to furrow irrigation (Olitta *et al.*, 1978).

Radha (1985) in 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 ashgourd. While trials conducted in ashgourd at the Agronomic Research Station, Chalakudy in the same soil type revealed that the number of fruits per plant increased with increase in the level of irrigation (ICAR, 1982).

Reddy and Rao (1983) worked on the response of bittergourd 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. Ramesh (1986) working on green chilli observed that drip irrigation at 0.5 E_P produced significantly higher green fruit yield per plant (199.04 g/plant) compared to 0.3 E_P (133.50 g/plant).

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) compared to latter treatment (33.15 t/ha), although the difference was not significant.

Mannini and Gallinga (1987) compared the three irrigation rates (50, 100 and 150% x maximum evapotranspiration) in unheated green house with cucumber. They recorded the highest yield, number and individual fruit weight with irrigation at 150 per cent x ETm.

In a greenhouse cucumber study, Eliades (1988) reported that the yield was highest in the 1.0 x potential evapotranspiration and significantly lower in the 0.6 x potential evapotranspiration. 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 watermelon. Drip irrigation in cabbage recorded higher yields (218 q/ha) compared to surface irrigation (159 q/ha) 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.

Gutal *et al.* (1990) reported that drip irrigation recorded higher yield of sugarcane ranging from 121.78 to 125.17 tonnes per hectare compared to flood irrigation (119.56 t/ha). Drip method of irrigation in tomato recorded higher yield of 48 tonnes per hectare compared to 32 tonnes per hectare with flood irrigation (Jahdav *et al.*, 1990).

Yingjajaval and Markmoon (1993) in an irrigation and fertiliser trial at Thailand found that increasing the irrigation rate from 100 to 150 or 200 per cent potential evapotranspiration increased the total yield of cucumber by 12 and 13 per cent respectively. In a field trial at Bangalore, during the summer season of 1990-91 using cucumber revealed that irrigation scheduled to replenish 120 per cent of pan evaporation recorded the highest yield (36 t ha^{-1}). This treatment resulted in 25 per cent more of early harvestable yield (Prabhakar and Naik, 1993).

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 irrigation was due to fruit number rather than fruit size. A field trial conducted in Bangalore revealed that highest yield of cucumber (36 t ha^{-1}) obtained due to higher fruit number per vine coupled with greater average fruit weight (Prabhakar and Naik, 1993).

Chartzoulakis and Drosos (1995) reported that fruit number per plant was significantly reduced at 0.65 x ETm and 0.4 x ETm as compared to 0.85 x ETm under drip irrigation in brinjal. Number of fruit per plant 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).

Hanna *et al.* (1996) reported that in trials conducted at the Red River Research Station, Louisiana, on tomato cultivars *Sunmaster* and *solar set* with treatments of transplants planted 7.5 or 15 cm deep and early morning or afternoon drip irrigation, the greater planting depth significantly increased marketable and total yield. Average fruit weight was not influenced by planting depth. Early morning drip irrigation increased marketable and total yields and average fruit weight compared with afternoon irrigation.

According Limbulkar *et al.* (1998) in a trial at Rahuri, cucumbers were drip irrigated at intervals of 2 or 3 days at rates equivalent to 110, 90, 70 or 50 per cent of the water lost by evapotranspiration. In another treatment surface irrigation was applied to replace 90% of the water lost by evapotranspiration, yields decreased as irrigation rate decreased. The restoration of 90 per cent of water lost by drip irrigation gave higher yields than by surface 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 dt/ha, respectively. It was concluded that, drip irrigation is more suitable for cucumber cultivation than sprinkler irrigation.

The review indicates the superiority of drip irrigation over other methods. Irrigation levels of 100-150 per cent PET as well as 120 per cent of EP have been found to give highest yields in various cucurbits. Wetting of 30-40 per cent of allotted area to the crop with daily net irrigation under low discharge rate and low pressure system through drip helped in maintaining the root zone profile at field capacity always with ideal relationship of soil-water-plant and microbial activities (Magar, 1998). He has also observed a consistency in water saving to the extent of about 60 per cent and increased in yield to the tune of 30 per cent in various kinds of crops due to drip irrigation.

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.

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

Bhella (1988a) studied the effect of trickle irrigation and black mulch on growth, yield and mineral composition of watermelon and reported greatest stem growth, early and total yield from plants grown with polythene mulch in combination with trickle irrigation. 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, 1988b)

Abdel (1990) reported in an experiment conducted at Erbel using onion cultivar 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.

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

Quadir (1992) conducted an experiment on watermelon using straw, clear polyethylene and black polyethylene mulches and unmulched control. Marketable fruit yield per plant 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).

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

Khalak and Kumaraswamy (1992) in an experiments 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.

In an experiment conducted by Farias *et al.* (1994) cucumber seeds were sown in beds and covered with clear, white or black plastic mulch. Controls were not mulched. Beds received micro irrigation. The highest number of fruits and yield were obtained with clear plastic mulch. White or black mulch also significantly increased yield. Similarly Larios *et al.* (1994) found that clear polyethylene gave more marketable yield in cucumber than white and black mulches.

In mulch cum drip irrigation studies in a sandy loam soil in Okra, Sunilkumar (1998) 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 farmer's field in Germany revealed that root density and distribution were varied markedly with different drip layouts and management.

Kunzelmann and Paschold (1999) in their comparative study of drip and sprinkler irrigation for pickling cucumber in Germany revealed that, drip irrigation in combination with a film mulch accelerated seedling development, thus leading to earlier yields, prolonged harvest periods and higher yields. Yields under drip and sprinkler irrigation were 547 and 400 dt ha^{-1}, respectively.

The review indicates the beneficial effect of polythene mulch and drip irrigation on growth and yield. Polythene mulches: red, black or transparent are generally found to be more effective than bio-mulches in cucurbits.

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.

Bucks *et al.* (1984) reported that 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 generally decreased.

Gajare (1982) observed that 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) working on green chilli 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) working on comparative performance of drip and furrow method of irrigation in tomato 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 yields. But furrow resulted in higher soil moisture stress near the ground surface.

According to Batra and Kalloor (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 l hr^{-1} in a field experiment in a vertisol. A radial spread of 31.0 cm and 26.25 cm were observed at the surface for the lowest (2 l hr^{-1}) and the highest (5 l hr^{-1}) discharges respectively. The vertical advances were 105.65 and 118.5 cm for 2 l hr^{-1} and 5 l hr^{-1} emitter discharges respectively. 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 l 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 at Agriculture Canda Research Station and it revealed that a distinct cone shape of > 50 per cent available soil water extending from the emitter down to a depth of > 45 cm occurred in a drip irrigation whereas the 50 per cent available soil water zone in a microjet system was an elongated semicircle from the soil surface to depth of 35 cm.

Bell *et al.* (1998) reported that subsurface drip irrigation and associated mandatory minimum tillage practices significantly reduced the incidence of lettuce drop (*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.*

The conclusion from the review is that under drip irrigation water content is always near to field capacity in the root zone but unsaturated, hence gravitational force is minimum. Slow and frequent watering eliminates wide fluctuation of soil moisture ensures a better distribution and interaction with soil aeration and nutrient supply and consequently favours for the growth and yield of crops.

2.5.2 Soil moisture extraction pattern and consumptive use

Loomis and Crandall (1977) indicated that cucumbers extracted 50 per cent of the total amount of water consumed from the upper 30 cm of the soil profile, 30 per cent from the next 30 cm and 10 per cent from the next 30 cm.

Pumpkins and squashes have a spreading but rather shallow root system while cucumbers are shallow rooted (Choudhury, 1983). 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) reported that 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 per cent 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.

From the review it can be concluded that at optimum level of irrigation the consumptive use of cucumber is around 500 mm in the summer when grown in sandy loam soils. About 50 per cent of moisture extraction is from the top 15 cm layer and the remaining 50 per cent is almost uniformly from the bottom 15-30 and 30-45 cm.

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 minimising evaporation rather than reducing the transpiration* by the crop. Therefore moisture conservation and utilisation 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

Gutal *et al.* (1992) conducted a study to find out the mulching effects on the yield of tomato crop. The results obtained showed that 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.

In a study conducted by Chakraborty and Sadhu (1994) greater soil moisture conservation was observed 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) 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.

Mikhov *et al.* (1995) 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.

2.6.2 Effect of mulch on soil temperature

Franklin and Ravmond (1966) stated that 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 per cent more than the control without mulch.

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 cm 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, India, 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.

The review indicated that the effect of organic mulches on soil temperature was not significant as compared to that of plastic mulches, which generally increased the soil temperature by 2-3°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.

According to Davies *et al.* (1993) 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 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 per cent and 87 per cent respectively.

According to Monks *et al.* (1997) 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 were evaluated 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.

Black polythene completely controls weed growth and clear polythene favours weed growth. While cereal straw is less effective in controlling weed growth, sugarcane trash greatly reduced weed growth.

2.6.4 Effect of mulch on growth and yield

Kapitany (1971) reported that 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.

Cerne (1984) observed that 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 eggplant 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 eggplant 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.

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)

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 and 158.94 q/ha with straw and black polythene mulch respectively, compared to 91.15 q/ha with no-mulch.

Davies *et al.* (1993) in a field experiment conducted at Abernethy, 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.

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.

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 rice straw mulch in improving growth and yield (Chakraborty Sadhu, 1994).

In field trials conducted by Farghali (1994) aubergine plants grown on a clay soil were mulched with black or white polyethylene sheets applied before planting. Compared with 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.

Studies by Farias *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. 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.

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 per cent 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 sawdust 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, thus registering 28.4 per cent yield enhancement over unmulched control. In bhindi, 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).

2.7 The comparative efficiency of drip irrigation in vegetables

Drip irrigation enables application of water at the root zone of the crops through plastic laterals and drippers. Since the water is applied directly to the root zone, losses due to seepage, percolation and evaporation are eliminated. 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 drip irrigation in vegetables are given below.

Singh *et al.* (1978) reported that drip irrigation gave highest water use efficiency (WUE) in round gourd (5.10 q/ha-cm) and watermelon (10.3 q/ha-cm) than furrow irrigation system (3.70 q/ha-cm) and (8.40 q/ha-cm), respectively, Goldberg *et al.* (1976a) studied comparative effect of irrigating tomatoes 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.

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 kg/ha) were higher in drip irrigated plot due to more number of branches compared to furrow irrigation.

Srinivas (1986) working on watermelon reported that drip irrigation resulted in nearly 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) compared to furrow irrigation (15.64 kg/ha cm), which was due to higher yield under drip irrigation.

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

Yadav *et al.* (1989) found that 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 ratio, 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 per plant (5.03 kg) and number of fruits per plant 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).

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) compared to furrow irrigation (64 kg/ha-cm).

Jahdav *et al.* (1990) reported that drip irrigation in tomato recorded high WUE (2.16 t/ha-cm) compared to 0.98 t/ha-cm 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) was 50 per cent more in comparison to flood irrigated crop (32 t/ha). Irrigation water saving was to the tune of 31.5 per cent with drip.

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

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}.

Kadam *et al.* (1993) recorded higher WUE (374 kg ha-cm^{-1}) under drip irrigation than furrow irrigation (214 kg ha-cm^{-1}) in Okra. Sivanappan and Padmakumari (1980) recorded the highest WUE of 362.20 ha-cm^{-1} under drip, whereas it was 118.78 kg ha-cm^{-1} in furrow irrigation in brinjal.

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.

Sunilkumar (1998) reported that under drip irrigation system crop water use efficiency enhanced by 289, 218, 311 per cent at the irrigation schedules of 0.04, 0.06 and 0.08 MPa, respectively in Okra.

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.

According to Kunzelmann and Paschold (1999) pickling cucumber (cucumis sativus) was grown under drip (1 litre/h and 30 cm distance controlled by tensiometers) and sprinkler irrigation (controlled by Geisenheim method) in Germany. On a 3 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.

2.8 Nutrient uptake and its composition

The absorption of N, P and K by cotton and soybeans increased linearly in response to the soil moisture level from the wilting point to field capacity (Brown *et al.*, 1960).

Tukey and Schoff (1963) reported that decomposable mulches like legume hay, peanut hulls, corn cobs, straw and saw dust had better effect on soil properties like availability of phosphorus and potassium, soil moisture, water penetration rate and aeration than non decomposable mulch like granular form rubber, grass fibre and gravel.

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 1b per acre respectively and the nutrients removed by the harvested fruits was 40, 6 and 55 lb per acre respectively (McCollum 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 (Jessal *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 quantum 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 Sagiv (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 55th 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 that 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 l^{-1} and for K it was 4000-5500 mg l^{-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 bittergourd 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, 0.2-05 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 leaf age (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 per plant 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 days after sowing (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.

2.9 Economic feasibility of mulch-cum-drip 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, Pillicode revealed that irrigation at IW/CPE ratio 0.5 had the maximum cost: benefit ratio for both the crops.

Jadhav *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) was 50 per cent more in comparison to flood irrigated crops (32 t/ha). 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 (KAU, 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/- per ha obtained by the use of plastic mulch in cotton was closely followed by maize stover mulch (Rs. 7,188/- per ha).

According to Minasian *et al.* (1994) results of an economic analysis of four drip irrigation system 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) and benefit: cost ratio (2.75) were obtained when irrigation was scheduled at 25 mm CPE in combination with 150 kg N/ha on latteritic soil of Konkon in bell pepper (*Capsicum annuum* L. var. grossum sendt).

Veeraputhiran (1996) reported that, incorporation of paddy waste, coirpith and sawdust in cucumber 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%) for sawdust over control.

Hugar (1996) noted that the benefit cost 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.

Asokaraja (1998) recorded higher discounted benefit cost ratio of 9.89 due to drip than surface irrigation (5.44) in tomato. 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.

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 for lettuces. Optimal use of weather forecasts to schedule irrigation was estimated to increase annual value by $ 1000/ha per year.

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

Materials and Methods

MATERIALS AND METHODS

A field experiment on drip irrigation and mulching in oriental pickling melon (*Cucumis melo* var. *Conomon* (L.) makino) was conducted during the summer season (December 13 to April 23) of 1999-2000 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, Trichur district, Kerala.

3.2 Cropping history

The experimental site was 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.

Table 1 Soil characteristics of the experimental field

Particulars	Value	Procedure adopted
1) Mechanical composition		
• Course sand (%)	27.1	Robinson's International pipette method (Piper, 1950)
• Fine sand (%)	23.9	
• Silt (%)	22.8	
• Clay (%)	26.2	
• Textural class	Sandy clay loam	I.S.S.S. system, (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	
• Bulk density (g cm^{-3})		Core method (Blake, 1965)
0 - 30 cm	1.34	
30 - 60 cm	1.36	
• Particle density(g cm^{-3})	2.16	Pycnometer method (Blake,1965)
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 photometery (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)

3.4 Climate and weather data

The experiment was conducted during the summer season of 2000. The daily data on different weather elements viz, maximum and minimum temperature (°C), sunshine hours, relative humidity (%), wind speed (km h^{-1}), mean evaporation (mm/day) and rainfall (mm) were collected from the Principal Agrometeorological Station of the College of Horticulture, Vellanikkara for the crop period from December, 1999 to February, 2000. 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 local (*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 I. The details are presented below:

Design	: Factorial Randomised Block Design (RBD)
Replications	: three
Number of treatments	: 15
Total number of plots	: 45
Plot size	: 4 x 3 m

Table 2. Mean weekly weather parameters of the crop growth period (December 1999- February 2000)

Standard week no.	Month and date	Surface air temperature (^{0}C)		Relative humidity (%)		Wind speed (Kmh^{-1})	Sunshine (hr/day)	Evaporation (mm)	Rainfall (mm)	Soil temperature (15 cm depth)	
		Max.	Min.	Morning	Evening					Morning	Evening
	1999										
50	December 10-16	31.8	22.6	78	49.6	4.4	8.1	4.5	-	26.8	37.5
51	December 17-23	31.4	22.6	72	47	7.8	8.7	6.4	-	26.3	37.4
52	December 24-31	31.4	23.4	68	43	8.8	8.8	7.0	-	26.4	37.9
	2000										
1	January 1-7	32.2	23.8	71	45	8.5	9.6	6.9	-	26.8	38.0
2	January 8-14	31.9	24.3	73.6	50.7	8.7	7.6	6.5	-	28.0	38.0
3	January 15-21	33.5	22.4	78	37	5.1	9.5	6.2	-	26.9	39.4
4	January 22-28	33.8	22.1	82	39	5.3	9.9	5.9	-	26.8	39.6
5	Jan. 29- Feb. 4	33.7	19.1	74	41	7.3	10.1	7.1	-	25.9	38.9
6	February 5-11	33.2	22.9	92	57	2.9	7.2	4.5	-	28.3	39.4
7	February 12-18	34.2	23.0	80	44	4.1	9.3	6.0	-	26.9	40.8
8	February 19-25	33.2	22.6	90	59	2.5	8.7	4.7	-	27.1	40.1

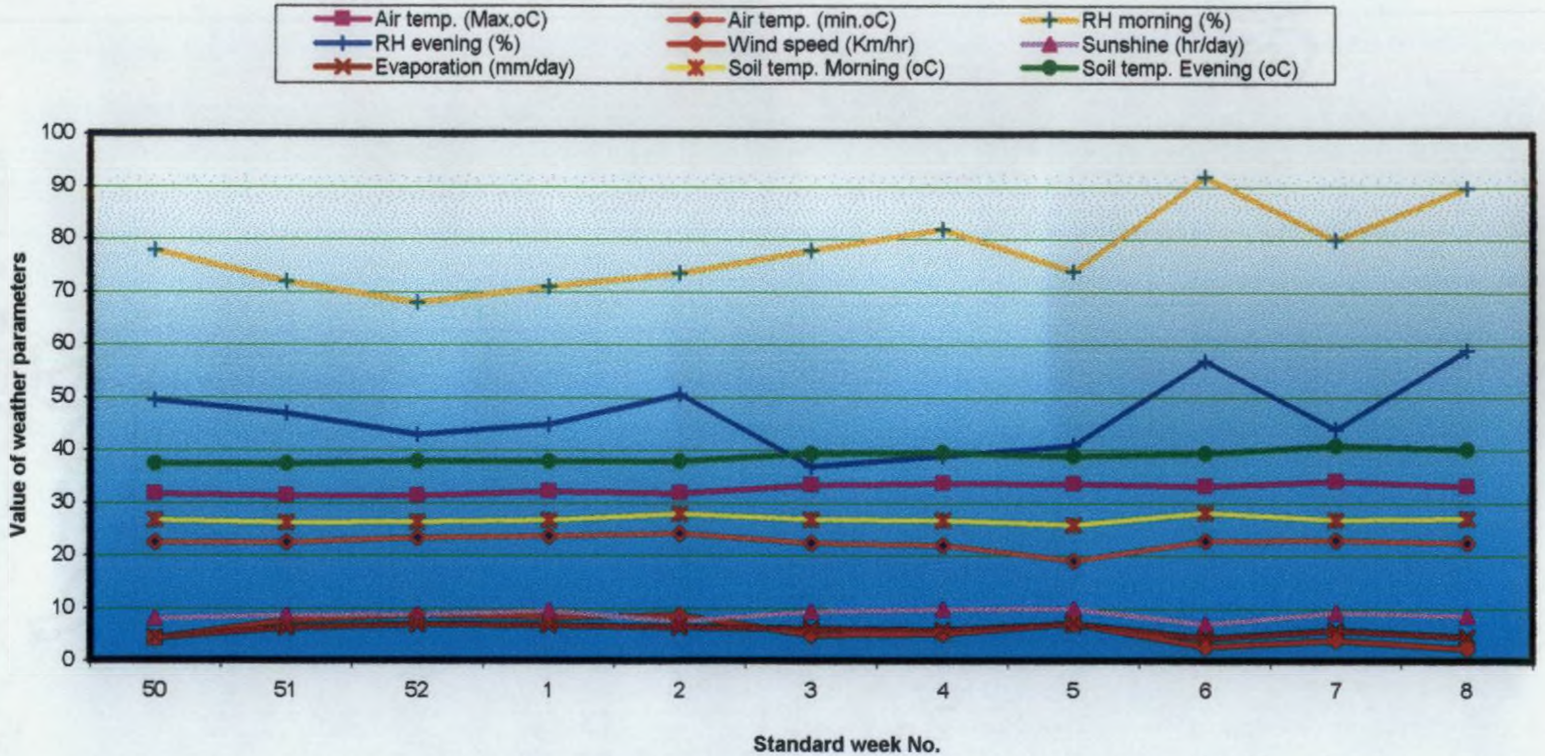


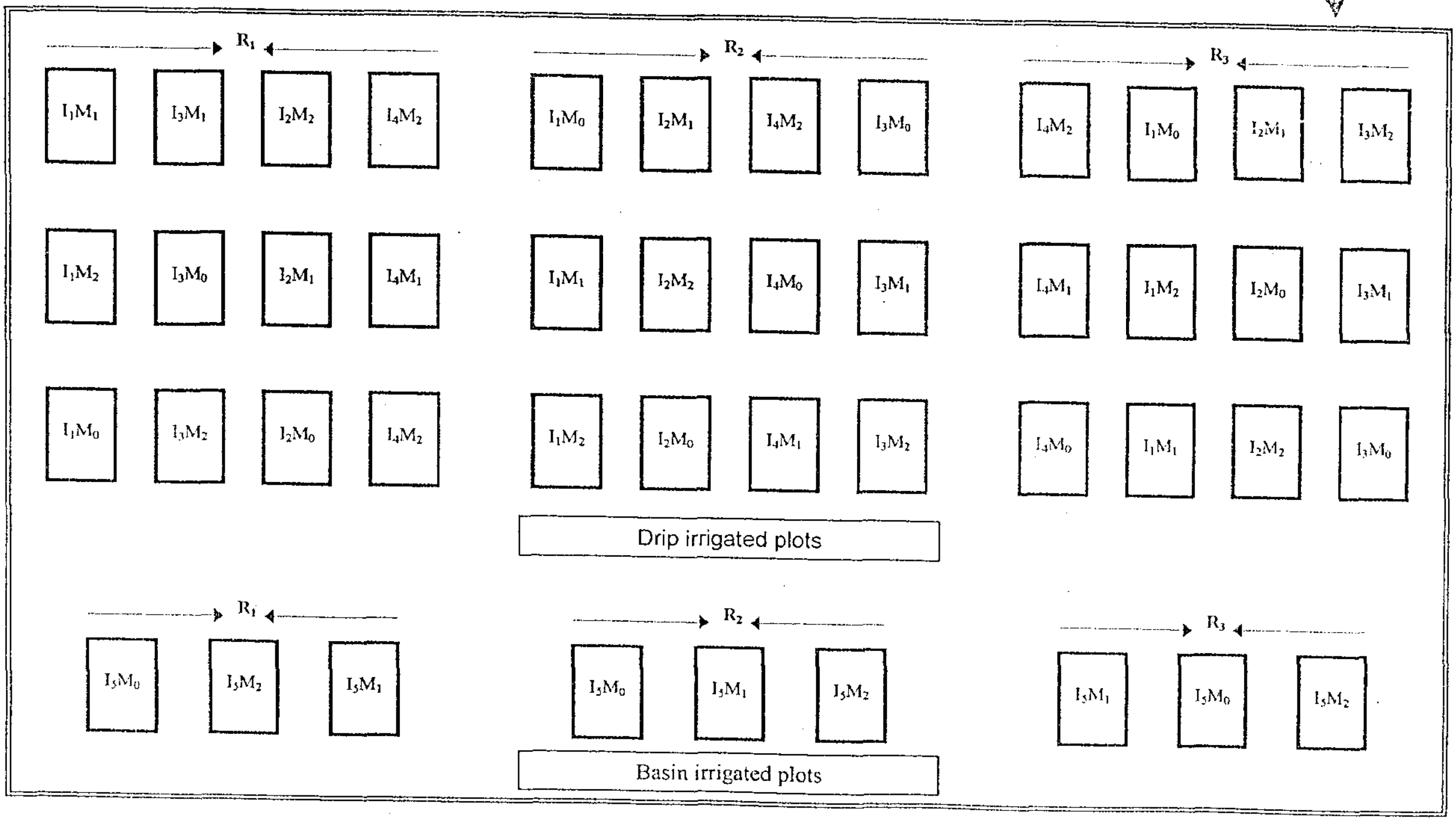
Fig.1 Mean weekly weather parameters for the crop growth period (December 1999 - February 2000)

Fig2. Lay out plan of the experiment

Distance between plots 1.5m X 2m
Distance between Replications = 3m
Distance between drip and basin = 6m

Plot size 3m X 4m
Number of pits per plot 4

N
W E



Spacing	: 2 x 1.5 m
Number of plants per pit	: Four
Number of pits per plot	: Four
Systems of irrigation	: Drip and basin method
Effective root zone	: 60 cm depth and 75 cm radius

3.6.2 Treatments

The treatments consisted of combinations of five irrigation levels and three moisture conservation methods. The details were as given below.

3.6.2.1 Irrigation levels

I_1 : Drip irrigation @ 50% Ep

I_2 : Drip irrigation @ 75% Ep

I_3 : Drip irrigation @ 100% Ep

I_4 : Drip irrigation @ 125% Ep

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

3.6.2.2 Moisture conservation methods

M_0 : No mulch

M_1 : Paddy waste (Straw bits and Chaff @ 3 kg pit^{-1})

M_2 : Black low density polyethylene sheet (LDPE)

Plate Ia. Field layout preview

Plate Ib. Drainage channel preview

Plate I

Ia.

Ib.

3.6.2.3 Combination of treatments

I_1M_0	I_2M_0	I_3M_0	I_4M_0	I_5M_0
I_1M_1	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 site 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 by tractor mounted post hole digger at 2 x 1.5 m. 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 and it is presented in Plate I. In addition each plot was levelled by manual labour to avoid uneven distribution of water within the plots.

3.7.2 Manure and fertiliser 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 (1993) @ 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

On 13th December 2000, six seeds pit^{-1} were sown uniformly. On the same day seeds were also sown in polythene bags for gap filling. 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 cane was given @ 5 l pit^{-1} for 10 days. Thereafter irrigation was done on alternate days @ 10 l pit^{-1} upto 19th day after sowing. Differential irrigation according to the treatments was started from the 20th day after sowing when the plants were well established. Drip irrigation was given every day based on the evaporation value of the previous day and the rate was fixed by multiplication of daily Ep with the corresponding percentage as per the treatments.

The required amount of water was provided through single dripper pit^{-1} at the rate of 2 l hr^{-1}. There were 24 rows of cucumber pits, each of which containing six pits. Two storage tanks each of 500 l capacity were kept on platforms of 1 m height above ground at the centre of the southern boundary of the experiment field. Each tank was installed to irrigate 12 rows. Each tank was connected to a main line made of rigid PVC pipe having 3 inch diameter and 22 m length. To each main line 12 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. Six drippers were connected to each lateral through 4 mm LDPE dripper laterals at positions opposite to the pits. Each dripper made of poly-proplelene material trickled water at the centre of every pit. Both the tanks were constantly kept filled with water by connecting the pumping line. The inside end of the outlet of the tanks was covered with wire mesh to filter out the impurities from entering in to the pipe system. For each line of lateral a separate control valve was provided at the beginning. Everyday at 7 am all the 24 taps were opened. Once the required quantity of water was allowed to drip down, the tap of that particular treatment was closed. In the case of I_5 basin irrigated control, measured quantity of water @ 45 l pit^{-1} per three days interval was constantly given in the prepared basin. The details of irrigation schedule and quantity of water used are given in Table 3.

3.7.5 After cultivation

Hand weeding was done once in the mulched plots and twice in the non-mulched plots. The soil was also stirred with hoe before mulching.

3.7.6 Mulching

Mulching was done 20 days after planting. Black low-density polyethylene sheet of 100 μm density and paddy waste (Straw bits and Chaff @ 3 kg pit^{-1}) were used as mulching material. During mulching small holes were made in the polythene sheets for passing through each plants and dripper. The rest part of the pit as well as interspace was fully covered with LDPE sheets. Paddy waste was spread around the plants to a radius

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

Treatment	Irrigation interval	Quantity of water used			Total quantity of water applied (mm)
		Pre-treatment irrigation (mm)	Irrigation as per treatment (mm)	Effective rain fall (mm)	
I_1	Daily	56.60	159.15	-	215.75
I_2	Daily	56.60	238.73	-	295.33
I_3	Daily	56.60	318.30	-	374.90
I_4	Daily	56.60	397.90	-	454.50
I_5	Once in 3 days	56.60	458.37	-	514.97

of 75 cm. When the plants started to vine, the inter-spaces between the plants were covered uniformly with dried coconut leaves.

3.7.7 Plant protection

Garlic extraction and Carbaryl 50 per cent WP were sprayed 10 and 20 days after sowing as prophylatic measure against the attack of red pumpkin beetle and termite. Serpentine leaf minor was controlled by spraying acephate 0.2 per cent at 35 DAS. At fruit development stage attack of mites and fruit flies were brought under control by spraying dicofol and dimecron @ 0.05 per cent.

3.7.8 Harvesting

Fruits were harvested when they were fully matured (When they got dark golden yellow colour). This was judged by visual appearance. All fruits were harvested in a single stage at 72 DAS.

3.8 Soil moisture studies

3.8.1 Soil sampling

Soil samples were collected by 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 extent of depletion.

3.8.2 Consumptive use of water

Consumptive use of water was estimated based on water balance model as 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 3 metres 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 gravimeteric content upto the root depth of 60 cm. Irrigation water was worked out by directly adding water applied into 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 was finally reduced to:

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

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

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

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 20th day after sowing 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 per cent utilisation from the total moisture used by the crop. Moisture distribution pattern was also worked out from these data.

3.8.4 Water use efficiency

Field WUE and crop WUE were computed by using the following formula and expressed as kg fruit m^{-3}.

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

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

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 $plot^{-1}$. All growth observations were taken from the same plants. Biometeric observations taken during the course of investigation were as follows:

3.9.1 Number of vines per plant

3.9.2 Length of vines

3.9.3 Number of leaves per vine

3.9.4 Leaf area

3.9.5 Leaf area index

3.9.6 Duration for 1st flowering

3.9.7 Numbers of female and male flowers

3.9.8 Female-male flower ratio

3.9.9 Percentage of fruit set

3.9.10 Shoot dry matter production

3.9.11 Root depth and lateral distribution

3.9.12 Root dry weight

3.9.13 Weed dry weight

3.9.14 Soil temperature

3.9.15 Number of fruits per plant

3.9.16 Length and Girth of fruit

3.9.17 Mean weight of individual fruit

3.9.18 Fruit volume

3.9.19 Fruit yield per plant and per hectare

3.9.1 Number of vines per plant

The number of vines were recorded from four plants per plot at 30, 45, 60 days after sowing and at the time of the harvest.

3.9.2 Length of vines

The length of vines were taken from each plot from two selected plants at 30, 45 and 60 days after sowing and at harvest. The length of all the vines were measured from the base to the growth tip and the mean length of vine per plant was worked out.

3.9.3 Number of leaves per vine

The total number of leaves per vine was counted from two plants per pit, at 30, 45 and 60 DAS and at the time of harvest of the crop. From this, the mean number of 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 per leaf 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 per plant to get the average leaf area. The average leaf areas were worked out at 30, 45, 60 DAS and at the time of 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, 45 and 60 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 Duration for 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 per plant was recorded upto 60 DAS and the ratio of female flowers to male flowers was calculated.

3.9.8 Percentage of fruit set

Total number of female flowers and fruit set were recorded upto 60 DAS, from which the percentage was calculated.

3.9.9 Shoot Dry matter production

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

3.9.10 Root depth and lateral distribution

The root of crops was traced out by a trench profile method. A trench having 1.25 cm X 50 cm X 60 cm length, width and depth respectively was dug with spade, shovel, metal fork and spatulas close to the plant. After a part of a whole root system exposed, the maximum depth upto which roots were found was measured from the side wall of the root system as it can be observed on Plate II.

3.9.11 Root dry weight

Root sample was taken by the excavation method (Bohm, 1979). The roots of the crop were traced out by removing the surface layer of soil beginning from the stem (Plate IIa). The entire root system was finally dug out. In addition, the vertical and horizontal moisture distribution pattern was also noted. The dry weight of the roots was determined after careful washing with water to remove the adhering soil. Weight was taken after drying in an oven at 80 ± 5°C to a constant weight and reported as g $plant^{-1}$.

3.9.12 Dry weight of weeds

Weed samples were collected from 1 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}.

3.9.13 Soil temperature

Glass mercury thermometers were installed in 15 cm depth and a good contact with the surrounding soil with bulb was done carefully. The thermometers were placed at 45^0 angle with the help of supporter (as it can be observed in Plate VIII). Observations were taken at 7:30 AM and 2:30 PM IST and from their mean, soil temperature per treatment was worked out.

3.9.14 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.

Plate II. Methods of root sampling followed

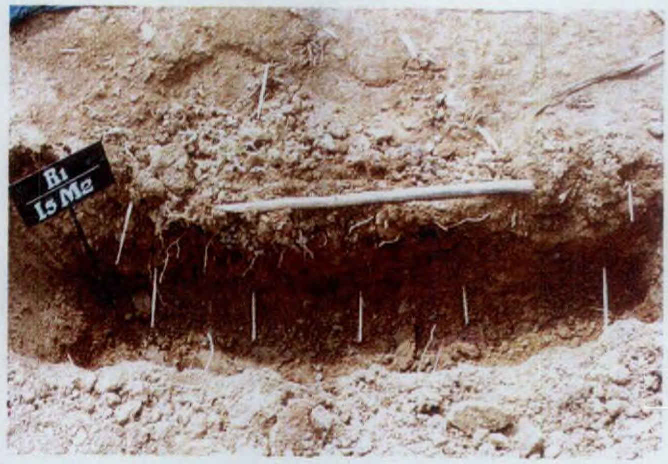
IIa. Excavation method

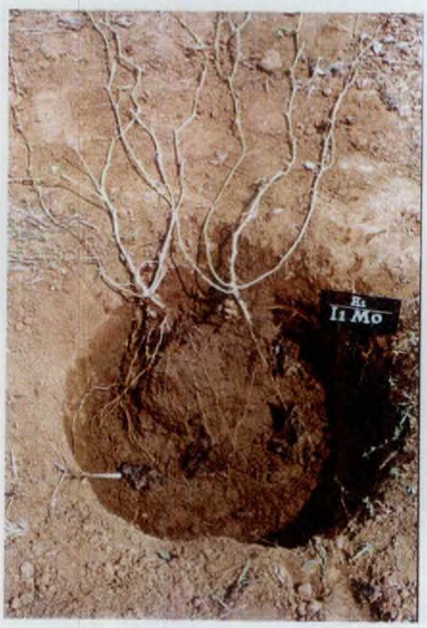
IIb. Trench profile method

Plate II

IIa.

IIb.





3.9.15 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. 16 Mean weight of fruits

The mean weight of a fruit was calculated from total fruit yield and total number per plot.

3.9.17 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.

3.9.18 Fruit yield per plant and per hectare

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

3.10 Plant analysis

Leaf samples were collected at three stages of crop growth viz, 30, 60 and 75 days after sowing. 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 microkjeldahl 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 drip irrigation system used for the experiment was taken as one fifth of the total cost of the materials as it is assumed that a unit of drip irrigation 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). The treatments were compared by DMRT.

Results

RESULTS

The results obtained from the experiment on the "Drip irrigation and mulching on oriental pickling melon (*Cucumis melo*) var. *Canamon* (L.) makino)" are furnished in this chapter.

4.1 Growth components

4.1.1 Number of vines per plant

The data on mean number of vines per plant at different growth stages viz., 30, 45 and 60 DAS and at harvest are given in Table 4 and their analysis of variance in Appendix I(a). The vine morphology also can be observed from Plate VII(a).

The result indicated that, mulches and irrigation levels had significant effect on vine number $plant^{-1}$ at all the growth stages, but their interaction was not significant (Appendix II(a)).

At 30 days after sowing (DAS) effect of plastic mulch (M_2) and paddy waste on vine number was equal and significantly superior to no mulch (M_0). Where as at 45 DAS plastic mulch was significantly superior to no-mulch control and paddy waste (straw and chaff). The lowest value was recorded by the control (M_0) and was significantly inferior to paddy waste (M_1) and black polythene mulch (M_2). This trend remained same there after.

Among the irrigation treatments, number of vines per plant was the highest at all stages of observation when the crop was drip irrigated with 125 per cent of E pan. At 30 DAS, I_4 produced significantly the highest number of vines and it was closely followed

Table 4. Influence of mulch and irrigation on number of vines per plant at different growth stages

Treatments	30 DAS	45 DAS	60 DAS	75 DAS
Mulch				
M_0	3.6[b]	4.1[c]	4.3[c]	4.3[c]
M_1	3.8[a]	4.3[b]	4.8[b]	4.8[b]
M_2	4.0[a]	4.7[a]	5.2[a]	5.2[a]
Irrigation				
I_1	3.6[c]	4.2[c]	4.5[c]	4.5[c]
I_2	3.8[bc]	4.3[bc]	4.8[abc]	4.8[abc]
I_3	3.9[b]	4.5[ab]	4.9[ab]	4.9[ab]
I_4	4.2[a]	4.3[a]	5.1[a]	5.1[a]
I_5	3.6[c]	4.3[bc]	4.7[bc]	4.7[bc]
Interaction	NS	NS	NS	NS

Figures with same alphabets do not differ significantly at 5 % level .

by drip irrigation at 100 per cent of E pan (I_3). The lowest number of vine was recorded by drip irrigation at 50 per cent of E pan (I_1) and control [basin method of irrigation @ 45 l at three days interval (I_5)]. I_1 and I_5 were at par and significantly inferior to all others.

At 45 DAS, I_4 (125% of Ep) recorded the maximum number of vines, but was at par with I_3 (100% of Ep). The lowest value was recorded by drip irrigation at 50 per cent Ep and was significantly inferior to I_4 and I_3.

Similarly at 60 DAS the maximum number of vine was recorded by I_4 and was at par with I_3 and I_2. The lowest number of vines was recorded in drip irrigation at 50 per cent of Ep (I_1) and it was significantly inferior to I_4 and I_3. This trend remained same at 75 DAS also.

In general the result indicated that, significantly higher number of vines per plant was produced under plastic mulching. Though inferior to polythene mulching, straw mulching was significantly superior to unmulched control. In the irrigation treatments maximum vines were recorded from drip irrigation at 125 per cent Ep, which was significantly superior to drip irrigation at 50 per cent Ep and control though not significantly superior to drip irrigation at 100 or 75 per cent Ep. The interaction between mulches and irrigation was not significant.

4.1.2 Average length of vines

The data on average length of vines per plant at growth stages of 30, 45 and 60 DAS and at the time of harvest are given in Table 5 and their analysis of variance in Appendix I(b).

The result indicated that, mulches and irrigation levels had significant effect on vine length $plant^{-1}$ at all the growth stages. But their interaction was not significant [Appendix II(a)].

At all stages of observation vine length was significantly the highest under polythene mulch. Vine length under paddy waste mulching was significantly higher than unmulched control at all stages except at 30 DAS, even though it was significantly inferior to polythene mulching.

Among the irrigation treatments, at 30 DAS drip irrigation at 125 per cent of Ep recorded the highest vine length and was at par to drip irrigation at 100 per cent of Ep. This was significantly superior to others. The lowest vine length was recorded at drip irrigation with 50 per cent of Ep and was significantly inferior to I_4, I_3 and I_2. But it was at par with basin irrigation @ 45 l in three days interval (I_5), which has been getting more or less equal amount of water to that of I_4 (125% of Ep).

At 45 DAS I_4 recorded maximum length of vine and was significantly superior to I_1, I_2 and I_5, but it was at par with I_3 (100% of Ep). The minimum length of vine was recorded from I_1 (50% of Ep) and was significantly inferior to all others, while I_5 was at par with I_2 (75% of Ep).

At 60 DAS, the longest vine was recorded from I_4 (125% of Ep) and was significantly superior to all others. This was followed by I_3 (100% of Ep). The minimum vine length was recorded by I_1 (50% of Ep) and was significantly inferior to all others.

At harvest (75 DAS), the maximum vine length was recorded from I_4 (125% of Ep) and was at par with I_3 (100% of Ep). This was followed by I_2 (75% of Ep) which

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

Treatments	30 DAS	45 DAS	60 DAS	75 DAS
Mulch				
M_0	46.3^{b}	124.3^{c}	156.4^{c}	164.3^{c}
M_1	47.1^{b}	132.5^{b}	165.7^{b}	177.0^{b}
M_2	52.9^{a}	145.1^{a}	187.1^{a}	193.1^{a}
Irrigation				
I_1	44.7^{c}	124.2^{c}	156.9^{e}	162.7^{c}
I_2	49.9^{b}	134.0^{b}	169.0^{c}	178.4^{b}
I_3	51.6^{a}	138.7^{a}	177.1^{b}	185.3^{a}
I_4	52.7^{a}	142.4^{a}	181.8^{a}	191.2^{a}
I_5	45.1^{c}	130.7^{b}	163.9^{d}	172.9^{b}
Interaction	NS	NS	NS	NS

Figures with same alphabets do not differ significantly at 5 % level.

was at par with I_5 (basin method) and the least vine length was observed in I_1 (50% of Ep) which was significantly inferior to others.

In short the results indicated the significant effect of polythene mulching on vine length. Drip irrigation at 125 per cent of Ep recorded the highest vine length and was at par with 100 per cent Ep at all stages except at 60 DAS and these two levels of irrigation were significantly superior to all others.

4.1.3 Number of leaves per vine

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

The result indicated that mulch and irrigation treatments had significant influence on number of leaves at all the growth stages taken, where as their interaction was not significant (Appendix II(a)).

Application of polythene mulch (M_2) recorded maximum number of leaves per vine at 30, 45, and 60 DAS and was significantly superior to others. At 75 DAS application of paddy straw and chaff mulch (M_1) recorded significantly higher number of leaves than others. This was followed by polythene mulch. The lowest number of leaves was recorded from the control with no mulch (M_0) and was significantly inferior to others at all the growth stages.

Among the irrigation treatments, I_4 (125% of Ep) recorded significantly the highest number of leaves per vine at all the growth stages of observation except at 30 DAS, where it was at par with I_3. This was followed by irrigation at 100 per cent of Ep (I_3) which was significantly superior to I_1, I_2 and I_5. The lowest value was recorded

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

Treatments	30 DAS	45 DAS	60 DAS	75 DAS
Mulch				
M_0	6.3^{b}	15.5^{c}	19.5^{c}	16.5^{c}
M_1	6.6^{b}	16.7^{b}	21.6^{b}	19.7^{a}
M_2	7.7^{a}	18.4^{a}	23.7^{a}	17.4^{b}
Irrigation				
I_1	5.9^{c}	15.1^{d}	19.6^{e}	15.3^{d}
I_2	7.1^{b}	16.6^{c}	21.6^{c}	17.6^{c}
I_3	7.4^{ab}	17.6^{b}	22.4^{b}	19.0^{b}
I_4	7.8^{a}	18.6^{a}	24.1^{a}	19.8^{a}
I_5	6.0^{c}	16.4^{c}	20.4^{d}	17.7^{c}
Interaction	NS	NS	NS	NS

Figures with same alphabets do not differ significantly at 5 % level .

from irrigation at 50 per cent of Ep and was significantly inferior to others at all stages except at 30 DAS where it was at par with I_5.

In general, the effect of black polythene mulch was significant on number of leaves per vine over paddy-waste mulch and unmulched control. Among the irrigation treatments number of leaves at all the stages was significantly the highest when the crop was drip irrigated at 125 per cent Ep except at 30 DAS where it was at par with I_3. Second best irrigation schedule was drip irrigation at 100 per cent Ep. Drip irrigation at 50 per cent Ep had the least effect on leaf number per vine.

4.1.4 Leaf area

The data on average leaf area (cm^2) at different growth stages; viz., 30, 45, 60 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 the growth stages taken, whereas their interaction was not significant [Appendix II(b)].

At 30, 45 and 60 DAS application of polythene mulch recorded the maximum leaf area which was significantly superior to all other treatments. At 75 DAS leaf area was significantly the highest under paddy waste mulching. Effect of paddy waste mulching was significant over control at 45, 60 and 75 DAS. The lowest value was recorded by control at all stages.

With respect to irrigation, I_4 (125% of Ep) recorded the maximum average leaf area at all the growth stages of observation and was significantly superior to all other irrigation schedules. The second highest value was recorded from drip irrigation at

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

Treatments	30 DAS	45 DAS	60 DAS	75 DAS
Mulch				
M_0	88.3^b	103.3^c	113.9^c	97.3^b
M_1	89.9^b	109.8^b	122.4^b	112.3^a
M_2	95.9^a	118.9^a	131.1^a	97.5^b
Irrigation				
I_1	88.3^d	100.6^d	112.6^d	89.6^d
I_2	91.3^{bc}	107.9^c	121.1^c	98.0^c
I_3	92.8^b	114.8^b	127.2^b	106.5^b
I_4	95.9^a	119.9^a	130.2^a	111.6^a
I_5	88.5^{cd}	110.1^c	120.1^c	106.0^b
Interaction	NS	NS	NS	NS

Figures with same alphabets do not differ significantly at 5 % level.

100 per cent Ep at all stages of observation, but it was at par with I_5 (basin method) at the time of harvest and with I_2 at 30 DAS. The lowest value was recorded by irrigation at 50 per cent of Ep, which was significantly inferior to all other treatments at all the stages of observation except at 30 DAS where it was at par with I_5.

Over all the result indicated that paddy waste mulching was superior to control and by the time of harvest, it produced leaves having the highest leaf area. However at the active growing stages (30-60 DAS) polythene mulching was significantly superior to paddy waste mulching and control. In the case of irrigation, leaf area increased progressively with increase in the Ep values and significantly the best effect was observed with I_4.

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 III and IV show leaf coverage of the plant at 30 DAS, while the general view of leaf coverage at different growth stages it can be observed from Plate IV. 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, plastic mulch recorded the maximum value and it was significantly superior to paddy waste mulching and control at all the growth stages with an exception that, at harvest (75 DAS), it was significantly inferior to paddy waste mulching. The effect of paddy waste mulching was significantly superior to

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

Treatments	30 DAS	45 DAS	60 DAS	75 DAS
Mulch				
M_0	0.269^c	0.874^c	1.301^c	0.938^c
M_1	0.307^b	1.071^b	1.699^b	1.419^a
M_2	0.397^a	1.395^a	2.199^a	1.219^b
Irrigation				
I_1	0.251^c	0.868^d	1.338^d	0.827^d
I_2	0.329^b	1.041^c	1.690^c	1.098^c
I_3	0.364^b	1.219^b	1.913^b	1.339^b
I_4	0.420^a	1.402^a	2.179^a	1.501^a
I_5	0.257^c	1.036^c	1.546^c	1.196^c
Interaction	NS	NS	NS	NS

Figures with same alphabets do not differ significantly at 5 % level.

Plate III. Plant leaf coverage as influence by mulch and irrigation at 30 DAS

I_1M_0- Drip irrigation at 50% Ep without mulching

I_4M_0- Drip irrigation at 125% Ep without mulching

I_5M_0- Basin irrigation @ 45 l pit^{-1} in 3 days interval with out mulching

I_1M_2- Drip irrigation at 50% Ep with polythene mulching

I_4M_2- Drip irrigation at 125% Ep with polythene mulching

I_5M_2- Basin irrigation @ 45 l pit^{-1} in 3 days interval with polythene mulching

Plate III

I_1M_0

I_1M_2

I_4M_0

I_4M_2

I_5M_0

I_5M_2

Plate IV. General preview of the field and leaf coverage at different growth stage

- At 45 DAS
- At 60 DAS
- At harvesting stage

Plate IV

45 DAS

60 DAS

Harvesting stage

control at all the stages. The effect of paddy waste mulching on LAI was very prominent at about the time of harvest, where its effect was significantly superior even to plastic mulching. At all stages control was significantly inferior to M_1 and M_2.

With respect to irrigation, at all the growth stages drip irrigation at 125 per cent Ep (I_4) recorded the maximum value of LAI, and was significantly superior to other treatments. Though at all the growth stages, the effect of drip irrigation at 100 per cent Ep (I_3) was significantly inferior to I_4, it was significantly superior to others with an exception at 30 DAS where it was at par with I_2 (75% of Ep). The lowest value of LAI was recorded from irrigation at 50 per cent of Ep (I_1) at all the growth stages except at 30 DAS where it was at par with control (I_5).

In short, the result revealed the significance of mulching on LAI. During the active growth stages (30-60 DAS) polythene mulching was significantly the best. But at harvest effect of paddy waste mulching was significantly the best. LAI increased progressively with increase in the level of Ep and at all the stages the effect of I_4 recorded significantly the highest LAI. Second best schedule was drip irrigation at 100 per cent Ep. Drip irrigation at 50 per cent Ep had the least effect on LAI.

4.1.6 Shoot dry matter production at harvest

The data related to dry matter production (g) per plant at the time of harvest are presented in Table 9 and the analysis of variance in Appendix I(f).

The influence of mulch and irrigation on shoot dry matter production was significant, but their interaction was not significant (Appendix II(b)).

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

Treatments	Shoot dry weight (g $plant^{-1}$)
Mulch	
M_0	47.4^{c}
M_1	53.0^{b}
M_2	62.7^{a}
Irrigation	
I_1	47.2^{d}
I_2	53.4^{c}
I_3	58.1^{b}
I_4	62.0^{a}
I_5	51.3^{c}
Interaction	NS

Figures with same alphabets do not differ significantly at 5 % level .

Among the mulches, spreading of polythene recorded maximum shoot dry matter production and was significantly superior to incorporation of paddy waste and control. The no mulch control was significantly inferior to both types of mulching.

With respect to irrigation, the treatment that received 125 per cent Ep (I_4) recorded significantly the highest dry matter. This was followed by irrigation at 100 per cent of Ep (I_3). Though inferior to I_4, it was superior to others. The control which received more or less equal amount of water as that of I_4 by basin method was only significantly superior to irrigation at 50 per cent Ep (I_1) and was at par with I_2 (75% of Ep). It may be concluded that polythene mulching had a better effect than paddy waste mulching on shoot dry weight. Among the drip irrigation treatments, plant dry weight increased significantly with increase of every 25 per cent of Ep and the highest value obtained with 125 per cent Ep (I_4). The effect of control (I_5) was at par with that of I_2 only, and was significantly inferior to I_3 and I_4.

4.1.7 Root depth

The data on maximum root depth at the time of harvest are presented in Table10 and Plate II, which is given in materials and methods, shows root distribution. The analysis of variance is presented in Appendix I(f).

The result indicated that mulch and irrigation had significant influence on root depth, whereas their interaction was not significant [Appendix II(b)].

Application of mulch significantly influenced root depth. However unlike the other growth parameters, the difference between black polythene and paddy waste (Straw and Chaff) mulch was not significant.

Among the irrigation treatments, I_3 (100% of Ep) recorded the maximum root depth and it was at par with I_4 (125% of Ep) and their influence was significantly superior to others. In other words, I_1 (50% of Ep), I_2 (75% of Ep) and I_5 (basin method control) were at par with each other and significantly inferior to I_3 and I_4.

The results in general showed that root depth (cm) was more in mulched plots compared to no-mulch control and with respect to irrigation, the effect was more pronounced in drip irrigation with 100 and 125 per cent Ep. There was progressive increase in root depth from 50 to 100 per cent Ep.

4.1.8 Lateral distribution of roots

The data on lateral spread of roots observed at the time of harvest are presented in Table 10 and the analysis of variance in Appendix I(f).

The result showed that mulch and irrigation had significant influence on lateral distribution of root, whereas their interaction was not significant [Appendix II(b)].

The maximum lateral spread of root was recorded from polythene mulch, but it was at par with paddy waste mulch. Both of them were significantly superior to the treatments with out mulch.

With respect to irrigation, the maximum lateral spread of root was recorded from control that received basin irrigation @ 45 l in three days interval. This was closely followed by irrigation at 125 per cent of Ep (I_4) and 100 per cent of Ep (I_3). These three treatments were at par and I_5 was significantly superior to I_1 and I_2. However I_3 and I_4 were at par with I_1 and I_2.

In general the result indicated that, mulching significantly influenced lateral spread of roots. But the difference between polythene and paddy waste was not significant. In case of irrigation, the lateral spread was the highest for basin method of irrigation than the drip method. Within the drip method the lateral spread was higher for treatments scheduled at 100 and 125 per cent Ep.

4.1.9 Dry weight of root

The data related to dry weight of root taken at the time of harvest is presented in Table 10 and 10a. Plate V also shows that total root size plant $^{-1}$. In addition analysis of variance is presented in Appendix I(f).

The result of dry weight of roots indicated that both main effects of mulch and irrigation and their interaction were significant Table 10a.

The highest dry weight of root was recorded from polythene mulch (M_2) and was significantly superior to others. This was followed by paddy-waste-mulch. The lowest root dry weight was recorded from the control with out mulch (M_0). This was significantly inferior to M_1 and M_2.

Root dry weight increased in drip irrigation from 50 per cent Ep to 125 per cent Ep. Drip irrigation at 125 per cent of Ep (I_4) recorded significantly the highest dry weight of roots. This was followed by irrigation with 100 per cent Ep (I_3) and basin method of irrigation @ 45 l in three days interval (I_5) and they were at par with each other. The lowest value of root dry weight was recorded from irrigation at 50 per cent Ep (I_1) and was at par with I_2 (75% of Ep).

Table 10. Root dry weight (g plant^{-1}), maximum depth and spread as influenced by mulch and irrigation

Treatments	Maximum depth of root (cm)	Maximum lateral length of root (cm)	Root dry weight (g plant^{-1})
Mulch			
M_0	35.3^{b}	84.3^{b}	4.9^{c}
M_1	39.0^{a}	90.4^{a}	5.4^{b}
M_2	41.1^{a}	91.6^{a}	5.9^{a}
Irrigation			
I_1	36.3^{b}	85.2^{b}	4.7^{c}
I_2	37.3^{b}	85.6^{b}	4.8^{c}
I_3	41.5^{a}	90.3^{ab}	5.8^{ab}
I_4	40.9^{a}	89.9^{ab}	6.2^{a}
I_5	36.4^{b}	92.9^{a}	5.3^{b}
Interaction	NS	NS	Sig

Table 10 a. Root dry matter production (g plant^{-1}) as influenced by combined effect of mulch and irrigation

Treatments	**M_0**	**M_1**	**M_2**
I_1	4.3^{h}	4.7^{gh}	5.2^{efg}
I_2	4.4^{h}	4.6^{gh}	5.4^{cdef}
I_3	4.8^{fgh}	6.3^{ab}	6.4^{a}
I_4	5.9^{abc}	6.1^{ab}	6.5^{a}
I_5	4.9^{fgh}	5.3^{def}	5.8^{bcd}

Figures with same alphabets do not differ significantly at 5 % level .

Plate V. Root growth as influenced by mulch and irrigation

I_1M_0- Drip irrigation at 50% Ep + no mulching

I_1M_1- Drip irrigation at 50% Ep + paddy waste mulch

I_1M_2- Drip irrigation at 50% Ep + black polythene mulch

I_2M_0- Drip irrigation at 75% Ep + no mulching

I_2M_1- Drip irrigation at 75% Ep + paddy waste mulch

I_2M_2- Drip irrigation at 75% Ep + black polythene mulch

I_3M_0- Drip irrigation at 100% Ep + no mulching

I_3M_1- Drip irrigation at 100% Ep + paddy waste mulch

I_3M_2- Drip irrigation at 100% Ep + black polythene mulch

I_4M_0- Drip irrigation at 125% Ep + no mulching

I_4M_1- Drip irrigation at 125% Ep + paddy waste mulch

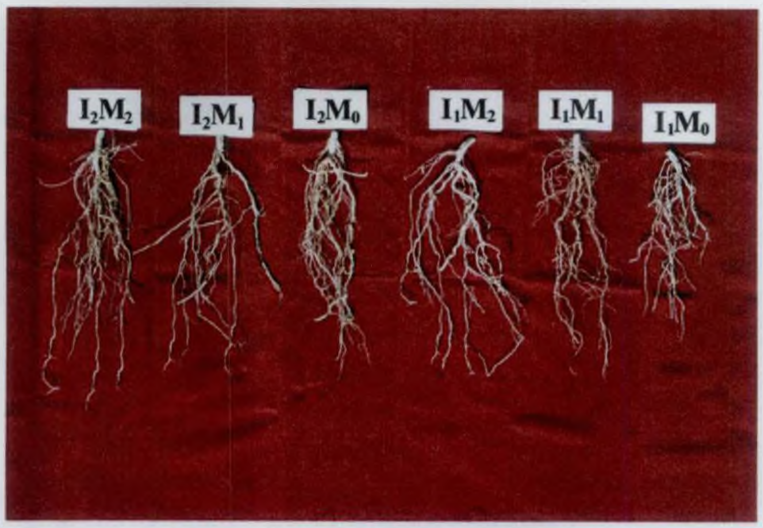
I_4M_2- Drip irrigation at 125% Ep + black polythene mulch

I_5M_0- Basin irrigation @ 45 l pit^{-1} + no mulching

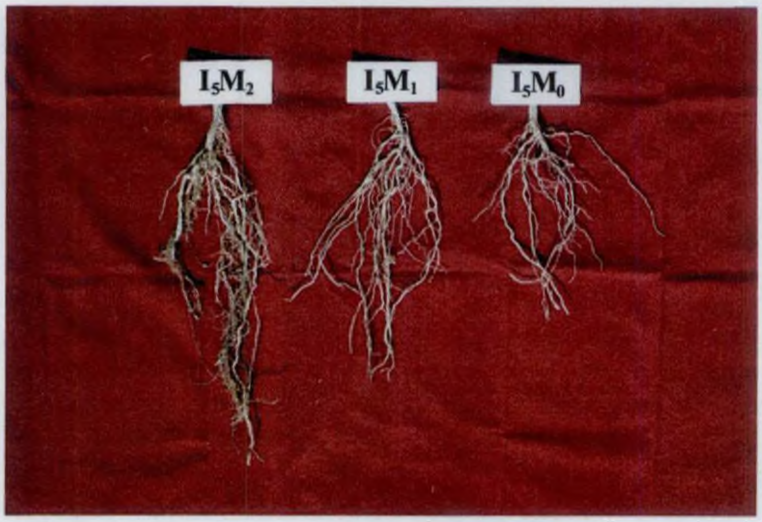
I_5M_1- Basin irrigation @ 45 l pit^{-1} + paddy waste mulch

I_5M_2- Basin irrigation @ 45 l pit^{-1} + black polythene mulch

Plate V


I_2M_2
I_2M_1
I_2M_0
I_1M_2
I_1M_1
I_1M_0


I_4M_2
I_4M_1
I_4M_0
I_3M_2
I_3M_1
I_3M_0


I_5M_2
I_5M_1
I_5M_0

The interaction between irrigation and mulch significantly influenced root dry matter production. Where drip irrigation was scheduled at 50 per cent Ep (I_1), polythene mulch recorded the highest root dry weight, which was significantly superior to control and at par to paddy waste mulch. At 75 per cent Ep (I_2), M_2 was significantly superior to both M_0 and M_1. At 100 per cent Ep (I_3), M_1 and M_2 were significantly superior to M_0. At 125 per cent Ep (I_4) there was no significant difference between control and mulching. Nevertheless M_2 recorded the highest root dry weight in farmers practice of irrigation (I_5), but M_2 produced significantly more root dry weight than M_0. However, the difference between M_2 and M_1 did not vary significantly.

The results clearly indicated the superiority of polythene mulching over straw mulching and control. Under drip irrigation, root dry weight increased progressively from 50 per cent Ep to 125 per cent and significantly the best dry weight was observed at 125 per cent Ep. Polythene mulching produced the highest root dry matter under $I_1$and I_2 as compared to paddy waste and control. Where as under I_3 and I_5 no significant difference between polythene and paddy waste mulching and under I_4 no significant difference among mulch treatments.

Among the irrigation treatments under M_0 , I_4 was the best and under polythene and paddy waste mulches I_3 and I_4 were significantly superior.

4.2 Yield and yield attributes

The data relating to yield and yield components are presented below this title.

4.2.1 Days taken to first flowering

The data on days taken to first flowering of cucumber var. Mudicode local as influenced by mulch and irrigation are given in Table 11 and analysis of variance in Appendix I(g).

The effects of mulch and irrigation on days taken to first flowering were significant. However, their interaction was not significant [Appendix II(c)].

The treatment with out mulch (M_0) recorded significantly the lowest number of days to first flowering. Application of polythene mulch and paddy waste took more days for first flowering and they were significantly different from the treatment with no mulch. However, incorporation of paddy waste was at par with application of polythene mulch.

In the case of irrigation, cucumber which received the lowest quantity of water through drip irrigation at 50 per cent of Ep flowered first and the days taken to first flowering was significantly shorter than that of other treatments. The remaining schedule took almost identical days to their first flowering and the difference between them was not significant.

It can be concluded that unmulched as well as lightly irrigated cucumber plants flowered earlier than mulched or moderately and heavily irrigated plots.

4.2.2 Number of female flowers per plant

The data on number of female flowers taken at 60 DAS are presented in Table 11 and analysis of variance in Appendix I(g).

The influence of mulch and drip irrigation was significant, but their interaction was not significant [Appendix II(c)].

Application of polythene mulch (M_2) recorded the maximum number of 5.9 female flowers plant^{-1}. This was at par with paddy waste mulch, which recorded 5.6 female flowers plant^{-1} at 60 DAS. Both of them were significantly superior to no-mulch control, which recorded 5.1 female flowers plant^{-1}.

Among the irrigation treatments, irrigation with 50 per cent of Ep (I_1) recorded the lowest number of female flowers (5.0 plant^{-1}) and it was significantly inferior to all others. The control with basin method of irrigation (I_5) recorded 5.7 female flowers per plant, which was at par with irrigation at 75, 100 and 125 per cent of Ep (I_2, I_3 and I_4).

From the above data it can be generalized that, mulching increases number of female flowers per plant. Drip irrigation at 50 per cent Ep significantly reduced female flower production, but there was no significant difference between 75, 100 or 125 per cent Ep and basin method of irrigation @ 45 l in three days intervals.

4.2.3 Number of male flowers

The data related to the number of male flowers are presented in Table 11 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 (193.8 plant^{-1}) was recorded from polythene mulch (M_2) and it was significantly superior to paddy waste mulch and control. This was followed by paddy waste mulch (M_1), which recorded 177.2 male flowers plant^{-1} and was significantly superior to no-mulch control, which recorded 162.4 male flower $plant^{-1}$. Therefore, polythene mulch and paddy waste recorded 19 and 9 per cent more male flowers respectively over control.

There had been a progressive increase in the number of male flowers when quantity of water used in drip irrigation increased from 50 to 125 per cent Ep. I_4 (125 per cent Ep) recorded the highest number of male flowers (193.7 $plant^{-1}$) and this was followed by control (I_5) which recorded (183.7 $plant^{-1}$) was at par with I_4 and I_3. The lowest number of male flowers (157.3 $plant^{-1}$) was recorded with I_1 (50 per cent of Ep.).

Overall the result indicated that number of male flowers was highly influenced by application of irrigation and type of mulch. Polythene mulch was superior to paddy waste mulch. In the case of irrigation the average number of male flowers steadily increased with the level of drip irrigation and the highest value noted at 125 per cent Ep. However I_5 was at par to I_4.

4.2.4 Female-male flower ratio

The data on female to male flower ratio are presented in Table 11 and analysis of variance in Appendix I(g).

Mulch or irrigation in no way significantly influenced the ratio of female to male flowers and their interaction also was not significant [Appendix II(c)].

4.2.5 Fruit setting

The data on fruit setting percentage of female flowers are presented in Table 11 and analysis of variance in Appendix I(g).

Table 11. Flower characteristics as influenced by mulch and irrigation

Treatments	Days taken for flowering	Number of female flowers plant^{-1}	Number of male flowers plant^{-1}	Female-male flower ratio (x 10^{-2})	Fruit set (%)
Mulch					
M_0	29.27^b	5.1^b	162.4^c	3.2^a	47.6^b
M_1	29.80^a	5.6^a	177.2^b	3.2^a	51.7^a
M_2	30.00^a	5.9^a	193.8^a	3.0^a	52.4^a
Irrigation					
I_1	28.67^b	5.0^b	157.3^d	3.2^a	49.0^b
I_2	29.89^a	5.5^a	171.7^c	3.2^a	52.7^a
I_3	30.00^a	5.7^a	182.7^b	3.2^a	53.3^a
I_4	30.00^a	5.7^a	193.7^a	3.0^a	53.8^a
I_5	29.89^a	5.7^a	183.7^{ab}	3.1^a	44.0^c
Interaction	NS	NS	NS	NS	NS

Figures with same alphabets do not differ significantly at 5 % level .

The data indicated that the fruit setting rate was influenced by the main effect of mulch and irrigation, whereas their interaction was not significant [Appendix II(c)].

The highest fruit setting percentage was recorded from mulched plots irrespective of the type of mulch. The values recorded from polythene and paddy waste mulches were 52.4 and 51.7 per cent respectively. While the lower value was recorded from the control with out mulch (47.6 per cent) and it was significantly inferior to others.

Among the irrigation treatments I_4 (125 per cent of Ep), I_3 (100 per cent of Ep) and I_2 (75 per cent of Ep) recorded the highest value of 53.8, 53.3 and 52.7 per cent respectively and they were at par with each other. The lowest rate of fruit setting (44%) was recorded from the control, basin method of irrigation @ 45 l in three days interval and was significantly inferior to others. The second lowest fruit set (49%) was recorded from irrigation with 50 per cent of Ep (I_1).

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 lowest for basin method of irrigation @ 45 l in three days (I_5). The variation between I_2, I_3 and I_4 was not significant.

4.2.6 Average weight of fruits

The data on mean single fruit weight in gram are presented in Table 12 and analysis of variance in Appendix I(h).

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

The maximum mean weight of a fruit was recorded from black polythene mulch (M_2). This was significantly superior to that of paddy waste mulch (M_1) and no-mulch control (M_0). The lowest mean weight (765.2 g) was recorded by the application of paddy waste and this was at par with the value (788.6 g/fruit) recorded by the control with no-mulch.

4.2.7 Mean fruit length

The data related to fruit length (cm) are given in Table 12. Plate VI shows the maximum and average fruit length, while analysis of variance is given in Appendix I(h).

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

Among the mulch treatments, application of polythene mulch (M_2) recorded the longest fruit, and was significantly superior to paddy waste mulch (M_1) and no-mulch control (M_0). The lowest value was recorded from no-mulch control and it was at par with paddy waste mulch.

4.2.8 Mean fruit girth

The data on mean fruit girth (cm) are presented in Table 12 and analysis of variance in Appendix I (h).

Similar to other fruit size parameters, influence of mulch on fruit girth was significant, where as influence of irrigation and the interaction between them were not significant [Appendix II(c)].

Table 12. The effect 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	788.6^b	27.7^b	27.5^b	803.5^b
M_1	765.2^b	27.5^b	27.2^b	779.9^b
M_2	893.9^a	29.2^a	28.7^a	911.7^a
Irrigation				
I_1	793.9^a	27.5^a	27.3^a	809.6^a
I_2	808.0^a	25.9^a	27.7^a	823.5^a
I_3	804.9^a	28.2^a	27.9^a	820.1^a
I_4	845.4^a	28.9^a	28.4^a	862.3^a
I_5	827.3^a	28.1^a	27.6^a	847.2^a
Interaction	NS	NS	NS	NS

Figures with same alphabets do not differ significantly at 5 % level .

The result showed that the effect of polythene mulch on fruit girth was significantly superior to others. The effect of paddy waste mulch was not different from the control without mulch.

4.2.9 Average fruit volume

The data on mean fruit volume in cm^3 are given in Table 12 and analysis of variance in Appendix I(h). Plate VI shows the maximum and average fruit size.

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

From the mulch treatments, the effect of polythene mulch on fruit volume was the maximum and significantly superior to others. The effect of paddy waste like the result obtained on fruit length, girth and average weight per fruit was not different from the control with no-mulch. Therefore both were at par and significantly inferior to polythene much (M_2).

Overall, the results indicated that, the fruit characteristics, such as mean weight, length, girth and volume were significantly influenced by application of polythene mulch. However, the influence of paddy waste mulch was not statistically different from the control with no-mulch. Unlike the growth parameters, the above fruit characters were not significantly influenced by the variation in drip irrigation levels or farmers practice of basin irrigation. Therefore, the variations in fruit characteristics were observed only under mulching.

Plate VI. Fruit size as influenced by polythene mulching

I_1M_0 – Drip irrigation at 50% Ep without mulch

I_4M_0 – Drip irrigation at 125% Ep without mulch

I_5M_0 – Basin irrigation @ 45 l pir^{-1} without mulch

I_1M_2 – Drip irrigation at 50% Ep + polythene mulch

I_3M_2 – Drip irrigation at 100% Ep + polythene mulch

I_4M_2 – Drip irrigation at 125% Ep + polythene mulch

Plate VI

I_1M_0

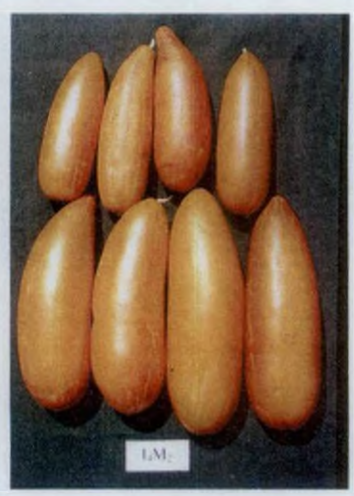
I_4M_0

I_5M_0

I_1M_2

I_3M_2

I_4M_2



4.2.10 Number of fruits per plant

The data on number of fruits $plant^{-1}$ are presented in Table 13 and the analysis of variance in Appendix I(i). Plate VIIa shows the maximum fruit number per plant in I_4M_2.

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

Both the paddy waste and polythene mulched plants produced significantly more number of fruits per plant than unmulched control. However the number of fruits were maximum (3.10 $plant^{-1}$) for polythene mulch (M_2), and that under paddy waste mulch (M_1) recorded 2.91 $plant^{-1}$. Their difference was not statistically significant. The lowest value (2.44 $plant^{-1}$) 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 was recorded from irrigation at 125, 100 and 75 per cent of Ep. Their values were higher over the control, which was receiving irrigation water @ 45 l in three days (I_5) by 24, 24 and 16 per cent respectively. I_4, I_3 and I_2 were at par with each other. The lowest number of fruits (2.48 $plant^{-1}$) was recorded from I_1 (50% of Ep) and was at par with the control.

The results can be summarized as follows. Mulching irrespective of type had positive influence on number of fruits per plant. In the case of irrigation, maximum number of fruits per plant was obtained from 75, 100 and 125 per cent of Ep by drip method.

4.2.11 Fruit yield per plant

The data related to fruit yield (kg plant^{-1}) are presented in Table 13 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)].

Mulches had significant influence on fruit yield per plant. Polythene mulch recorded significantly the maximum fruit yield per plant and it was followed by paddy waste and the difference between them was significant. The lowest value (1.91 kg plant^{-1}) was recorded from the control and was significantly inferior to mulched plots.

With respect to irrigation fruit yield per plant increased progressively with increase in Ep from 50 per cent to 125 per cent. The maximum value of 2.61 kg plant^{-1} was recorded at 125 per cent of Ep and was significantly superior to others except to 100 per cent Ep. This was closely followed by irrigation at 100 per cent of Ep and it was at par with I_2 (75% of Ep). The lowest fruit yield of 1.98 kg plant^{-1} was obtained from I_1 (50% of Ep) and it was at par with the control.

Overall, application of mulch significantly influenced fruit yield per plant and the maximum and significantly superior yield plant^{-1} was recorded from the polythene mulch. As the level of irrigation increased from 50% of Ep to 125% of Ep in the drip method, the yield plant^{-1} was also increased. Drip irrigation at 50 per cent Ep and farmers practice of basin irrigation once in three days with 45 litres were significantly inferior to drip irrigation at 75, 100 and 125 per cent Ep.

4.2.12 Fruit yield per ha

The result on fruit yield (t ha^{-1}) is presented in Table 13 and analysis of variance in Appendix I(i). Plate VIII shows the yield trend before harvest.

The results showed that both mulch and irrigation had significant influence on fruit yield in t ha^{-1} (Table 13). The interaction between mulch and irrigation was not significant and it is presented in Table 13a.

The results clearly indicated the beneficial effect of mulch on fruit yield. The maximum yield of 36.5 t ha^{-1} was recorded from the treatments with black polythene mulch and it was significantly superior to paddy waste mulch and the control, which recorded 29.24 and 25.47 t ha^{-1} respectively. The lowest yield was recorded by control and was significantly inferior to the mulched treatments.

Among the irrigation treatments, I_4 (125 per cent of Ep) recorded the maximum yield of 34.8 t ha^{-1} closely followed by I_3 (100 per cent of Ep) with mean yield of 32.78 t ha^{-1}. Though I_4 was at par with I_3, it was significantly superior to I_1, I_2 and I_5. I_3 and I_2 were at par and both were superior to I_1 and I_5. The lowest yield (26.1 t ha^{-1}) was recorded from irrigation with 50 per cent of Ep. Statistically the control with irrigation @ 45 l in three days was at par with I_1 (50 per cent of Ep).

It can be summarized that mulch had significant influence on fruit yield. Polythene mulching produced 11 t ha^{-1} more fruits over control while the corresponding figure for paddy waste mulching was 3.77 t ha^{-1}. Polythene mulching produced 7.29 t ha^{-1} more fruits than paddy waste mulching. With increase in the level of Ep under drip irrigation, yield of cucumber also increased progressively and the highest yield was

Table 13. Number of fruits and yield as influenced by mulch and irrigation

Treatments	Number of fruits plant^{-1}	Fruit yield	
		Kg plant^{-1}	T ha^{-1}
Mulch			
M_0	2.44^{b}	1.91^{c}	25.47^{c}
M_1	2.91^{a}	2.21^{b}	29.24^{b}
M_2	3.10^{a}	2.71^{a}	36.53^{a}
Irrigation			
I_1	2.48^{b}	1.98^{c}	26.10^{c}
I_2	2.91^{a}	2.33^{b}	31.07^{b}
I_3	3.10^{a}	2.46^{ab}	32.78^{ab}
I_4	3.10^{a}	2.61^{a}	34.82^{a}
I_5	2.51^{b}	2.05^{c}	27.31^{c}
Interaction	NS	NS	NS

Figures with same alphabets do not differ significantly at 5 % level.

Table 13a. Fruit yield (t/ha) as influenced by combined effect of mulch and drip irrigation

Treatments	M_0	M_1	M_2
I_1	19.86^{g}	24.97^{f}	33.47^{bc}
I_2	26.11^{ef}	29.72^{cdef}	37.36^{b}
I_3	27.92^{def}	32.22^{cd}	38.20^{b}
I_4	28.89^{cdef}	32.36^{cd}	43.19^{a}
I_5	24.58^{f}	26.92^{ef}	30.42^{cde}

Figures with same alphabets do not differ significantly at 5 % level .

Plate VIIa. Plant growth and fruit bearing habit as observed in I_4M_2

VIIb. Fruits harvested and heaped from the experiment plots

Plate VII

VIIa.

VIIb.

obtained at 125 per cent Ep. It was significantly superior to 50 and 75 per cent Ep and farmer's practice of irrigation (I_5).

4.3 Effect of mulch and irrigation on weed growth and soil temperature

The data on weed growth and soil temperature as influenced by the main effects of 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 14 and analysis of variance in Appendix I(j). Influence of mulch and irrigation were significant on weed dry matter production.

The dry matter production of 228.7 g m^{-2} was observed from the plots with no-mulch, but in the plots with mulch of paddy waste, it was only 130.4 g m^{-2}. In the polythene mulched plots, 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 the maximum weed dry matter production of 238.3 g m^{-2} was observed from the basin method of irrigation (I_5) and it was significantly the highest over others. This was followed by I_4 (125 per cent of Ep). The lowest weed growth and dry matter production (143.0 g m^{-2}) was observed from I_1 which received the lowest level of irrigation. The differences between I_2, I_3 and I_4 were not significant.

The interaction effect of much and irrigation on weed growth in terms of dry weight (g m^{-2}) was not significant.

Table 14. Weed dry weight as influenced by mulch and irrigation

Treatments	Weed dry weight ($g\ m^{-2}$)
Mulch	
M_0	228.7 [a]
M_1	130.4 [b]
M_2	0.0
Irrigation	
I_1	143.0 [b]
I_2	165.7 [b]
I_3	174.2 [b]
I_4	176.5 [b]
I_5	238.3 [a]
Interaction	NS

Figures with same alphabets do not differ significantly at 5 % level.

Plate VIII. Weed growths and yield as influenced by irrigation and mulch

I_1M_0 – Drip irrigation at 50% Ep without mulch

I_4M_0 – Drip irrigation at 125% Ep without mulch

I_5M_0 – Basin irrigation @ 45 l pir^{-1} without mulch

I_1M_2 – Drip irrigation at 50% Ep + polythene mulch

I_4M_2 – Drip irrigation at 125% Ep + polythene mulch

I_5M_2 – Basin irrigation @ 45 l pir^{-1} + polythene mulch

Plate VIII

I_1M_0

I_1M_2

I_4M_0

I_4M_2

I_5M_0

I_5M_2

It can be concluded that while polythene mulching completely checked weed growth, paddy waste mulching controlled weed growth by 43 per cent. Basin method of irrigation caused significantly highest weed infestation. Under drip irrigation, though weed growth increased with the increase in the rate of water applied the extent of weed growth was less by 33 - 46 per cent as compared to basin method of irrigation. At all levels of irrigations, there was significant reduction of weed growth by paddy waste mulching, while under polythene mulching the weed growth was completely checked as it can be observed in Plate VIII.

4.3.2 Soil temperature

The data related to average soil temperature at 15 cm depth taken during the crop growing period of February 1-25 of 2000 is given in Table 15.

Observation on average soil temperature showed that application of polythene mulching increased soil temperature by 2°C at 15 cm soil depth at 15 cm radius from the emitter as compared to the control with out mulch. The effect of paddy waste was not much better from the control.

Soil temperature at 15cm depth was higher at lower level of irrigation and decreased with increase in level of irrigation. It was the highest (30.3°C) at I_1 (50% of Ep) and gradually decreased as the level of irrigation increased and reached the lowest (28.8°C) with basin method of irrigation (I_5). On average there was a decrease in average soil temperature at 15 cm soil depth by 0.5°C - 0.9°C as irrigation levels increased from

Table 15. Soil temperature at 15-cm depth as influenced by mulch and irrigation

Treatments	Soil temperature at 15 cm depth		
	Morning (°C)	Evening (°C)	Mean (°C)
Mulch			
M_0	28.1	29.5	28.8
M_1	28.4	29.8	29.1
M_2	29.6	31.9	30.8
Irrigation			
I_1	29.5	31.0	30.3
I_2	28.8	30.7	29.8
I_3	28.5	30.7	29.6
I_4	28.3	30.5	29.4
I_5	28.3	29.2	28.8

I_1 to I_4 in the drip method, and decreased by 1.5°C under basin method of irrigations compared to I_1.

4.4 Nutrient composition in cucumber leaf

The data related to the composition of N, P and K in leaf at different growth stages are given in the following captions.

4.4.1 Nitrogen content of leaf

The data on total nitrogen content in leaves at 30, 60 and 75 DAS are given in Table 16 and analysis of variance in Appendix I(k).

The result showed that both main effects and interaction of mulch and irrigation was significant on total leaf nitrogen content (%) at all the growth stages.

At all the growth stages of 30, 60 and 75 DAS application of polythene mulch recorded the maximum nitrogen content of 4.71, 4.97 and 2.89 per cent respectively. This was significantly superior to paddy waste mulch and control. The effect of paddy waste mulch was significantly superior to control. The lowest value (4.33, 4.54 and 2.62 per cent) was recorded at the growth stages of 30, 60 and 75 DAS respectively from control with no mulch and it was significantly inferior to both the mulches.

At 30 DAS, among the irrigation treatments, I_4 (125 per cent of Ep) and I_3 (100 per cent of Ep) recorded the maximum total nitrogen content of 4.88 and 4.84 per cent respectively and they were significantly superior to others besides being at par with each other. The lowest value (4.08 per cent N) was recorded from the treatment which received drip irrigation at 50 per cent Ep (I_1).

At 60 DAS similar to the above the highest per cent of N (5.28 and 5.15) in leaf was recorded from irrigation at 125 and 100 per cent of Ep (I_4 and I_3) respectively and they were at par. The lowest value (4.37 per cent N) was also recorded from the lowest level of drip irrigation with 50 per cent of Ep (I_1).

At harvest (75 DAS) also the maximum per cent of N (2.94) in leaf was observed from I_4 (125 per cent of Ep) and this was significantly superior to others. This was closely followed by I_3 (100 per cent of Ep), that recorded 2.87 per cent of N. The basin method of irrigation (control), which recorded 2.71 per cent of N was at par with I_2 (75 per cent of Ep). However the lowest value (2.6 per cent N) was observed from I_1 (50 per cent of Ep) as it was at all the growth stages.

The interaction between mulch and irrigation on N content of leaf at growth stages of 30 and 60 DAS and at the time of harvest is given in Tables 16a –16c.

At 30 DAS, mulches had significant interaction with irrigation treatments. With every irrigation treatment, polythene mulch recorded significantly the highest leaf N content. Though leaf N content of paddy waste mulched treatments with each level of irrigation was significantly superior to control, it was significantly inferior to polythene mulch. Thus the superior effect of polythene mulch on leaf N content in all the irrigation treatments at the early growth stage of 30 DAS was very clear.

At 60 DAS the interaction between mulches and irrigation treatments did not behave exactly as at 30 DAS. With I_1, polythene mulch produced significantly highest leaf N content of 4.67 per cent. With I_2, even though polythene mulching recorded the highest leaf N content (4.75%), it was at par with paddy waste mulch (4.62%). While I_2M_2 was significantly superior to I_2M_0, I_2M_1 was at par with I_2M_0. At I_3 level of drip

Table 16. The influence of mulch and irrigation on leaf nitrogen content (%) at different growth stages

Treatments	30 DAS	60 DAS	75 DAS
Mulch			
M_0	4.33^{c}	4.54^{c}	2.62^{c}
M_1	4.52^{b}	4.83^{b}	2.81^{b}
M_2	4.71^{a}	4.97^{a}	2.89^{a}
Irrigation			
I_1	4.08^{c}	4.37^{c}	2.64^{d}
I_2	4.38^{b}	4.58^{b}	2.71^{c}
I_3	4.84^{a}	5.15^{a}	2.87^{b}
I_4	4.88^{a}	5.28^{a}	2.94^{a}
I_5	4.40^{b}	4.51^{bc}	2.71^{c}
Interaction	Sig	Sig	Sig

Figures with same alphabets do not differ significantly at 5 % level.

Table 16 a. Nitrogen content of leaves (%) under mulch and irrigation treatments at 30 DAS

Treatments	M_0	M_1	M_2
I_1	3.91^{i}	4.05^{h}	4.28^{f}
I_2	4.14^{g}	4.37^{e}	4.62^{d}
I_3	4.62^{d}	4.89^{b}	5.02^{a}
I_4	4.77^{bc}	4.87^{b}	5.00^{a}
I_5	4.22^{f}	4.39^{e}	4.60^{d}

Table 16 b. Nitrogen content of leaves (%) under mulch and irrigation treatments at 60 DAS

Treatments	M_0	M_1	M_2
I_1	4.14^{e}	4.31^{de}	4.67^{b}
I_2	4.37^{cde}	4.62^{bc}	4.75^{b}
I_3	4.71^{b}	5.31^{a}	5.42^{a}
I_4	5.19^{a}	5.36^{a}	5.29^{a}
I_5	4.28^{de}	4.53^{bcd}	4.73^{b}

Table 16 c. Nitrogen content of leaves (%) under mulch and irrigation treatments at harvest (75 DAS)

Treatments	M_0	M_1	M_2
I_1	2.45^{f}	2.68^{de}	2.78^{d}
I_2	2.50^{f}	2.71^{de}	2.92^{ab}
I_3	2.61^{e}	2.96^{ab}	3.03^{a}
I_4	2.89^{bc}	2.99^{ab}	2.94^{ab}
I_5	2.64^{e}	2.71^{de}	2.80^{cd}

Figures with same alphabets do not differ significantly at 5 % level .

irrigation, both polythene and paddy waste mulches were at par and significantly superior to the control. Leaf N content did not vary significantly between M_0, M_1 and M_2, when cucumber was drip irrigated with 125 per cent Ep. With I_5, effect of M_1 and M_2 did not vary significantly, but M_2 was significantly superior to M_0, while M_1 was at par with M_0.

At harvest (75 DAS) with drip irrigation at 50 and 100 per cent Ep polythene and paddy waste mulches recorded significantly higher leaf N content over control, though the difference between them did not vary significantly. When the crop was drip irrigated with 75 per cent Ep, leaf N content with polythene mulch was significantly the highest. The difference between paddy waste mulch and control also was significant. At I_4 level of drip irrigation, the differences between the control and mulches were not significant. In the basin method of irrigation (I_5) the difference in leaf N content between polythene and control was significant, while the difference between paddy waste mulch and polythene mulch as well as control and paddy waste did not vary significantly.

In general, the leaf N content at 30 DAS ranged from 4.08 to 4.88 per cent. Thereafter it showed slight increase and by 60 DAS it varied from 4.37 to 5.28 per cent. By the time of harvest leaf N content reduced drastically, and its value ranged from 2.62 to 2.94 per cent. Mulching helped in a higher accumulation of N in the leaves. At all the growth stage polythene mulched plants had significantly higher leaf N content than that paddy waste mulched and the unmulched plants. Leaf N content was the highest at all the stages with drip irrigation at 125 per cent Ep. However, the leaf N content at 125 per cent Ep was at par with that of 100 per cent Ep at 30 and 60 DAS, while at 75 DAS the former was significantly superior to the latter. The effects of these two irrigation treatments (I_3 and I_4) were significantly superior to all other irrigation treatments.

4.4.2 Phosphorus content of leaf

The data on composition of phosphorus in leaf (%) as influenced by mulch and drip irrigation are presented in Table 17 and analysis of variance in Appendix I(l).

The result indicated that the effects of mulch and irrigation were significant at growth stages of 30, 60 DAS and at harvest. While their interaction was significant only at harvest (75 DAS).

The result showed that, at 30 DAS irrespective of irrigation levels, the maximum value of 0.53% P was recorded in polythene mulched plots and was significantly superior to control. This was closely followed by mulch of paddy waste, which recorded 0.51 per cent of P and was at par with polythene mulch and control. However the lowest value (0.49% P) was recorded from the control with no-mulch.

At 60 DAS, the trend was exactly the same as at 30 DAS. But the per cent of P content in leaf reduced almost by half. The values recorded were 0.299, 0.282 and 0.262 per cent of P for polythene mulch, paddy waste mulch and no mulch control respectively.

At harvest (75 DAS) the maximum values of 0.265 and 0.260 per cent P were recorded from black polythene mulch and paddy waste mulch respectively and they were at par. The lowest value (0.228 per cent P) was recorded from the control and was significantly inferior to both the mulched treatments.

Among the irrigation treatments, at 30 DAS the highest value (0.527 per cent P) was recorded from irrigation with 125 per cent of Ep and it was at par with I_3

(100 per cent Ep), I_2 (75 per cent of Ep) and I_5. The lowest value (0.482% of P) was observed from the lower level of irrigation (50% of Ep) which was at par with I_2 and I_5.

At 60 DAS similar to the above, the highest value (0.305% P) was recorded in I_4 (125% of Ep) and was at par with I_3 (100% of Ep) and I_5. The lowest value of 0.256% was recorded from irrigation with 50 per cent of Ep and was at par with I_2 and I_5. I_3 and I_4 were significantly superior to I_1 and I_2.

At 75 DAS unlike the case at 30 and 60 DAS the maximum value of 0.272 per cent of P was recorded from the basin method (I_5) and was at par with irrigation of 125 per cent Ep (I_4), these two treatments were significantly superior to the others. This was closely followed by I_3 (100% of Ep). The lower values (0.232 and 0.229% P) were recorded from I_1 (50% of EP) and I_2 (75% of EP) respectively and they were significantly inferior to others.

The P content at harvest for different treatment combinations are given in Table 17a

Significant interaction between mulch and irrigation was observed only at the time of harvest. At I_1 level of drip irrigation and with I_5, paddy waste mulch record the highest leaf P percentage, which was significantly superior to control and at par with polythene mulch. At I_2 and I_3 levels of drip irrigation significantly highest leaf P content was obtained under polythene mulch. Leaf P content under paddy waste mulch was significantly higher than that under control at I_2, but at par with control at I_3. At I_4 level of drip irrigation highest leaf P content was obtained with polythene mulch, but was at par with paddy waste mulch. Leaf P content of I_4M_0 treatment combination was significantly inferior to both I_4M_2 and I_4M_1.

Table 17. The influence of mulch and irrigation on phosphorous content of leaves (%) at different crop growth stages

Treatments	30 DAS	60 DAS	75 DAS
Mulch			
M_0	0.487^{b}	0.262^{b}	0.228^{b}
M_1	0.506^{ab}	0.282^{ab}	0.260^{a}
M_2	0.527^{a}	0.299^{a}	0.265^{a}
Irrigation			
I_1	0.482^{b}	0.256^{b}	0.232^{c}
I_2	0.505^{ab}	0.265^{b}	0.229^{c}
I_3	0.523^{a}	0.301^{a}	0.258^{b}
I_4	0.527^{a}	0.305^{a}	0.264^{ab}
I_5	0.498^{ab}	0.279^{ab}	0.272^{a}
Interaction	NS	NS	Sig

Table 17 a. Phosphorous content (%) at harvest under different treatment combinations

Treatments	**M_0**	**M_1**	**M_2**
I_1	0.204^{f}	0.254^{cd}	0.238^{de}
I_2	0.205^{f}	0.230^{e}	0.252^{cd}
I_3	0.242^{de}	0.257^{cd}	0.275^{b}
I_4	0.246^{de}	0.266^{bc}	0.281^{ab}
I_5	0.241^{de}	0.294^{a}	0.281^{ab}

Figures with same alphabets do not differ significantly at 5 % level .

In short, leaf P content was the highest at 30 DAS and it ranged between 0.482 and 0.527 per cent. By 60 DAS, leaf P content was reduced by about 50 per cent and varied between 0.256 and 0.305 per cent. Between 60 and 75 DAS, the reduction in leaf P content was meager and it varied between 0.228 to 0.272 per cent. Leaf P content increased significantly due to mulching. Leaf P content increased with increase in the level of Ep. Under drip irrigation highest value was observed with 125 per cent Ep (I_4) and was at par with I_2, I_3 and I_5 at 30 DAS, and with I_3 and I_5 at 60 and 75 DAS. Leaf P content of basin method of irrigation with 45 litres once in three days was higher and at par with I_4 at all the stages of growth. In drip irrigation with 50 per cent of Ep leaf P content was statistically inferior to I_3 and I_4. Interaction between mulch and irrigation was significant only at harvest. At all irrigation levels polythene mulched treatments had significantly higher leaf P content over control, but paddy waste mulched treatments had significantly higher leaf P content over control at I_1, I_2, I_4 and I_5 levels of irrigation. Polythene mulched treatments had significantly higher leaf P content over paddy waste mulched treatments only at I_2 and I_3 levels of irrigation. Thus, polythene mulches had a better effect with irrigation at I_2 and I_3 than that of paddy waste mulch. In the remaining irrigation treatments (I_1, I_4 and I_5) significant difference was not observed between mulching materials. However in each irrigation treatments application of mulches significantly increased leaf P content at harvest.

4.4.3 Potassium content of leaf

The data on percentage of K content in leaf at growth stage of 30 and 60 DAS and at harvest are presented in Table18 and analyses of variance in Appendix I(m).

The result indicated that both mulch and irrigation had significant influence on percentage of K in leaf at all the growth stages. Their interaction was significant only at the time of harvest (75 DAS).

At 30 DAS the effect of black polythene mulch was the maximum with 2.98% of K and it was significantly superior to others. This was followed by application of paddy-waste-mulch, which was significantly superior to control. The lowest value (2.79% K) was recorded from no mulch control (M_0). This trend remained the same at 60 DAS also. But the values recorded were 1.93, 1.89 and 1.83 per cent K for M_2, M_1 and M_0 respectively and these were lower than that recorded at 30 DAS. At 75 DAS also the maximum value of 1.83 per cent was observed from M_2 and was at par with M_1. The lowest value was recorded from the no-mulch control (M_0), which was significantly inferior to the mulched plots.

Among the irrigation treatments, at 30 DAS significantly maximum value (3.02%) of K was recorded from irrigation with 100 per cent of Ep (I_3). This was followed by 125 per cent Ep. The basin method (I_5) was at par with I_2 (75% of Ep), and these two were significantly inferior to I_3 and I_4. The lowest value was recorded from irrigation with 50 percent of Ep (I_1).

At 60 DAS, the maximum values (2.07 and 2.03% of K) were observed from irrigation with 100 and 125 per cent of Ep (I_3 and I_4). These two were at par and significantly superior to others. The lowest value of 1.77 per cent K was recorded from the basin method (I_5) and from I_1 (50% of Ep).

At harvest, though the K content was low, the trend was not different from that observed at 30 DAS. Significantly maximum value of K (2.05%) was recorded from

I_3 (100% Ep). This was followed by I_4, which was also significantly superior to I_1, I_2 and I_5. The lowest value of 1.58 per cent K was observed from the lowest level of irrigation (I_1). I_5 (basin method) was at par with I_2 (75% Ep) and they were significantly superior to I_1.

The mean K content of leaves at different mulch and irrigation combination at harvest (75 DAS) are presented in Table 18a.

At I_1 level of drip irrigation, mulch treatments do not differ from unmulched plots significantly. At I_2 level unmulched control recorded the highest leaf, K content which was significantly superior to paddy waste mulch and at par with polythene mulch. At I_3 level, polythene mulched plants recorded the maximum leaf K content, which was significantly superior to unmulched control, but was at par with paddy waste mulch. At I_4 and I_5 both the mulches recorded significantly higher leaf K content than the control with no mulch, the effects of mulches were at par.

The results can be summarized as follows. Mulches significantly influenced the K content of leaves. Significantly highest leaf K content was observed under polythene mulch at 30 and 60 DAS. At harvest leaf K content under polythene mulch was at par with that under paddy waste mulch, paddy waste mulch was significantly superior to unmulched control. Highest leaf K content was observed at 100 per cent Ep (I_3) at all the growth stages. At 30 and 75 DAS it was significantly superior to all others, while at 60 DAS it was at par with I_4. Second highest leaf K content was observed at 125 per cent Ep, which also was significantly superior to I_1, I_2 and I_5. Leaf K content was the lowest at 50 per cent of Ep and it increased steadily upto 100 per cent Ep. Potash content in the leaf was highest at 30 DAS where it ranged from 2.73 to 3.02 per cent. At 60 DAS, its

Table 18. The influence of mulch and irrigation on potassium content of leaves (%) at different crop growth stages

Treatments	30 DAS	60 DAS	75 DAS
Mulch			
M_0	2.79^c	1.83^c	1.75^b
M_1	2.89^b	1.89^b	1.82^a
M_2	2.98^a	1.98^a	1.83^a
Irrigation			
I_1	2.73^d	1.77^c	1.58^d
I_2	2.89^c	1.87^b	1.74^c
I_3	3.02^a	2.07^a	2.05^a
I_4	2.96^b	2.03^a	1.91^b
I_5	2.84^c	1.77^c	1.73^c
Interaction	NS	NS	Sig

Table 18a. Potassium content (%) at harvest under different treatment combinations

Treatments	**M_0**	**M_1**	**M_2**
I_1	1.60^{ef}	1.53^f	1.60^{ef}
I_2	1.80^c	1.68^{de}	1.75^{cd}
I_3	1.93^b	2.08^a	2.13^a
I_4	1.80^c	1.98^b	1.93^b
I_5	1.62^{ef}	1.82^c	1.75^{cd}

Figures with same alphabets do not differ significantly at 5 % level .

content varied from 1.77 to 2.07 per cent. At the time of harvest leaf K content ranged from 1.58 to 2.05 per cent. At the lower levels of irrigation (I_1 and I_2) mulches had no significant influence on leaf K content over unmulched control, while at the higher levels of irrigation (I_3, I_4 and I_5) mulched treatments recorded significantly higher leaf K content than unmulched control. However, the differences between the two types of mulches were not significant.

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 at 16-18 hours after irrigation are given in Tables19 and 20 consecutively. The periodical mean of soil moisture content (% w/w) for the crop growth period of 40, 60 and 75 DAS are given in Appendix III.

The result of lateral moisture distribution indicated that, in all the irrigation treatments, soil moisture content was higher in mulched situation as compared to unmulched situation. Application of black polythene (M_2) retained more moisture in each lateral section compared to no-mulch and the mulch of paddy waste in all irrigation levels. Even though paddy waste mulch (M_1) retained relatively lower moisture in comparison to M_2, it retained higher moisture as compared to the control with no-mulch.

Among the irrigation treatments, the maximum soil moisture content was observed with basin method of irrigation (I_5). Whereas, the lowest per cent of soil moisture among different sections of lateral distances were observed with the 50%

Table 19. Soil moisture content (% w/w) before irrigation at 0-60 cm depth on different distance from the dripper as influenced by mulch and irrigation

Treatments	Lateral distance from the dripper			
	0-15 cm	15-30 cm	30-45 cm	45-60 cm
I_1M_0	14.17	13.11	12.94	11.94
I_1M_1	15.25	13.96	13.52	12.84
I_1M_2	15.94	14.97	14.75	13.93
I_2M_0	16.25	15.06	13.99	12.72
I_2M_1	16.73	14.89	14.46	13.17
I_2M_2	17.00	15.75	15.20	14.39
I_3M_0	17.56	16.07	15.83	15.07
I_3M_1	18.12	17.07	16.44	15.18
I_3M_2	18.70	17.95	16.98	16.03
I_4M_0	19.01	18.49	17.57	16.10
I_4M_1	19.66	19.34	17.76	16.50
I_4M_2	20.50	19.10	18.70	17.29
I_5M_0	20.03	19.65	18.53	17.52
I_5M_1	21.23	20.26	19.07	17.32
I_5M_2	21.79	20.58	19.15	17.93

of Ep). From I_1 to I_5 level of irrigation there was a progressive increase of soil moisture content in all the lateral sections. Soil moisture content was the highest in the lateral distance of 0-15 cm from the dripper in all irrigation treatments irrespective of the mulches. Thereafter, it gradually decreased and the minimum values were observed at lateral distance of 45-60 cm.

The mean lateral distribution of soil moisture at the depth of 0 - 60 cm indicated that, the soil moisture content along the radial distance reduced gradually, as the distance from the dripper increased. The moisture content for mulched treatments were higher for each radial distance as compared to the control without mulch. The maximum value was recorded with polythene mulch for each irrigation levels. Among the irrigation treatments, highest soil moisture was recorded by basin method of irrigation (I_5). Among the drip irrigation treatments, soil moisture level increased with increase in Ep.

In the vertical distribution of soil moisture also mulched plots retained more moisture in all the three depths studied. Overall paddy straw mulching retained 2.2 to 4.2 per cent more moisture than control, while polythene mulch retained 7 to 8.2 per cent more moisture than control.

Moisture content increased with increase in level of irrigation in all the depths. Minimum value was recorded by 50% Ep and maximum by I_5 or the farmer's practice of irrigating once in three days with 45 litres. At each level of irrigation 15-30 cm depth retained 12-21 per cent more moisture than the surface layer of 0-15 cm. The highest content of soil moisture at each level of irrigation was observed in the bottom layer of 30-60 cm which had 24 to 29 per cent more moisture than the surface layer of 0-15 cm.

Table 20. 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	11.32	13.78	14.07
I_1M_1	11.81	14.68	15.21
I_1M_2	13.37	15.60	16.09
I_2M_0	12.67	15.01	15.81
I_2M_1	12.92	15.28	16.24
I_2M_2	13.53	16.05	17.14
I_3M_0	13.92	17.09	18.04
I_3M_1	14.51	17.28	18.15
I_3M_2	15.05	17.91	19.32
I_4M_0	14.93	18.37	20.17
I_4M_1	16.01	18.92	20.01
I_4M_2	16.41	19.17	21.09
I_5M_0	16.81	18.62	20.98
I_5M_1	17.34	19.65	21.40
I_5M_2	17.68	19.94	21.90

It can be concluded that depth wise also mulching helped to conserve more moisture. Effect of polythene mulch was better than that of paddy waste mulch. Moisture content increased with increase in the level of irrigation upto the depth of 60 cm studied. Lower most layer of 30-60 cm retained the highest amount of water than the 15-30 and 0-15 layers in all the irrigation treatments.

4.5.2 Consumptive use (Cu)

The data on mean seasonal consumptive use (CU) in mm, for the total crop growth period is given in Table 21.

Among the mulch treatments, the maximum consumptive use (308.22 mm) was recorded in plots with out mulch. The lowest value of CU (298.92 mm) was recorded from the application of black polythene mulch (M_2). Whereas paddy waste-mulch recorded 305.17 mm of CU and it was higher than M_2, but lower than the control with no-mulch.

From the irrigation treatments, the maximum seasonal consumptive use 435.66 mm) was observed in the basin method (Control) which received irrigation @ 45 l in three days. The lowest value of CU (168.02 mm) was recorded from the lowest level of irrigation with 50 per cent of Ep (I_1). Overall, consumptive use increased with increasing level of irrigation. The influence of mulch on CU was less compared to the influence of irrigation treatments. The variation in CU among the mulched and the unmulched plots was not of much difference (Table 22).

Table 21. Mean seasonal consumptive use (mm) as influenced by mulch and irrigation

Treatments	M_0	M_1	M_2	**Mean**
I_1	175.45	169.75	158.85	168.02
I_2	241.83	242.73	236.43	240.33
I_3	308.90	305.80	298.30	304.33
I_4	378.08	372.85	365.58	372.18
I_5	436.85	434.67	435.45	435.66
Mean	308.22	305.17	298.92	

Table 22. Mean daily consumptive use (CU), mean daily pan evaporation and average crop coefficient as influenced by mulch and irrigation

Treatments	Mean daily CU (mm)	Mean daily pan evaporation (mm)	Average crop coefficient
Mulch			
M_0	4.30	6.07	0.71
M_1	4.20	6.07	0.69
M_2	4.15	6.07	0.68
Irrigation			
I_1	2.33	6.07	0.38
I_2	3.34	6.07	0.55
I_3	4.23	6.07	0.70
I_4	5.17	6..07	0.85
I_5	6.05	6.07	1.00

4.5.3 Crop coefficient

The data on mean daily CU and crop coefficient for different periods and overall average are presented in Table 22 and 23.

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 (0.71) for plots with no-mulch and it was lower (0.68) for treatments with polythene mulch, but the difference among the mulch treatments was low. Among the irrigation treatments, the maximum crop coefficient value (1.0) was recorded from the basin method of irrigation as control. This was followed by I_4 (125 % of Ep) and I_3 (100% of Ep), which recorded 0.85 and 0.70 crop coefficient values. While the lowest value of KC (0.38) was recorded from the lowest level of irrigation of 50 per cent of Ep (I_1). In general, the crop coefficient values increased with an increase of level of irrigation.

The periodical crop coefficient values also, followed the same trend as the mean daily crop coefficient. However, the CU and crop coefficient values varied with crop age and growth. The CU and Kc values increased gradually from the early seedling stage to flowering and reached maximum at fruit enlargement and development stage and gradually reduced towards maturity and harvest (60-75 DAS). Therefore, as indicated above, the periodical crop coefficient was maximum for treatments with higher level of irrigation and it was lower for lower irrigation levels.

Table 23. Mean 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		61-75 DAS		Average	
	CU	Kc	CU	Kc	CU	Kc	CU	Kc	CU	Kc
I_1	1.70	0.31	1.90	0.29	3.48	0.59	1.88	0.32	2.33	0.38
I_2	1.70	0.31	3.13	0.48	4.91	0.83	3.25	0.56	3.34	0.55
I_3	1.70	0.31	3.99	0.61	6.38	1.08	4.53	0.78	4.23	0.70
I_4	1.70	0.31	4.76	0.73	8.18	1.39	3.98	0.68	5.17	0.85
I_5	1.70	0.31	4.29	0.66	9.74	1.65	8.07	1.38	6.05	1.00

4.5.4 Water use efficiency

The data on field water use efficiency (FWUE) and crop water use efficiency (CWUE) are given in Table 24.

Mulching increased crop and field water use efficiencies. Among the mulches, the maximum field WUE (107.52 kg/ha-mm) and crop WUE (136.96 kg/ha-mm) were recorded by black polythene mulch (M_2). This was followed by application of paddy waste mulch (M_1), which recorded 85.99 and 105.78 kg/ha-mm of field and crop WUE respectively. While the lowest values (73.24 and 88.85 kg/ha-mm) of field and crop WUE, respectively were recorded by the control with no-mulch (M_0).

Both FWUE and CWUE decreased progressively with an increase in the level of irrigation. The maximum field and crop water use efficiencies (122.30 and 158.68 kg/ha-mm) respectively was recorded by the lowest level of irrigation of 50 per cent Ep (I_1). This was followed by I_2 and I_3, which recorded (129.55 and 107.94 kg/ha-mm) crop WUE respectively. FWUE and CWUE were the lowest under basin method of irrigation (I_5) compared to other irrigation treatments. Percentage decrease of FWUE and CWUE in I_5 amounted to 64.8 and 60.5 compared to I_1 respectively. In general, irrigation WUE was found decreasing with increasing level of irrigation and mulching had a positive effect.

4.5.5 Soil moisture depletion pattern

The data regarding the relative 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 25 and illustrated in Fig.23.

Table 24. Effect of mulch and irrigation on water use efficiency

Treatments	FWUE (Kg ha-mm^{-1})	CWUE (Kg ha-mm^{-1})
Mulch		
M_0	73.24	88.85
M_1	85.99	105.78
M_2	107.52	136.96
Irrigation		
I_1	122.30	158.68
I_2	105.24	129.55
I_3	87.43	107.94
I_4	76.60	93.78
I_5	53.02	62.69

In all the treatments the upper most layer (0-15 cm) recorded the maximum moisture depletion ranging from 41 to 60 per cent irrespective of mulch and level of irrigation. While the lowest moisture depletion range of 5.33-28.67 per cent was observed from the lower most layer of 30-60 cm depth.

The variation in moisture depletion among the mulch treatments at 0-15 cm ranged from 48.2 to 53.2 percentage and the corresponding variations in 15-30 and 30-60 cm layers were 29.6-30.8 and 16.2-20.8. There was practically no difference in moisture depletion among M_0, M_1 and M_2 from the 15-30 cm layer, while in the 0-15 cm layer, M_2 depleted 5 per cent more moisture than control (M_0) and in 30-60 cm layer moisture depletion by M_2 was less by 4.6 per cent compared to control (M_0). M_1 behaved more or less like M_0 in each layer.

Among the irrigation treatments depletion percentage varied much in the surface 0-15 and bottom 30-60 cm layers. In the surface layer of 0-15 depletion percentage was the lowest with the treatment receiving the lowest quantity of water. Percentage depletion increased from 41in I_1 to 62 in I_5 depending upon the increase in the quantity of water received in irrigation. Contrary to this in the bottom layer of 30-60 cm depletion was the minimum in I_5, which received the maximum amount of water. In this layer depletion percentage increased with decrease in the amount of water applied. In the middle layer of 15-30 cm, moisture depletion remained almost constant around 29.3-32.3 per cent among the irrigation treatments.

Table 25. 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	48.20	30.80	20.80
M_1	49.80	29.60	20.60
M_2	53.20	30.40	16.20
Irrigation			
I_1	41.00	30.00	28.67
I_2	42.33	31.00	26.67
I_3	48.67	29.33	22.00
I_4	58.00	28.67	13.33
I_5	62.00	32.33	5.33

4.6 Economics of production

The data pertaining the economics of production of cucumber crop 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 26 and 27. The details of investment and cost of production are given in Appendix IV.

Among the mulches, the highest net profit of Rs.1,46,346 ha^{-1} was recorded by polythene mulching and this was followed by the application of paddy waste mulch, which recorded a net profit of Rs.1,15,640 ha^{-1}. The lowest net return of Rs.89,232 ha^{-1} was recorded from no mulch (M_0).

The net income per rupee invested for treatments with polythene and paddy waste mulch were 2.01 and 1.90 rupees respectively. The lowest (Rs.1.40) net income per rupee invested was recorded from treatments with out mulch.

Among the irrigation treatments the highest net profit of Rs.1, 41,044 per ha was recorded from drip irrigation with 125 per cent of Ep (I_4). This was followed by I_3 and I_2 which recorded net profits of Rs.1, 30,640 and 1,22,235 ha^{-1} respectively. The lowest net profit of Rs.95, 574 ha^{-1} was obtained from the basin method and this was closely followed by drip irrigation with 50 per cent Ep (I_1), which recorded a net profit of Rs.95, 871 ha^{-1}.

The net income per rupee invested per ha also followed similar trend to the above. The maximum (2.10) net income per rupee invested was recorded by I_4 and the lowest value 1.40 by the basin method (I_5).

Table 26. Economics of cucumber production per hectare as influenced by mulch and irrigation

Treatments	Total cost of production (Rs)	Gross return (Rs)	Net profit (Rs)	Net income per rupees invested
Mulch				
M_0	63599.90	152832	89232.10	1.40
M_1	60879.86	176520	115640.14	1.90
M_2	72821.56	219168	146346.44	2.01
Irrigation				
I_1	62449.03	158320	95870.97	1.52
I_2	64244.50	186480	122235.47	1.89
I_3	66040.00	196680	130639.97	1.98
I_4	67835.60	208880	141040.40	2.10
I_5	68266.30	163840	95573.67	1.40

Result of economics of irrigation and mulching treatment combinations presented in Table 27 indicated that, at each level of irrigation, polythene mulching tremendously increased the net profit over M_0, while paddy waste mulching had a moderate effect. At I_1, paddy waste mulching recorded a net profit of Rs.58, 878, while polythene mulching raised the net return to Rs.1, 31,317 per ha. At I_2, the corresponding figures were Rs.94, 583 and Rs.1, 52,861 per ha respectively. At I_3, net return with M_0 and M_2 were Rs.1, 03,347 and Rs.1, 56,106 per ha respectively. At I_4 the corresponding figures per ha were Rs.1, 07,672 and Rs.1, 84,250 respectively. When the farmers practice of irrigation was applied with no mulching, the net profit was Rs.81, 381 ha^{-1} while its combination with polythene mulch raised the net profit to Rs.1, 07,199 ha^{-1}.

The corresponding increase in net profit at I_1, I_2, I_3, I_4 and I_5 with polythene mulch over no mulch were in the order of Rs.72, 438; 58,278; 52,458; 76,579 and 25,818 respectively. Therefore the response of polythene mulching was the highest at I_4 level followed by I_3 level. Polythene mulching had only a limited influence when irrigation was scheduled as per the farmer's practice of basin irrigation.

Among the combinations, I_4M_2 recorded the highest net profit Rs.1,84,250 per ha and was followed by I_3M_2 (Rs.1,56,106 ha^{-1}). The third best combination was I_2M_2 (Rs.1, 52,861 ha^{-1}). Next in the order was I_3M_1 (Rs.1, 32,167 ha^{-1}), but it was very close to I_1M_2 (Rs.1, 31,317 ha^{-1}).

At the different levels of drip irrigation (I_1 to I_4) polythene mulching increased the net income per rupee invested to a great extent, similarly the effect of paddy waste mulching also was not much different except with I_4 it was more lower and with I_3 it was

Table 27. Cost economics of cucumber production per hectare as influenced by combinations of mulch and irrigation.

Treatments	Total cost per hectare (Rs)	Gross income ha^{-1}		Net profit per hectare (Rs)	Net income per Rs invested
		Yield (Kg ha^{-1})	Value in Rs		
I_1M_0	60281.8	19860	119160	58878.2	0.98
I_1M_1	57561.8	25830	154980	97418.2	1.69
I_1M_2	69503.5	33470	200820	131316.5	1.89
I_2M_0	62077.3	26110	156660	94582.7	1.52
I_2M_1	59357.3	29770	178620	119262.7	2.01
I_2M_2	71299.0	37360	224160	152861.0	2.14
I_3M_0	63872.8	27920	167520	103647.2	1.63
I_3M_1	61152.8	32220	193320	132167.2	2.16
I_3M_2	73094.5	38200	229200	156105.5	2.14
I_4M_0	65668.5	28890	173340	107671.5	1.63
I_4M_1	62948.3	32360	194160	131211.7	2.08
I_4M_2	74890.0	43190	259140	184250.0	2.46
I_5M_0	66099.1	24580	147480	81380.9	1.23
I_5M_1	63379.1	26920	161520	98140.9	1.55
I_5M_2	75320.8	30420	182520	107199.2	1.42

slightly higher. In the case of I_5, paddy waste recorded the highest net income per rupee invested.

Among the combinations, the highest net income per rupee invested was recorded by I_4M_2 (2.45), this followed by I_3M_1 (2.16). The third best combination was equally shared by I_3M_2 (2.14) and I_2M_2 (2.14).

The results in general indicated the superiority of black polythene mulching in each level of irrigation on net income per hectare. Net profit per rupee invested was higher at I_4 along with polythene mulch followed by I_3M_1, I_3M_2 and I_2M_2.

4.6.1 Additional benefits of drip irrigation

The data related to the comparative benefits of drip irrigation in relation to basin method are presented in Table 28.

The data revealed that drip irrigation considerably saved water in addition to increasing productivity of the crop. Among the drip treatments irrigation scheduled at 50 per cent of Ep (I_1) saved 138 per cent water while only 13 per cent of water was saved from I_4 (125% Ep). The highest increment in yield (27.5%) was observed from I_4 and followed by I_3 (100% Ep) with 25 per cent increment of yield. While I_1 showed 4.4 per cent reduction in yield as compared to the conventional basin method of irrigation. Therefore, the result indicated that, by adopting drip method of irrigation there is a chance of extending irrigation to an additional area of 13 to 75 per cent by making use of the saved water in addition to the yield advantage of 13.8 to 27.5 per cent.

Table 28. Benefit of drip irrigation in water saving, yield and extension of irrigated area as compared to basin method

Treatment	Quantity of water used (ha-mm)	Yield (t ha^{-1})	As compared to basin method		
			Water saving (%)	Yield advantage (%)	Increase in irrigable area (ha)
Drip method					
I_1	215.75	26.10	138	-4.40	1.39
I_2	295.33	31.07	75	13.80	0.75
I_3	374.90	32.78	37	20.03	0.37
I_4	454.50	34.82	13	27.50	0.13
Basin method					
I_5	514.97	27.31	-	-	-

Discussion

DISCUSSION

The results of the investigation on "Drip irrigation and mulching on oriental pickling melon (*Cucumis melo* var. *Conomon* (L.) makino)" are briefly discussed below.

5.1 Crop growth

The result of the study shows that application of mulch material and drip irrigation increased growth attributes such as vine number, vine length, leaf number, leaf area, leaf area index (LAI), shoot dry matter production (DM) and root growth and dry matter production significantly (Table 4-10 and Fig.3-10).

Mulching had significant influence on both vine numbers per plant and vine length. Among the mulches, polythene mulch was found significantly superior to paddy waste mulch, which in turn was significantly superior to unmulched control.

Leaf number, leaf area and leaf area index were also significantly influenced by the application of mulch. Polythene mulch was significantly superior at all growth stages, except at harvest (75 DAS) where paddy waste mulch appeared to be superior over others. During active growth stages, polythene mulch had a better influence and by harvest senescence and drying of leaves were as in unmulched control. This might be due to the fact that bare ground and polythene sheet help in early senescence and leaf drying by harvest due to heat reflection, whereas as organic mulches like paddy waste helps to prolong vegetative growth resulting in more number of leaves per vine, leaf area and leaf area index at harvest.

Mulches significantly influenced dry matter production. Among the mulches black polythene mulch was the best followed by paddy waste mulch. Higher number of vines per plant, more vine length, more number of leaves and bigger leaves produced under mulching contributed to the increased dry matter production under mulching.

Both polythene and paddy waste mulching increased lateral distribution and depth of roots equally as compared to the control with no-mulch. However the root dry weight was significantly superior in treatments with application of black polythene mulch and paddy waste mulching followed it. The vegetative growth above ground was highest in treatments with polythene mulch as a result of favourable effects created in soil moisture, aeration, weed free situation etc and in a similar manner root growth also was increased by mulching with polythene.

The higher vegetative growth under polythene mulch might be due to availability of better conditions favouring growth. There was 100 per cent weed suppression under polythene mulch (Fig.15). Soil temperature increased by about 2°C under polythene mulch as compared to others (Table15). The soil remained under good tilth below the polythene mulch as it was at the time of sowing. Soil moisture increased under polythene mulch by 9.2, 7 and 7.3 per cent in the vertical layers of 0-15, 15-30 and 30-60 cm, respectively. Similarly at the lateral distances of 0-15, 15-30, 30-45 and 45-60 cm, soil moisture increased by 8, 7.2, 7.7 and 8.5 per cent, respectively under the polythene mulch over unmulched control. The better physical conditions and weed free situation favoured an ideal condition for growth, thereby resulting in better growth. This growth was supported by the better absorption of NPK as evidenced by the highest contents of these elements in the leaf samples analysed at different stages. The results obtained in this study are in conformity with the results of Halsey (1985), Gutal *et al.*(1992), Chakraborty and Sadhu (1994), Ravinder *et al.* (1997), Shrivastava *et al.* (1994), Taber (1993) and Cebula (1995) in different vegetable crops.

Therefore better moisture regime, good physical condition, higher soil temperature and weed free situation favoured better growth under polythene mulching.

In the case of paddy waste mulching its effect on soil temperature, weed control, checking evaporation loss, increasing soil moisture content, uptake of nutrients etc. were not as effective as under polythene mulch, but it was significantly better compared to control and was lesser in performance only to the polythene mulching.

Growth characters varied significantly due to levels and methods of irrigation. Plant growth such as vine number, vine length, leaf number, leaf area, LAI, plant DM, root growth and dry weight were significantly influenced by irrigation scheduling (Tables 4 –10 and Fig.3 - 10).

Vegetative growth above ground increased almost linearly with increase in level of drip irrigation from 50 to 125 per cent Ep. Growth was significantly the highest at 125 per cent Ep (I_4) in the case of leaf number per vine, leaf area, LAI and dry matter production. Only in the case of number of vines per plant and mean length of vine, drip irrigation at 125 per cent Ep was at par with drip irrigation at 100 per cent Ep. Second best level of drip irrigation was that with 100 per cent Ep. It was significantly superior to drip levels at 75 and 50 per cent Ep and farmer's practice of basin irrigation in terms of length of vines, number of leaves per vine, leaf area, LAI and DM. Vine number, vine length, number of leaves per vine, leaf area, LAI and DM under drip at 75 per cent Ep was almost statistically at par with farmer's practice of basin irrigation @ 45 litres once

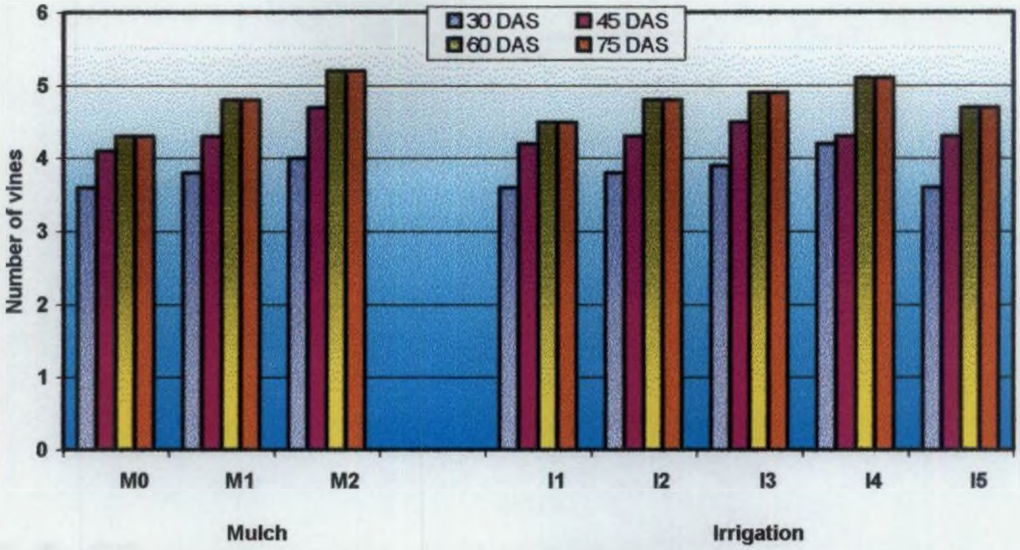


Fig 3. Effect of mulch and irrigation on number of vines per plant at different growth stages

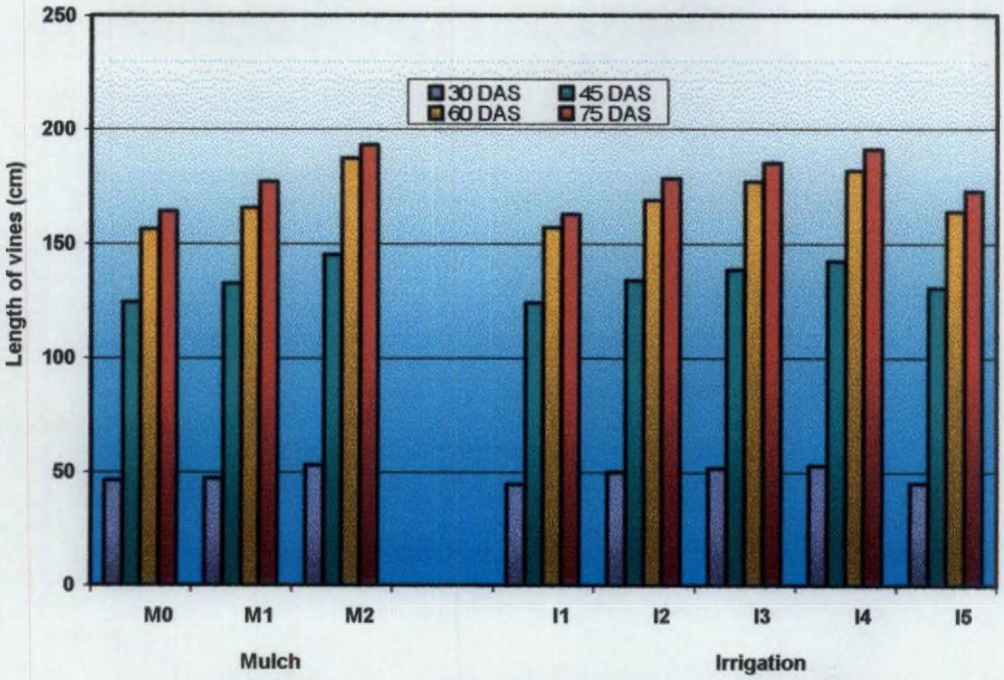


Fig 4. Effect of mulch and irrigation on length of vines at different growth stages

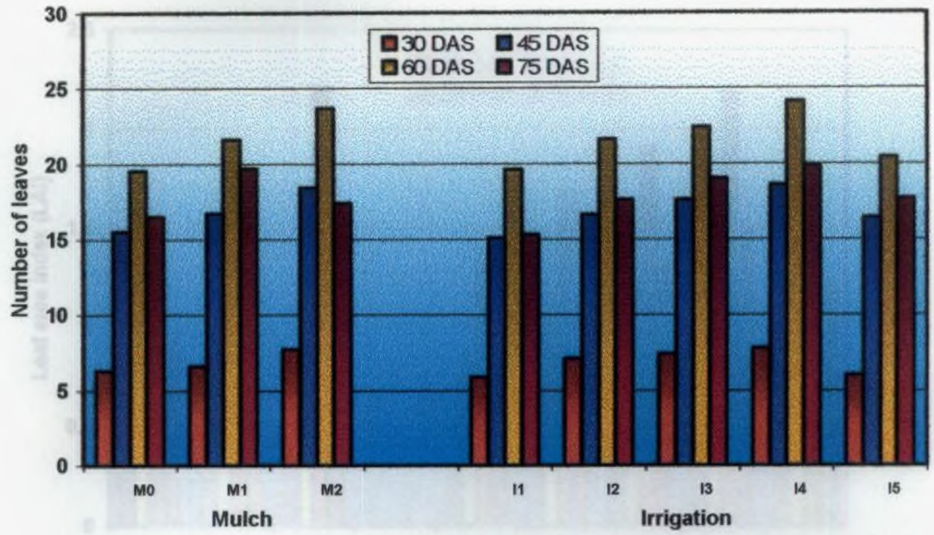


Fig 5. Number of leaves per vine as influenced by mulch and irrigation at different growth stages

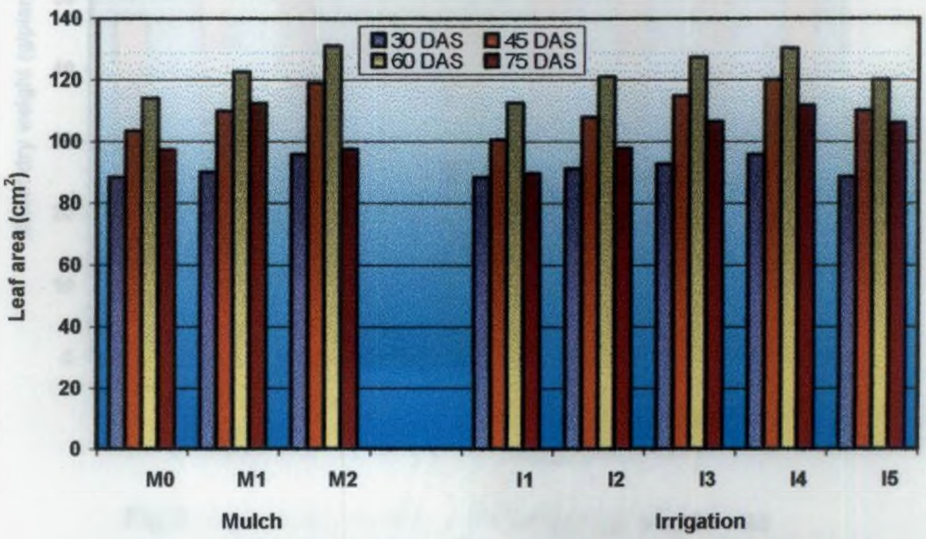


Fig 6. Leaf area as influenced by mulch and irrigation at different growth stages

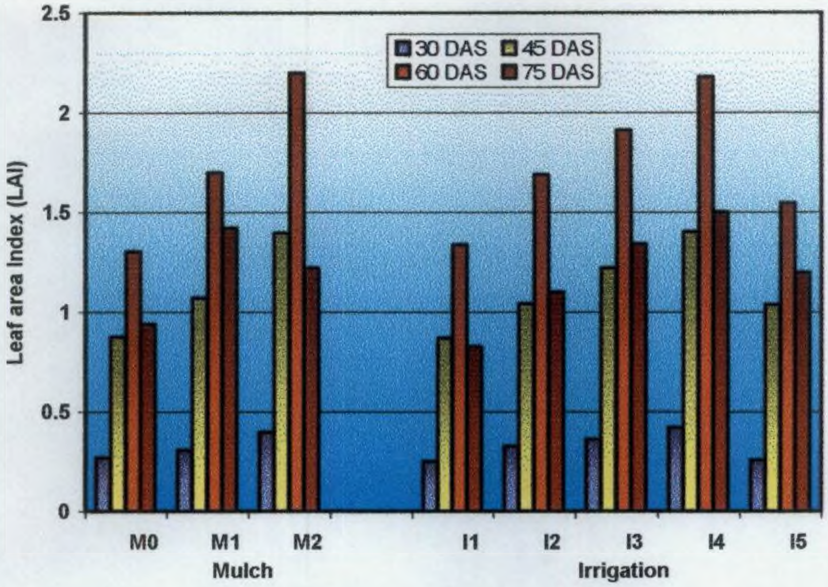


Fig 7. Leaf area index (LAI) as influenced by mulch and irrigation at different growth stages

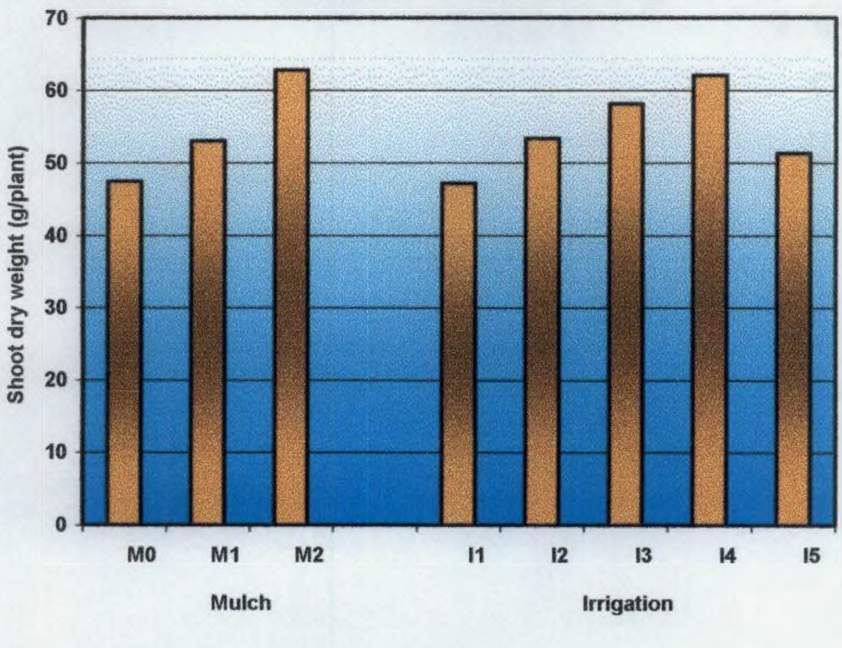


Fig 8. Shoot dry matter production (g plant^{-1}) as influenced by mulch and irrigation

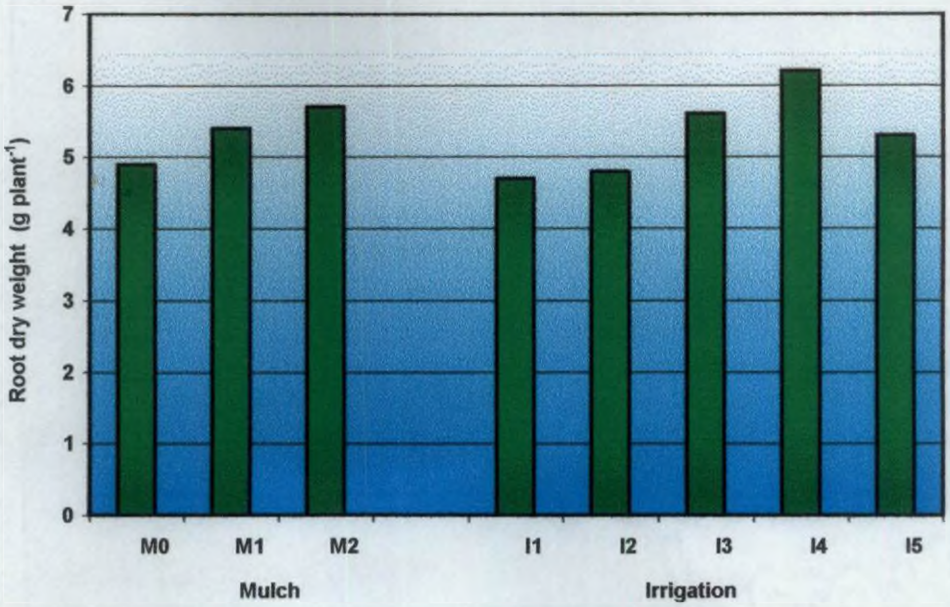


Fig 9. Root dry weight (g plant^{-1}) as influenced by mulch and irrigation

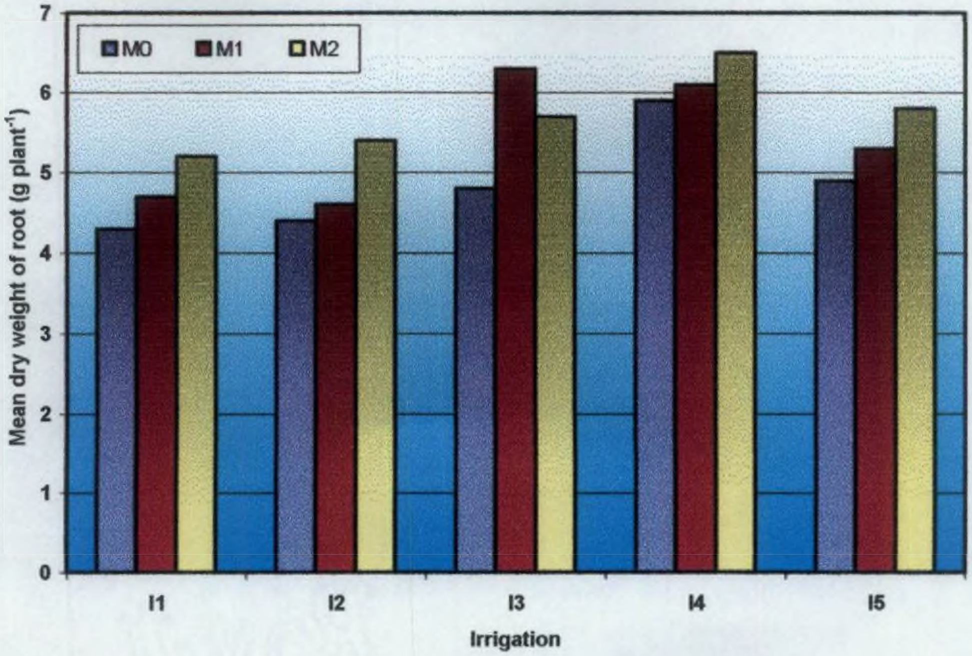


Fig 10. Root dry weight as influenced by combination of mulch and irrigation treatments

in three days. Drip irrigation at 50 per cent Ep was significantly inferior to all levels of irrigation. The results clearly indicate that, best growth of cucumber is obtained under drip irrigation at 125 per cent Ep and the performance diminishes directly proportional to the decrease in water level from 125 per cent Ep to 50 per cent Ep.

Highest root dry weight was observed with I_4 followed by I_3. Maximum root penetration vertically was observed with I_3 followed by I_4. However, maximum lateral spread of root was observed with I_5.

The variation in growth between the drip methods seemed to be due to different levels of irrigation. The lower levels failed to meet the physiological and atmospheric demand of moisture. Many studies have reported linear response in plant growth due to increase in water application rate (Beese *et al.*, 1982; Hegde 1987a and Singh *et al.*, 1990).

Plant growth is determined by the number and size of cells by which the plant parts are built and is influenced by light, moisture regimes and supply of nutrients. Both the number and length of vines, leaf number and size are considerably influenced by soil water supply, aeration and frequency. The maximum number of vines (5.1), length of vines (191 cm), leaf number per vine (19.8) and leaf area index (2.1) were observed at higher levels of drip irrigation schedule (125% of Ep). This ultimately increased plant DM and root dry weight.

The irrigation treatments receiving the larger quantity of water (I_4) accumulated more dry matter per plant (62.0 g) compared to the lowest level (I_1), which recorded (47.2 g). Similarly the root dry weight also was maximum (6.2 g) in I_4 and was lowest (4.7 g) in the lowest level (50% of Ep). As melons require higher soil moisture, its growth was found greatly enhanced by an adequate supply of soil moisture by drip irrigation at 125 per cent Ep.

The maximum reduction of growth was observed at the lowest level of drip irrigation scheduled at 50 per cent Ep. This is due to lesser number of vines (4.5), shorter length of vines (162.7 cm), lesser number of leaves per vine (15.3), lowest leaf area (89.6 cm^2) and lower LAI (1.33) and ultimately the plant DM and root dry weight were also found to be the lowest.

Water deficit is likely to affect two vital processes of growth viz., cell division and cell enlargement due to inactivation of photosynthesis and according to Begg and Turner (1976), cell enlargement is greatly affected and resulted in poor growth. This is in agreement with the findings of Flocker *et al.* (1965) in cantaloupes and Yamashitat *et al.* (1982) in cucumber.

Photosynthesis is the basic process for the build up of organic substances by the plant, whereby, sunlight provides the energy required for reducing CO_2 to sugar as the end product of the process. This sugar serves as the building material for all other organic components of the plant. The less optimally irrigated plants would produce less dry matter, as reduction in water content brings about a similar reduction in the photosynthetic efficiency (Arnon, 1975). A similar trend was noted by Thomas (1984) in bitter gourd and by Radha (1985) in pumpkin, ash gourd and melon. Several studies indicated higher growth and yield at higher level of irrigation. Locascico *et al.* (1981) indicated higher diameter of tomato plants irrigated at 1.0 Ep than irrigation given at 0.5 Ep. Beese *et al.* (1982) worked on sweet pepper under drip irrigation and found linear response to water application rates at 0.8, 1.0, 1.2 and 1.4 times the control with regard to leaf area and dry matter production. Harold *et al.* (1988) reported that higher water application rate resulted in higher soil water content and higher root density.

The basin method of irrigation with 45 litres in three days interval though receiving equal or more quantity of water as compared to I_4 (125% of Ep) was inferior to both I_3 and I_4 when growth is considered. The main reason for such a result might be, that in the drip irrigation with 100 or 125 per cent of Ep, the moisture replenishment was for longer period (3-5 hr), at a lower rate (2 l hr^{-1}), at frequent interval (daily) at the root zone of the plant. So soil moisture is always near field capacity. Where as in the common farmers practice of basin method of irrigation taken as control, water was given once in three days interval (45 l pit^{-1}), root zone of the crop is under saturation for about 24-48 hr. and at field capacity or below only for one day. Therefore the physical condition of the soil including aeration and moisture status are most favourable under drip irrigation at 100 and 125 per cent Ep than the conventional basin method. Though I_5 received more moisture in basin method than I_4 or I_3, due to favourable moisture and aeration under drip system, cucumber growth was highly favoured under I_3 and I_4 schedules and water was more efficiently utilised. More over weed growth also was higher in basin method.

As most terrestrial plants can not transfer oxygen from their aerial parts to their roots at a rate sufficient to provide for root respiration, the soil itself must be well aerated as it is in the drip case. These reasons may also have validity in describing the variation observed related to lateral and vertical distribution of roots in terms of length. In the basin method, the lateral spread of root was maximum (92.9 cm) and was followed by I_4 and I_3, whereas in terms of vertical distribution of root, maximum was at I_4 and I_3, while in the basin method it was at par with I_1 and I_2. The lower vertical and latter root distribution at I_1 and I_2 might be due to soil moisture stress caused by lower level of application. In the basin method, since the soil physical condition is not as convenient as drip method, plants may have resorted to extend their roots laterally near to soil surface for aeration rather than extending their roots down to the depth.

In all the growth parameters indicated above, the interaction effect was not significant, with exception to root dry weight.

5.2 Flower production and setting

Among the flowering characteristics observed, the ratio of female to male flowers was not significantly influenced by mulching or irrigation. However day's to first flowering, number of male and female flowers showed a significant difference among mulches as well as among irrigation schedules (Table 11 and Fig.11-12).

Application of mulch produced significantly higher number of male and female flowers, but it took about 30 days for first flowering. That is one day more as compared to the control without mulch. However significant difference was not observed between types of mulch in respect to days taken to first flowering and in number of female flowers till 60 DAS. But male flowers were significantly higher with polythene mulching as compared to paddy waste mulching. The ratio between female and male flowers did not vary significantly among the mulch treatments. There was significantly higher fruit setting percentage under polythene and paddy waste mulches.

Application of mulches had positive influence on number of flowers and on rate of fruit set and survival. 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 a better vegetative growth conducive for more flower production and a better fruit setting. Among the mulches polythene was better than paddy waste.

Among the irrigation treatments, I_1 (50%of Ep) took the minimum period to first flowering. It also had the significantly lowest male and female flower production (Table 11 and Fig.11).

Treatments, I_2, I_3, I_4 and I_5 took more days to first flowering and were at par. Similarly these treatments had significantly higher female flowers than I_1. Male flowers increased linearly from I_1 to I_4. Female to male flower ratio did not vary significantly among the irrigation treatments. In the case of fruit setting percentage, the lowest value of 44 per cent was recorded by I_5 followed by I_1. Irrigation treatments I_2, I_3 and I_4 recorded higher fruit setting ranging from 52.7 to 53.8 per cent.

Plants receiving daily the lowest level of drip irrigation first came to flowering phase. This resulted in earlier female flower production and when the moisture stress became more acute at the full-grown stage, it would reduce the rate and number of appearance of female primordia. Larson (1975) stated that a slight water stress could reduce the rate of appearance of female flower primordia. In the higher level of irrigation as moisture status was favourable, vegetative growth continued for more time than the case in I_1. Moreover as moisture status in soil was ideal for better vegetative and reproductive growth, flower production was promoted by higher level of irrigation. Molnar (1965) in melon and Thomas (1984) noted in bitter gourd that there was an increase of female flower production at higher level of irrigation.

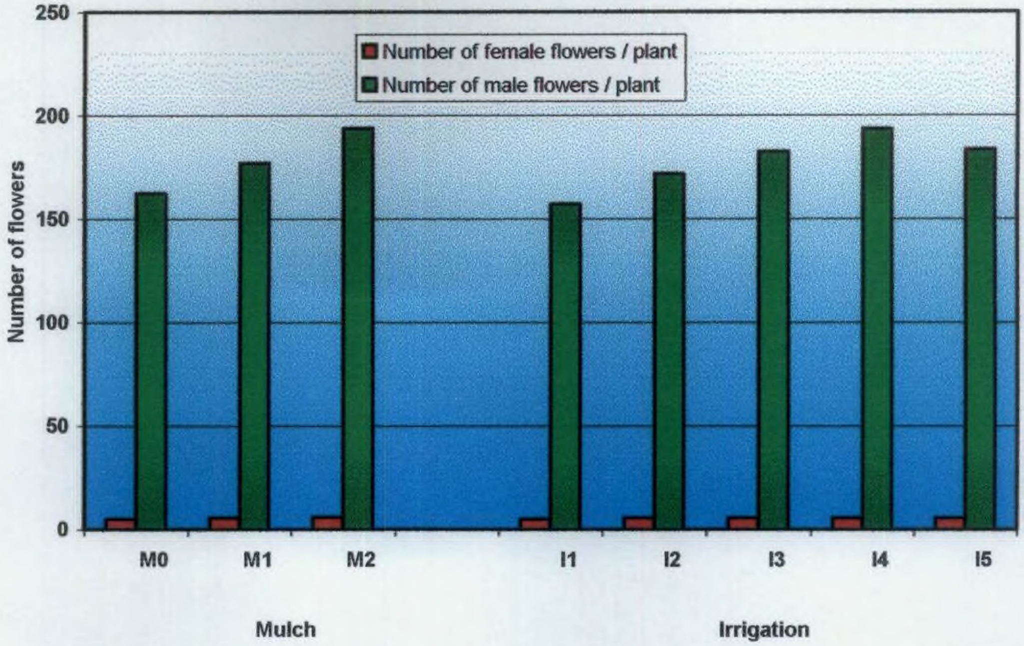


Fig 11. Number of female and male flowers as influenced by mulch and irrigation

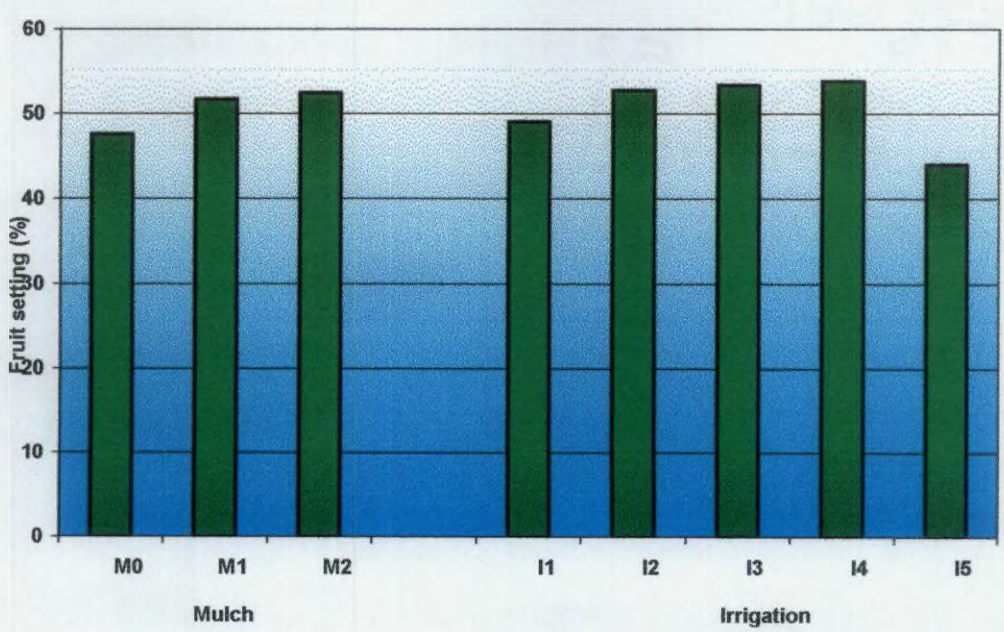


Fig 12. Fruit setting (%) as influenced by mulch and irrigation

Female flower survival rate in terms of fruit set was significantly influenced by level and method of irrigation (Table 11 and Fig.12). The lowest rate of fruit set (44%) was observed from the basin method of irrigation (I_5) as compared to drip irrigation method. The second lowest rate of fruit set (49%) was observed from the lower level of daily drip irrigation (I_1). Where as I_2, I_3 and I_4 were at par and resulted in 52.7 - 53.8 per cent of fruit set.

The result of fruit setting percentage (Table 11) clearly indicated that the rate of survival was lowest in the basin method. Though basin method received the highest quantity of irrigation water, it had the lowest fruit setting percentage. Generally after flood irrigation, the soil is becoming saturated with water upto 48 hours. During this period, practically there is no root activity in the absence of air in soil. A proper balance of water and air is available for about 24 hours as the net irrigation is scheduled on the third day. Therefore the physical conditions in the soil like wetness, aeration etc. has not favoured a higher fruit set in the basin method.

The poor fruit set recorded from the daily drip irrigated plants with 50 per cent Ep would be due to moisture stress, since irrigation was scheduled at the lowest level of the atmospheric demand (i e. at 50% Ep). When there is scarcity of water in the soil the first response is fruit drop. The favourable effect of frequent irrigation with sufficient water on yield attributes has been reported by Neil and Zunio (1972) and Singh and Singh (1978) in melons.

5.3 Yield attributes

Mulching with black polythene sheet significantly influenced mean weight of fruit, fruit length, fruit girth and volume (Table 12). While application of paddy waste was only at par with no-mulch control. In respect to yield attributes the influence of irrigation levels or methods was not significant.

Polythene mulching (M_2) recorded 13, 5.4, 4.3 and 13.4 per cent increase in average fruit weight, fruit length, fruit girth and fruit volume respectively over control with no-mulch. This might be because of complete weed control observed with polythene mulching, which reduced competition for nutrient, moisture, sunlight and space, thereby providing more resources for crop growth (Table12). In addition the growth attributes were higher with polythene mulching due to better soil physical conditions. These factors might have contributed to an increase of fruit size and fruit weight through efficient physiological activities.

Mulching produced significantly more number of fruits per plant than control. Though polythene mulch produced 3.1 fruits per plant as compared to 2.91 fruits by paddy waste, the differences between them was not significant. More growth obtained with mulches have helped in producing more number of fruits also (Table 13 and Fig.13).

Drip irrigation levels of 125, 100 and 75 per cent of Ep were significantly superior to the lowest level of drip irrigation at 50 per cent Ep and farmer's practice of basin irrigation. The results thus clearly indicates the favourable effect of mulching and drip irrigation with 75 to 125 per cent Ep on fruit number.

5.4 Fruit yield

Mulches and irrigation schedules significantly influenced fruit yield (Table 13 and Fig.14). Among the mulches fruit yield was maximum (36.5 t ha^{-1}) with polythene mulching. The treatment with paddy waste mulch recorded a yield of 29.24 t ha^{-1}, while the corresponding yield with control was 25.47 t ha^{-1}. The increase in yield has been 43.4 per cent with polythene mulching and 14.8 per cent with paddy waste mulching over the control with no mulching. The yield attributes like number of fruits per plant and mean weight of fruits were also significantly higher under polythene mulching than control.

More moisture retention, good soil physical condition, higher soil temperature, weed free situation and better nutrient uptake associated with polythene mulching promoted more number of flowers, higher fruit set, higher fruit number, bigger fruit size and higher fruit weight. In the case of the paddy waste mulching, its effect on soil temperature, weed control, checking evaporation loss, maintaining soil physical condition and nutrient uptake were not as effective as polythene mulch and hence its effect on growth and yield of oriental pickling melon was not as good as that of polythene mulch, but it was far better than the control without mulch. Overall the increase in yield was due to increases in number of fruits and total fruit weight per plant caused by the main effect of mulching. This result is in conformity with the findings of Maurodii (1979), Singh *et al.* (1990), Anabayan (1988),Veerabadran (1991), Clark and Moore (1991), Saravan ababu (1994). These workers have observed application of mulching materials increased yield in varying crops.

The total yield (t ha^{-1}) was maximum in daily drip irrigation with 125 per cent Ep (34.82 t ha^{-1}) and it was at par with 100 per cent Ep (32.78 t ha^{-1}) and superior to all other irrigation treatments. These were closely followed by daily drip irrigation with 75 per cent Ep. The lowest yield was obtained from daily drip irrigation with 50 per cent Ep (26.10 t ha^{-1}) and it was at par with the control basin method of irrigation (27.31 t ha^{-1}). The yields increment were 27.5, 20.0 and 13.8 per cent with I_4, I_3 and I_2 respectively over control. This clearly indicates the necessity for scheduling drip irrigation in cucumber at 100 to 125 per cent Ep. It is also worthwhile to note that even drip irrigation at 75 per cent Ep is significantly superior to I_5. Drip irrigation at 50 per cent Ep was at par with the farmer's practice of basin irrigation @ 45 litres once in three days. The result clearly indicates that basin flood irrigations with enough quantity of water once in three days as practised by farmers is equivalent only to a drip irrigation schedule with 50 per cent of Ep. This means that the greater quantity of water used in basin method of irrigation has not benefited the crop.

In the drip method there was an increasing trend in yield with increasing level of irrigation from 50 to 125 per cent Ep. Drip irrigation at 125 per cent of Ep replenishment greatly increased number of fruits per plant, fruit weight per plant and fruit yield (t ha^{-1}) by 28, 30 and 27.5 per cent respectively over control and it was at par with irrigation at 100 per cent Ep. The quantity of water received through daily drip irrigation at 125 per cent Ep was almost similar to that received through basin method of irrigation once in three days. However the moisture replenishment in drip irrigation with 100 or 125 per cent Ep was for longer continuous time in low amount (2 lhr^{-1}) and the soil moisture is always near field capacity unlike the basin method in which the crop root

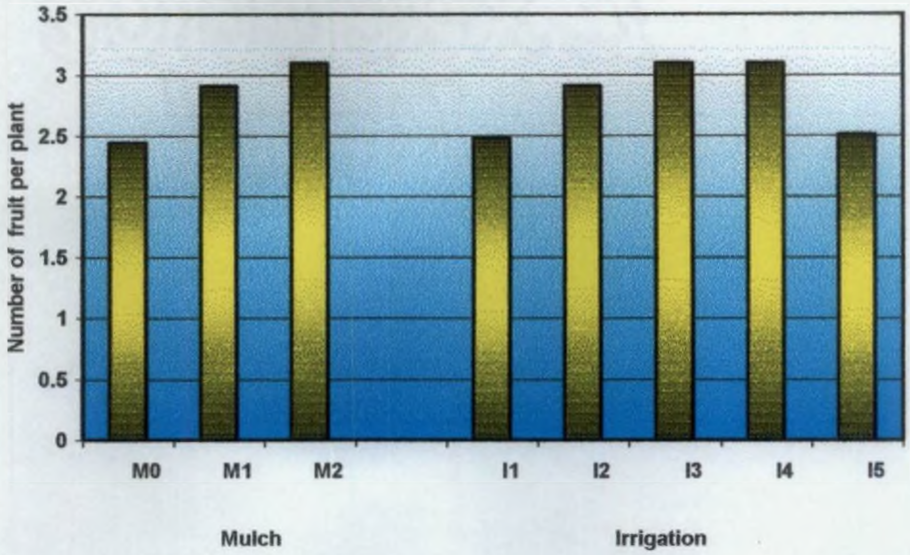


Fig 13. Number of fruits per plant as influenced by mulch and irrigation

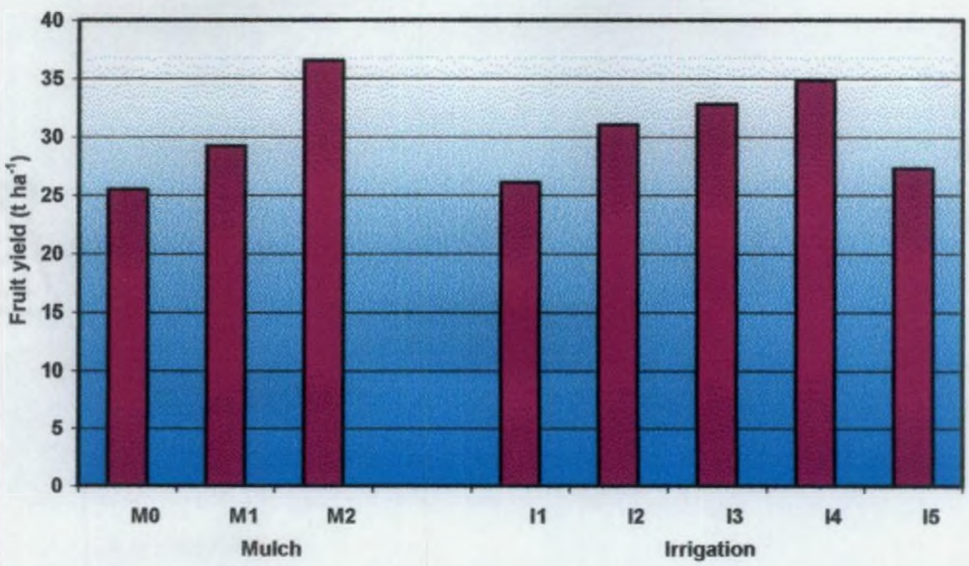


Fig 14. Fruit yield (t ha^{-1}) as influenced by mulch and irrigation

zone was under saturation for about two days and at field capacity or below field capacity only for one day.

Therefore, the physical conditions of the soil including aeration and moisture status were most favourable under drip irrigation at 100 and 125 per cent Ep than that with flooded basin irrigation. This may also have a conditioning effect on the soil physical and chemical characteristics. The decrease in yield with decrease in the quantity of water applied through irrigation indicates the insufficiency of water applied. Below 100 per cent replenishment of Ep by drip method growth characters and yield attributes were significantly affected. Inadequate supply of water would create internal moisture deficit in plants leading to slowing down of photosynthesis, cell formation, cell elongation, division etc. and ultimately affecting the crop performance in terms of growth and yield. The results of studies of Jassal *et al.* (1970), Desai and Patil (1984), Thomas (1984), Radha (1985), Prabhakar and Naik (1993), Yingjajaval and Markmoon (1993), Begg and Turner (1976) have indicated the deleterious effects of moisture stress in vegetable crops.

The result clearly indicates the necessity of drip system of irrigation than the conventional system of basin irrigation. It also indicates the necessity of scheduling drip irrigation at 100 or 125 per cent Ep in the case of oriental pickling melon for maximum yield.

Higher yields were obtained with drip irrigation at 75, 100 and 125 per cent Ep when combined with polythene mulching and at 100 and 125 per cent Ep in combination with paddy waste mulching compared to other combinations.

5.5 Drip irrigation and mulching on weed and soil temperature

5.5.1 Weed dry weight

The result of weed growth in terms of dry matter produced (Table 14 and Fig.15) indicates that, the weed growth was significantly reduced with application of mulch and with decrease in irrigation levels.

Weed growth was checked due to mulching. Polythene mulching completely checked weed growth, while paddy waste mulching reduced weed growth by 43 per cent as compared to the control with no mulch. Complete absence of sunlight under black polythene mulch completely checked growth of weeds under it. Since partial light was available under paddy waste mulch, weeds were able to grow though the intensity was much reduced. Solarization effect under black polythene mulch also would have contributed to weed control.

Under drip irrigation, though weed growth increased with the increase of water applied, the extent of weed growth, was less by 26-40 per cent as compared to the basin method of irrigation. This might be due to the limited wetted zone with the drip method as compared to the basin method.

The combination of irrigation treatments with polythene mulching showed 100 per cent checking of weed and the combination of drip irrigation levels (I_1, I_2, I_3 and I_4) along with paddy waste mulching, significantly reduced weed dry weight by 33-46 per cent. The maximum weed growth was observed in each level of irrigation with no mulch combination (Table 14 and Fig.16). This is mainly due to the effect of mulches and methods of irrigation.

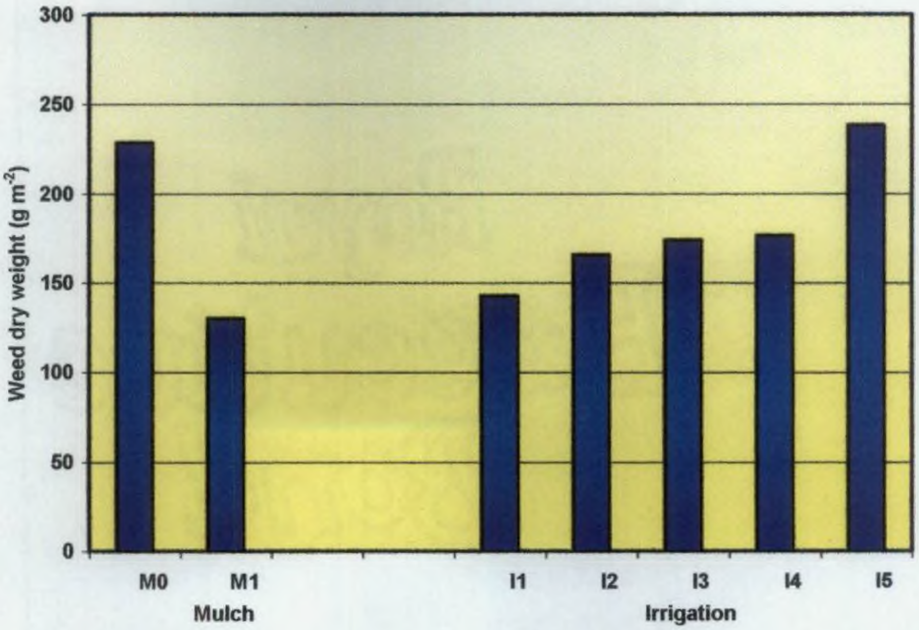


Fig 15. Weed dry weight (g m^{-2}) as influenced by Mulch and Irrigation at harvest

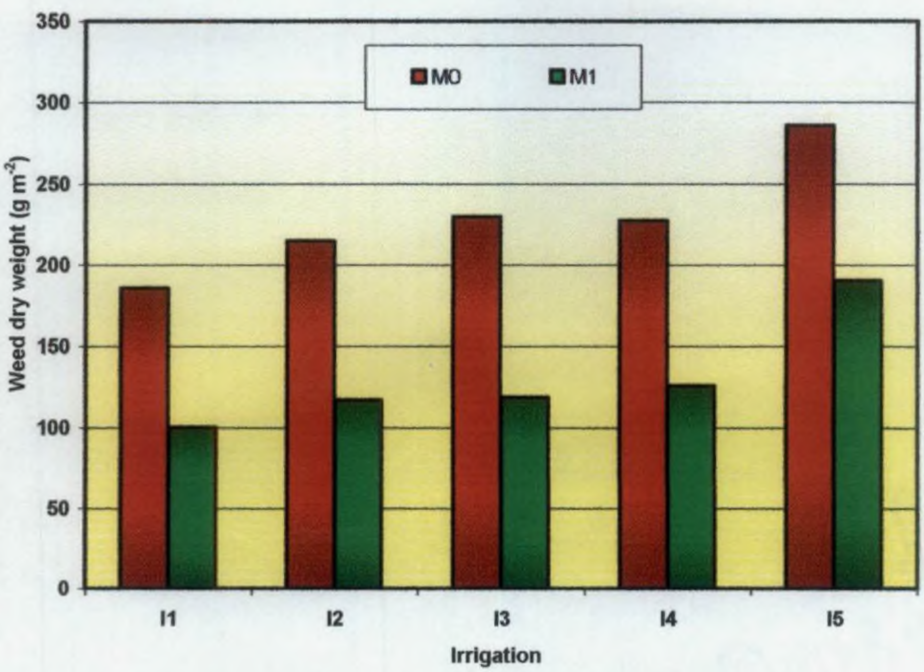


Fig 16. Weed dry weight as influenced by treatment combinations

5.5.2 Soil temperature

Black polythene mulching considerably increased soil temperature at 15 cm depth by 2°C over the control with no mulching. Paddy waste mulching showed only slight increase (0.3°C) as compared to the control as evidenced in Table 15. This might be due to the fact that, polythene mulch is able to absorb more heat as compared to the paddy waste and thereby could increase the soil temperature.

Soil temperature at 15 cm depth, also showed variation with irrigation treatments. It was the highest at lower level of irrigation I_1 (50% Ep) and gradually showed slight decrease with increase of level of irrigation. The reduction in soil temperature in the drip method was 0.5 to 0.9°C as irrigation level increased from 50 to 125 per cent Ep and the reduction of soil temperature was to the tune of 2° C under I_5 compared to I_1. These might be due to the fact that, in the higher level of irrigation water was supplied for longer period of time, therefore, the increase in time of application and soil moisture content might had a cooling effect.

5.6 Chemical composition of leaves

Application of mulch significantly increased the N, P and K content in leaves at 30, 60 and at the time of harvest as indicated in Table 16-18 and Fig.17-19.

At the growth stages of 30, 60 and at harvest, polythene mulching highly influenced the nutrient content of leaves and recorded maximum concentration of N (4.71, 4.97 and 2.89) per cent, P (0.527, 0.299 and 0.265) per cent and K (2.98, 1.98 and 1.83) per cent respectively. Whereas the influence of paddy waste mulching was significantly inferior in its effect on leaf N content and was at par with respect to P content at all the stages as compared to polythene mulching. Similarly, its effect on leaf K content was inferior at 30 and 60 DAS, but it was at par at the time of harvest. However, the influence of both mulch types was superior over the control with no mulching.

The superior effect of polythene mulching on N, P and K concentration in leaves might be due to the favourable influence on soil moisture regimes created in the root zone of the crop; 100 per cent weed suppression reduced competition for nutrients; the soil remained under good tilth below the polythene mulch as it was at the time of sowing; increased soil temperature by 2°C under polythene mulching, which might have improved activities of micro-organisms involved in decomposing and releasing of nutrients from the FYM and also may be due to hastening of plant physiological activities. With respect to paddy waste mulching, its effects on weed control, increasing soil temperature, maintaining soil moisture and aeration, were not as effective as polythene mulch and hence its effect on leaf nutrient concentration was not as good as polythene mulching, but it was significantly better over the control with no-mulch.

Higher percentages of N and P concentration in leaves was observed with higher level of daily drip irrigation at 125 per cent Ep (I_4) and it was mostly at par with I_3 (100% of Ep). This was followed by basin method of irrigation (I_5) and I_2 (75% of Ep). In the case of K concentration it was the highest at drip irrigation with 100 per cent Ep and was significantly superior to I_4 both at 30 and 75 DAS and the lowest concentration observed with drip irrigation at 50 per cent Ep (Table 16-18 and Fig.16-17).

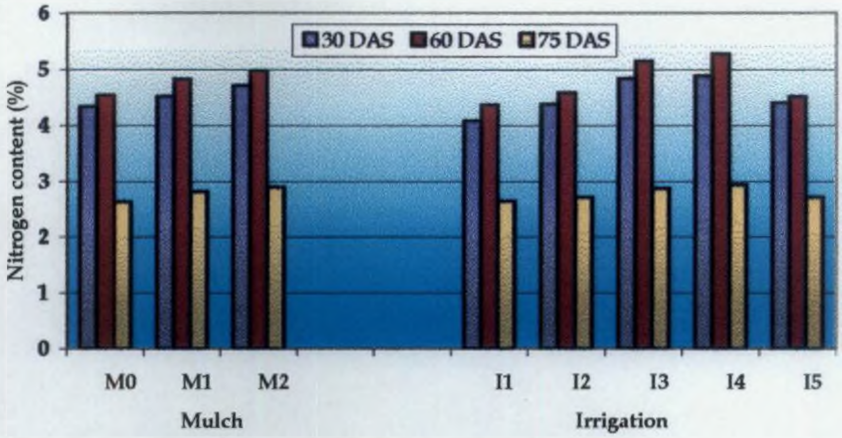


Fig 17. Leaf nitrogen content (%) as influenced by mulch and irrigation at different growth stages

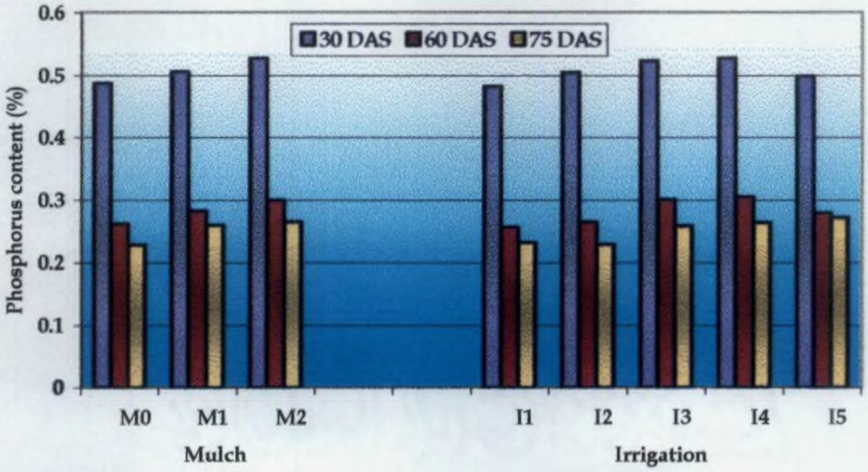


Fig 18. Leaf phosphorus content (%) as influenced by mulch and irrigation at different growth stages

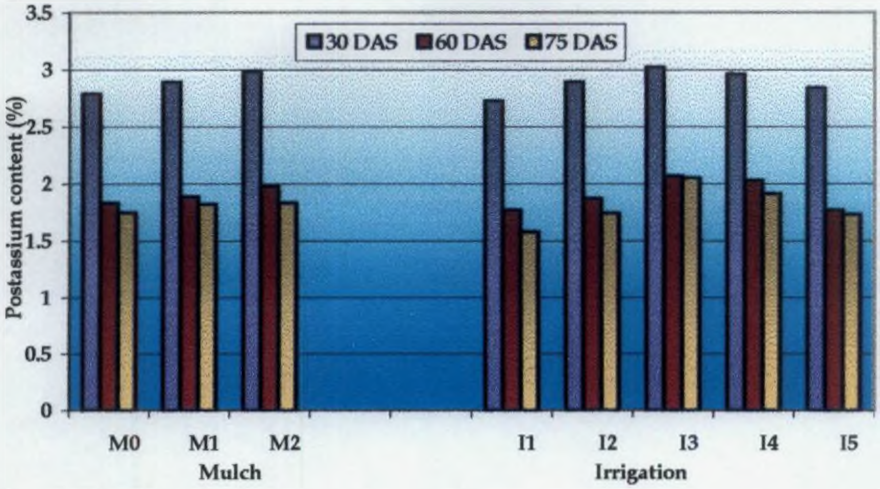


Fig 19. Leaf potassium content (%) as influenced by mulch and irrigation at different growth stages

The results thus indicate the significant beneficial influence of irrigation schedules on nutrient uptake and its concentration in leaves. The higher concentration of nutrients with increase of levels of irrigation under drip method might be attributed to better uptake of nutrients with the favourable soil moisture regimes available at the root zone of the crop. This result is in agreement with the findings of Brown *et al.* (1960) in cotton, Tamaki and Naka (1971) in broad bean, Sharma and Prasad (1973) in bhindi, Cocueci *et al.* (1976) in squash and Thomas (1984) in bittergourd. The decrease in nutrient concentration in leaves under basin method of irrigation with adequate quantity of water may be due to unfavourable conditions in the root zone, which inhibit maximum uptake of nutrients. This may be due to unfavourable balance between air and water in the root zone of the crop, which is mostly under saturated condition for about two-third of the time.

Tamaka *et al.* (1964) pointed out that nutrient absorption by the plant is controlled by nutrient availability in the soil, nutrient adsorption power of the soil and the rate of increase in dry matter. The concentration and availability of various elements in the soil for the plant growth depends upon the soil solution phase, which is controlled by the amount of soil water. So the availability of soil water is of great significance to plant needs in terms of metabolic requirement, plant's ability to absorb nutrients and the soils ability to supply them (Black, 1973). Irrigation at higher levels of 100 to 125 per cent of Ep under drip method created favourable conditions and promoted root growth and rendered nutrients more available. Irrigation at 50-75 per cent of Ep was insufficient to meet the water requirement of the crop and has not favoured nutrient uptake as at 100 or 125 per cent Ep.

The leaf N content showed slight increase in concentration upto 60 DAS and reduced radically at the time of harvesting. This might be because of split application of N at sowing, vine production and at flowering and this periodical application would have allowed more uptake of N at active growth stages. The reduction at harvest could be due to mobility of nutrients at later stage for production of substances to be translocated to fruits.

The leaf P and K concentrations were higher at the early growth stages of 30 DAS and thereafter gradually reduced nearly by 50 per cent at the time of harvest. This variation in concentration might be due to the fact that P is applied only basally and K upto 20-25 days after sowing. Generally the absorption is active upto the active growth stages and at the later stages nutrients would be transported to fruits.

The interaction between mulch and irrigation was significant at all stages in respect of N, and only at harvest in case of P and K (Table 16-18 and Fig.20-22). Higher leaf N concentration was observed at each level of irrigation when the crop was mulched with polythene followed by paddy waste. At the active growth and fruit development stages (30 and 60 DAS) the interaction between mulch and irrigation on leaf P and K content was not significant. It was significant only at the time of harvest. In the case of phosphorus, polythene mulched plots had higher leaf P content than paddy waste mulched plots in each irrigation schedules. Regarding potassium concentration, it was seen that there was no difference among the mulch treatments in leaf K content at I_1 and I_2. However at higher levels of irrigation (I_3, I_4 and I_5) both polythene and paddy waste mulches had significantly higher leaf K content.

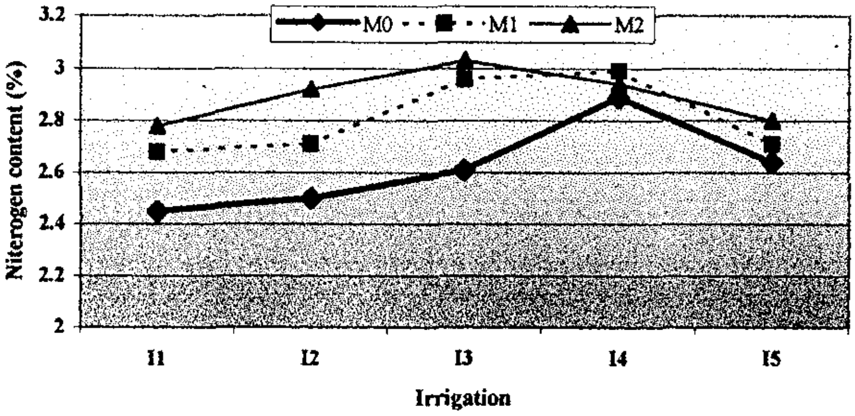


Fig 20. Leaf nitrogen content at harvest under treatments of mulch and irrigation

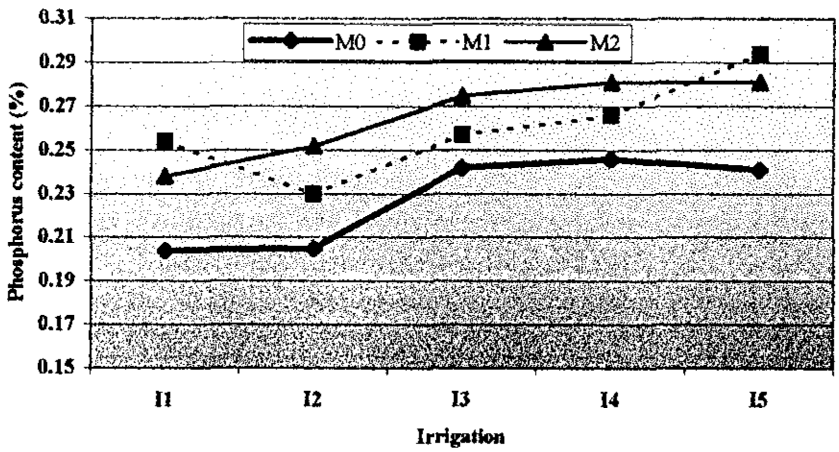


Fig 21. Leaf phosphorus content at harvest under treatments of mulch and irrigation

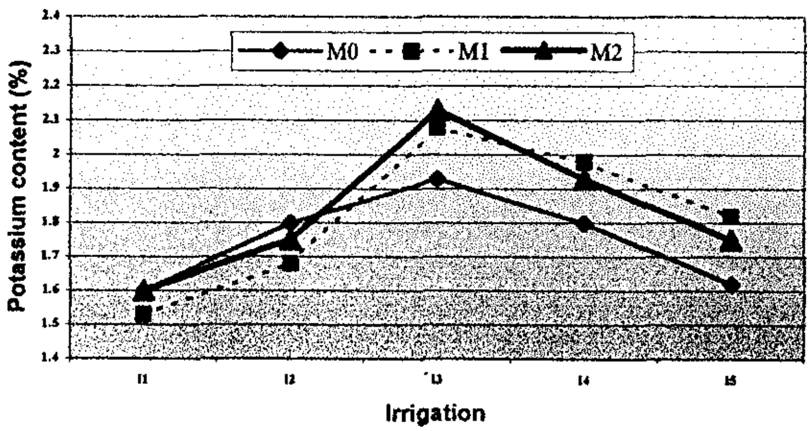


Fig 22. Leaf potassium content at harvest under treatments of mulch and irrigation

5.7 Soil moisture studies

5.7.1 Soil moisture distribution

Soil moisture content gradually reduced 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 every irrigation schedule. While polythene mulch increased soil moisture content by 7.2 to 8.5 per cent in the lateral distances from 0-60 cm over control, paddy waste mulch could increase it only by 2.25 to 4.6 per cent.

The moisture content under each irrigation schedule laterally increased with increase of quantity of irrigation water applied (Table 19-20).

In the lateral distribution of soil moisture, I_5 recorded the highest level from 0-60 cm. The increase in moisture percentage under I_2, I_3, I_4 and I_5 over I_1 at 0-15 radial distances were in the order of 10, 19.9, 30.4 and 39. The corresponding increase in the 15-30 cm radial distance was 8.7, 21.5, 35.5 and 43.9. At 30-45 radial distance the increase in moisture percentage under I_2, I_3, I_4 and I_5 over I_1 was in the order of 5.6, 19.2, 30.7 and 37.3. The corresponding increase of soil moisture in the 45-60 cm radial distance was in the order of 4.1, 19.6, 28.9 and 36.4, respectively.

The mean soil moisture content in 0-30 cm lateral distance remained constant and near field capacity in drip irrigation of 125, 100 and 75 per cent Ep when combined along with polythene or paddy waste mulching, whereas in the case of basin method mostly it was found at saturation. This occurred due to the difference in irrigation system and application rate. Many researchers in their critical review have opined in favour of drip mainly because of its capacity to maintain favourable soil water potentials constantly without causing severe aeration problems. Bucks *et al.* (1984) reported that in drip irrigation the soil water content in a position 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 near to field capacity in root zone but unsaturated hence gravitational force is minimum. Slow and frequent watering eliminated wide fluctuation of soil moisture under drip irrigation resulting in better growth and yield. The observations of the trials are in conformity with the findings of Sivanappan (1998).

In respect to vertical soil moisture distribution, paddy waste mulching retained 2.2 to 4.2 per cent more moisture over control. While polythene mulch retained 7 to 9.2 per cent more moisture than control. In the 0-15 depth, I_2, I_3, I_4 and I_5 retained 7.2, 19.1, 29.9 and 42 per cent more moisture than I_1. The corresponding figures in the 15-30 cm depth are 5.5, 18.7, 28.1 and 32 and in the 30-60 cm depth being 8.5, 22.4, 35.1 and 41.7 per cent respectively.

Moisture content increased with increases of level of irrigation depth-wise. The lower layer of 30-60 cm retained the highest moisture percentage than 15-30 and 0-15 cm layers in all irrigation treatments (Table 19). This might be because of 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 resulting in lower moisture content at 0-30 cm depth as compared to the lower most layer of 30-60 cm.

Higher rates of moisture removal was observed from the top layer of 0-15 cm in the higher levels of irrigation and in the lower level of irrigation (I_1) mostly from 0-30 cm. This might be due to surface evaporation and the lower moisture status may have forced the crop to remove from the lower layers as compared to treatments with higher levels of irrigation. According to Pelletier and Tan (1993) the soil moisture distribution assumed a shape of distinct cone of more than 50 per cent available water extending from the emitter down to a depth of more than 45 cm in drip system. Sunilkumar (1998) also observed similar result in okra.

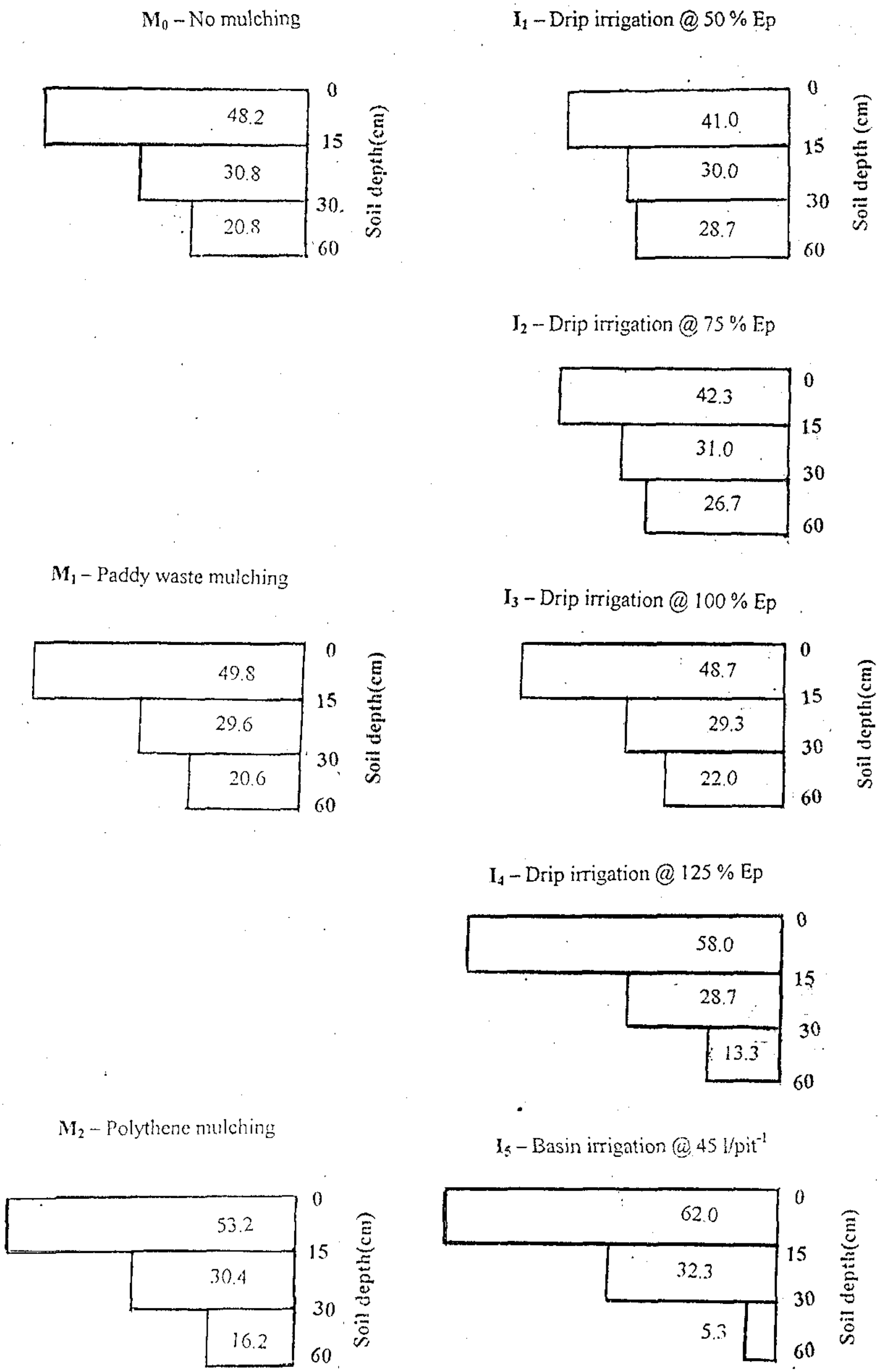
5.7.2 Soil moisture depletion

Maximum depletion of soil water was observed from the top 15 cm layer irrespective of the moisture conservation and irrigation treatments (Table 25 and Fig.23).

Among the mulch treatments M_0 depleted 48.2 per cent from the 0-15 cm layer and 30.8 per cent from 15-30 cm and 20.8 per cent from 30-60 cm layer. Paddy waste mulch (M_1) almost behaved like M_0. However under polythene mulch (M_2), 53.2 per cent moisture was depleted from 0-15 cm, 30.4 per cent from 15-30 cm and 16.2 per cent from 30-60 cm.

In the irrigation treatments, moisture depletion among the treatments varied considerably only in the 0-15 cm and 30-60 cm layers, while in the middle layer of 15-30 cm it was negligible. In the 0-15 cm layer with increase in per cent of Ep applied through drips, percentage depletion increased progressively from 41 per cent in I_1 to 58 per cent in I_4. However the maximum depletion of 62 per cent was observed under I_5. In the middle layer of 15-30 cm the variation among irrigation treatments was negligible and it varied from 28.6 to 32.33 per cent only. In the bottom layer of 30-60 cm contrary to the increasing trend of depletion with increase in moisture applied, depletion decreased proportionality to the increase of level of Ep applied from 50 to 125 per cent. It

Fig.23. Soil moisture depletion pattern (%) as influenced by mulch and irrigation



decreased from 28.67 per cent in I_1 to 13.33 per cent in I_4. In I_5 the depletion still went down to 5.33 per cent.

Over all, the maximum depletion was observed from the top 15 cm layer and decreased with soil depth. This might be due to the fact that, besides transpiration, losses from the soil surface were considerable and also the root of the crop were mostly confined to the top surface layers. Another fact observed was that, with decrease of irrigation levels from higher to drier regimes, the extraction of more water from the lower layer of 30-60 cm increased when compared to the wet regimes. This may be due to proliferation of root system to utilize soil moisture from the deeper layers under drier regimes. Similar observations were reported by Loomis and Crandall (1977) in cucumber, Thomas (1984), Siby (1993) in water melon, Radha (1985) in pumpkin, ash gourd and oriental pickling melon and Thampatti *et al.* (1993) in bittergourd and Veeraputhiran (1996) in oriental pickling melon.

5.7.3 Consumptive use and crop coefficient

The consumptive use as indicated in Table 21 and Fig.24 was less with polythene mulched crop (298.92 ha-mm) and paddy waste mulched crop (305.17 ha-mm) as compared to unmulched crop (308.22 ha-mm). The black polythene mulched treatments recorded lower consumptive use as it conserved more moisture in soil, while bare soil lost moisture quickly as evaporation loss and also there was higher evapo-traspiration due to highest weed growth (228.7 g m^{-2}). Reduced moisture loss under mulch has been pointed out by Chennabasavanna *et al.* (1992), Gutal *et al.* (1992) in tomato, Chakraboty and Sadhu (1994) in tomato, Yoon *et al.* (1995) in capsicum.

There was an increase in the total consumptive use as irrigation level increased (Table 21 and Fig.24). The highest consumptive use was 435.66 ha-mm with basin method of irrigation (I_5) and was followed by I_4, I_3, I_2 and I_1 in the drip method, with consumptive uses of 372.18, 304.33, 240.33 and 168.02 mm-ha respectively. The drip method of irrigation (I_1, I_2, I_3 and I_4) reduced the consumptive use by 61.4, 44.8, 30.1 and 14.6 per cent while yield at I_1 reduced by 4.4 per cent and increased by 13.8, 20.0 and 27.5 per cent at I_2, I_3 and I_4 respectively over the basin method of irrigation which received irrigation water @ 45 litres in three days interval (I_5).

The higher consumptive use with basin method with reference to the drip method could be due to many reasons. In drip method water was applied most efficiently, exactly to replace water used during the previous day in lower pressure ($2\ l\ h^{-1}$), so that there were minimum losses due to deep percolation, wetting of areas not under root zone or evaporation from land surfaces and from foliage. In addition due to partial wetting of soil, weed infestation was lesser in the drip method as compared to the basin irrigation (Table 14). Moreover frequent supply of moisture at higher volume may result in higher evapo-transpiration and other losses in basin method. Similar reports were opined by Sivanappan (1994), Desai and Patil (1984), Thomas (1984), Radha (1985) and Siby (1993).

Consumptive use was the lowest with polythene mulch in each irrigation levels and was the highest with no mulch. This is due to more moisture conservation under polythene mulching.

The mean daily crop coefficient was maximum (0.71) for plots with no mulch and was lowest (0.68) for treatments with polythene mulch. With respect to irrigation

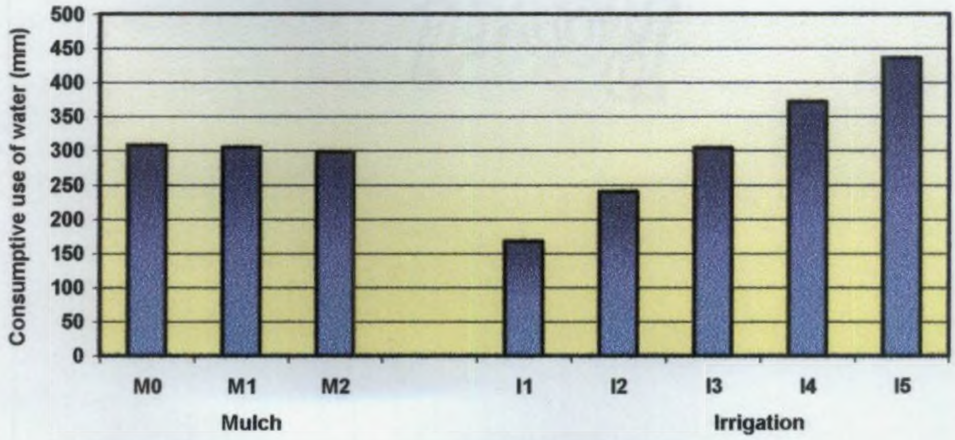


Fig 24. Consumptive use of water (mm) as influenced by mulch and level of irrigation

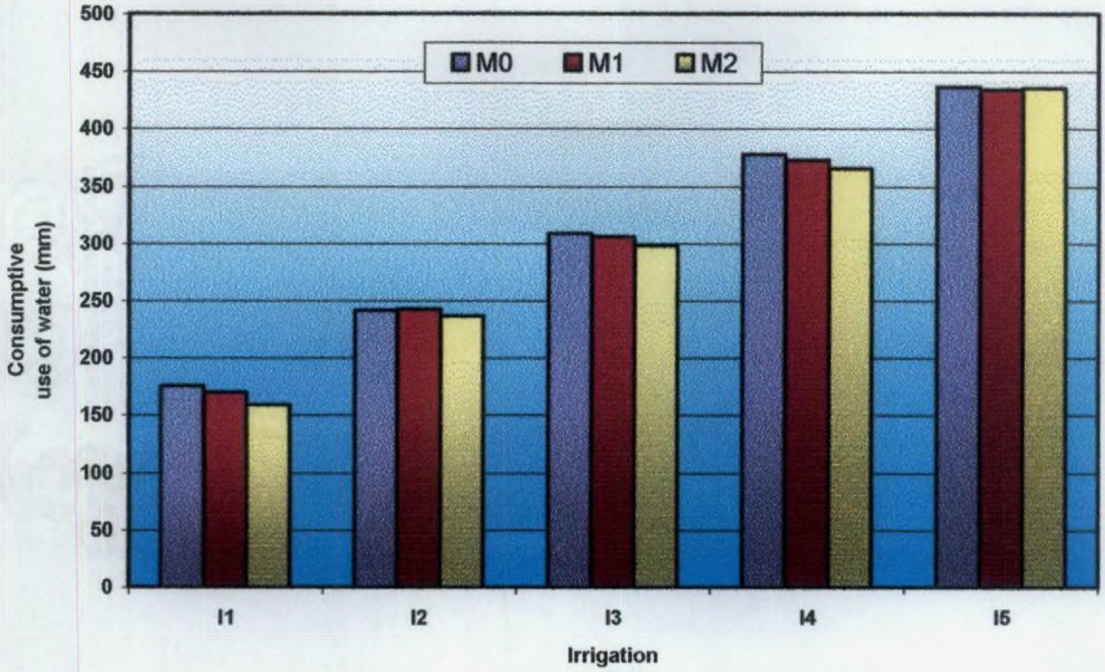


Fig 24a. Mean consumptive use of water (mm) as influenced by the combination of mulch and irrigation treatments

treatments, mean daily crop coefficient values varied widely between the treatments and were in the order of 0.38, 0.55, 0.70, 0.85 and 1.0 respectively corresponding to I_1, I_2, I_3, I_4 and I_5. There was an increase in crop coefficient with an increase in soil moisture. This is to be expected because as there was a similar increase in consumptive use with increase in soil wetness from I_1 to I_5.

The periodical mean consumptive use and crop coefficient values varied with crop age and growth in irrigation schedules (Table 23). The CU and Kc values increased gradually from early seedling stage (1-20 DAS) to fruit enlargement and development stage (41-60 DAS) and gradually reduced towards maturity and harvest (60-75 DAS).

The peak periodical mean CU at 41-60 DAS may be due to the full canopy development of the crop associated with fruit enlargement and development. Moreover the meteorological parameters like high wind speed, low humidity etc. (Table 23) also might have contributed to the higher CU at this stage. The periodical mean daily crop coefficient also followed the same trend. While the subsequent decline in crop coefficient values at 60-75 DAS would be probably due to the reduction in crop canopy and lower physiological activities as the crop was at its senescence stage. Similar trend was observed by Loomis and Crandall (1977) in cucumber, Radha (1985) in pumpkin, ashgourd and oriental pickling melon and Veeraputhiran (1996).

5.7.4 Water use efficiency

Mulched crops recorded higher field and crop water use efficiencies (Table 24 and Fig.25). The increase in the field WUE due to application of polythene mulch and paddy waste were 46.7 and 17.4 per cent respectively and the corresponding figures for

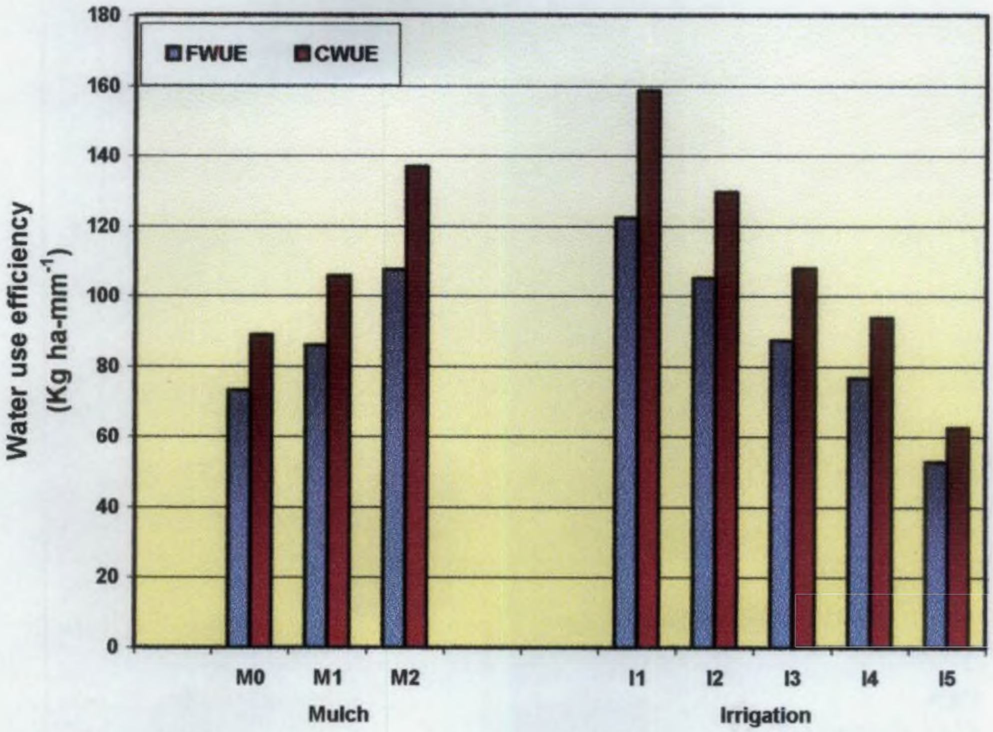


Fig 25. Effect of mulching and level of irrigation on water use efficiency

crop WUE were 54.1 and 19.1 respectively over control. Increase in WUE by application of black polythene mulch was observed by Gupta and Acharya (1994), by addition of paddy straw by Kalaghat *et al.* (1990) and by Veeraputhiran (1996) in cucumber. The higher field and crop WUE with application of mulch is due to lower consumptive use (CU) and higher fruit yield.

Water use efficiency decreased with increase in the level of irrigation (Table 25 and Fig.25). I_1 (50% of Ep) recorded the maximum field and crop WUE of 122.30 kg ha- mm^{-1} and 158.68 kg ha-mm^{-1} respectively and the lowest field and crop WUE of 53.02 and 62.69 kg ha-mm^{-1} respectively was recorded by the Control (I_5). An increase in yield or a reduction in water use, either way, brings out higher water use efficiency. Water above the optimum level may be lost in the form of excessive evaporation, transpiration or excess as deep percolation. Therefore, the excess water applied in I_5 could not find a favourable response in yield.

A higher CWUE was observed at I_1 (50% of Ep), I_2 (75% of Ep) and I_3 (100% of Ep) to the tune of 158.68, 129.55 and 107.94 kg ha-mm^{-1} respectively. This may be due to the fact that, the crop would have actively tried to maximise the use of water at the minimum critical level to optimum moisture level. Water above the optimum level may be lost in the form of excessive ET or else may not result equivalent increase in yield above the optimum limit of the potential of the crop in water use efficiency.

5.8 Economics of drip irrigation and mulching on oriental pickling melon

The economic analysis of irrigation and mulching on oriental pickling melon clearly indicated the superiority of application of mulch on gross return and net profit (Table 26 and Fig.26).

The highest net profit was recorded from the treatments with polythene mulch. The increase in the net profit due to the application of black polythene sheet and paddy waste mulch over the control with out mulch were Rs. 57,114 and Rs. 26,408 per ha respectively. Hence use of polythene or paddy waste mulch has increased net profit by 64 and 29.6 per cent respectively compared to the control. The increase in net income per rupee invested was also in the order of 2.01 and 1.9 respectively.

Over all, the total cost including the cost of polythene mulch was Rs. 72,822 per ha and this was 14.5 per cent higher than the cost incurred in treatments with paddy waste or with out mulch. The favourable influence of application of polythene mulch on control of weed, soil moisture and temperature resulted in a significant increase of yield. Because of this, it is found to be superior in net return over control and paddy waste mulch.

The net profit and net return per rupee invested increased with increase in levels of drip irrigation from 50 to 125 per cent Ep (Table 26 and Fig.26.). The highest net profit of Rs. 1,41,044 ha^{-1} was recorded from drip irrigation with 125 per cent Ep (I_4). This was fallowed by I_3 and I_2 with net profits of Rs. 1,30,640 and 1,22,235 ha^{-1} respectively. The lowest net profit of Rs. 95,574 ha^{-1} was obtained from the basin method and it was closely followed by drip irrigation at 50 per cent Ep (I_1). The net profit from irrigation schedules at 125, 100 and 75 per cent Ep was higher by 47.6, 36.7 and 27.9 per cent respectively over the basin method as control. The net return per rupee invested also followed the same trend and it was 2.10, 1.98 and 1.89 for irrigation schedules of I_4 (125% of Ep), I_3 (100% of Ep) and I_2 (75% of Ep) respectively.

The results of economic analysis of treatment-combinations also indicated that, the highest net return in each irrigation level was obtained from the combination with polythene mulch and this was followed from the combination with paddy waste mulch (Table 27 and Fig.27).

The increase in net profit at I_1, I_2, I_3, I_4 and I_5 with polythene mulch are in the order of Rs. 72,438; 58,278; 52,458; 76,579 and 25,818 and with paddy waste are in the order of Rs. 3,540; 24,680; 28,520; 23,540 and 16,760 ha^{-1} respectively over the corresponding control treatments with no-mulch.

Among the combinations I_4M_2, I_3M_2, I_2M_2, I_3M_1 and I_1M_2 recorded the highest net profits of Rs. 1,84,250; 1,56,106; 1, 52,861; 1,32,167 and 1,31,317 ha^{-1} respectively and these combinations were the best among the others.

Net returns per rupee invested were the highest in I_4 (125% Ep) schedule of irrigation combined with polythene mulch and these were followed by I_3 (100% Ep) in combination with paddy waste or polythene mulch and I_2 when combined with polythene mulch. The net return per rupee invested for irrigation treatments of I_1, I_2, I_3, I_4 and I_5 in combination with polythene mulch were 1.89, 2.14, 2.14, 2.46 and 1.42 respectively and when they combined with paddy waste were 1.69, 2.01, 2.16, 2.08 and 1.55 respectively, where as with out application of mulch were 0.98, 1.52, 1.63, 1.63 and 1.23 respectively.

Drip irrigation considerably saved water in addition to higher yield and net profit over the conventional method of basin irrigation (Table 28). The water saved from irrigation schedules of I_1, I_2, I_3, and I_4 were 138, 75, 37 and 13 per cent respectively. These can be used to irrigate additional areas of 1.39, 0.75, 0.37 and 0.13 ha respectively as compared to the control. But the yield advantages were in the order of -4.4, 13.8, 20.0

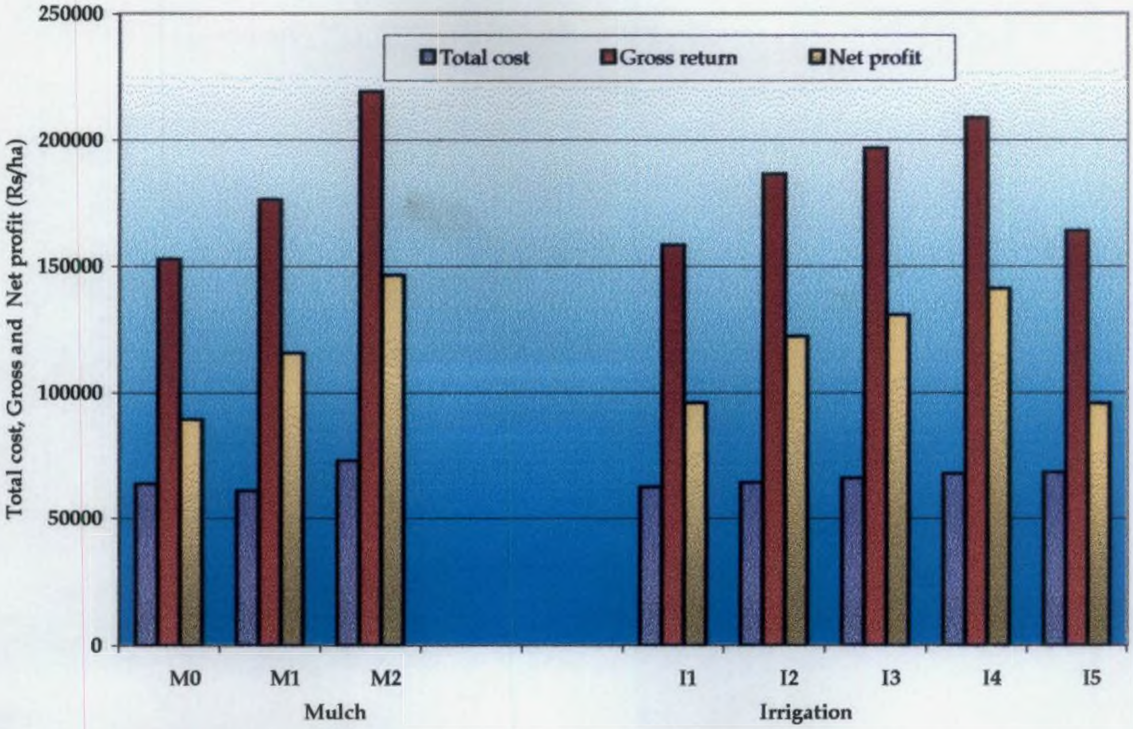


Fig 26. Economics of cucumber produciton per hectare as influence by mulch and irrigation

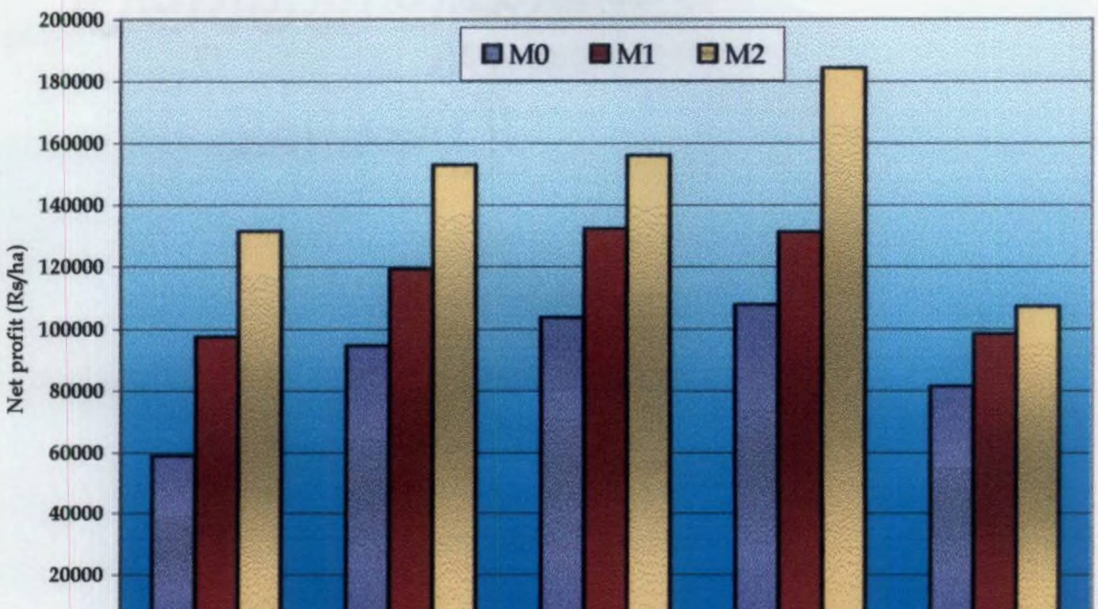


Fig 27. Net profit as influenced by combination of mulch and irrigation treatments

and 27.5 per cent for each irrigation schedules over the basin method of irrigation. Therefore the results clearly indicated that, adopting drip irrigation method not only increases yield and return alone, but also due to efficient application, helps in water saving and opens a chance of extending irrigation to additional areas. Results of several studies in vegetables also have indicated that, the water required to irrigate one hectare of vegetable by basin method can be used to irrigate more than 2.5 ha of same vegetable by drip method (Sivanappan and Palaniswamy, 1978; Sheela, 1988 and Sunilkumar 1998).

Summary

SUMMARY

A field experiment was conducted at Agricultural Research Station, Mannuthy, Thrissur during the summer season of December, 1999 to April 2000 to study the effect of "Drip irrigation and mulching on 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 lower in available phosphorous. The weather during the period was almost normal with an average daily pan evaporation (6 mm), relative humidity (46.6-78%) and wind speed (5.95 km h^{-1}). During the cropping season no rainfall was received.

The experiment was laid out in randomised block design (RBD) with three replications. The treatments consisted of combinations of five irrigation levels (drip irrigation at 50, 75, 100 and 125 per cent of Ep and farmers practice of basin method of irrigation @ 45 litres in three days interval as control) and three mulch treatments (control, paddy waste and low-density black polythene mulch). Hence totally it consisted of 15 treatment combinations. The oriental pickling melon variety Mudicode local was used for this study.

The important results obtained and the conclusions drown out from the investigation are summarized here under.

1) Polythene mulch significantly influenced number of vines per plant over paddy waste mulching and control. The effect of paddy waste mulch also was significantly superior to control. Among the irrigation treatments, daily drip irrigation at 125 per cent Ep recorded the highest number of vines per plant and was at par with 100 per cent Ep and both were the best in number of vines per plant over the other irrigation schedules. The control basin method was only at par with I_2 (75% of Ep).
2) Average vine length per plant was higher under mulched situation. Application of black polythene and paddy waste mulch increased vine length by 17.5 and 7.7 per cent respectively. Vine length of plants was higher when irrigation was scheduled at 125 and 100 per cent Ep with drip method and the increases in vine length were 10.5 and 7.2 per cent respectively over the basin method, which recorded maximum vine length of 162.7 cm.
3) Application of mulch significantly increased leaf number, leaf area and leaf area index (LAI) over the control. Polythene mulching was found to be superior at all growth stages, except at harvest where paddy waste mulch emerged significantly superior to polythene mulch. It was clearly observed that the life span of leaves under polythene mulching was shorter because of quick drying and fast senescence of old leaves probably due to excess heat reflected from the polythene. Overall, black polythene and paddy waste mulching exhibited favourable influence on leaf parameters and enhanced leaf number by 21.5 and 10.5, leaf area by 15.1 and 7.5 and leaf area index by 69 and 30.5 per cent respectively by 60 DAS.

4) Drip irrigation at 125 and 100 per cent of Ep exhibited significant and favourable influence on leaf number, leaf area and LAI over the drip irrigation schedules of 50 and 75 per cent Ep and over the farmers practice of basin method of irrigation. Irrigation at 125 and 100 per cent Ep increased leaf number by 18.1 and 9.8, leaf area by 9.2 and 5.9 and leaf area index by 40.9 and 23.7 per cent respectively over the control by 60 DAS.

5) Plant dry matter production was significantly improved when mulching was undertaken. The plants under polythene and paddy waste mulching produced 32.3 and 11.8 per cent more dry weight respectively, than that produced by the control without mulching. Significantly higher dry matter was produced by polythene mulching than paddy waste mulching. With respect to irrigation, the plant dry matter production increased with increase in level of irrigation in the drip method and reached the maximum with I_4 (125% of Ep), while the control receiving more or less, equal amount of water to I_4 was only at par with I_2 (75% of Ep). Overall, I_4 (125% of Ep) and I_3 (100% of Ep) produced 20.8 and 13.3 per cent more dry weight over the control of basin method. I_4 was significantly superior to all other schedules followed by I_3.

6) Both mulching materials (polythene and paddy waste) improved lateral distribution and depth of roots equally over the control with no mulching. However the root dry weight significantly increased by 16.3 over the control and by 5.6 over the paddy waste mulching, when black polythene mulch was applied. Among the irrigation schedules the maximum root depth was recorded from I_3 (100% of Ep) and I_4 (125% of Ep) and the maximum lateral distribution observed

with I_5, I_4 and I_3, all of which were at par. But the root dry weight was maximum (6.2 g plant^{-1}) in I_4 and was significantly superior to all others. In the basin method of irrigation root depth was lower (36.4 cm) and most roots found distributed laterally in the most upper layer of 0-25 cm.

7) Interaction of mulching and irrigation significantly influenced root dry weight. In general mulches favourably influenced root dry weight at I_1, I_2, I_3 and I_5. The plants under the combinations of I_4M_2, I_3M_1, I_4M_1, I_4M_0 and I_5M_2 produced the root dry weight of 6.5, 6.3, 6.1, 5.9 and 5.8 grams per plant respectively.

8) Days taken to first flowering was more in the mulched plots as compared to no mulch. With respect to irrigation scheduling, days taken to first flowering was significantly shorter in I_1. Significant variation in days taken to first flowering was not observed among the other irrigation schedules (I_2, I_3, I_4 and I_5).

9) The plants under mulching produced higher number of female and male flowers and registered higher fruit set. Significant variation was not observed between polythene and paddy waste mulching in number of female flowers and fruit set. Polythene mulching produced on an average 15.7, 19.3 and 10.1 per cent more number of female and male flowers and higher rate of fruit set respectively over the control with out mulch.

10) Lower number of female and male flowers was observed from the lower level of drip irrigation, I_1 (50% of Ep) and lower survival (fruit set) from I_5 (basin method of irrigation). No significant variation was observed among irrigation schedules of I_2, I_3, I_4 and I_5 in number of female flowers and among I_2, I_3 and I_4 in survival of fruiting buds. Overall I_4 and I_3 on an average resulted in 53.8

and 53.3 per cent fruit set while the basin method registered only 44 per cent of fruit set.

11) Flower ratio was not significantly influenced by both mulch and irrigation levels. Similarly, the interaction of mulch and irrigation has not imposed significant variation in respect to flower characters.

12) Application of polythene mulch significantly increased average single fruit weight, fruit girth, length and volume over paddy waste mulch and control. The extent of increase of the above characters under polythene mulching over control was in the order of 13, 5.4, 4.3 and 13.5 per cent. No significant variation was observed between paddy waste mulching and control. Irrigation treatments did not impose significant variation on the above fruit characters.

13) Mulching had significant influence on higher number of fruits and higher fruit yield per plant and per hectare. Significant variation was not observed between polythene and paddy waste mulching on number of fruits per plant, but in yield, polythene mulching was significantly superior to others. Overall, polythene mulching produced 3.10 fruits $plant^{-1}$ or 2.71 kg $plant^{-1}$ and 36.53 t ha^{-1} and showed an increase of 27, 41.9 and 43.4 per cent respectively over the control with no mulching.

14) Yield increased with increase in level of irrigation and plants under drip irrigation of 125 and 100 per cent of Ep produced higher number of fruits per plant and total yield. The lowest yield was registered from the lower level of drip irrigation I_1 (50% of Ep) and it was at par with the basin method of irrigation receiving water @ 45 litres in three days interval. The increase in

number of fruits per plant, yield (kg per plant) and total yield (t ha^{-1}) at irrigation scheduling of 125 per cent Ep was 23.5., 27.3 and 27.5 per cent and at 100 per cent Ep 23.5, 20 and 20 per cent respectively over the basin method of irrigation (I_5).

15) The black polythene mulched plants were totally free from weed growth, while application of paddy waste reduced weed growth only by 43 per cent as compared to the control without mulch. In case of irrigation treatments, weed growth increased with increase in level of irrigation. The maximum weed growth (158.9 g m^{-2}) was registered from the basin method and lowest weed growth (95.49 g m^{-2}) was observed from the lower level of drip method. The dry weight of weed registered from basin method was higher by 35, 36.9, 43.8 and 66.6 per cent as compared to that registered from drip methods of I_4, I_3, I_2 and I_1 respectively.

16) The combination of mulch and irrigation had imposed influence on weed growth. Higher weed growth was observed in irrigation levels with no mulch and it was the highest in I_5M_0, I_4M_0 and I_3M_0 with 285.9, 227.4 and 229.9 g m^{-2}) respectively.

17) Black polythene mulch increased soil temperature by about 2°C over unmulched control at 15 cm depth. Soil temperature at 15 cm depth showed a tendency to spring up with a decrease in the quantity of water applied in irrigation.

18) Nitrogen, phosphorus and potassium contents of leaves were significantly higher in plants with application of mulches. Polythene mulching recorded the highest NPK content at all growth stages and it was at par in phosphorus concentration

(at 30, 60 and 75 DAS) and in potassium content at 75 DAS with paddy waste mulching. In general the leaf NPK content declined as the age of the plant increased and reduced nearly by 50% at harvest.

19) The NPK content of leaves considerably increased with increase in the level of irrigation and reached the maximum at 100 and 125 per cent of Ep for N, at 100 and 125 per cent Ep for P, and at 100 per cent Ep for K at all the growth stages. The basin method of irrigation was only at par with I_2 (75% of Ep) in respect to N and K content of leaves.

20) The combined effect of irrigation and mulching had favourable influence on nitrogen content of leaves at 30, 60 and 75 DAS and phosphorus and potassium content only at 75 DAS.

21) Mulching due to its effect in reducing surface evaporation and increasing retention has helped in maintaining higher soil moisture content even at longer lateral distance. The mean soil moisture content in 0-30 cm lateral distance remained constant and near field capacity in drip irrigation at 125, 100 and 75 per cent Ep when combined with application of mulch, whereas in the case of basin method it was mostly under saturation. Soil moisture content gradually reduced as radial distance from the dripper increased.

22) Soil moisture increased depthwise also under mulching. Polythene mulching increased moisture content of soil by 7 to 9.2 per cent in the top 60 cm depth, while paddy waste increased it only to the extent of 2.2 to 4.2 per cent. Depthwise soil moisture increased with increase in the level of irrigation. Minimum moisture content was recorded by I_1 and maximum by I_5.

23) The soil moisture depletion was higher from the top 15 cm of the soil layer. There was relatively more depletion from the lower depth in the lower level of irrigation. A slight increase in moisture depletion was observed from the surface layer when mulching was applied.

24) Consumptive use was less with polythene mulched crop (298.92 ha-mm) and paddy waste mulched crop (305.17 ha-mm) as compared to unmulched crop (308.22 ha-mm). There was an increase in the total consumptive use as irrigation level increased. Consumptive use of water was the highest to the tune of 435.66 ha-mm in basin method of irrigation. The drip method of irrigation (I_1, I_2, I_3 and I_4) reduced consumptive use by 61.4, 44.8, 30.1 and 14.6 per cent respectively over the control.

25) The mean daily crop coefficient value was maximum (0.71) for plots with no mulch and it was lower (0.68) for treatments with application of polythene mulch. With respect to irrigation, mean daily crop coefficient increased with increase in level of irrigation and the values for I_3, I_4 and I_5 were 0.70, 0.85 and 1.0 respectively. The periodical mean consumptive use and crop coefficient value varied with crop age and reached the peak between 41 and 60 DAS and reduced towards maturity.

26) Application of polythene and paddy waste mulch substantially increased the field water use efficiency (FWUE) by 46.7 and 17.4 per cent and the crop water use efficiency (CWUE) by 54.1 and 19.1 per cent respectively over the control with no mulching. In case of irrigation both FWUE and CWUE decreased with increase of level of irrigation. On an average the FWUE and CWUE in the drip

method was higher by 84.6 and 95.8 per cent respectively as compared to the control basin method of irrigation.

27) Total cost of production of cucumber in a hectare including the cost of polythene was Rs. 72,821.56 and this was higher by 14.5 per cent than the cost required with paddy waste or without mulch, but the highest net profit was recorded from treatments with polythene mulching. The increase in the net profit due to the application of black polythene sheet and paddy waste mulch were Rs. 57,114.34 (64%) and Rs. 26,408.04 (29.6%) over the control respectively. Similarly there was substantial increase in net return per rupee invested under polythene and paddy waste mulching.

28) The net profit and net return per rupee invested increased with increase in the level of irrigation under drip system. The net profits recorded from daily drip irrigation at 125, 100 and 75 per cent Ep were Rs. 1,41,044.40, Rs. 1,30,639.97 and Rs. 1,22,235.47 ha^{-1} respectively. The lowest net profit (95, 573.67 ha^{-1}) was obtained from the basin method. The increase in net profit at 125, 100 and 75 per cent Ep were 47.6, 36.7 and 27.9 per cent respectively over the control and the net return per rupee invested were 2.1, 1.98 and 1.89 respectively.

29) There has been a substantial increase in net return due to the mean effect of mulches and drip irrigations. In each irrigation level total return increased by combination with polythene mulch and was followed by combination with paddy waste mulch. The highest net returns of Rs.1,84,250.0, Rs. 1,56,105.5 and Rs. 1,52,861.0 respectively were obtained from the combination of I_4 (125% of Ep), I_3 (100% of Ep) and I_2 (75% of EP) with polythene mulch.

30) Drip irrigation considerably saved water in addition to increasing crop yield and net profit. The results of economic analysis and yield indicated that, by adopting drip method of irrigation at 75, 100 and 125 per cent Ep, there is a chance of extending irrigated area by 75, 37 and 13 per cent, yield by 13.8, 20.03 and 27.5 per cent and net income by 27.9, 36.7 and 47.6 per cent respectively as compared to the basin method of irrigation.

From the study it may be concluded that, among the irrigation levels and methods, 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 per cent Ep. The above schedules when combined with black polythene mulch were superior to paddy waste mulch and unmulched control.

Polythene mulching was found to be superior in conserving soil moisture, in maintaining soil physical condition, in increasing soil temperature and controlling weed growth and as the result of this increased water use efficiency, growth, yield and net profit were achieved with polythene mulching.

There is a necessity for drip irrigation at 125 per cent Ep along with polythene mulching and this can be recommended for additional production of 18.6 tonnes of fruits per hectare with an increase of net profit by 126.4 per cent and water saving by 13 per cent over the control along with polythene mulching (I_5M_0).

Moreover in areas with water scarcity drip irrigation at 100 or 75 per cent Ep along with polythene mulching can be recommended depending on the availability of water. Drip irrigation at 100 or 75 per cent Ep with polythene mulch can bring about additional benefits like increased fruit yield by 55.4 and 52.0 percentage, net income by 91.8 and 87.8 percentage and water saving by 37 and 75 percentage over the control (I_5M_0).

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DRIP IRRIGATION AND MULCHING IN ORIENTAL PICKLING MELON

(*Cucumis melo* var. *Conomon* (L.) makino)

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ABSTRACT OF THE THESIS

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ABSTRACT

A field experiment on drip irrigation and mulching on oriental pickling melon (*Cucumis melo* var. *Conomon* [L.] makino) was conducted during the summer season of December 1999 to April 2000 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 schedules of irrigation (drip irrigation at 50, 75, 100 and 125 per cent Ep and basin method of irrigation once in three days @ 45 litres per pit as control) and three mulching treatments (control, paddy waste @ 3 kg pit^{-1} and low density black polythene mulch). In drip irrigation water was replenished daily according to Ep recorded in the previous day. The variety used in the study was Mudicode Local.

The study revealed that, polythene mulching increased the soil moisture content, consumptive use, water use efficiency and completely checked the growth of weeds. It also increased soil temperature by 2°C and improved NPK content of leaves as compared to the control and paddy waste mulching. Because of this and other benefits, polythene mulching resulted in higher number of vines, length of vines, leaf number and leaf area index by 20.9, 19.6, 21.5 and 69.2 per cent respectively over the control with no mulch. Similarly increased fruit number, fruit weight per plant and fruit yield (t ha^{-1}) by 27, 41.9 and 43.4 per cent respectively. The economic analysis also showed a considerable increases in net income and net profit per rupee invested by 64 and 43.6 per cent over the control. In the case of paddy waste mulching, its beneficial influences on soil temperature, weed growth, checking evaporation loss and in maintaining soil physical condition, were not as effective as polythene mulching. Hence its effect on growth, yield and net return on oriental pickling melon was not as good as that of polythene mulching, but it was better than with no mulching.

Oriental pickling melon responded more to drip irrigation. Drip irrigation maintained favourable soil potential constantly without causing severe aeration problems due to its special capacity in providing water to plants at effective root zone, daily, at lower rate (2 l h^{-1}) for longer period of time and at predetermined rate. Hence water content in the soil was always near field

capacity but unsaturated. Therefore slow and frequent watering eliminated wide fluctuation of soil moisture and resulted in better growth, yield, water use efficiency and higher net profit.

Growth, yield and net income increased with increase in level of daily drip irrigation from 50 to 125 per cent Ep and reached the maximum at I_4 (125% Ep). Drip irrigation at 125 and 100 per cent Ep increased vine number (8.5, 4.3), vine length (10.5, 7.2), leaf number (18.1, 9.8), leaf area index (40.9, 23.7), plant dry matter production (20.8, 13.3), fruit number per plant (23.5, 23.5) and fruit yield per plant (27.3, 20) per cent respectively.

The yields obtained from drip irrigation at 125, 100 and 75 per cent Ep were 34.82, 32.78 and 31.07 t ha^{-1} respectively as compared to the basin method with yield of 27.31 t ha^{-1} and the increases in yield over control were more by 27.5, 20 and 13.8 per cent respectively. These treatments also increased water saving by 13, 37 and 75 and net income by 47.6, 36.7 and 27.9 per cent respectively over the basin method of irrigation.

The combination of mulches and irrigation schedules increased fruit yield, water use efficiency, net profit and net return per rupee invested over the individual effects of irrigation. Best fruit yield; net profit and net return per rupee invested were obtained when the crop was drip irrigated at 125 per cent Ep combined with black polythene mulch. Second best treatment was the combination of drip irrigation at 100 per cent Ep with black polythene mulch. It is also worth to note that the combination of drip irrigation at 75 per cent Ep with polythene mulch or at 100 per cent Ep with paddy waste mulching emerged to be the third best treatments. The combination of I_4M_2, I_3M_2, I_2M_2 and I_3M_1 increased yield by 41.9, 25.6, 22.8 and 19.7 per cent, water saving by 13, 37, 75 and 37 per cent and net return by 71.9, 45.6, 42.6 and 34.7 per cent respectively over the control (I_5) with similar mulching material.

Appendices

APPENDIX I

a) ANOVA table for number of vines

Source	Degree of freedom	Mean Square			
		30 DAS	45 DAS	60 DAS	75 DAS
Replication	2	0.101	0.006	0.143	0.143
Mulch (M)	2	0.510**	1.768**	3.039**	3.039**
Irrigation (I)	4	0.571**	0.297**	0.476*	0.476*
M X I	8	0.043	0.028	0.053	0.053
Error	28	0.060	0.049	0.124	0.124

** 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	60 DAS	75 DAS
Replication	2	2.022	11.667	10.867	27.222
Mulch (M)	2	196.289**	1646.600**	3706.667**	3124.289**
Irrigation (I)	4	122.444**	449.556**	898.144**	1102.444**
M X I	8	2.928	4.739	24.444	23.594
Error	28	2.141	22.690	17.343	50.317

** 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	60 DAS	75 DAS
Replication	2	0.022	0.022	1.089	0.867
Mulch (M)	2	8.022**	32.622**	66.156**	39.267**
Irrigation (I)	4	6.589**	15.033**	28.200**	25.856**
M X I	8	0.106	0.983	0.683	0.739
Error	28	0.308	0.665	0.779	0.629

** 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	60 DAS	75 DAS
Replication	2	13.091	9.756	25.749	14.411
Mulch (M)	2	243.974**	924.739**	1112.066**	1112.656**
Irrigation (I)	4	90.624**	476.342**	460.915**	672.873**
M X I	8	5.490	7.456	10.735	9.958
Error	28	8.665	8.349	8.349	4.904

** 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	60 DAS	75 DAS
Replication	2	0.002	0.008	0.094	0.034
Mulch (M)	2	0.064**	1.037**	3.041**	0.877**
Irrigation (I)	4	0.047**	0.374**	0.955**	0.584**
M X I	8	0.002	0.010	0.049	0.015
Error	28	0.002	0.013	0.043	0.018

** Significant at 1 per cent level
* Significant at 5 per cent level

f) ANOVA table for shoot dry matter production and root characteristics

Source	Degree of freedom	Mean Square			
		Shoot dry matter	Root depth	Root lateral spread	Root dry weight
Replication	2	25.753	15.325	37.553	0.209
Mulch (M)	2	893.028**	128.562**	228.633**	2.834**
Irrigation (I)	4	301.408**	57.337**	98.609**	3.284**
M X I	8	9.517	1.533	14.453	0.303*
Error	28	15.502	10.397	24.220	0.108

** 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 flowering	Number of female flowers	Number of male flowers	Female male flower ratio	Fruit set (%)
Replication	2	0.689	0.011	93.267	0.019	7.665
Mulch (M)	2	2.156**	2.200**	3701.400**	0.085	98.195**
Irrigation (I)	4	2.967**	0.787**	1724.300**	0.100	151.571**
M X I	8	0.100	0.111	31.400	0.034	9.129
Error	28	0.322	0.170	115.052	0.078	4.808

** 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	2315.089	0.840	4.373	2252.289
Mulch (M)	2	70537.356**	12.868**	9.153**	74048.606**
Irrigation (I)	4	3761.411	2.353	1.558	3962.181
M X I	8	14254.411	3.469	1.942	14768.564
Error	28	8626.494	2.250	1.541	8919.704

** 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	0.032	0.041	0.032
Mulch (M)	2	1.592**	2.644**	1.592**
Irrigation (I)	4	0.776**	0.652**	0.776**
M X I	8	0.072	0.058	0.072
Error	28	0.079	0.038	0.079

** 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	485.885
Mulch (M)	1	72548.369**
Irrigation (I)	4	7518.539**
M X I	4	133.587
Error	18	670.655

** Significant at 1 per cent level
* Significant at 5 per cent level

k) ANOVA table for Nitrogen

Source	Degree of freedom	Mean Square		
		30 DAS	60 DAS	75 DAS
Replication	2	0.002	0.045	0.004
Mulch (M)	2	0.523**	0.732**	0.299**
Irrigation (I)	4	1.037**	1.486**	0.143**
M X I	8	0.008**	0.053**	0.024**
Error	28	0.002	0.024	0.004

** Significant at 1 per cent level
* Significant at 5 per cent level

l) ANOVA table for Phosphorous

Source	Degree of freedom	Mean Square		
		30 DAS	60 DAS	75 DAS
Replication	2	0.000	0.000	0.001
Mulch (M)	2	0.006**	0.005**	0.006**
Irrigation (I)	4	0.003**	0.004**	0.003**
M X I	8	0.000	0.000	0.000**
Error	28	0.000	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		
		30 DAS	60 DAS	75 DAS
Replication	2	0.004	0.002	0.003
Mulch (M)	2	0.126**	0.078**	0.030**
Irrigation (I)	4	0.116**	0.184**	0.295**
M X I	8	0.004	0.006	0.019**
Error	28	0.004	0.003	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 and length of vines and number of leaves per vine

Treat-ment	Number of vines				Length of vines				Number of leaf per vine			
	30 DAS	45 DAS	60 DAS	75 DAS	30 DAS	45 DAS	60 DAS	75 DAS	30 DAS	45 DAS	60 DAS	75 DAS
I_1M_0	3.500^{d}	3.917^{f}	4.167^{e}	4.167^{e}	42.33^{e}	112.7^{h}	140.0^{i}	144.7^{h}	5.333^{f}	13.00^{g}	17.33^{h}	14.00^{i}
I_1M_1	3.667^{cd}	4.167^{def}	4.500^{de}	4.500^{de}	43.67^{e}	124.0^{fg}	155.3^{gh}	162.0^{g}	5.667^{ef}	15.00^{f}	19.33^{g}	17.00^{fg}
I_1M_2	3.667^{cd}	4.500^{bcd}	4.750^{cde}	4.750^{cde}	48.00^{cd}	136.0^{de}	175.3^{de}	181.3^{cde}	6.667^{de}	17.33^{cd}	22.00^{cd}	15.00^{hi}
I_2M_0	3.500^{d}	3.917^{f}	4.250^{e}	4.250^{e}	47.00^{d}	123.7^{fg}	156.3^{gh}	166.0^{fg}	6.333^{def}	15.00^{f}	19.67^{g}	16.33^{gh}
I_2M_1	3.750^{cd}	4.333^{ef}	4.750^{cde}	4.750^{cde}	48.33^{cd}	133.3^{de}	164.7^{f}	177.7^{def}	7.000^{cd}	16.67^{cde}	21.33^{def}	19.00^{cd}
I_2M_2	4.000^{bc}	4.667^{bc}	5.250^{abc}	5.250^{abc}	54.33^{b}	145.0^{abc}	186.0^{c}	191.7^{bc}	8.000^{abc}	18.00^{bc}	23.67^{b}	17.33^{efg}
I_3M_0	3.750^{cd}	4.167^{def}	4.500^{de}	4.500^{de}	48.33^{cd}	130.0^{ef}	164.0^{f}	172.0^{efg}	6.667^{de}	16.33^{def}	20.00^{fg}	17.33^{efg}
I_3M_1	4.000^{bc}	4.417^{cde}	4.833^{cde}	4.833^{cde}	49.33^{cd}	136.3^{de}	172.3^{de}	184.7^{cde}	7.333^{cd}	17.33^{cd}	23.00^{bc}	21.00^{ab}
I_3M_2	4.000^{bc}	4.833^{ab}	5.500^{ab}	5.500^{ab}	57.00^{a}	149.7^{ab}	195.0^{b}	199.3^{ab}	8.333^{ab}	19.00^{ab}	24.33^{b}	18.67^{cde}
I_4M_0	3.833^{bcd}	4.250^{cdef}	4.500^{de}	4.500^{de}	50.00^{c}	134.3^{de}	168.3^{ef}	177.3^{def}	7.333^{bcd}	17.67^{bcd}	21.67^{cde}	18.00^{def}
I_4M_1	4.250^{ab}	4.500^{bcd}	5.000^{bcd}	5.000^{bcd}	50.67^{c}	139.7^{cd}	175.0^{de}	188.0^{bcd}	7.333^{bcd}	17.67^{bcd}	24.00^{b}	21.67^{a}
I_4M_2	4.500^{a}	5.167^{a}	5.667^{a}	5.667^{a}	57.33^{a}	153.3^{a}	202.0^{a}	208.3^{a}	8.667^{a}	20.33^{a}	26.67^{a}	19.67^{c}
I_5M_0	3.500^{d}	4.000^{ef}	4.250^{e}	4.250^{e}	44.00^{e}	121.0^{g}	153.3^{h}	161.3^{g}	5.667^{ef}	15.33^{ef}	19.00^{g}	17.00^{fg}
I_5M_1	3.500^{d}	4.250^{cdef}	4.750^{cde}	4.750^{cde}	43.33^{e}	129.33^{efg}	161.3^{fg}	172.7^{efg}	5.667^{ef}	16.67^{cde}	20.33^{efg}	19.67^{bc}
I_5M_2	3.750^{cd}	4.500^{bcd}	5.000^{bcd}	5.000^{bcd}	48.00^{cd}	141.7^{bcd}	177.0^{d}	184.7^{cde}	6.667^{de}	17.33^{cd}	22.00^{cd}	16.33^{gh}

b) Mean effect of mulch and irrigation levels on leaf area, leaf area index, plant dry matter production and on root depth and lateral distribution

Treatment	Leaf Area				Leaf Area Index				Should Dry Matter production	Maximum depth of root	Maximum lateral spread of root	Weed dry weight (g)
	30 DAS	45 DAS	60 DAS	75 DAS	30 DAS	45 DAS	60 DAS	75 DAS				
I_1M_0	85.67^{f}	93.87^{h}	102.3^{h}	85.17^{h}	0.213^{h}	0.643^{h}	0.983^{i}	0.660^{i}	38.67^{h}	33.27^{de}	81.20^{e}	185.8^{b}
I_1M_1	88.30^{def}	99.0^{g}	112.4^{g}	99.63^{f}	0.243^{fgh}	0.827^{fgh}	1.313^{ghi}	1.020^{fgh}	46.77^{fg}	36.30^{cde}	87.53^{bcde}	100.3^{c}
I_1M_2	91.00^{def}	108.9^{de}	122.9^{def}	83.93^{h}	0.297^{fgh}	1.133^{cde}	1.717^{def}	0.800^{hi}	56.03^{cd}	39.23^{abcd}	86.80^{cde}	-
I_2M_0	87.23^{ef}	100.5^{fg}	112.2^{g}	91.50^{g}	0.260^{fgh}	0.787^{gh}	1.270^{ghi}	0.847^{ghi}	47.93^{efg}	35.13^{de}	83.23^{de}	214.6^{b}
I_2M_1	90.53^{def}	107.1^{e}	122.0^{ef}	107.8^{c}	0.317^{def}	1.030^{def}	1.647^{efg}	1.297^{cde}	51.23^{defg}	37.43^{bcde}	85.33^{cde}	116.9^{c}
I_2M_2	96.17^{bc}	116.1^{bc}	129.1^{c}	94.63^{g}	0.410^{bc}	1.307^{c}	2.153^{bc}	1.150^{def}	60.90^{bc}	39.40^{abcd}	88.27^{abcde}	-
I_3M_0	89.20^{def}	104.8^{ef}	119.8^{f}	103.8^{de}	0.297^{efgh}	0.953^{efg}	1.443^{fgh}	1.000^{efg}	52.00^{def}	37.90^{bcde}	86.20^{cde}	229.9^{b}
I_3M_1	91.10^{cdef}	114.4^{c}	128.0^{cd}	115.6^{b}	0.357^{cde}	1.167^{cde}	1.903^{cde}	1.563^{ab}	56.60^{cd}	42.13^{abc}	91.50^{abcd}	118.5^{c}
I_3M_2	98.13^{ab}	125.2^{a}	134.0^{b}	100.2^{ef}	0.440^{b}	1.537^{b}	2.393^{b}	1.373^{bcd}	65.63^{b}	44.43^{a}	93.30^{abc}	-
I_4M_0	92.60^{cde}	113.6^{cd}	122.6^{ef}	105.2^{cd}	0.347^{cde}	1.137^{cde}	1.593^{efgh}	1.137^{def}	54.30^{cde}	38.00^{bcde}	86.73^{cde}	227.4^{b}
I_4M_1	93.33^{bcd}	119.8^{b}	128.7^{c}	120.7^{a}	0.387^{bcd}	1.303^{c}	2.073^{bcd}	1.750^{a}	58.73^{bcd}	41.83^{abc}	90.83^{abcd}	125.6^{c}
I_4M_2	101.90^{a}	126.2^{a}	142.3^{a}	109.0^{c}	0.527^{a}	1.767^{a}	2.870^{a}	1.617^{ab}	72.87^{a}	42.90^{ab}	92.23^{abcd}	-
I_5M_0	86.87^{f}	103.7^{efg}	112.5^{g}	100.7^{ef}	0.230^{gh}	0.850^{fgh}	1.213^{hi}	0.967^{fgh}	44.20^{gh}	32.30^{e}	84.33^{cde}	285.9^{a}
I_5M_1	86.20^{f}	108.7^{de}	120.6^{f}	117.7^{ab}	0.230^{gh}	1.027^{def}	1.560^{efgh}	1.467^{bc}	51.77^{def}	37.40^{bcde}	94.87^{ab}	190.6^{b}
I_5M_2	92.57^{cde}	118.1^{bc}	127.1^{cde}	99.53^{f}	0.310^{defg}	1.230^{cd}	1.863^{cde}	1.153^{def}	57.93^{cd}	39.53^{abcd}	97.53^{a}	-

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

Treatment	Days for first flowering	Number of female flowers plant^{-1}	Number of male flowers plant^{-1}	Female-male flower ratio (x 10^{-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	28.33^{d}	4.00^{d}	140^{g}	3.45^{a}	45.54^{c}	686.0^{d}	25.43^{c}	26.10^{c}	699.5^{d}	2.2^{e}	1.49^{h}	19.86^{g}
I_1M_1	28.67^{cd}	5.00^{cd}	155^{fg}	3.23^{a}	49.12^{cde}	792.7^{abcd}	27.77^{abc}	27.37^{bc}	808.5^{abcd}	2.5^{cde}	1.94^{fg}	24.97^{f}
I_1M_2	29.00^{bcd}	5.33^{abcd}	177^{cde}	3.01^{a}	52.23^{abc}	903.0^{ab}	29.37^{ab}	28.37^{abc}	920.7^{ab}	2.8^{bcd}	2.51^{cd}	33.47^{bc}
I_2M_0	29.33^{abcd}	5.00^{bcd}	156^{fg}	3.21^{a}	47.97^{de}	818.3^{abcd}	28.27^{abc}	27.70^{abc}	833.7^{abcd}	2.4^{de}	1.96^{fg}	26.11^{f}
I_2M_1	30.00^{ab}	5.67^{abc}	171^{def}	3.31^{a}	55.19^{a}	716.3^{cd}	26.50^{bc}	26.80^{bc}	729.2^{cd}	3.1^{ab}	2.23^{def}	29.72^{cdef}
I_2M_2	30.33^{a}	5.77^{abc}	188^{bcd}	3.08^{a}	55.05^{a}	889.3^{abc}	28.93^{ab}	28.60^{ab}	907.7^{abc}	3.2^{ab}	2.80^{bc}	37.36^{b}
I_3M_0	29.67^{abc}	5.33^{abcd}	167^{ef}	3.20^{a}	50.80^{bcd}	773.0^{bcd}	27.77^{abc}	27.57^{abc}	786.7^{bcd}	2.7^{bcd}	2.10^{efg}	27.92^{def}
I_3M_1	30.00^{ab}	5.80^{ab}	182^{bcde}	3.19^{a}	55.29^{a}	757.3^{bcd}	27.67^{abc}	27.37^{bc}	771.8^{bcd}	3.2^{ab}	2.42^{de}	32.22^{cd}
I_3M_2	30.33^{a}	6.07^{a}	199^{ab}	3.12^{a}	53.68^{ab}	884.3^{abc}	29.27^{ab}	28.63^{ab}	901.7^{abc}	3.3^{ab}	2.86^{b}	38.20^{b}
I_4M_0	29.67^{abc}	5.43^{abcd}	182^{bcde}	2.99^{a}	53.24^{ab}	754.3^{bcd}	27.87^{abc}	27.33^{bc}	769.5^{bcd}	2.9^{abcd}	2.17^{defg}	28.89^{cdef}
I_4M_1	30.00^{ab}	5.63^{abc}	190^{abcd}	2.97^{a}	52.54^{abc}	827.0^{abcd}	28.60^{ab}	27.93^{abc}	843.5^{abcd}	3.0^{abc}	2.43^{de}	32.36^{cd}
I_4M_2	30.33^{a}	6.13^{a}	209^{a}	2.95^{a}	55.55^{a}	955.0^{a}	30.27^{a}	29.93^{a}	973.8^{a}	3.4^{a}	3.24^{a}	43.19^{a}
I_5M_0	29.33^{abcd}	5.00^{cd}	167^{ef}	3.00^{a}	48.61^{f}	911.3^{ab}	29.10^{ab}	28.60^{ab}	928.3^{ab}	2.0^{e}	1.84^{g}	2458^{f}
I_5M_1	30.33^{a}	6.10^{a}	188^{bcd}	3.20^{a}	46.14^{e}	732.7^{bcd}	27.00^{bc}	26.40^{bc}	746.7^{bcd}	2.8^{bcd}	2.02^{fg}	26.92^{ef}
I_5M_2	30.00^{ab}	6.00^{a}	196^{abc}	3.07^{a}	45.38^{e}	838.0^{abcd}	28.13^{abc}	27.70^{abc}	854.7^{abcd}	2.7^{bcd}	2.28^{def}	30.42^{cde}

d) Mean effect of mulch and irrigation levels on leaf nutrient content (P and K)

Treatment	Phosphorous		Potassium	
	30 DAS	60 DAS	30 DAS	60 DAS
I_1M_0	0.4623^{b}	0.2353^{d}	2.650^{g}	1.733^{hi}
I_1M_1	0.4843^{ab}	0.2563^{cd}	2.750^{fg}	1.767^{gh}
I_1M_2	0.4987^{ab}	0.2770^{abcd}	2.783^{ef}	1.800^{gh}
I_2M_0	0.4823^{ab}	0.2490^{cd}	2.750^{fg}	1.833^{fgh}
I_2M_1	0.5023^{ab}	0.2683^{abcd}	2.917^{cd}	1.867^{efg}
I_2M_2	0.5290^{a}	0.2780^{abcd}	3.000^{bc}	1.917^{def}
I_3M_0	0.5013^{ab}	0.2797^{abcd}	2.917^{cd}	1.950^{de}
I_3M_1	0.5217^{ab}	0.3027^{abc}	3.000^{bc}	2.050^{bc}
I_3M_2	0.5450^{a}	0.3210^{ab}	3.150^{a}	2.200^{a}
I_4M_0	0.5060^{ab}	0.2877^{abcd}	2.867^{def}	2.000^{cd}
I_4M_1	0.5297^{a}	0.3000^{abc}	2.950^{cd}	2.000^{cd}
I_4M_2	0.5440^{a}	0.3270^{a}	3.067^{ab}	2.100^{b}
I_5M_0	0.4843^{ab}	0.2600^{bcd}	2.783^{ef}	1.650^{i}
I_5M_1	0.4913^{ab}	0.2820^{abcd}	2.850^{def}	1.783^{gh}
I_5M_2	0.5190^{ab}	0.2937^{abcd}	2.883^{cde}	1.867^{efg}

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	12.70	14.30	14.30
I_1M_1	12.64	15.23	15.90
I_1M_2	13.80	16.01	16.54
I_2M_0	13.30	15.22	16.59
I_2M_1	13.70	15.90	16.68
I_2M_2	14.38	16.71	17.11
I_3M_0	14.40	18.40	18.80
I_3M_1	14.87	17.20	18.56
I_3M_2	15.54	18.43	19.70
I_4M_0	15.80	19.10	22.50
I_4M_1	16.62	20.00	20.80
I_4M_2	16.92	19.52	21.81
I_5M_0	17.94	19.41	21.94
I_5M_1	18.41	20.32	22.60
I_5M_2	19.25	20.91	23.39

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

Treatments	Depth (cm)		
	0 – 15	15 – 30	30 – 60
I_1M_0	10.10	13.90	13.10
I_1M_1	10.94	14.70	14.50
I_1M_2	12.20	15.20	15.11
I_2M_0	11.70	14.70	14.30
I_2M_1	11.92	14.86	15.72
I_2M_2	12.40	15.40	17.30
I_3M_0	13.20	16.29	17.23
I_3M_1	13.96	16.83	17.70
I_3M_2	14.40	17.30	18.50
I_4M_0	14.20	17.50	18.40
I_4M_1	15.30	18.00	19.10
I_4M_2	15.80	18.90	19.90
I_5M_0	15.70	17.64	19.60
I_5M_1	16.40	18.83	20.40
I_5M_2	16.80	19.50	21.40

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

Treatments	Depth (cm)		
	0 – 15	15 – 30	30 – 60
I_1M_0	11.16	13.15	14.81
I_1M_1	11.85	14.10	15.22
I_1M_2	14.10	15.58	16.63
I_2M_0	13.00	15.11	16.55
I_2M_1	13.15	15.07	16.32
I_2M_2	13.80	16.04	17.02
I_3M_0	14.17	16.58	18.10
I_3M_1	14.70	17.82	18.20
I_3M_2	15.20	18.00	19.75
I_4M_0	14.80	18.50	19.60
I_4M_1	16.10	18.77	20.12
I_4M_2	16.50	19.10	21.56
I_5M_0	16.80	18.80	21.40
I_5M_1	17.20	19.80	21.20
I_5M_2	17.00	19.41	20.90

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	13.66	14.12	13.93	13.24
I_1M_1	14.97	14.88	14.54	13.95
I_1M_2	15.60	15.26	15.93	15.25
I_2M_0	16.00	16.28	14.50	13.35
I_2M_1	16.86	16.19	15.30	13.35
I_2M_2	16.74	16.31	15.96	15.26
I_3M_0	17.13	16.03	16.72	16.32
I_3M_1	16.84	17.29	17.75	16.29
I_3M_2	18.03	18.78	17.74	16.99
I_4M_0	19.05	19.81	19.38	17.94
I_4M_1	19.75	20.66	18.60	17.61
I_4M_2	20.22	19.38	19.86	18.20
I_5M_0	21.16	20.45	19.64	17.82
I_5M_1	22.08	20.52	20.79	18.51
I_5M_2	23.46	22.25	19.94	19.08

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	13.42	12.47	12.35	11.14
I_1M_1	14.56	13.33	13.13	12.47
I_1M_2	15.33	14.02	14.22	13.15
I_2M_0	15.10	13.65	13.34	12.23
I_2M_1	15.28	14.26	14.08	13.03
I_2M_2	15.86	15.07	15.18	14.17
I_3M_0	16.91	16.60	14.86	13.93
I_3M_1	18.17	16.89	15.56	14.02
I_3M_2	18.80	17.19	16.05	14.78
I_4M_0	18.76	17.40	16.18	14.45
I_4M_1	19.78	18.21	16.59	15.25
I_4M_2	20.48	19.01	17.37	15.99
I_5M_0	18.15	18.38	17.79	18.15
I_5M_1	19.91	19.73	17.75	16.74
I_5M_2	21.08	20.00	19.00	17.00

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	15.42	12.74	12.55	11.45
I_1M_1	16.21	13.68	12.90	12.11
I_1M_2	16.89	15.63	14.45	13.40
I_2M_0	17.64	15.26	14.13	12.59
I_2M_1	18.06	14.21	13.99	13.14
I_2M_2	18.39	15.87	14.46	13.73
I_3M_0	18.64	15.58	15.90	14.96
I_3M_1	19.36	17.03	16.02	15.22
I_3M_2	19.28	17.87	17.15	16.31
I_4M_0	19.23	18.25	17.16	15.90
I_4M_1	19.45	19.15	18.10	16.63
I_4M_2	20.81	18.90	18.87	17.68
I_5M_0	20.77	20.13	18.15	16.59
I_5M_1	21.69	20.53	18.67	16.72
I_5M_2	20.83	19.50	18.50	17.70

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	3,000.0	21,000.0
2	2" PVC pipe	100m	35.0	3,500.0
3	12mm lateral	3,350m	3.96	13,266.0
4	4mm extension tube	3,333m	1.65	5,499.45
5	Dripper (2 l h^{-1})	3,333	4.5	14,998.5
6	Belt wash	134	13.0	1,742.0
7	Pin connecter	3,333	1.1	3,666.3
8	2" PVC end cap	2	8.0	16.0
9	2" MTA	7	9.75	68.25
10	2" FTA	7	14.5	101.5
11	2" bend	7	12.0	84.0
12	2"coupling	7	9.5	66.5
13	2" valve	7	350	2,450.0
14	Drip installation cost (contract basis)	-	-	3,500.0
Total				69,958.50

Cost of drip system per season is taken one fifth of total (Rs. 13,991.70) by the assumption that drip system will serve for five season

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

SL No.	Treatments	Quantity	Unit Cost (Rs)	Total Cost (Rs/ha)
1	M_1 (Paddy waste mulch)			
	_ cost of mulching material	Free of cost	-	-
	_ transport and spreading cost	33 women	80	2,640.00
2	M_2 (Polythene mulch)			
	_ cost of mulching material	833 Kg	55	45,815.00
	_ cost of spreading	15 men	130	1,950.00
	Total			47,765.00

One third cost of polythene per season plus total spreading cost (Rs. 17,221.67) was taken for calculating cost economics per season.

c) Cost of inputs per hectare

Sl. No.	Inputs	Quantity	Unit Cost (Rs)	Total Cost (Rs/ha)
1	Seed	0.75 Kg	700.0	525.00
2	FYM	20 t	400.0	8,000.00
3	Urea	152 Kg	4.8	729.60
4	Rock Phosphate	125 Kg	2.4	300.00
5	MOP (Muriate of Potash)	42 Kg	4.44	186.48
6	Acephate	1.5 Kg	752.0	1,128.00
7	Dicofol	0.75 l	400.0	300.00
Total				11,169.08

d) Labour cost for irrigation and cost for electricity

Sl. No.	Treatments	Quantity	Unit Cost (Rs)	Total Cost (Rs)
1	I_1 (Drip irrigation @ 50% of Ep)			
	_ labour cost	27 men	130	3,510.0
	_ electricity cost	108 units	0.75	81.0
	Total			3,591.0
2	I_2 (Drip irrigation @ 75% of Ep)			
	_ labour cost	40.5 men	130	5,265.0
	_ electricity cost	162 units	0.75	121.5
	Total			5,386.5
3	I_3 (Drip irrigation @ 100% of Ep)			
	_ labour cost	54 men	130	7,020.0
	_ electricity cost	216 units	0.75	162.0
	Total			7,182.0
4	I_4 (Drip irrigation @ 125% of Ep)			
	_ labour cost	67.5 men	130	8,775.0
	_ electricity cost	270 units	0.75	202.50
	Total			8,977.5
5	I_5 (Basin irrigation 45 l per pit	180 men	130	23,400.0

One third cost of polythene plus total spreading cost (Rs. 17,221.67) was taken for calculating cost economics per season

e) Cost of cultivation

Sl. No.	Particulars	Quantity	Unit Cost (Rs)	Total Cost (Rs)
1	Ploughing by tractor	8 h + 1 man	-	890.0
2	Digging of corners and trimming of bunds	3 men	130	390.0
3	Pit preparation by tractor	32 h + 8 men	-	4,080.0
4	Application of FYM and filling	8 women	80	640.0
5	Incorporation of FYM and filling	20 men	130	2,600.0
6	Sowing of seeds	3 women	80	240.0
7	Pot watering upto 19 DAS	72 women	80	5,760.0
8	Basal fertiliser application	8 women	80	640.0
9	Thinning and gap filling	6 women	80	480.0
10	Top dressing of fertiliser	8 women	80	640.0
11	Collection and spreading of coconut fronds	25 women	80	2,000.0
12	Chemical spraying (3 times)	9 men	130	1,170.0
13	Harvesting and transportation	50 women	80	4,000.0
Total				23,530.0

f) Cost of weeding per hectare

Sl. No.	Treatments	Quantity	Unit Cost (Rs)	Total Cost (Rs/ha)
1	**M_0** (Un-mulched)			
	- 1st weeding	50 women	80	4,000.0
	- 2nd weeding	50 women	80	4,000.0
	Total	100 women	80	8,000.0
2	**M_1** (Paddy waste mulch)			
	- 1st weeding	33 women	80	2,640.0
3	**M_2** (Polythene mulch	-	-	-

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

Treatment	Cost of drip structure 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	23530.0	8000.0	3591.0	-	60281.8	119160.0	58878.2
I_1M_1	13991.7	11169.1	23530.0	2640.0	3591.0	2640.0	57561.8	154980.0	97418.2
I_1M_2	13991.7	11169.1	23530.0	-	3591.0	17221.7	69503.5	200820.0	131316.5
I_2M_0	13991.7	11169.1	23530.0	8000.0	5386.5	-	62077.3	156660.0	94582.7
I_2M_1	13991.7	11169.1	23530.0	2640.0	5386.5	2640.0	59357.3	178620.0	119262.7
I_2M_2	13991.7	11169.1	23530.0	-	5386.5	17221.7	71299.0	224160.0	152861.0
I_3M_0	13991.7	11169.1	23530.0	8000.0	7182.0	-	63872.8	167520.0	103647.2
I_3M_1	13991.7	11169.1	23530.0	2640.0	7182.0	2640.0	61152.8	193320.0	132167.2
I_3M_2	13991.7	11169.1	23530.0	-	7182.0	17221.7	73094.5	229200.0	156105.5
I_4M_0	13991.7	11169.1	23530.0	8000.0	8977.5	-	65668.5	173340.0	107671.5
I_4M_1	13991.7	11169.1	23530.0	2640.0	8977.5	2640.0	62948.3	194160.0	131211.7
I_4M_2	13991.7	11169.1	23530.0	-	8977.5	17221.7	74890.0	259140.0	184250.0
I_5M_0	-	11169.1	23530.0	8000.0	23400.0	-	66099.1	147480.0	81380.9
I_5M_1	-	11169.1	23530.0	2640.0	23400.0	2640.0	63379.1	161520.0	98140.9
I_5M_2	-	11169.1	23530.0	-	23400.0	17221.7	75320.8	182520.0	107199.2