IRRIGATION SCHEDULING AND MOISTURE CONSERVATION IN WATER MELON

(*Citrullus lanatus* [Thumb.] Matsam & Nakai)

By

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THESIS

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DECLARATION

I hereby declare that this thesis entitled "**Irrigation scheduling and moisture conservation in water melon (*Citrullus lanatus* [Thumb.] Matsam & Nakai)**" is a bonafide record of research work done by me during the course of research and that the thesis has not previously formed the basis for the award to me of any degree, diploma, fellowship or other similar title, of any other University or Society.

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We, the undersigned members of the Advisory Committee of **Mr.Ajith, C.B.,** a candidate for the degree of **Master of Science in Agriculture** with major in **Agronomy**, agree that the thesis entitled "**Irrigation scheduling and moisture conservation in water melon (*Citrullus lanatus* [Thumb.] Matsam & Nakai)**" may be submitted by Mr.Ajith, C.B., in partial fulfilment of the requirements for the degree.

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Dedicated to my beloved

Parents

CONTENTS

ABBREVIATIONS

Cu	:	Consumptive use
DAS	:	Days after sowing
IW/CPE	:	Irrigation water/ Cumulative pan evaporation
MCM	:	Moisture conservation methods
WUE	:	Water use efficiency
BI	:	Before irrigation
AI	:	After irrigation
NS	:	Not significant
Sig.	:	Significant

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INTRODUCTION

INTRODUCTION

India is the second largest producer of vegetables in the world and accounts for 12 per cent of the world output. Daily per capita consumption of vegetables in India is deplorably below the recommended dietary standard as production of vegetables in India is far below the increasing demand. In Kerala, the annual vegetable production is estimated to be 5.78 lakh tonnes from an area of 85122 ha (FIB, 1998) whereas the requirement of the state is 14.35 lakh tonnes (KAD, 1998). The daily per capita consumption of vegetables in Kerala is 130 g which is far less than the recommended daily intake of 300 g. It is estimated that anticipated production will be much less than the requirement of vegetables in future. This necessitates concerted research efforts to increase the productivity and improve the quality of the vegetables.

In Kerala, the availability of cultivable land is limited and hence the vegetable production can be enhanced only through intensive multiple cropping practices giving more emphasis to the efficient use and management of water resources and other production inputs. Therefore, utilization of summer rice fallows with assured irrigation facilities has great relevance and wide applicability.

Water melon [*Citrullus lanatus* (Thumb) Matsam & Nakai.] is a tropical cucurbitaceous vegetable widely grown in India. The mature fruits are with attractive colour, sweet taste and refreshing effects on consumption. The fruits are also a good source of vitamin C, sugar and minerals (Bose and Son, 1986). This is the one and only dessert vegetable crop of Kerala. Though there is heavy demand for the fruits of water melon during summer months, its cultivation is seen only in limited areas in the state. As a result 80 per cent of the fruits of water melon consumed in the state come from other neighbouring states.

One of the reasons for the slow acceptance of water melon as a crop in the state is the lack of suitable agrotechniques. Water is the most critical factor which limits the cultivation of vegetables in summer as it needs frequent irrigation.

Prevalence of dry weather conditions during summer season necessitates frequent irrigation. But precise information on the effect of irrigation on the growth and yield of water melon and optimum irrigation requirement of the crop are lacking.

Moreover, water use efficiency is also very less in summer vegetables due to enormous loss of water through evaporation, seepage and deep percolation. Therefore development of suitable moisture conservation practices which eliminates the necessity for frequent irrigation for summer grown water melon will be of great help to the growers as it can largely reduce the cost of cultivation and increase water use efficiency.

With these considerations in view investigations on the "Irrigation scheduling and moisture conservation in water melon (*Citrullus lanatus* (Thumb.) Matsam & Nakai)" were initiated. The study was conducted at the Agricultural Research Station, Mannuthy during the summer season of 1999 with the following objectives.

1. To study the effect of irrigation and moisture conservation methods on growth and yield of water melon.
2. To compare the levels of irrigations and to compare the different moisture conservation practices on growth and yield.
3. To study the interaction between levels of irrigation and moisture conservation methods.
4. To workout the moisture extraction pattern, consumptive use and water use efficiency.

5. To understand to what extent the incorporation of moisture retaining ameliorants in the root zone depth of water melon can enhance moisture conservation ability of the soil and if so to what extent scheduling of irrigation can be modified for better water economy for vegetable.
6. To workout the economics of cultivation.

REVIEW OF LITERATURE

REVIEW OF LITERATURE

Over the past few decades, research on water management of field crops has received considerable attention. However, not much work has been reported on the water requirement of vegetables, particularly water melon. It is cultivated in a very limited scale in the summer rice fallows and sandy river banks of Northern Kerala where plentiful supply of water is available. Studies regarding quantity and interval of irrigation as well as the effect of moisture conservation methods on water requirement of water melon are very meagre. Hence the relevant literature available on these aspects of water melon along with few other cucurbits is briefly reviewed.

The literature reviewed are classified under the following sections.

2.1 Effect of irrigation
2.2 Consumptive use and water requirement
2.3 Irrigation scheduling based on evaporation data
2.4 Methods of irrigation
2.5 Importance of moisture conservation in vegetables
2.6 Effect of moisture conservation methods
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2.11 Soil moisture and nutrient uptake
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2.1 Effect of irrigation

For the successful cultivation of vegetables, an adequate supply of water throughout the growing season is a must. Water available for agriculture is decreasing and this coupled with ever increasing demand of the growing population for food and other primary needs stresses the need for the most efficient utilization of each unit of water used for irrigation.

Water melon, a cucurbitaceous vegetable requires plenty of water for higher production. A lot of research works were done to study the effect of irrigation on cucurbits. However, there is not much information available on the effect of irrigation on water melon. The literature pertaining to the studies on the effect of levels of irrigation on cucurbit vegetables are reviewed here under.

2.1.1 Effect of irrigation on growth attributes

In the studies of Belik (1961), it was revealed that the optimum condition for cucumber development during the early growth phase was 80-90 per cent of full moisture capacity. Flocker *et al.*, (1965) reported that frequent and heavy irrigation increased the vine growth and succulence in melons. Irrigation during the entire growing season was more effective in cucumber (Borna, 1969).

Dimitrov (1973) in a field trial found that a field capacity of 70-80 per cent maintained over the entire season was the most economic treatment in water melon, giving a total yield of 26,160 kg ha^{-1}.

Escobar and Gausman (1974) noticed that in Mexican squash the leaves of the plants under higher water stress were thicker and smaller, containing less water than the plants under lower water stress. Leaf area in cucumber was greatly reduced under water stress (Cummins and Kretchman, 1974).

Tomitaka (1974) reported highest plant growth of cucumbers at a medium soil moisture level of pF 2.0. Michael (1978) revealed that the soil moisture at about 15 cm depth should not be allowed to drop below 70 per cent of total available moisture for better growth of vegetable crops. In a drip irrigation experiment in water melon variety Sugar Baby, irrigation during the fruit development stage which continues for about a month resulted in average yield increase of 24.2 tonnes ha^{-1} (Rudich *et al.*, 1978). Pai and Huckeri (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.

Experiments conducted with pickling cucumbers (variety Premier) Ortega and Kretchman (1982) noticed that a reduction in the rate of vine growth and the number of nodes when the plants were subjected to stress for a period of one week. Growth was found to be completely inhibited after two weeks of stress.

Thomas (1984) found that bitter gourd responded well to frequent irrigations and higher levels of fertilizers. Frequent irrigation at low depletion of available soil moisture was congenial for growth and development of cucurbits. However, heavy irrigations at frequent intervals were found to be detrimental for crop growth.

Desai and Patil (1984) reported that for water melon highest plant growth was obtained from plants irrigated at IW/CPE ratio of 1.0.

In green house cucumber studies, Heissner *et al.* (1987) found that the experimental and linear phases of leaf growth were unaffected by soil moisture tension in the upper layers, but from 70 days after planting, the leaf area decreased more rapidly with higher moisture tension.

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

Hegde (1988) indicated that for water melon frequent irrigation, when the soil matrix potential at 15 cm depth reached –25 kPa, resulted in maximum dry matter accumulation and distribution, leaf area index, leaf area duration and net assimilation rate, leading to higher fruit yield compared with irrigation at –50 and –70 kPa.

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.

Studies of Philips *et al.* (1996) revealed that water melon yields were highest for treatments which received the most irrigation water, indicting that relatively high soil moisture contents based on the instrument readings should be maintained.

2.1.2 Effect of irrigation on yield and yield attributes

Adequate soil moisture enhances the number of female flowers, fruit set, fruit number and size of the fruits in watermelon.

2.1.2(a) Effect on number of female flowers and fruit set

Abolina *et al.* (1963) observed that the melon plants watered regularly produced greater number of female flowers.

Trial conducted by Pew and Gardner (1983) on musk melon showed that earlier fruit set and earlier maturity was obtained by irrigation when soil moisture tensions at the 25 cm depth reached 50 or 75 kPa compared with 25 kPa.

Trial conducted at Agricultural Research Station, Mannuthy revealed that the total number of female flowers produced increased progressively with higher levels of irrigation in water melon grown in summer rice fallow (Siby, 1993).

2.1.2(b) Effect on fruit size and weight

Flocker *et al.* (1965) indicted that increase in yield by irrigation in cucumber was due to fruit size. While, studying the cultural practices requirements of summer squash, Bradely and Rhodeo (1969) concluded that the fruit weight was significantly increased by weekly irrigation compared with fortnightly irrigation.

The drip irrigation trial conducted by Singh and Singh (1978) revealed that the yield increase of cucurbitaceous crops by irrigation was associated with increase in the fruit weight.

Studies in ash gourd at the Agronomic Research Station, Chalakudy indicated that the weight of fruits increased with increase in the level of irrigation (ICAR, 1982).

In musk melon, larger fruit size and earlier maturity were obtained by irrigating when soil moisture tensions at the 25 cm depth reached 50 or 75 kPa compared with 25 kPa (Pew and Gardner, 1983).

In an irrigation and fertilizer trial by Hegde (1989) irrigation at –25 kPa and the highest nitrogen rate resulted in the highest yields in watermelon.

In the field studies conducted in the summer season at 1990-91 in Bangalore showed that highest yield of cucumber (36 t ha^{-1}) was obtained due to higher fruit number per vine coupled with greater average fruit weight (Prabhakar and Naik, 1993). Yingjajaval and Markmoon (1993) found that in cucumber the yield increase by irrigation was due to fruit number rather than fruit size. By increasing the water supply from a dry regime to a weekly irrigation regime significantly increased the mean fruit weight.

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 (18.4 tonnes ha^{-1}) of good quality fruits.

2.1.2(c) Effect on number of fruits

The drip irrigation trial conducted by Singh and Singh (1978) revealed that the yield increase of cucurbitaceous crops by irrigation was associated with number of fruits per plant.

According to Hayness and Herrying (1980), irrigation at 0.7 bar produced the highest yields of marketable squash. However the number of marketable fruit was maximum with irrigation at 0.3 bar. Studies in ridge cucumbers showed that 60 per cent more fruits were produced with irrigation than without irrigation in ridge cucumbers (Henriksen, 1980).

Trials conducted in ash gourd at the Agronomic Research Station, Chalakudy revealed that the number of fruits per plant increased with increase in the level of irrigation (ICAR, 1982).

The field trial during the summer season of 1990-91 at Bangalore showed that the highest yield of cucumber (36 t ha^{-1}) was due to higher fruit number per vine coupled with greater average fruit weight (Prabhakar and Naik, 1993). Yinggajaval and Markmoon (1993) showed that in cucumber increasing the irrigation rate increased the total yields and it was due to fruit number rather than fruit size. Nerson *et al.* (1994) reported that increasing the water supply from a dry farming regime to weekly irrigation regime had only a small effect on fruit number.

2.1.2(d) Effect on yield

The yield of melon increased by irrigation when soil moisture tension at the 45 cm depth reached three bars (Flocker *et al.*, 1965).

Downes (1966) in the sprinkler irrigation studies revealed that the average yield of melon was increased when irrigation at frequent intervals was practiced. Dunkel (1966) indicated that the highest yield of cucumber was obtained when the soil moisture did not go below 70 per cent of field capacity.

In the cultural practices studies on summer squash, Bradley and Rhodeo (1969) concluded that irrigation at 7, 14 and 21 days interval made very little difference to the yield harvested frequently, but at the 21 days interval the ones over yield was markedly reduced. The fruit weight and fruit yield of musk melon significantly increased by weekly irrigation compared with fortnightly irrigation (Jassal *et al.*, 1970).

The yield increase of cucurbitaceous crops by irrigation was associated with increased number of fruits per plant and increased fruit weight. Abreu *et al.* (1978) obtained highest average yield of melon (13.02 t ha^{-1}) when irrigation was applied at 0.7 atmosphere.

According to Hayness and Herring (1980), irrigation at 0.7 bar produced the highest yields of marketable squash. Chernovel (1980) observed that the night irrigated plants gave highest yield followed by evening, morning and mid-day irrigation. During dry weather, weekly irrigation should be given to pumpkin and cucumber for maximum yield (Katayal, 1980).

Kashi (1981) obtained maximum yield in musk melons with irrigation intervals of six and eight days. Green house cucumber studies by Mannini and Ronenzzi (1983) showed that irrigation at an interval of three to six days did not affect cucumber yield, but the volume of water applied was important. Irrigation at

60 per cent available soil moisture was ideal for multiharvest and at 25 per cent for once over harvest for highest yield in cucumber (Tau *et al.*, 1983).

The study conducted by Pew and Gardner (1983) on musk melon showed that higher yield was obtained by irrigating when soil moisture tension at the 25 cm depth reached 50 or 75 kPa compared with 25 kPa.

Radha (1985) in an experiment conducted at the Agricultural Research Station, Mannuthy revealed that there was no significant difference in yield between irrigating at 25, 50 and 75 per cent depletion of available soil moisture for pumpkin, oriental pickling melon and ash gourd.

Irrigation studies on fluted pumpkin by Asoegwu (1991) showed that irrigating every six days produced significantly higher number of seeds while irrigating every three days gave the best leaf yield and pod yield. Pulekar and Patil (1988) found that the yield of water melon was significantly increased due to irrigation scheduling at 10 mm CPE (3 days interval).

The marketable fruit yield of summer squash was greatest when the plants were irrigated at 25 kPa of soil water tension (Stansell and Smittle, 1989).

Experiment conducted during the summer season of 1990-91 at Bangalore revealed that the highest yield of cucumber (36 t ha^{-1}) was obtained with most frequent irrigation scheduled to replenish 120 per cent of pan evaporation (Prabhakar and Naik, 1993). Yingjajaval and Markmoon (1993) found that in cucumber increasing the irrigation rate from 100-150 or 200 per cent potential evapotranspiration increased the total yields by 12 and 31 per cent respectively.

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}.

The effect of irrigation frequency and nitrogen rate on onion seed production was studied and it was seen that irrigation at 10 day interval with 80 kg nitrogen per ha in split application gave the highest yield of quality seeds (Bhonde *et al*., 1996).

Philips *et al*. (1996) in a field experiment scheduling micro-irrigation found that water melon yields were highest for treatments which received the most irrigation water indicating that relatively high soil moisture contents based on the evapotranspiration instrument reading should be maintained.

Deek *et al*. (1997) in a field study in tomato revealed that the highest yield (51.4 tonnes ha^{-1}) was obtained under three irrigations per week with 504 mm total water supply whereas under irrigation once a week 35.3 tonnes ha^{-1} were produced with 353 mm total water supply.

In mulch cum drip irrigation system in okra, Sunilkumar (1998) found that mean plant height was higher under mulch situation than unmulch situation in furrow and drip irrigation system irrespective of levels of irrigation.

2.1.2(e) Effect on quality of fruits

Krynska *et al*. (1976) found that irrigation lowered the fruit dry matter, vitamin C and sugar content in both fresh and processed cucumber. Elkner and Radzikowska (1976) found that irrigation particularly in years of low rainfall increased firmness, improved the taste and reduced percentage of hollow cucumbers, but decreased dry matter, total N and NO_3 N in the fruit.

Minimum yield and enhanced solid content in musk melons was obtained with irrigation intervals of six and eight days (Kashi, 1981).

Water management and method of irrigation studies by Neil and Zunio (1972) revealed that higher irrigation rate improved the flavour and decreased firmness in melon. Highest percentage of sugar content and TSS in the fruit occurred in unirrigated plots irrigated at the lowest frequency (Caro and Linsalata, 1977).

From the above mentioned reviews we can conclude that irrigation on cucurbits increase the number of female flowers, early fruitset, fruit size and weight, number of fruits per plant, fruit quality and ultimately the yield.

2.2 Consumptive use and water requirement

In designating water use by the crops, the term consumptive use includes all the water consumed by the plants plus the water evaporated from the bare land and water surfaces in the area occupied by the crop.

Experiments conducted by Whitaker and Davis (1962) revealed that irrigation requirement of water melon and cucumber was 150 ha mm each and that for pumpkins and summer and winter squashes was 180 ha mm each. Dunkel (1966) showed that optimal yields of cucumber could be obtained, when 600-750 mm of water was applied.

Neil and Zunio (1972) in a water requirement study showed that the maximum evapotranspiration in irrigated cantaloupes was 60 per cent of potential evapotranspiration and between flowering and fruit formation it was 55 per cent of potential evapotranspiration. The water uptake increased during fruit enlargement. At harvest, water uptake was 85 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 fruitset, 1008 m3 ha-1 upto fruit enlargement, 882 m^3 ha^{-1} upto prematurity and 280 m^3 ha^{-1} to harvest.

In a trial to find out the relationship between development and water utilization 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.

In a trial to find out the amount and nature of water consumption in musk melon, Konishi (1974) found that the total water consumption by a fruit bearing plant with a leaf area of about 11000 cm^2 was 85-90 litres. As the plant grows the ratio of water consumption per plant to panevaporation increased to a maximum at the netting stage and then declined with aging. He also observed that young leaves transpired faster than old leaves and water consumption was less by the plants without fruit.

In cucumber, the evapotranspiration rate declined with a decrease in the soil moisture level (Tomitaka, 1974). The highest yield of cucumber (2.6 kg m^{-2}) was obtained when 70-100 l m^{-2} of water was applied during the plant growing phase through 20-23 individual irrigations, followed by 480-570 l m^{-2} during fruiting in 92-94 individual irrigations.

The consumptive use of cucumber increased during flowering and early fruiting and then leveled off during late harvest (Loomis 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 panevaporimeter (kc) increased to a maximum of 1.5 during the early harvest season.

The water requirement of water melon for the total growing period for a 100 day crop ranged from 400-600 mm (Doorenbos and Kassan, 1979). The consumptive use of water melon increased as the irrigation levels increased from 0.6 to 1.2 IW/CPE ratios. The increased irrigation levels also increased the water requirement from 360 to 580 mm. The optimum water requirement for the highest yield was 540 mm (Desai and Patil, 1984).

Trials conducted at the Agronomic Research Station, Chalakudy revealed that the consumptive use increased with increase in the level of irrigation in the case of bitter gourd (Thomas, 1984). Experiments 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 the case of cucumber and other cucurbits like pumpkin and ash gourd (Radha, 1985). This was supported by Jacob (1986) and Thankamani (1987). Field water use efficiency increased with decrease in irrigation frequency (Hegde, 1987).

The water consumption of winter squash at three different soil moisture tension of 30, 50 and 80 kPa was 12.79, 12.75 and 12.44 cm respectively. The corresponding values for the spring crop were 15.18, 13.98 and 14.97 cm (Safadai, 1987).

Eliades (1988) with cucumber in a heated greenhouse observed that the average water requirement during the whole growing period was equivalent to 0.7x pan evaporation. For the greenhouse cucumber (Hybrid Monara) the average water consumption per plant per day was 360 ml during the period from transplanting to flowering, 800 ml from flowering to the start of fruiting, 11600 ml from the start of fruiting to 50 per cent fruiting and 1200 ml during ripening stage (Maeda Martinez, 1988).

Yadav *et al.* (1989) found that in water melon, water use efficiency was higher with irrigation at 83 mm cumulative pan evaporation and it was lowest with 62.5 mm cumulative pan evaporation. 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 day^{-1}) nearly equal to the evaporation (Komamura *et al.*, 1990).

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. 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 (El-Gindy *et al.*, 1991).

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^{-1} mm^{-1} (Prabhakar and Naik, 1993).

Experiments conducted at the Agronomic Research Station, Chalakudy revealed that the consumptive use and the ratio of evapotranspiration to the pan evaporation (Et/Eo) values of bitter gourd increased progressively with levels of nitrogen and irrigation. At higher moisture regimes the variation in consumptive use and Et/Eo values did not reflect in crop yield. 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).

Trials in ash gourd by Menon and Marykutty (1993) showed that field water use efficiency increased with decrease in IW/CPE ratio. An increase of 51.61 per cent field water use efficiency could be observed when irrigation level shifted from 0.75 to 0.25 IW/CPE ratio. The amount of water used is about one half of that used at 0.75 ratio. This might be the reason for significant increase in field water use efficiency at 0.25 IW/CPE ratio.

It can be thus concluded from the above review that consumptive use depends on the physiological stages of crop, evaporative demand of atmosphere and duration of the crop. The consumptive use increased with increasing levels of irrigation and the water use efficiency decreased with increasing levels of irrigation. Cucurbitaceous vegetable crops require about 500-600 mm of water through frequent irrigations.

2.3 Irrigation scheduling based on evaporation data

An evaporimeter is an instrument which integrates the effect of all the different climatic elements furnishing them their natural weightage (Dastane, 1967). Evaporation values measured from a standard USWB class-A open pan evaporimeter are extensively used for scheduling of irrigation using a suitable IW/CPE ratio (Sharma and Dastane, 1969, Sharma *et al.*, 1975; Vamadevan, 1980).

Prihar *et al.* (1975) observed that under Indian conditions, where instrumentation is limited, irrigation scheduling based on application to a fixed depth after the lapse of a given evaporation value from the USWB pan evaporimeter holds great promise.

Consumptive use of water which is the main part of water requirement of a crop is governed primarily by meteorological parameters. The high correspondence 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).

Experiments conducted by Singh and Singh (1978) recorded high total yields with drip irrigation, at 65 per cent of the evaporation from a class-A pan evaporimeter in crops like bottle gourd, round gourd, and water melon in loamy sandy soils of hot arid regions. Studies on scheduling irrigation to bitter gourd and cucumber at the Agronomic Research Station, Chalakudy indicated that 3 cm irrigation at IW/CPE ratio of 0.4 was optimum for both the crops in summer rice fallows (ICAR, 1981). Similar studies in ash gourd recorded the highest yield at IW/CPE ratio of 1.0 which was on par with the IW/CPE ratio of 0.7. Both there were significantly superior to the IW/CPE ratio of 0.4 (ICAR, 1982).

In an irrigation and date of sowing study conducted by Desai and Patil (1984) revealed that of the four irrigation ratios (IW/CPE 0.6, 0.8, 1.0 and 1.2) good plant growth, fruit quality and the highest yield of water melon was obtained from irrigation at IW/CPE ratio of 1.0. Srinivas *et al.* (1984) studied the effect of four (25, 50, 75 and 100%) levels of evaporation replenishment under drip and furrow irrigation and indicated that replenishment of 25 per cent evaporation losses under drip and 50 to 70 per cent evaporation losses under furrow irrigation were optimum for realizing higher yields of watermelon.

Thomas (1984) in the studies conducted at the Agronomic Research Station, Chalakudy, it was found that IW/CPE ratio of 1.2 was the most ideal for cucurbits. The results of the trial conducted during the summer season of 1986 using bitter gourd and snake gourd at the Agricultural Research Station, Mannuthy revealed that irrigation at IW/CPE ratio of 1.0 gave the highest yield in both the crops (Jacob, 1986; Thankamani, 1987).

Mannini and Gallinga (1987) compared the three irrigation rates (50, 100 and 150% x maximum evapotranspiration) (ETM) in an unheated greenhouse 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.

In watermelon cultivar sugarbaby, Yadav *et al.* (1989) recorded the maximum number of edible fruits per plant, total soluble solids and yield with frequent irrigations at 83 mm cumulative pan evaporation. In melons, Mustard and Yard (1990) found that vitreous flesh disorder might be due to too much of water during fruit ripening and he also suggested that irrigation must be reduced to 40-50 per cent of evapotranspiration during the last week before harvest. In an irrigation schedule for pumpkin and oriental pickling melon with can evaporimeter, depletion upto 75 percentage of the available soil moisture did not significantly affect the yield of the two crops (Radha Lakshmanan *et al.*, 1990).

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. This treatment also resulted in 25 per cent more of early harvestable yield (Prabhakar and Naik, 1993).

Yingjajaval and Markmoon (1993) in an irrigation and fertilizer 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. An irrigation study by Sostaric and Madjar (1996) showed that 120 mm of water was needed for water melon and it should be applied as 40 mm applications at the beginning of June and twice more at 15 day intervals.

It can thus be seen that scheduling of irrigation to cucurbitaceous vegetables based on evaporation data and more particular with IW/CPE ratio is reliable and that scheduling irrigation at an IW/CPE ratio of 1 to 1.2 best suits cucurbits.

2.4 Methods of irrigation

Cucurbits are generally irrigated by furrow or basin methods.

The root development in the field grown cucumber was better with flood irrigation than sprinkler or no irrigation. Sharma and Dastane (1969) emphasized that to achieve high irrigation efficiency, uniform water distribution and uniform high yields check basin should be microlevelled. Drip irrigation produced yields of melon twice as high as sprinkler irrigation (Goldberg and Shamueli, 1970).

Caro and Linsalata (1977) observed that furrow irrigation increased the yield and mean fruit weight but did not affect the number of fruits per plant. For ridge cucumbers there was no significant difference in yield and quality between drip irrigation and overhead manual watering.

Water melon grown around buried pitchers (30 cm diamter) gave an economic return only with water replinishment every third day (Mandal, 1978). The different effects of the drip and perforated hose irrigation methods in water melon were compared in a plastic green house. Harvest date was earlier with the perforated method, but yield was higher with the drip (Toyama and Takeuchi, 1980).

The comparative effect of pitcher irrigation and pot watering in cucumber was studied by Balakumaran *et al.* (1982). They reported that yields were slightly higher in pot watered plants, but water economy was appreciably greater under pitcher irrigation. Reddy and Rao (1983) worked on the response of bitter gourd to pitcher and basin systems of irrigation. They found that the yield was highest in plots with pitcher filled every 4^{th} day and lowest in plots with basin filled every 5^{th} day. In bitter gourd pitcher irrigated plots have the lowest yield.

Trials conducted by Mannini and Gallinga (1987) revealed that irrigation methods had no effect on the yield of cucumber grown in unheated green house.

The comparative study between sub surface and sprinkler irrigated cucumber showed that sub surface irrigation produced better yields than sprinkler irrigation. Srinivas *et al.* (1989) observed that drip irrigation gave higher yield than furrow irrigation in water melon. The water use efficiency of water melon was lesser in surface irrigation followed by sprinkler and drip irrigation.

The effect of furrow, microtube, drip, porous clay tube and porous plastic tube irrigation systems on cucumber was studied by Chartzoulakis and Michelakis (1990). 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.

2.5 Importance of moisture conservation in vegetables

Moisture conservation is one of the important cultural practices in the growing of vegetable crops. Both surface and subsurface moisture conservation techniques are practiced. Surface moisture conservation techniques are more common than subsurface moisture conservation techniques.

Moisture conservation techniques have several advantages like reduction of tillage operations, reduction of weed growth, reduction of evaporation from soil, increasing the water absorption by soil, regulation of soil temperature, inducing better root growth and nutrient availability and increasing the organic matter content of soil etc.

2.6 Effect of moisture conservation methods

Different types of materials have been tried from rocks to stones to slowly decomposing materials like sawdust and wood sharings, alfalfa and bean straw, hay and manures for their effect on soil moisture conservation (Lamb and Chapman, 1943).

Hapmans and Van Immerzeel (1988) studied the soil water characteristic and hydraulic conductivity functions for the surface and subsurface horizons. They found that degree of reduction in evapotranspiration was governed by capacity of subsoil to transport water from the ground water to the root zone.

2.6.1 Effect on water economy

Generally mulches are used for various reasons. However water conservation and erosion control are the most important for agriculture in dry season (Unger, 1971; Black and Siddoway, 1979 and Subbaiah *et al.*, 1978).

Crop residues and other plant waste products like straw, stover, leaves, corn cob, sawdust, wood chips etc. acted as cheap source of organic material readily available permitting water to enter the soil readily. When maintained at adequate levels, these materials reduced evaporation and increased water content in soil (Gupta, 1975).

In England, Goode and White (1958) compared the effects of clean cultivation and permanent straw mulch on soil moisture. They found that under the mulch, soil moisture remained close to the field capacity throughout the summer. Similarly in the relatively dry conditions of south west Finland, Vuorinen (1958) reported that mulching with straw reduced from four to two the number of irrigations needed to prevent the soil moisture tension raising to 700 mm Hg. Mulching with sawdust, peat and straw increased the levels of moisture in a polish cherry orchard.

Lal (1972) in an experiment with mulches in tropical soil stated that water conservation characteristics of soil was improved by mulches. He also observed that mulched plots had higher soil moisture content throughout the growing season than the unmulched plots for both 0-10 and 10-20 cm depth. He also noticed that mulching indirectly influenced the waterholding capacity and moisture release characters of soil.

In cardamom, paddy husk and coir dust were most effective in conserving soil moisture and reducing the number of irrigations required (Reghothama, 1981).

Study on plastic house tomatoes by Suwwan and Judah (1985) indicated that compared with unmulched soil 15.15 and 25.76 per cent of water applied were saved by the white and black mulch treatments respectively. They also found that water use efficiency was similar for the two mulch treatments but considerably higher than that of bare soil. Four field trials on turmeric were conducted at Punjab

Agricultural University, Ludhiana, using paddy husk and wheat straw as mulch. The results revealed that the mulches changed the microclimate by conserving more moisture, modifying soil temperature, controlling weeds and thus economizing the use of irrigation water. It also showed that response of irrigation was much higher with the application of mulch as compared to no mulch (Mahey *et al.*, 1986).

Voorhes (1986) in a laboratory study found that soil that had been amended with sawdust had absorbed more water at 2, 24 and 48 hrs after initial wetting respectively than the soil that had not been amended with sawdust. Kalaghatagi *et al.* (1990) found that total water use was lowest and water use efficiency was highest by using rice straw and black polythene as mulch in maize.

Kotoky and Bhattacharya (1991) found that the moisture status under paddy husk, water hyacinth and paddy straw mulched plots were found to be higher in comparison to control plots in banana. Wang and Zhao (1991) observed that mulching with 3.75 to 4.5 t ha^{-1} of straw found to be an effective measure to reduce the interplant evaporation from a wheat paddock. The experiments showed that water consumption was reduced and the reduction in effective evaporation was approximately 35 per cent which was equal to the irrigation requirement of one watering (750 m^3 ha^{-1}). Channabasavanna *et al.* (1992) recorded an increase of soil moisture level of 10.4 per cent in straw mulch and 29.6 per cent in polyethylene mulch over control.

Effectiveness of coir pith as a moisture conserving agent in rainfed agriculture has been reported by Ramaswamy and Kothandaraman (1991) and Veerabadran (1991). The moisture content of the subsoil upto 60 cm depth was consistently higher in the coir waste mulch treatment in the cotton and cotton green gram cropping system (Rajendran, 1991). It was also reported that waterholding capacity of the soil increased by 4.0 per cent due to coir pith addition.

Santhirasegaram (1965) found that water holding capacity of cinnamon lands of Srilanka was increased in direct proportion to the amount of coir pith incorporated into the soil. In coconut gardens coir dust can be buried instead of coconut husks as a moisture conservation practice. Maximum benefit can be obtained by burying coir dust in layers of 8 cm thick alternated with 5 cm thick soil layers.

Mulching in pineapple plot with wood shavings, rice husk and sawdust enhanced soil moisture retention compared with no mulch control (Asoegwu, 1991). Channappa (1994) in an in-situ moisture conservation study conducted at Bangalore revealed that incorporation of maize residue @ 4 t ha^{-1} continuously for three years had its good effects on water retention. The moisture content at sowing time in residue incorporated plots was 11.24 and 14.03 per cent in 0-15 and 15-30 cm depths compared to 8.85 and 13.39 per cent respectively in plots without residue. In an irrigation study in cucumber the yield from irrigation at IW/CPE ratio 1.2 (13 irrigations) without any moisture conservation materials was at par with that of irrigation at IW/CPE ratio 0.8 (8 irrigations) with moisture conservation materials (Veeraputhiran, 1996).

It can be concluded from the above review that application of organic materials either on the surface or sub-surface increase the moisture content of the soil and increase the water use efficiency of the crops.

2.6.2 Effect on growth and yield

Ivonova and Ivonova (1976) found that sawdust at 30 or 60 per cent of soil volume added to greenhouse soil two weeks before planting and incorporated to a depth of 25 cm increased the cucumber yield of 10-14.7 per cent. Mavrodii (1979) reported that adding chopped straw or saw dust in combination with fertilizers, increased the yields of cucumbers by 3.3-3.5 kg m^{-2}.

When pearl millet grain husks were incorporated with bentonite at 2.5-3.0 kg per pit they increased the yields in cucurbits. Bentonite alone did not give any result (Singh *et al.*, 1979). Iapichino and Gagliand (1984) observed the greater growth of water melon and earlier appearance of first female flowers in polythene mulched plots.

Cerne (1984) observed that in pickling cucumbers mulching with polythene increased the yields by 149 per cent, vine length by 183 per cent, leaf number by 163 per cent and main root length by 128 per cent.

Uthaiah and Lingaiah (1989) in their study on the effect of mulches on coconut seedling establishment revealed that coir pith laid at 10 cm thickness recorded the highest plant survival of 86.7 per cent. Vani *et al.* (1989) observed that use of yellow polythene, transparent polythene and straw mulch reduced the levels of mosaic disease incidence in musk melon and increased the plant growth and yield of 36, 74 and 51 per cent respectively.

In sandy soil, coir pith application at 10 t ha^{-1} resulted in increased pod yield at peanut (Arunachalam, 1987). Beside this, its usefulness in increasing the yield of a number of crops viz., sorghum, pearl millet, finger millet, maize and cotton under rainfed condition to the tune of 10-30 per cent over control was reported by many workers (Anabayan, 1988; Athmananthan, 1988; Veerabadran, 1991). The response of turmeric and sun flower to coir pith was better than FYM (Nagarajan *et al.*, 1989).

Corrales *et al.* (1990) found that incorporation of chicken manure, sugarcane bagasse and sawdust into the soil of the plant bed significantly increased the leaf area, flowering rate and yield in sweet pepper. Clark and Moore (1991) found that using of pine sawdust and woodchips to a depth of six inches as mulch increased the yield in rabbit eye and high bush blue berry compared with control although the differences were not significant.

Devaraj and Chockalingam (1991) observed that coir pith mulching along with ridges and furrows in sugarcane produced highest cane yields of 82.5 t ha^{-1} compared with 71.3 t ha^{-1} for no mulch. Application of rice husk, sawdust as mulch produced significantly more leaf area in pineapple (Asoegwu, 1991).

The best rubber seedling development was observed in a 80:20 sawdust:soil mixture (Reis, 1991). Abdel Galil (1992) recorded the higher percentage of germination of mango seeds sown in 2 inches deep in sawdust. Trials conducted at Bangalore with potatoes cv. Kufri jyothi revealed that dry matter accumulation and tuber yield were highest with plastic mulching followed by rice straw mulching (Khalak and Kumaraswamy, 1992).

Experiments conducted with cucumbers grown in 50 cm deep trenches filled with rice straw covered with a 10 cm layer of clay or sand showed that straw media gave higher yields than sand or clay alone. Rice straw covered with sand gave higher plant fresh weight and dry matter content (Abou-El-Hassan *et al.*, 1993).

Stang *et al.* (1993) found that incorporation of arid sphagnum peat or mixed pine hard wood sawdust increased plant growth, spread and vigour of "Erntedank" and "Korella" lingenberry. Sari *et al.* (1994) found that cultivation of squash and cucumber under 2 m high polyethylene tunnels with clear polyethylene mulches raised the early and total yield of squash by 29 per cent and 30 per cent respectively and those of cucumbers by 51 per cent and 25 per cent respectively. Mulch tended to produce shorter and fatter cucumbers but had no effect on squash size or shape.

Sawdust mulch consistently depressed the yield and yield components of onion more than millet stover and groundnut shell mulch (Adetunji, 1994).

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 without mulch control. Veeraputhiran (1996) in an irrigation study in cucumber found that length of vine, number of leaves, leaf area, leaf area index etc. were increased by the addition of moisture conservation materials. The plants received the incorporation of paddy waste and coir pith produced 27 and 17 per cent more yield respectively compared to control.

It could be seen from the above review that moisture conservation techniques significantly increase the growth, yield and yield attributes of many crops.

2.6.3 Effect on nutrient status

Borthakur and Bhattacharya (1992) observed that in guava plantations application of paddy husk and paddy straw as mulch increased the level of organic matter content of soil.

An experiment was conducted on mulching and spacing on yield and quality of tomato under rainfed condition. The study revealed that there was a significant increase in P uptake by 33 per cent in straw mulching and 153 per cent in polyethylene mulch over no mulch (Channabasavanna *et al.*, 1992). Plastic film mulch in cucumber increased the N, P, K, Mg and Ca uptake by 79.2 per cent.

According to Adetunji (1994) there was no significant difference in N, P and K uptake of onion between groundnut shell and millet straw mulch. The least nutrient uptake was observed under sawdust mulch.

2.7 Comparison of moisture conservation methods

Field trials conducted at the Agronomic Research Station, Chalakudy revealed that mulching with dried leaves recorded the highest yield of amorphophallus followed by that with paddy waste and coir dust (Mathew *et al.*, 1988). Groundnut and rice husk could give efficient water savings and good yields of pineapple than white translucent and black coloured plastic mulches (Shajari *et al.*, 1990).

An experiment on sugarcane cv. COC-771 showed that commercial cane sugar per cent and content were not affected by either sugarcane trash or coir pith mulching applied along the furrows or ridges or on both (Devaraj and Chockalingam, 1993).

Asoegwn (1991) found that rice husk and sawdust mulch produced significantly more leaf area than wood shavings and without mulch in pineapple plots. Among the mulches viz., rice husk, sawdust and wood chips mulched to a depth of 5 cm recorded the highest yield in pineapple (Obiefuna, 1991).

Experiments conducted at Bangalore with potatoes cv. Kufri jyothi revealed that drymatter accumulation and tuber yield were highest with plastic mulching followed by rice straw mulch (Khalak and Kumaraswamy, 1992). The highest shoot growth of custard apple was recorded for the straw mulch treatment followed by black plastic, sawdust, coarse sand mulches and control. The yield of high bush blue berry was highest in bark mulched plots than peat and sawdust mulch (Mercick and Smolarz, 1995). In cucumber, the highest fruit yield per ha and per plant was produced by paddy waste incorporation and was at par with that of coir pith incorporation. It produced 27 and 17 per cent more yield respectively compared to control (Veeraputhiran, 1996).

The above review clearly shows that the materials used for moisture conservation techniques have varying effectiveness on crop yield.

2.8 Effect of interaction of irrigation and moisture conservation methods

An interaction occurs when the response of one factor is modified by the effect of another factor. A positive interaction occurs when the response of two or more inputs used together is greater than the sum of their individual responses.

In tomato, irrigation and mulching studies by Suryanarayana and Venkateswarlu (1981) revealed that rice straw mulching with irrigation once in 15 days gave the highest fruit yield.

Mahey *et al.* (1986) in an experiment conducted at Punjab Agricultural University, Ludhiana showed that interaction effect of irrigation and mulching was significant on rhizome yield of turmeric. Paddy husk and wheat straw mulches where irrigation was scheduled at 40 mm CPE increased the rhizome yield at a greater magnitude as compared to those when irrigation was applied either 60 or 80 mm CPE. 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 20 per cent depletion gave highest yield followed by sawdust mulch with 40 per cent depletion. This was superior than paddy husk or paddy straw mulches with either 20 per cent or 40 per cent depletion.

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).

Tindall *et al.* (1991) in a sprinkler irrigation study revealed that irrigation increased the tomato yield with a straw mulch along with adopting daily or twice weekly irrigation.

According to Jagtap and Warhal (1993) the interaction effects of irrigation and mulching were not significant. However, the number of flower buds per cluster and percentage fruit retention in ber were higher in pitcher irrigation with sugarcane trash or sawdust mulch, while per cent fruit set and yield were more in normal irrigation with sawdust and sugarcane trash. In water melon variety Sugar Baby, Khade *et al.* (1995) found that mulching did not save irrigation water, but had a beneficial effect on yield for 40 mm CPE mulched treatment, compared with 40 mm CPE unmulched treatment.

Veeraputhiran (1996) in a study in cucumber found that the significant effect of moisture conservation materials on the growth attributes were pronounced only at closer intervals of irrigation and the effects were more pronounced after 45 DAS.

The above review indicates that presence of a moisture conservation technique may modify the effect of irrigation.

2.9 Soil moisture depletion pattern

The percentage of moisture use by the crop from different layers refers to the soil moisture depletion pattern.

According to Whitaker and Davis (1962), the root system of all economic cucurbits is extensive but shallow. They also found that root growth often equals or exceeds vine length laterally and is very rapid and extensive in the upper 12-18 inches of soil. Vittum and Flocker (1967) pointed out that cucurbits are with medium or deep root systems that require large amount of water. Under irrigation, the main root mass of water melon was in the 8.5-17 cm soil layer.

Zabara (1978) found that in irrigated cucumbers, the root distribution at bearing was 64.5 per cent at 0-10 cm depth, 28.5 cm per cent at 10-20 cm depth and 6.2 per cent at 20-30 cm depth. In the case of unirrigated cucumber the figures were 53.7 per cent at 0-10 cm, 29 per cent at 10-20 cm and 14.9 per cent at 20-30 cm.

The field experiment conducted at Agronomic Research Station, Chalakudy by Thomas (1984) revealed that bitter gourd depleted 42-48 per cent of total soil moisture from the top 15 cm soil layer. 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 regions, dry regions extracted more soil water from the lower soil layer. Radha (1985) also recorded similar observations.

Ells *et al.* (1989) in a four year study on scheduling irrigation for cucumber found that best combination of high yield and high water use efficiency was obtained by irrigating when 40 per cent of the available water was depleted. Bitter gourd extracted major part of the water from upper layers of soil irrespective of the irrigation treatments. More than 60 per cent of the squash roots were located in the top six inches of soil throughout the season (Ells *et al.*, 1994). In cucumber, the soil moisture depletion was higher from the top 15 cm of the soil layer. There was relatively more depletion from the lower depths in drier regimes (Veeraputhiran, 1996).

From the above works we can understand that most part of cucurbits roots are located in the top 0-30 cm layer of soil and the moisture extraction is found to be the highest from the upper layer of the soil profile.

2.10 Critical stages of growth

In irrigation scheduling, the concept of critical stages of the crop has also to be taken into consideration. Critical stage refers to the stage of the crop growth when soil water stress will have a lasting effect on crop growth and yield.

In cucumber the period between flowering and fruit ripening is considered to be critical for fruit development (Varga, 1973). During this period, it was necessary to supply the crop with 40 mm of water. But excessive water was found to be deleterious. Hammet *et al.* (1974) found that a constant supply of moisture is necessary during the growth of cucumbers especially during flowering and fruiting. Ware and Mc Collum (1980) found that the most critical period occurs at the time of flowering.

In gherkin cucumber, there was a marked reduction in the total and saleable crop when water was not available during early flowering and particularly during fruiting stage (Riley, 1990).

Irrigation from the start of flowering and at full bloom is particularly beneficial. Fruit enlargement also requires large supply of water. Drought during flowering results in deformed, nonviable pollen grains leading to poor yield (Hegde, 1993).

It can be seen from the above review that pre flowering, flowering and fruit development are the critical stages for cucumbers.

2.11 Soil moisture and nutrient uptake

Nutrient absorption is directly affected by the level of soil moisture, as well as indirectly by the effect of water on the metabolic activity of the plant, soil aliation and the salt concentration of the soil solution.

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

Sharma and Prasad (1973) found that N uptake of bhindi was higher with irrigation of soil moisture tension of 0-0.5 atm as compared to 0-0.25 and

0-0.75 atm respectively. They also reported that irrigation had failed to produce any significant effect on N content in plant parts.

Singh (1975) studied the effect of different soil moisture regimes along with graded doses of fertilizers on berseem fodder and he found that the percentage of N, P and K decreased with increase in moisture level from 25 per cent to 75 per cent. An increase in soil moisture level increased the total uptake of N significantly. The uptake of P and K also increased with water regimes, but did not reach the level of significance.

While evaluating the effect of soil moisture regimes of 25, 50 and 100 per cent available moisture on green gram, Varma and Subba Rao (1975) observed that a moisture regime of 50 per cent to be optimum for maximum N content in plant parts.

Kharkar and Deshmukh (1976) reported that in cotton and sorghum, the K uptake was increased with increase in the soil moisture upto a certain level beyond which it decreased. Reports from Carrasco and Puente (1979) showed that water stress in strawberries increased the leaf N concentration but decreased the P and K concentration.

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 (Gamayun, 1980). Balasubramanian and Yayock (1981) observed that moisture stress during peg and pod development stages in groundnut at 9 to 13 weeks after sowing lowered the uptake of N.

According to Panchalingam (1983), N, P and K content of leaves and uptake in brinjal become reduced as the soil water deficit increased. Swiader (1985) found that irrigated pumpkins accumulated more N, P and K than dryland pumpkin.

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

Hegde (1987a) showed that irrigating water melon 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. Srinivas *et al.* (1989) found that frequent irrigation with 100 per cent pan evaporation replenishment resulted in the highest N, P, K, Ca and Mg uptake in water melon. Veeraputhiran (1996) in a field study in cucumber revealed that N, P and K content of leaves were significantly higher in plants which received incorporation of paddy waste. Higher levels of irrigation also markedly increased the N and K content of leaves upto 45 DAS and P content upto 75 DAS.

From the review, we can realize that in general, higher soil moisture content leads to higher mineral uptake by plants.

2.12 Chemical composition and nutrient uptake

Fiskell and Breland (1967) found that the leaf K content of cucumber decreased sharply with increasing yield, but the leaf N content was not affected.

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 cucumber was 90, 12 and 145 lb per acre respectively and the nutrients removed by the harvested fruits were 40, 6 and 55 lb per acre respectively (Mc Collum and Miller, 1971). The percentage 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).

Wilrox (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.

The characterisation of nutrient uptake by musk melon grown in hydrophonic culture was studied by Kagohaski *et al.* (1978). They found that the rates of N uptake rose gradually before pollination, increased rapidly after pollination, remained high for about 15 days and then suddenly fell to pre-pollination levels. Total uptake of nitrate N was higher during the early stages while that of K was lower during the later stages of the plant cycle.

Laske (1979) in a study in domestic cucumbers, recorded the crop removal of 500 kg ha^{-1} N during the growing season. He noted that when N=1, the removal of $N:P_2O_5:K_2O$ was 1.0:0.4:2.0. Tesi *et al.* (1981) observed that nutrient requirements were greatest during fifteen days preceding the first harvest and during the subsequent fifteen days.

Thomas (1984) found that the N, P and K uptake of the crop followed a trend more or less similar to that of dry matter production at all the growth stages. Swader (1985) found that the concentration of N, P and K in foliage generally decreased as pumpkin's age increased. Hegde (1987b) observed that the concentration of all nutrients decline with fruit maturity in water melon.

Choliaras and Mavromatis (1991) in a study showed that K concentration of summer grown cucumber leaves and the corresponding soil samples were lower than the optimum level. Roppongi (1991) found that with the rapid growth of cucumbers, the optimum levels of nitrate N in petioles were 800-1200 ppm at the mid harvest and 100-300 ppm during the late stage of the harvest, while slower growth the optimum level was 1000-2000 ppm for all the stages.

In the studies conducted at Northern Territory, Australia using water melon, Smith (1991) observed that the peak N uptake occurred around 46 days after planting coinciding with fruitset and rapid increase in ground cover. The standard press sap composition of cucumber nitrate N was 1000-1600 mg^{-1} and for K it was 4000-5500 mg^{-1} (Drews and Fisher, 1992).

Petsas and Lulakis (1995) observed that in musk melon cv. Galia-71 in cold greenhouse, the production of approximately 5.2 kg fruit per plant, 10.97 g N, 2.6 g P, 21.20 g K, 15.06 g Ca and 4.68 g Mg per plant were taken by the plant. They also found that N, P, 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. Schacht and Schenk (1995) observed that 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.

2.13 Economics

One of our intentions of scheduling of irrigation is to reduce the cost involved in the cultivation as low as possible and to increase the economic product as high as possible. So utilization of each unit of water applied to the crop for getting maximum benefit is important. Calculation of cost-benefit ratio will be highly useful in determining the irrigation scheduling.

Thomas (1984) in a study conducted at Agronomic Research Station, Chalakudy on bitter gourd grown in summer rice fallow revealed that irrigation at the IW/CPE ratio of 1.2 recorded the maximum net return per rupee invested followed by IW/CPE ratio of 0.8.

The results of experiments of Jayakrishnakumar (1986) indicated that bhindi needed daily irrigation at Chalakudy condition for maximum yield, however, maximum profit was recorded when it was irrigated on attaining CPE values of 30 mm.

Water management and fertilizer studies conducted at the College of Agriculture, Vellayani showed that scheduling irrigation (5 cm depth) when the CPE value reached 25 mm was the most economic management for cucumber raised in summer rice fallows (KAU, 1991).

Rajagopal *et al.* (1989) in an experiment conducted in water melon and cucumber grown in summer rice fallows at the Regional Agricultural Research Station, Pilicode revealed that irrigation at IW/CPE ratio 0.5 had the maximum cost:benefit ratio for both the crops.

In a study conducted by Arunachalam (1987) coir waste application at 10 t ha^{-1} resulted in higher cost benefit ratio over mulching with sugarcane trashes, groundnut husk, maize cob pith, pearl millet straw and nonmulched control.

According to Channabasavanna *et al.* (1989), the use of polythene mulch in tomato cultivation caused a loss of Rs.1,443/- per ha where as the use of straw mulch gave a profit of Rs.2,986/- per ha over no mulch.

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). Incorporation of paddy waste, coir pith and saw dust 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 (Veeraputhiran, 1996). 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 0.08Mpa (Sunilkumar, 1998).

MATERIALS AND METHODS

MATERIALS AND METHODS

The present investigation was carried out to determine the irrigation requirement of water melon, variety Sugarbaby and to study to what extent the irrigation requirement of watermelon can be modified by soil moisture conserving methods. The experiment was conducted at the Agricultural Research Station, Mannuthy, Thrissur, Kerala during the period from December 1998 to March 1999. The details of the materials used and techniques adopted during the course of the investigation are briefly described below.

3.1 Site, climate and soil

The experimental area is situated at 10° 32' N latitude and 76° 10' E longitude and at an altitude of 22.5 m above the mean sea level. The area enjoys a typical warm humid tropical climate.

The weekly weather data for the cropping period obtained from the Department of Agricultural Meteorology, College of Horticulture, Vellanikkara are presented in Table 1 and Fig.1.

Composite soil samples from 0-60 cm depth taken before the commencement of the experiment were used for the determination of physiochemical properties and the data are presented in Table 2.

3.2 Cropping history

The experimental site is a double crop paddy wet land where every year a semidry crop during April-May to August-September and a wet crop during September-October to December-January were regularly cultivated. The land is usually left fallow during the summer season.

Table 1. Weekly weather parameters during the crop period (December 1998 – March 1999)

Standard week No.	Month and Date	Rainfall	Evapor-ation (mm)	Surface air temperature (°C)		Relative Humidity (%)		Sunshine Hours (h/day)
		Amount (mm)		Max.	Min.	Morning	Evening	
51	December 17 -23	0.0	29.3	31.4	22.4	79	57	8.6
52	December 24 - 31	0.0	40.8	31.1	22.0	76	40	8.2
1	January 1-7	0.0	39.5	31.9	21.8	75	45	9.4
2	January 8-14	0.0	34.8	32.5	21.9	79	43	9.5
3	January 15-21	0.0	48.2	32.2	22.8	70	40	10.0
4	January 22-28	0.0	41.2	32.5	19.5	74	32	7.9
5	January 29- February 4	0.0	31.5	33.9	22.1	83	39	10.1
6	February 5-11	22.8	35.8	34.0	23.4	80	44	9.2
7	February 12-18	0.0	43.9	34.7	23.2	79	39	10.0
8	February 19-25	0.0	53.0	34.2	24.5	70	33	6.9
9	February 26- March 4	0.0	53.4	36.4	22.2	74	33	10.4
10	March 5-11	0.0	40.6	36.5	23.8	92	34	9.9
11	March 12-18	0.0	34.2	35.2	25.0	89	54	8.4
12	March 19-25	0.0	31.7	34.8	25.0	91	55	8.4

Fig 1. Weather parameters during crop growth period

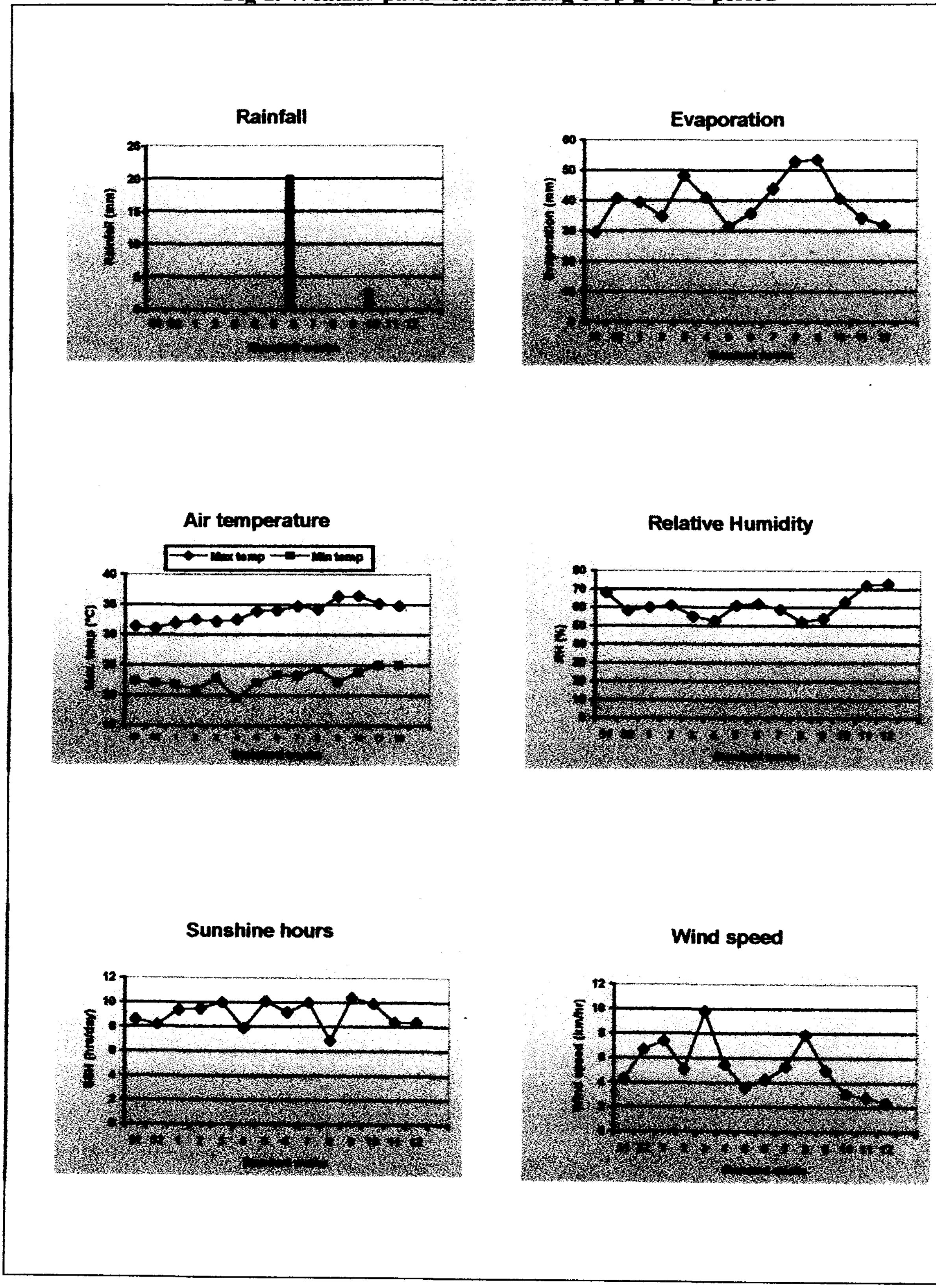
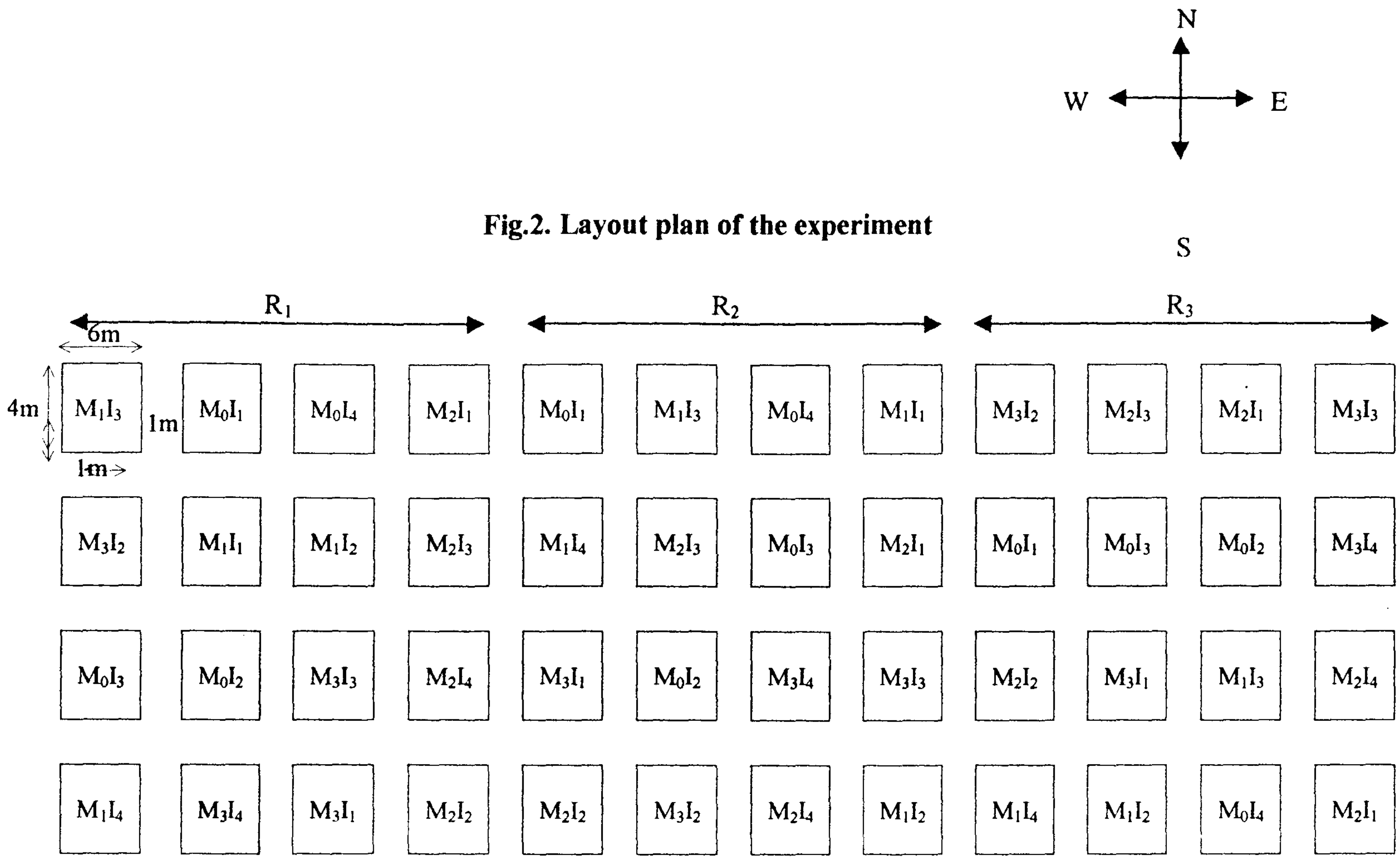


Table 2. Soil characteristics of the experimental site

Fraction	Per cent composition	Procedure adopted
1. Mechanical composition		
Course sand	26.44	Robinsons International
Fine sand	24.04	Pipette Method (Piper, 1950)
Silt	22.46	
Clay	27.31	
Texture class	Sandy clay loam	I.S.S.S. system
2. Physical constants of the soil		
Constant	Value	Procedure adopted
Field capacity (0.3 bars)	19.68%	Pressure plate apparatus (Richard, 1947)
Permanent wilting point (15 bars)	11.32%	,,
Bulk density (g cm^{-3})	1.34	Core method (Blake, 1965
Particle density (g cm^{-3})	2.16	Pymometer method (Blake, 1965)
3. Chemical properties		
Description of the properties	Value	Method employed
Organic carbon (%)	0.331	Walkley and Black rapid tiltration method (Jackson, 1958)
Available Nitrogen (kg ha^{-1})	233.8	Alkaline permanganate method (Subbiah and Asija, 1956)
Available phosphorus (kg ha^{-1})	39.2	Chlorostannous reduced molybdophosphorous blue colour method in hydrochloric acid system (Jackson, 1958)
Available potassium (kg ha^{-1})	112.8	Flame photometry, Neutral normal ammonium acetate extraction (Jackson, 1958)
Soil reaction (pH)	5.4	Soil water suspension of 1:2.5 using pH meter (Jackson, 1958)
Electrical conductivity (mmhos cm^{-1})	0.41	Supernatant of 1:2.5 soil:water suspension using EC bridge (Jackson, 1958)

Fig.2. Layout plan of the experiment



3.3 Crop and variety

Water melon, variety sugarbaby was used for this study. This variety is an American introduction. It's vines are medium long. The fruits are slightly smaller weighing on an average 2-5 kg, round having bluish black rind and deep pink flesh (TSS 11 to 13%) and brown small seeds.

3.4 Experimental technique

3.4.1 Layout

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

Design	: Randomised Block Design
Replications	: Three
Treatments	: Sixteen

<u>Notations</u>

A. Methods of application of paddy waste as moisture conserving material

Control - No application of paddy waste	M_0
Surface application of paddy waste @ 1/3 pit volume over the pit area	M_1
Uniform incorporation of paddy waste in the pit @ 1/3 pit volume by mixing with top soil used for filling	M_2
Application of paddy waste @ 1/3 pit volume as a bottom layer in the pit	M_3

B. Intervals of irrigation

Irrigation at IW/CPE ratio 0.6	I_1
Irrigation at IW/CPE ratio 1.0	I_2
Irrigation at IW/CPE ratio 1.4	I_3
Farmer's practice of daily irrigation @ 20 litres per pit	I_4

Number of treatments - sixteen (Combinations of 4 methods of application of moisture conserving material and 4 intervals of irrigation)

M_0I_1	M_1I_1	M_2I_1	M_3I_1
M_0I_2	M_1I_2	M_2I_2	M_3I_2
M_0I_3	M_1I_3	M_2I_3	M_3I_3
M_0I_4	M_1I_4	M_2I_4	M_3I_4

IW = 33 mm (50% of the available water of the rootzone taking the effective rootzone depth as 60 cm and effective radius of wetting as 75 cm)

Plot size	:	6 m x 4 m
Spacing	:	2 m x 3 m
Number of pits	:	4 pits per plot having 4 plants in each pit

3.5 Cultural practices

3.5.1 Land preparation

The land was ploughed well and then levelled. Plots of 6 m x 4 m size were taken leaving buffer strips of 1 m width all around the plot. Area inside each plot was scrupulously levelled and four pits of 60 cm depth and 60 cm diameter were taken at a spacing of 2 m x 3 m.

The pits were filled with top soil and the recommended quantity of farmyard manure at 10 kg per pit. Paddy waste @ 1/3 pit volume was applied according to the treatments mentioned above. Finally the basal dose of fertilizers were applied and mixed well with soil.

3.5.2 Sowing

The seeds were soaked overnight in water and sown on December 21^{st}, 1998. The seedlings were thinned to 4 plants per pit, three weeks after sowing.

3.5.3 Manures and fertilizer application

Farmyard manure at the rate of 20 t ha-1 was applied uniformly to all the plots as basal dose. Urea, mussoriephos and muriate of potash were used for supplying the nutrients and were applied as per package of practices recommendation of Kerala Agricultural University (1996) @ 70:25:25 kg N, P2O5 and K2O ha-1 respectively. Full doses of phosphorus and potassium and half of nitrogen were applied as basal dose at the time of sowing. The remaining dose of nitrogen was applied in two equal split doses at the time of vining and at the time of full blooming.

3.5.4 Irrigation

A pre sowing irrigation was given uniformly to all pits. There after light irrigations with rose cans were given till the seeds germinated. Uniform irrigation at the rate of 6 litres per pit per day was given for first 10 days and 10 litres of water per pit was given for the next 10 days after germination of seeds. From 21st day onwards irrigations were scheduled when the cumulative pan evaporation values attained 24 mm, 33 mm and 55 mm respectively for the IW/CPE ratios of 1.4, 1.0 and 0.6. For the treatment I_4, 20 litres of water was applied per pit per day till the end of the experiment.

The amount of water applied per pit was calculated by taking the effective radius of wetting and depth of root zone as 75 cm and 60 cm respectively. Based on these values, the volume of water to be applied to bring the soil to field capacity was calculated (it was 58 litres per irrigation). Pot watering was adopted in all the case. The details of irrigation are presented in Table 3.

Table 3. Details of the irrigation treatments

Treatments	Total number of irrigation	Interval of irrigation (days)	Quantity of water applied (mm)	Pre-treatment irrigation (mm)	Effective R.F. (mm)	Total quantity of water applied
I_1	6	9-11	198	85.1	23.40	306.50
I_2	8	5-7	264	85.1	11.30	360.40
I_3	10	3-6	330	85.1	21.48	436.58
I_4	42	Daily irrigation	477	85.1	22.60	584.70

3.5.5 After cultivation

The pits were kept weed free throughout the crop growth period. When the plants started to vine, the interspaces between the plants were mulched with dried coconut leaves.

3.5.6 Plant protection

Serpentine leaf miner attack was severe at initial stages and was controlled by application of Dimethoate @ 0.2%. At the beginning of the fruiting stage, attack of red pumpkin beetle was observed and it was controlled by the application of carbaryl 0.15 per cent spray.

3.5.7 Harvesting

The fruits were harvested when they were fully matured. The maturity was judged by visual appearance. The harvesting was completed by 85 days after sowing.

3.6 Soil moisture studies

3.6.1 Soil sampling

Soil samples were collected from one replication at three depths, 0 to 15 cm, 15-30 cm and 30-60 using an auger, at a distance of 10-15 cm away from the base of the plant. Soil samples were collected before and 48 hrs after irrigation.

Moisture estimations were made by gravimetric method and expressed as percentage on oven dry basis.

3.6.2 Consumptive use

The consumptive use of water by the crop under different treatments was worked out using the formula described by Michael (1978).

$$U = \sum_{i=1}^{n} \frac{M1i - M2i}{100} AiDi$$

where

U = water use from the root zone for successive sampling periods or within one irrigation cycle, mm.

n = number of soil layers sampled in the root zone depth D.

M1i = Soil moisture percentage after irrigation in the i^{th} layer

M2i = Soil moisture percentage before irrigation in the i^{th} layer

A = Apparent specific gravity of the i^{th} layer of the soil

D = Depth of i^{th} layer of soil, mm

Following each irrigation, soil moisture determination was done after 48 hrs. For this period PET obtained by multiplying pan evaporation value with crop factor 0.6 was taken for the calculation of consumptive use (Dastane, 1972). The effective rainfall determined based on the soil moisture content and the PET were also taken into account for computing consumptive use.

3.6.3 Soil moisture depletion pattern

The average relative soil moisture depletion from each soil layer in the root zone was worked out upto 60 cm for each irrigation interval. The PET values for the 48 hrs after each irrigation, extrapolated from the class-A pan evaporation data were added to the depletion in the first layer and total loss from each layer was determined on percentage basis at the end of the period.

3.6.4 Field water use efficiency (WUE) and crop WUE were computed using the following formulae and are expressed as kg $hamm^{-1}$

$$\text{Field WUE} = \frac{\text{Fruit yield (kg ha}^{-1}\text{)}}{\text{Total water applied (mm)}}$$

$$\text{Crop WUE} = \frac{\text{Fruit yield (kg ha}^{-1}\text{)}}{\text{Consumptive use (mm)}}$$

3.7 Biometric observations

3.7.1 Length of vine

The length of vine was recorded from three plants selected at random per plot at 30, 60 and 75 DAS. The length of main vine was measured from the base to the growing tip of the vine and the mean length of vine per plant was worked out.

3.7.2 Number of leaves per vine

The total number of leaves were recorded from three plants per plot at 30, 60 and 75 DAS. Finally mean number of leaves per vine was worked out.

3.7.3 Dry matter production

Dry matter content of the vegetative parts was recorded at the time of harvest. Two plants per plot were randomly chosen and cut close to the ground and kept in an oven at 80±5°C to a constant weight. The dry matter content was expressed as g $plant^{-1}$.

3.7.4 Leaf area

A set of leaves of varying maximum width was picked and measured in a leaf area meter. For each maximum width of leaves, leaf area was worked out by averaging five leaves. The leaves were grouped into two or three based on the maximum width. The average leaf area for each category was worked out and multiplied by the number of leaves to get the leaf areas of all categories and was divided by total number of leaves per plant to get the average leaf area. The average leaf area was worked out at three stages, viz., 30, 60 and 75 DAS.

3.7.5 Days to first flowering

The number of days taken by the first female flower to open from the date of sowing was recorded.

3.7.6 Volume of fruit

Volume of fruits from each plot was found out using water displacement method and the averages for four fruits worked out.

3.7.7 Mean weight of fruit

Weight of four fruits harvested from each plot from the various harvests was recorded and the mean weight was determined.

3.7.8 Yield of fruits

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

3.7.9 Sugar content

The non reducing sugars of samples were hydrolysed to reducing monosaccharide by treating with dilute acids. The total reducing sugars were estimated by titration with Fehlings solution.

3.7.10 TSS

Total soluble solids of the fruits were estimated using a pocket refractometer and the average for four fruits worked out.

3.8 Plant analysis

Leaf samples (3rd matured leaf from the tip of the vine) were collected at three stages of crop growth viz., 30, 60 and 75 DAS. Samples were oven dried at 80±5°C, ground and used for N, P, K analysis.

a) Nitrogen content

The total nitrogen content of leaf sample was determined by Microkjeldahl method (Jackson, 1958).

b) Phosphorus content

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

c) Potassium content

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

3.9 Statistical analysis

Data obtained were subjected to statistical scrutiny by applying the analysis of variance technique and significance was tested by 'F' test (Snedecor and Cochran, 1967).

RESULTS

RESULTS

The results of the experiment are furnished in this chapter.

4.1 Growth attributes

4.1.1 Vine length

The mean values of the length of main vine recorded at 30, 60 and 75 days after sowing (DAS) are presented in Table 4 and its analysis of variance in Appendix I.

The main effects of irrigation scheduling and moisture conservation methods (MCM) along with their interactions were found to be significant except at 30 DAS. At 30 DAS, main effect of MCM, was not significant on vine length.

At 60 DAS, surface application of paddy waste @ 1/3 pit volume over the pit area (M_1) recorded the maximum vine length but was at par with the uniform incorporation of paddy waste (M_2). The lowest value was recorded by the control plots (M_0) and was significantly inferior to the other treatments.

At 75 DAS, the vine length was maximum with uniform incorporation of paddy waste in the pit (M_2), but was at par with surface application of paddy waste and application of paddy waste as bottom layer in the pit. It can be concluded that after the initial growth stage of 30 DAS, vines length were more and almost equal in paddy waste surface mulched and uniformly incorporated treatments followed by bottom applied treatments. Control plots was always inferior to MCM applied plots.

Among the irrigation treatments, farmer's practice of daily irrigation (I_4) produced significantly the highest vine length at all the three stages of observation. The second best treatment was irrigation at IW/CPE ratio of 1.4 (I_3) and was significantly superior to irrigation treatments at IW/CPE ratio 1 (I_2) and 0.6 (I_1).

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Table 4. Length of vines (cm) as influenced by main effects of MCM and irrigation

Treatments	30 DAS	60 DAS	75 DAS
MCM			
M_0	67.93 [a]	256.05 [c]	266.04 [b]
M_1	67.45 [a]	290.26 [a]	291.34 [a]
M_2	68.59 [a]	288.38 [ab]	291.54 [a]
M_3	68.06 [a]	279.02 [b]	282.87 [a]
SEm±	0.28 NS	3.54 Sig.	3.43 Sig.
Irrigation			
I_1	61.94 [d]	220.68 [d]	224.19 [d]
I_2	64.59 [c]	275.47 [c]	279.04 [c]
I_3	67.61 [b]	301.13 [b]	304.29 [b]
I_4	77.88 [a]	316.44 [a]	324.27 [a]
Sem± Interaction	0.28 Sig.	3.54 Sig.	3.43 Sig.

MCM – Moisture conservation methods

DAS – Days after sowing

Table 4a. Mean length of vines (cm) at 30 DAS under MCM and irrigation treatments.

Treatments	M_0	M_1	M_2	M_3
I_1	61.4 [a]	62.3 [a]	62.2 [a]	61.9 [a]
I_2	65.2 [a]	64.1 [b]	65.8 [a]	63.3 [b]
I_3	70.3 [a]	63.3 [c]	68.8 [b]	68.1 [b]
I_4	74.9 [b]	80.1 [a]	77.7 [ab]	78.9 [a]
SEm±	0.579			

Table 4b. Mean length of vines (cm) at 60 DAS under MCM and irrigation treatments.

Treatments	M_0	M_1	M_2	M_3
I_1	232.7 [a]	250.0 [a]	192.7 [b]	207.4 [b]
I_2	242.9 [b]	284.5 [a]	291.9 [a]	282.6 [a]
I_3	255.1 [b]	320.7 [a]	313.5 [a]	315.3 [a]
I_4	293.5 [b]	305.9 [b]	355.5 [a]	310.9 [b]
SEm±	7.08			

Table 4c. Mean length of vines (cm) at 75 DAS under MCM and irrigation treatments.

Treatments	M_0	M_1	M_2	M_3
I_1	237.2 [a]	254.3 [a]	197.2 [a]	208.1 [b]
I_2	253.1 [b]	286.4 [a]	291.8 [a]	284.9 [a]
I_3	263.6 [b]	314.6 [a]	316.6 [a]	322.4 [a]
I_4	310.3 [b]	310.1 [b]	360.7 [a]	316.1 [b]
SEm±	6.87			

The lowest value was observed when water melon was irrigated at IW/CPE ratio of 0.6 (I_1) and its effect was significantly inferior to all the other treatments at all the above stages. The results have clearly indicated the superiority of farmer's practice of daily irrigation on vine length of watermelon.

At 30 DAS, when irrigation were scheduled at IW/CPE ratio of 0.6, 1.0 and 1.4, none of the mulched plots produced significantly more vine length over unmulched treatment, M_0. When the crop was daily irrigated, the situation changed. With daily irrigation @ 20 lit pit^{-1} (I_4), the highest vine length was observed in surface mulched (M_1) plots and was on par with M_2 and M_3 and significantly superior to control.

At 60 and 75 DAS length of vines followed similar trend in every treatment. When irrigation was scheduled at IW/CPE ratio 0.6, M_1 recorded the highest vine length which was on par with control and significantly superior to M_2 and M_3. At IW/CPE ratio 1.0 (I_2), M_2 recorded the highest vine length followed by M_1 and M_3. Mulched plots recorded significantly higher vine length than control plots. Recorded values of vine length of M_1, M_2 and M_3 were at par when irrigation was scheduled at IW/CPE ratio of 1.4 (I_3) both at 60 and 75 DAS and these were significantly superior to M_0. With daily irrigation @ 20 lit pit^{-1} (I_4), the maximum vine length was recorded by uniform incorporation of mulch material (M_2) and it was significantly superior to all other mulch treatments which were on par with control at both the stages.

4.1.2 Number of leaves

The data relating to the number of leaves of the main vine are given in Table 5 and the analysis of variance in Appendix II.

At 30 DAS, moisture conservation methods and irrigation scheduling significantly influenced the number of leaves per vine. But the interaction was not significant.

Table 5. Number of leaves per main vine as affected by main effects of MCM and irrigation.

Treatments	30 DAS	60 DAS	75 DAS
MCM			
M_0	8.7 [b]	31.5 [a]	29.7 [a]
M_1	9.6 [ab]	31.9 [a]	29.0 [a]
M_2	9.7 [ab]	33.1 [a]	31.2 [a]
M_3	10.9 [ab]	32.2 [a]	30.4 [a]
SEm±	0.4 Sig.	0.7 NS	0.7 NS
Irrigation			
I_1	8.4 [a]	28.2 [b]	25.9 [c]
I_2	9.4 [a]	27.6 [b]	25.7 [c]
I_3	10.3 [a]	35.8 [a]	33.1 [b]
I_4	10.7 [a]	37.0 [a]	35.6 [a]
SEm± Interaction	0.4 NS	0.7 Sig.	0.7 Sig.

Table 5a. Mean number of leaves per main vine under MCM and irrigation treatments at 60 DAS

Treatments	M_0	M_1	M_2	M_3
I_1	32.2 [a]	27.4 [b]	26.4 [b]	27.0 [b]
I_2	27.8 [a]	29.1 [a]	28.6 [a]	25.3 [a]
I_3	30.4 [b]	36.2 [a]	37.7 [a]	39.0 [a]
I_4	35.7 [b]	34.9 [b]	40.0 [a]	37.8 [ab]
SEm±	1.45			

Table 5b. Mean number of leaves per main vine under MCM and irrigation treatments at 75 DAS

Treatments	M_0	M_1	M_2	M_3
I_1	29.3 [a]	24.4 [a]	24.4 [a]	25.5 [a]
I_2	25.9 [a]	26.5 [a]	27.8 [a]	22.8 [a]
I_3	29.0 [b]	31.7 [b]	34.8 [a]	37.2 [a]
I_4	34.8 [ab]	33.6 [b]	38.1 [a]	36.1 [ab]
SEm±	1.40			

Application of paddy waste as a bottom layer in the pit (M_3) recorded the maximum number of leaves and was on par with the applications of same volume of paddy waste as surface mulch (M_1) or uniform mixing in the pit (M_2). Leaf number per vine was the lowest in the control plot and was significantly inferior to M_3.

At 60 DAS, the effects of none of the MCMs were significantly different. However uniform incorporation of paddy waste in the pit (M_2) recorded the highest value followed by application of the same volume of paddy waste at the bottom of the pit (M_3).

At 75 DAS also, the maximum value was recorded by the uniform incorporation of paddy waste in the pit (M_2) followed by application of same volume of paddy waste as a bottom layer in the pit (M_3). The lowest value was recorded by surface mulching of paddy waste (M_1) but was on par with M_0 and M_3.

Among the irrigation treatments, farmer's practice of daily irrigation recorded the highest leaf number per vine at all the three stages of observations, followed by irrigation at IW/CPE ratio 1.4.

At 30 DAS, the effect of farmer's practice of daily irrigation was on par with that of irrigation at IW/CPE ratio of 1 and 1.4; at 60 DAS on par with irrigation at IW/CPE ratio of 1.4 and at 75 DAS, farmer's practice of daily irrigation emerged to be significantly the best. Irrigation at the widest interval i.e., IW/CPE ratio of 0.6 (I_1) recorded the lowest values and was significantly inferior to farmer's practice (I_4) and irrigations at IW/CPE ratio of 1.4 (I_3) at 60 and 75 DAS.

Influence of mulch on irrigation was significant both at 60 and 75 DAS. At 60 DAS, when irrigation was scheduled at IW/CPE ratio 0.6, the effect of mulching was significantly inferior to control. No superiority of mulching over control was observed when the crop was irrigated at IW/CPE ratio 1.0. When the crop was irrigated at IW/CPE ratio 1.4, mulches had superiority over control and the highest value was observed with bottom layer mulch application and it was on par with M_1 and M_2 and significantly superior to control. When watermelon was irrigated daily @ 20 lit pit^{-1} maximum number of leaves were observed with uniform mulch incorporation (M_2) and it was on par with M_3 and significantly superior to M_1 and M_0.

At 75 DAS both at IW/CPE ratio 0.6 and 1.0 the effects of mulching did not vary significantly over control. At IW/CPE ratio 1.4, maximum number of leaves were produced in M_3 which was on par with M_2 and significantly superior to M_1 and M_0. When watermelon was irrigated daily @ 20 lit pit^{-1}, number of leaves were produced by M_2 which was on par with M_3 and M_0.

4.1.3 Dry matter production at harvest

The dry matter production per plant worked out at the time of harvest is presented in Table 6 and the analysis of variance in Appendix III.

The main effects of moisture conservation methods, irrigation and their interaction were significant on dry matter production.

The surface of mulching of paddy waste and uniform incorporation of paddy waste in the pit produced high dry matter and they were on par. Dry matter production was the lowest in control plots and was significantly inferior to the above treatments.

Irrigation treatments had a significant influence on dry matter production. The plants that received daily irrigation by farmer's practice of 20 lit/pit (I_4) on the average produced the highest dry matter which was significantly superior to all other irrigation levels. It was followed by irrigation at IW/CPE ratio 1.4 (I_3) which was also significantly superior to irrigation at IW/CPE ratio 1.0 and

Table 6. Dry matter production at harvest as influenced by main effects of MCM and irrigation (g/plant).

Treatments	Drymatter (g/plant)
MCM	
M_0	73.9 [b]
M_1	80.3 [a]
M_2	79.3 [a]
M_3	76.8 [ab]
Irrigation	
I_1	58.9 [d]
I_2	70.6 [c]
I_3	87.1 [b]
I_4	93.8 [a]
SEm±	1.3
Interaction	Sig.

Table 6a. Mean dry matter production at harvest under MCM and irrigation treatments.(g/plant)

Treatments	M_0	M_1	M_2	M_3
I_1	65.5 [a]	65.1 [a]	51.8 [b]	53.3 [b]
I_2	62.9 [b]	71.4 [a]	77.3 [a]	70.9 [a]
I_3	77.8 [b]	93.2 [a]	85.6 [ab]	92.2 [a]
I_4	89.8 [b]	91.6 [ab]	102.7 [a]	91.0 [ab]
SEm±	2.63			

0.6. Dry matter production was significantly the lowest in plots which received irrigation at the widest interval dictated by the IW/CPE ratio 0.6.

At the widest interval of irrigation at IW/CPE ratio 0.6, the maximum dry matter production was observed with control which was on par with surface application of paddy waste. As the interval of irrigation was reduced the effect of mulches became more pronounced. At IW/CPE ratio of 1, the highest dry matter production was recorded by M_2 which was on par with M_1, M_3 and significantly superior to control. At IW/CPE ratio 1.4, the highest dry matter production was recorded by M_1 which was on par with M_2 and M_3 and significantly superior to control. With daily irrigation, the effects of mulched treatments were superior to control. The highest dry matter production was noted in M_2 followed by M_1.

4.1.4 Leaf Area

The data on the average leaf area are given in Table 7 and the analysis of various in Appendix IV.

Moisture conservation methods, irrigation treatments and their interaction had significant effect on the leaf area at 30, 60 and 75 DAS.

At all the three stages of observations, surface application of paddy waste (M_1) recorded on the average the maximum leaf area which was significantly superior to all other treatments. The effects of all the other moisture conservation techniques including M_0 were on par.

With respect to irrigation, the maximum leaf area was recorded by farmer's practice of daily irrigation and it was on par with irrigation at IW/CPE ratio of 1.4. The effect of these treatments were significantly superior to I_1 and I_2 at 30, 60 and 75 DAS. The effects of I_1 and I_2 were on par.

Table 7. Leaf area as influenced by main effects of MCM and irrigation (cm^2).

Treatments	30 DAS	60 DAS	75 DAS
MCM			
M_0	30.05 [b]	49.57 [b]	35.33 [b]
M_1	35.13 [a]	55.39 [a]	40.88 [a]
M_2	28.92 [b]	48.16 [b]	35.44 [b]
M_3	29.81 [b]	49.58 [b]	37.11 [b]
Irrigation			
I_1	25.16 [b]	44.49 [b]	30.88 [b]
I_2	26.37 [b]	46.6 [b]	33.55 [b]
I_3	35.13 [a]	54.69 [a]	41.54 [a]
I_4	37.25 [a]	56.91 [a]	42.93 [a]
SEm±	1.238	1.224	1.072
Interaction	Sig.	Sig.	Sig.

Table 7a. Mean leaf area (cm^2) under MCM and irrigation treatments at 30 DAS.

Treatments	M_0	M_1	M_2	M_3
I_1	27.9^{a}	24.3^{a}	22.9^{a}	25.5^{a}
I_2	25.1^{a}	25.3^{a}	25.0^{a}	30.1^{a}
I_3	36.6^{ab}	42.5^{a}	32.7^{bc}	28.8^{c}
I_4	30.5^{b}	48.5^{a}	35.1^{b}	34.9^{b}
SEm±	1.238			

Table 7b. Mean leaf area (cm^2) under MCM and irrigation treatments at 60 DAS

Treatments	M_0	M_1	M_2	M_3
I_1	42.9^{a}	45.7^{a}	43.7^{a}	45.7^{a}
I_2	48.4^{a}	47.2^{a}	42.1^{a}	48.7^{a}
I_3	55.8^{b}	61.2^{a}	53.0^{bc}	48.7^{c}
I_4	51.2^{b}	67.4^{a}	53.8^{ab}	55.2^{ab}
SEm±	2.448			

Table 7c. Mean leaf area (cm^2) under MCM and irrigation treatments at 75 DAS

Treatments	M_0	M_1	M_2	M_3
I_1	29.1^{a}	31.4^{a}	31.5^{a}	31.6^{a}
I_2	33.2^{bc}	33.6^{b}	30.4^{c}	37.1^{a}
I_3	41.2^{b}	46.9^{a}	39.8^{b}	37.7^{b}
I_4	37.9^{a}	51.7^{a}	40.2^{a}	42.0^{a}
SEm±	2.144			

The influence of mulching on levels of irrigation was significant at 30, 60 and 75 DAS. At 30 DAS, the influence of mulching was not significant over control when irrigation was scheduled at IW/CPE ratio of 0.6 and 1.0. At IW/CPE ratio 1.4, the highest leaf area was observed with M_1 which was on par with control and significantly superior to M_2 and M_3. When the plants were irrigated daily @ 20 lit pit^{-1}, M_1 recorded the highest leaf area which was significantly superior to all other treatments which were on par.

At 60 DAS also the influence of mulched plots were not significantly superior to control when the crop was irrigated at IW/CPE ratio of 0.6 and 1.0. At IW/CPE ratio 1.4, significantly the highest leaf area was observed with M_1. When the crop was irrigated daily @ 20 lit pit^{-1} mulching had a significant influence over control. Highest leaf area was recorded by M_1 and was at par with M_2 and M_3.

75 DAS, when irrigation was scheduled at IW/CPE ratio 0.6, mulching had no impact on leaf area. At IW/CPE ratio 1.0, significantly the highest leaf area was observed with M_3. When irrigation was scheduled at IW/CPE ratio 1.4, the highest leaf area was recorded by M_1 which was statistically superior to all other treatments which were on par. With daily irrigation @ 20 lit pit^{-1} the influence of none of the mulching methods were significant over control.

4.2 Chemical composition of leaves

4.2.1 Nitrogen content

The data on the total nitrogen content of leaves at 30, 60 and 75 DAS expressed as percentage on dry weight basis are presented in Table 8 and the analysis of variance in Appendix V.

Main effects of both moisture conservation methods and levels of irrigation were significant with regard to the nitrogen content of leaves at 30, 60 and 75 DAS except at 60 DAS where MCM had no significant effect on nitrogen content of leaves.

Table 8. Nitrogen content of leaves (%) as affected by main effects of MCM and irrigation

Treatments	30 DAS	60 DAS	75 DAS
MCM			
M_O	3.06 [c]	3.92 [a]	4.21 [a]
M_1	3.14 [b]	3.90 [a]	4.07 [ab]
M_2	3.23 [a]	3.91 [a]	3.94 [b]
M_3	3.11 [bc]	3.87 [a]	4.04 [b]
SEm±	0.022	0.033	0.048
Irrigation			
I_1	3.00 [c]	3.86 [b]	4.12 [ab]
I_2	3.02 [c]	3.70 [c]	3.99 [bc]
I_3	3.19 [b]	3.94 [b]	3.96 [c]
I_4	3.34 [a]	4.10 [a]	4.20 [a]
SEm±	0.022	0.033	0.048
Interaction	Sig.	NS	Sig.

Table 8a. Mean Nitrogen content (%) under main effects of MCM and irrigation treatments at 30 DAS

Treatments	M_0	M_1	M_2	M_3
I_1	2.99 [a]	2.99 [a]	2.99 [a]	3.03 [a]
I_2	2.99 [ab]	3.00 [ab]	2.96 [b]	3.13 [a]
I_3	3.07 [bc]	3.30 [ab]	3.39 [a]	3.00 [c]
I_4	3.20 [b]	3.29 [ab]	3.58 [a]	3.29 [ab]
SEm±	0.044			

Table 8b. Mean Nitrogen content (%) under main effects of MCM and irrigation treatments at 75 DAS

Treatments	M_0	M_1	M_2	M_3
I_1	4.28 [ab]	4.43 [a]	3.71 [c]	4.06 [b]
I_2	4.10 [a]	3.87 [b]	3.94 [ab]	4.04 [ab]
I_3	4.27 [a]	330 [b]	3.99 [ab]	3.99 [ab]
I_4	4.27 [a]	3.29 [a]	4.11 [a]	4.06 [a]
SEm±	0.097			

At 30 DAS, uniform incorporation paddy waste (M_2) recorded the highest N content which was statistically superior to all other treatments. It was followed by surface (M_1) and bottom layer application of paddy waste (M_3) which were on par. The lowest value was recorded by control plots (M_0) which was on par with bottom layer application of paddy waste. At 75 DAS, the highest N content was observed in control plots (M_0) which was on par with surface mulch with paddy waste (M_1). The value of N content in M1 was on par with that of uniformly incorporated plots (M_2) and bottom layer applied (M_2) plots.

Regarding irrigation treatments, different levels of irrigation had significant effect on the N content at all the three stages of observation. Nitrogen content was significantly the highest in I_4 at all the three stages of observation except at 75 DAS where I_1 was at par with I_4. Both at 30 and 60 DAS, I_3 recorded the second highest N content in leaves. It was significantly superior to I_1 and I_2 at 30 DAS and at par with I_1 at 60 DAS. However, at 75 DAS, the leaf nitrogen content was the lowest with I_3. Leaf nitrogen contents were the lowest at 30 and 60 DAS when the crop was irrigated at the wider intervals of I_1 and I_2. However, at 75 DAS leaf N content with I_1 was the second highest and statistically at par with I_4 and I_2.

Influence of mulch on irrigation was significant at 30 and 75 DAS. At 30 DAS, when the irrigation was scheduled at IW/CPE ratio 0.6, influence of mulching was not significant over control. When the irrigation was applied at IW/CPE ratio 1.0, the highest N content was noticed with M_3 which was on par with control and M_1. At IW/CPE ratio 1.4, the highest N content was recorded by M_2 which was on par with M_1 and significantly superior to M_0 and M_3. When the crop was irrigated daily, the highest value of N was observed with M_2 which was on par with M_1 and M_3 and statistically superior than control. At 75 DAS, at all the irrigation levels, the nitrogen contents of control plots were on par with the mulched treatments with the highest nitrogen content.

4.2.2 Phosphorus content

The data on the P content of leaves at 30, 60 and 75 DAS are presented in Table 9 and the analysis of variance in Appendix VI.

The effect of moisture conservation on P content of leaves was not significant at any of the stages of observation.

Regarding irrigation it was significant at 30 and 60 DAS. Farmer's practice of daily irrigation helped in the accumulation of higher P in leaves at the different stages of observation. Both at 30 and 60 DAS, leaf P content was significantly the highest in I_4 and the second highest at 75 DAS and was at par with I_2 which recorded the highest value. Second highest leaf P content was observed in I_3 both at 30 and 60 DAS. It was significantly superior to I_1 and I_2 at these stages and significantly superior to I_1 at 75 DAS. Leaf P content was the lowest in I_1 and I_2. Only exception was at 75 DAS, where I_2 recorded the highest leaf P content.

The interaction effect between MCM and irrigation on P content of leaves was not significant at any of the stages of observation.

4.2.3 Potassium content

The data on the K content of leaves at 30, 60 and 75 DAS are presented in Table 10 and the analysis of variance in Appendix-VII.

Moisture conservation methods had no significant influence on the K content of the leaves at any of the stages of observations. Different levels of irrigation had influence on the K content at 30 DAS and 75 DAS. Farmer's practice of daily irrigation recorded the maximum K content at all stages of observation, which was significantly superior to all other treatments at 30 DAS, statistically at par with all treatments at 60 DAS and significantly superior to I_1 and I_2 at 75 DAS. It was followed by irrigation at IW/CPE ratio 1.4 (I_3) which was statistically superior to I_1 and I_2 at 30 and 75 DAS and at par with all treatments at

Table 9. Main effects of MCM and irrigation on P content of leaves (%)

Treatments	30 DAS	60 DAS	75 DAS
MCM			
M_O	0.18 [a]	0.23 [a]	0.21 [a]
M_1	0.18 [a]	0.23 [a]	0.22 [a]
M_2	0.18 [a]	0.23 [a]	0.21 [a]
M_3	0.17 [a]	0.25 [a]	0.21 [a]
SEm±	0.0011	0.0011	0.0011
Irrigation			
I_1	0.16 [d]	0.23 [c]	0.20 [c]
I_2	0.17 [c]	0.22 [d]	0.22 [a]
I_3	0.18 [b]	0.24 [b]	0.21 [b]
I_4	0.19 [a]	0.26 [a]	0.22 [a]
SEm±	0.001	0.001	0.001
Interaction	NS	NS	NS

Table 10. Main effects of MCM and irrigation on K content of leaves (%)

Treatments	30 DAS	60 DAS	75 DAS
MCM			
M_O	1.80 [a]	1.93 [a]	1.86 [a]
M_1	1.80 [a]	2.09 [a]	1.85 [a]
M_2	1.80 [a]	1.98 [a]	1.85 [a]
M_3	1.81 [a]	1.99 [a]	1.85 [a]
SEm±	0.0193	0.0661	0.025
Irrigation			
I_1	1.73 [c]	1.88 [a]	1.76 [b]
I_2	1.65 [d]	1.94 [a]	1 .78 [b]
I_3	1.89 [b]	2.08 [a]	1.92 [a]
I_4	1.95 [a]	2.09 [a]	1.95 [a]
SEm±	0.019	0.066	0.025
Interaction	NS	NS	NS

60 DAS. The lowest K contents were recorded at IW/CPE ratios of 0.6 and 1 and were statistically inferior to I_3 and I_4 at 30 and 75 DAS and on par with I_3 and I_4 at 60 DAS.

The interaction between MCM and levels of irrigation did not show any significant effect on leaf K content at any of the stages of observation.

4.3 Days to first flowering

The data on the days to first flowering is given in Table 11 and analysis of variance in Appendix VIII.

Main effect of moisture conservation methods on the days to first flowering was not significant. However, effect of irrigation on the number of days to first flowering was significant. Farmer's practice of daily irrigation recorded significantly lowest number of days to first flowering followed by irrigation at IW/CPE ratio 1.4 and IW/CPE ratio 1. Significantly the highest number of days to first flowering was recorded by irrigation at IW/CPE ratio 0.6.

Table 11. Days to first flowering as influenced by main effects of MCM and irrigation.

Treatments	Days taken for first flowering
MCM	
M_0	30.3 [a]
M_1	30.6 [a]
M_2	30.6 [a]
M_3	30.4 [a]
SEm±	0.106
Irrigation	
I_1	32.9 [a]
I_2	31.9 [b]
I_3	29.1 [c]
I_4	28.1 [d]
SEm±	0.106
Interaction	NS

The interaction effect between MCM and irrigation did not show any significance on the number of days to first flowering.

4.4 Yield attributes

4.4.1 Number of fruits per plant

The data on the number of fruits/plant is given in Table 12 and analysis of variance in Appendix VIII.

The main effects of irrigation and moisture conservation methods were significant on the number of fruits per plant.

All the mulching treatments had more number of fruits per plant than that of the control.

Among the irrigation treatments farmer's practice of daily irrigation (I_4) produced the highest number of fruits per plant which was on par with irrigation at IW/CPE ratio of 1.4 (I_3) and both these treatments were significantly superior to I_2 and I_1 which were on par.

The interaction between the moisture conservation methods and intervals of irrigation was not significant.

4.4.2 Volume of fruit

The data on the volume of fruit are presented in Table 12 and analysis of variance in Appendix VIII.

Main effects of both moisture conservation methods and irrigation was significant on the volume of fruit.

Among the moisture conservation methods, control plots recorded the maximum volume of fruit and it was significantly superior to all mulched treatments. The effects of all mulch applied treatments were on par.

Table 12. Main effects of MCM and irrigation on volume of fruit (cm^3), Mean weight (kg) and Number of fruits/plant.

Treatments	Volume of fruit (cm^3)	Mean weight (kg)	Number of fruits/plant
MCM			
M_0	1591 ^{a}	1.25 ^{c}	1.4 ^{b}
M_1	1210 ^{b}	1.66 ^{a}	1.8 ^{a}
M_2	1417 ^{b}	1.50 ^{b}	1.8 ^{a}
M_3	1428 ^{b}	1.48 ^{b}	1.6 ^{a}
Sem±	49.47	0.052	0.059
Irrigation			
I_1	1785 ^{a}	1.15 ^{b}	1.4 ^{b}
I_2	1154 ^{b}	1.21 ^{b}	1.5 ^{b}
I_3	1606 ^{b}	1.84 ^{a}	1.8 ^{a}
I_4	1785 ^{b}	1.69 ^{a}	1.9 ^{a}
SEm±	49.47	0.052	0.059
Interaction	NS	NS	NS

Regarding irrigation, IW/CPE ratio of 0.6 (I_1) recorded the highest volume of fruit and it was significantly superior to I_2, I_3 and I_4. The effect of I_2, I_3 and I_4 were on par.

The interaction effect between MCM and irrigation was not significant.

4.4.3 Mean weight of fruit

The data on the mean weight of fruit is presented in Table 12 and analysis of variance in Appendix VIII.

Main effects of moisture conservation methods and irrigation was significant on the mean weight of fruit.

Among the moisture conservation methods surface mulching (M_1) recorded the highest mean weight of the fruit. It was significantly superior to all other treatments. It was followed by uniform incorporation of paddy waste (M_2) and bottom layer application of paddy waste (M_3) which were on par. Control plots (M_0) recorded the lowest mean weight and was significantly inferior to mulched treatments.

In the case of irrigation, I_3 recorded the maximum mean weight of fruit closely followed by I_4 and these two treatments were on par and significantly superior to I_1 and I_2. The effects of I_1 and I_2 were on par.

The interaction between MCM and irrigation was not significant on the mean weight of the fruit.

4.4.4 Fruit yield per hectare

The data regarding the fruit yield per hectare and per plant are presented in Table 13 and the analysis of variance in Appendix III.

The main effects of irrigation and moisture conservation methods were significant on fruit yield.

Table 13. Main effects of MCM and irrigation on fruit yield

Treatments	Yield	
	t ha^{-1}	kg $plant^{-1}$
MCM		
M_O	14.73 [c]	2.21 [c]
M_1	20.52 [a]	3.12 [a]
M_2	17.84 [b]	2.68 [b]
M_3	17.16 [b]	2.57 [b]
Irrigation		
I_1	14.10 [b]	2.11 [b]
I_2	14.28 [b]	2.14 [b]
I_3	21.16 [a]	3.21 [a]
I_4	20.14 [a]	3.10 [a]
SEm±	0.82	0.122
Interaction	NS	NS

Among the MCM, surface application of paddy waste (M_1) recorded the highest yield (20.521 t/ha) which was significantly superior to all other treatments. It was followed by uniform incorporation of paddy waste (M_2) and bottom layer application of paddy waste (M_3) which were on par (17.849 t/ha and 17.16 t/ha respectively). The lowest value (14.736 t/ha) was recorded in control plots which was statistically inferior to all other treatments.

With respect to irrigation intervals, scheduling irrigation at IW/CPE ratio of 1.4 (I_3) recorded the highest yield (21.16 t/ha) which was followed by 20.146 t/ha obtained in farmer's practice of daily irrigation (I_4) which were on par. It was followed by 14.288 t/ha recorded in scheduling irrigation at IW/CPE ratio of 1 (I_2) and 14.104 t/ha recorded in IW/CPE ratio of 0.6 (I_1) which were on par and statistically inferior to I_3 and I_4.

The interaction between moisture conservation methods and intervals of irrigation was not significant.

4.5 Fruit quality

4.5.1 Sugar content

The data on the sugar content of the fruit are presented in Table 14 and the analysis of variance in Appendix IX.

Main effect of moisture conservation methods was not significant on the sugar content of the fruit.

Main effect of irrigation was significant on the sugar content of the fruit. Irrigation interval of IW/CPE ratio 0.6 (I_1) recorded the maximum sugar content which was significantly superior to all other treatments. It was followed by I_2 and I_3 which were on par. The lowest sugar content was observed in farmer's practice of daily irrigation which was statistically inferior to all other irrigation treatments.

The interaction effect between MCM and irrigation on sugar content of fruits was not significant.

4.5.2 T.S.S. content

The data on the T.S.S. content are presented in Table 14 and analysis of variance in Appendix IX.

MCM did not show any significant influence on the T.S.S. content of the fruits.

Irrigation had significant influence on the T.S.S. content of the fruits. Among the irrigation intervals, IW/CPE ratio of 0.6 recorded the highest T.S.S. content which was significantly superior to all other treatments. It was followed by IW/CPE ratio 1 (I_2) and 1.4 (I_3). I_2 was significantly superior to I_3 and the lowest value was recorded by farmer's practice (I_4) which was statistically inferior to all other irrigation treatments.

Table 14. Main effects of MCM and irrigation on sugar content and T.S.S of fruits.

Treatments	Sugar content (%)	T.S.S (°Brix)
MCM		
M_0	12.5 [a]	11.4 [a]
M_1	12.33 [a]	11.2 [a]
M_2	12.57 [a]	11.5 [a]
M_3	12.33 [a]	11.2 [a]
SEm±	0.146	0.163
Irrigation		
I_1	13.21 [a]	12.2 [a]
I_2	12.76 [b]	11.7 [b]
I_3	12.36 [b]	11.1 [c]
I_4	11.39 [c]	10.2 [d]
SEm±	0.146	0.106
Interaction	NS	NS

The interaction between moisture conservation method and irrigation was not significant.

4.6 Soil moisture studies

4.6.1 Soil moisture content

The data regarding the gravimetric soil moisture content (% w/w) before and 48 hours after irrigation at depths of 0-15, 15-30 and 30-60 cm are given in Table 15.

It is clear from the table, that application of paddy waste as MCM increased the soil moisture content at all the depths irrespective of the irrigation treatments. Surface application of paddy waste @ 1/3 pit volume over the pit area (M_1) retained more moisture than other MCM at 0-15 and 15-30 cm depth at all irrigation levels. At 30-60 cm layer also when irrigation was scheduled at IW/CPE ratio of 1.0 and 1.4, moisture content was the maximum when paddy waste was spread over the surface of pit compared to other MCMs. Application of paddy waste @ 1/3 pit volume as a bottom layer (M_3) retained more moisture content at 30-60 cm than M0 and M2 at all irrigation levels. It can be concluded that among the MCMs, surface application of paddy waste retained the highest moisture content at all depth and at all irrigation levels except irrigation at the widest interval of IW/CPE ratio of 0.6. Irrigation at closer intervals increased the moisture content at all depths in all the treatments. Irrespective of the MCM and irrigation intervals, soil moisture content increased with depth.

4.6.2 Soil moisture depletion pattern

Mean values of soil moisture depletion are given in Table 16 and illustrated in Fig. 16. In all the treatments upper most layer (0-15 cm) recorded the maximum moisture depletion, irrespective of the MCM and levels of irrigation. It accounted to 46.42 to 52.03 per cent. The moisture depletion patterns from the 15-30 and 30-60 cm layers were almost identical among the treatments and ranged

Table 15. Mean moisture content (% W/W) of soil before and after irrigation under main effects of MCM and irrigation.

Treatments	Depth of soil					
	0-15 cm		15-30 cm		30-60 cm	
	BI	AI	BI	AI	BI	AI
M_0I_1	7.22	14.89	9.28	16.58	10.69	18.1
M_0I_2	8.07	15.02	10.43	17.06	11.92	17.43
M_0I_3	7.85	16.36	12.23	18.39	13.22	19.6
M_1I_1	9.02	14.89	11.53	16.58	13.5	18.1
M_1I_2	11.81	18.49	11.53	18.22	13.31	19.79
M_1I_3	12.38	19.01	14.3	20.24	15.66	22.4
M_2I_1	8.76	15.83	10.08	17.52	11.05	19.09
M_2I_2	9.85	17.86	10.76	18.16	12.67	19.17
M_2I_3	11.28	17.36	13.39	19.44	14.97	21.5
M_3I_1	8.13	15.65	10.5	17.53	13.00	19.6
M_3I_2	9.8	15.95	10.89	17.55	12.02	19.7
M_3I_3	11.15	16.86	13.7	18.65	15.75	21.35

BI - Before irrigation, AI - 48 hours after irrigation

Table 16. Relative moisture depletion pattern from different soil layers in percentage as influenced by main effects MCM and irrigation.

Treatments	Relative soil moisture depletion (%)		
	0-15 cm	15-30 cm	30-60 cm
MCM			
M_0	49.07	27.62	24.55
M_1	52.03	23.46	24.65
M_2	47.37	26.94	25.58
M_3	46.42	26.41	26.68
Irrigation			
I_1	46.46	27.7	25.8
I_2	49.27	25.5	24.86
I_3	50.43	25.03	25.4

MCM - Moisture conservation method

from 23.46 to 27.7 per cent. Among the MCMs the moisture depletion from the surface layer of 0-15 cm was the maximum when paddy waste was spread on the surface of pit area and the lowest when the paddy waste was placed in the pit as a bottom layer. At 15-30 cm layer, moisture depletion was the maximum in M_0 plots, minimum from M_1 plots while from 30-60 cm, the highest depletion was observed in M_3 and minimum in M_0. Moisture depletion was more from the surface 0-15 cm in all the schedules. When irrigation interval was closer moisture depletion increased in the 0-15 cm layer slightly and from the lower layers maximum depletion increased when interval was wider.

4.6.3 Water use efficiency

The data on water use efficiency viz. crop water use efficiency (WUE) and field water use efficiency are given in Table 17.

Table 17. Water use efficiency as affected by main effects of MCM and irrigation (kg ha mm^{-1})

Treatments	Field water use efficiency	Crop water use efficiency
MCM		
M_O	35.59	36.64
M_1	48.51	50.84
M_2	43.63	47.71
M_3	41.73	44.20
Irrigation		
I_1	46.00	50.00
I_2	39.60	38.20
I_3	48.50	48.22
I_4	34.30	-

As evident from the table, moisture conservation methods had a remarkable influence on water use efficiency. Surface application of paddy waste (M_1) recorded the highest crop and field water use efficiency followed by uniform incorporation of paddy waste in the pit (M_2) and bottom layer application of paddy waste (M_3). The lowest water use efficiency was recorded by the control.

Regarding irrigation, the highest field water use efficiency was observed at IW/CPE ratio of 1.4, closely followed by irrigation at IW/CPE ratio of 0.6. The lowest field water use efficiency was recorded by farmers practice of daily irrigation. In the case of crop water use efficiency, the highest value was recorded by IW/CPE ratio of 0.6 (50.0) followed by IW/CPE ratio of 1.4 (48.2). Irrigation at IW/CPE ratio of 1 recorded the crop WUE of 38.2.

4.6.4 Consumptive use

The mean seasonal consumptive use from 20 DAS to the end of crop growth is given in Table 18.

Table 18. Mean seasonal consumptive use (mm) as influenced by main effects of MCM and irrigation.

Treatments	I_1	I_2	I_3	Mean
M_0	316.5	350.0	455.68	354.06
M_1	266.3	380.7	432.98	359.99
M_2	269.2	405.6	453.6	376.13
M_3	306.4	388.3	409.9	368.2
Mean	289.6	381.65	438.04	

The calculation of consumptive use from the daily irrigated plants was not possible. Consumptive use increased with increasing level of irrigation. The maximum consumptive use (438.04 mm) was recorded from the crop receiving irrigation at IW/CPE ratio 1.4 followed by irrigation at IW/CPE ratio 1 (381.65 mm) and the lowest recorded at IW/CPE ratio 0.6 (289.6 mm).

Among the moisture conservation treatments, maximum consumptive use was recorded from plots where paddy waste was uniformly incorporated in the pit (376.13 mm), followed by M_3 (368.2 mm) and M_1 (359.99 mm). The lowest consumptive use was recorded by the control (354.06 mm).

4.7 Economics of cultivation

The economics of various treatments, mean net profit and mean net return per rupee invested are presented in Table 19.

Among the moisture conservation methods, the highest net profit (Rs.43135) was recorded by surface application of paddy waste followed by uniform incorporation of paddy waste (Rs.28277) and bottom layer application (Rs.26722). Surface mulching enhanced net profit by Rs.27255 over control.

In the case of irrigation levels, the highest net profit of Rs.45803 was obtained when irrigation was given at IW/CPE ratio of 1.4, followed by Rs.29654 for farmer's practice of daily irrigation. The lowest net profit obtained with irrigation at IW/CPE ratio of 1.

With respect to net return per rupee invested, among the MCM, surface application of paddy waste recorded the highest net return per rupee invested (Rs.1.72), followed by uniform incorporation of paddy waste (Rs.1.46). The lowest value was obtained by control (Rs.1.27).

Among the irrigation levels, irrigation at IW/CPE ratio of 1.4 recorded the highest value (Rs.1.76) followed by farmer's practice of daily irrigation (Rs.1.42), followed by irrigation at IW/CPE ratio of 0.6. The lowest value (Rs.1.28) was recorded by irrigation at IW/CPE ratio of 1.

In the case of treatment combinations (Table 19a), surface application of paddy waste with irrigation at IW/CPE ratio of 1.4 recorded the highest net return per rupee invested (Rs.1.99) followed by surface mulching with farmer's practice of daily irrigation. It was followed by uniform incorporation of paddy waste with irrigation at IW/CPE ratio of 1.4. The lowest value (Rs.1.08) was with control plot with irrigation at IW/CPE ratio of 1.0.

Table 19. Economics of different treatments

Treatments	Total cost of production (Rs.)	Yield (kg/ha)	Income (Rs.)	Net profit (Rs.)	Net return per rupee invested (Rs.)
MCM					
M_0	57800	14736.00	73680.00	15880	1.27
M_1	59470	20521.00	102605.00	43135	1.72
M_2	60968	17849.00	89245.00	28277	1.46
M_3	59078	17160.00	85800.00	26722	1.45
Irrigation					
I_1	50826	14104.00	70520.00	19694	1.38
I_2	55416	14288.00	71440.00	16024	1.28
I_3	59997	21160.00	105800.00	45803	1.76
I_4	71076	20146.00	100730.00	29654	1.42

1 kg fruit - Rs.5.00, Urea - Rs. 4.25/kg, Mussoriephos - Rs. 2.2/kg
Muriate of Potash - Rs. 3.9/kg, Farm yard manure- Rs. 450/tonne
Labour charge - Rs. 135/man/day, Rs. 80/woman/day

Table 19a. Mean net return per rupee invested as influenced by MCM and levels of irrigation

Treatments	M_0	M_1	M_2	M_3	Mean
I_1	1.15	1.48	1.44	1.46	1.38
I_2	1.08	1.38	1.30	1.36	1.28
I_3	1.69	1.99	1.88	1.52	1.77
I_4	1.15	1.93	1.32	1.4	1.42
Mean	1.26	1.69	1.46	1.44	

DISCUSSION

DISCUSSION

The present investigation was taken up to study the influence of moisture conservation methods and levels of irrigation on the growth and yield of water melon cv. Sugarbaby in summer rice fallows. The results obtained are discussed below.

5.1 Crop growth

The results clearly show that mulching with paddy waste increased the growth attributes like vine length, number of leaves per vine, leaf area and dry matter production (Table 4 - 7 and Fig. 3 - 8). The significant superiority of paddy waste application as mulch over control on the length of vine was seen at 60 and 75 DAS. At these stages, the differences between the paddy waste incorporation methods were not much different.

In the case of number of leaves per vine, bottom layer application of paddy waste (M_3) produced significantly higher leaf number per vine than control and other treatments at 30 DAS, whereas at 75 DAS uniform incorporation of paddy waste in the pit (M_2) produced maximum number of leaves than all other treatments. In the case of number of leaves per vine, in general there was not much difference between the moisture conservation methods. Nevertheless, number of leaves were higher when paddy waste was either incorporated uniformly in the pit or applied as a bottom layer. The performance between control and surface application of paddy waste was almost identical and always lower than the other two methods.

At all the stages of observation leaf area was significantly the highest with surface mulching of paddy waste. Whereas the leaf area in other methods of applications of paddy waste did not vary much from that of control. Dry matter production was also the highest when paddy waste was applied as surface mulch but was on par with uniform incorporation as well as bottom layer application. The

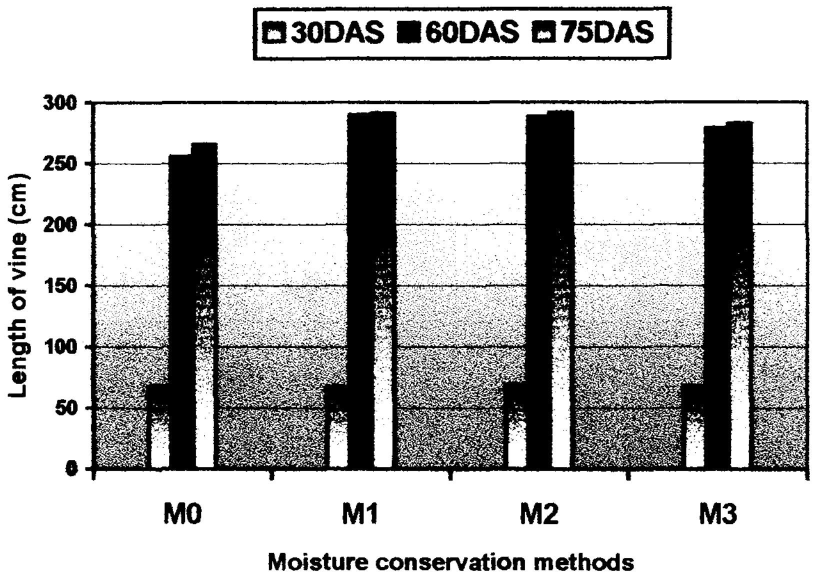


Fig 3.Effect of moisture conservation methods on vine length

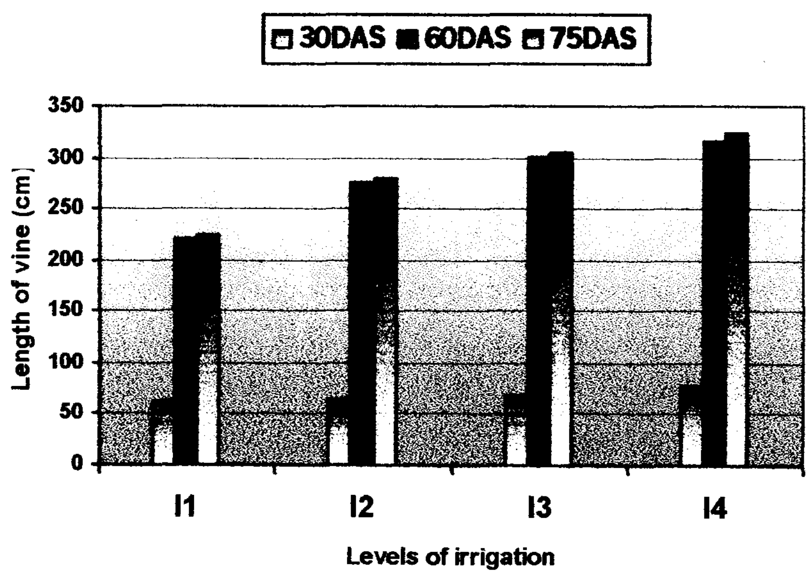


Fig 4. Effect of irrigation on vine length (cm)

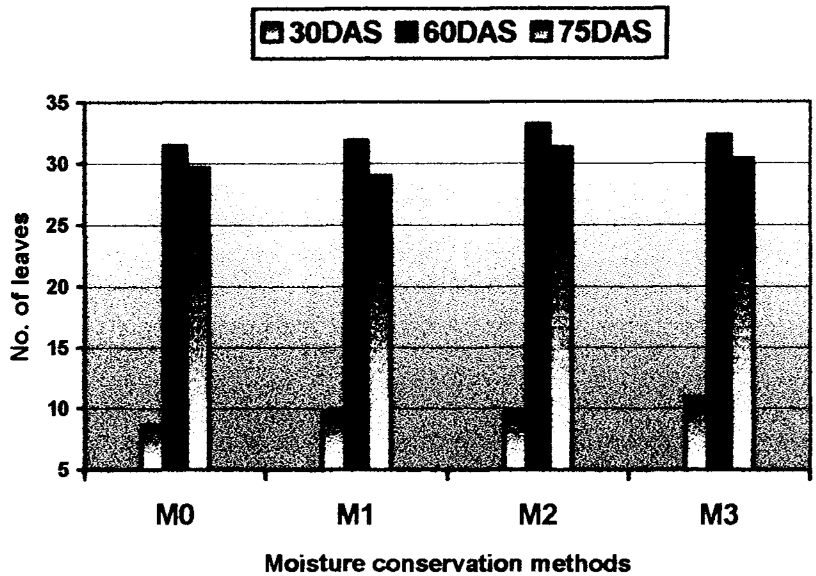


Fig 5. Effect of moisture conservation methods on number of leaves per vine

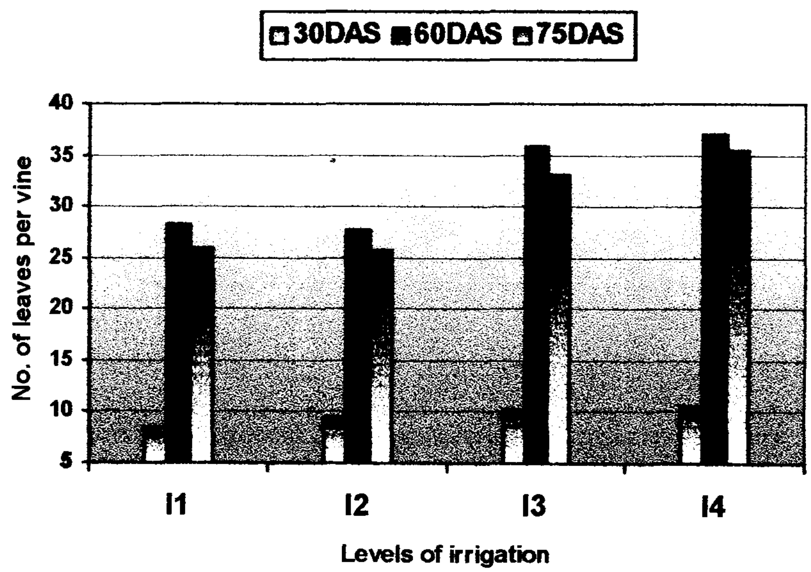


Fig 6. Effect of irrigation on number of leaves per vine

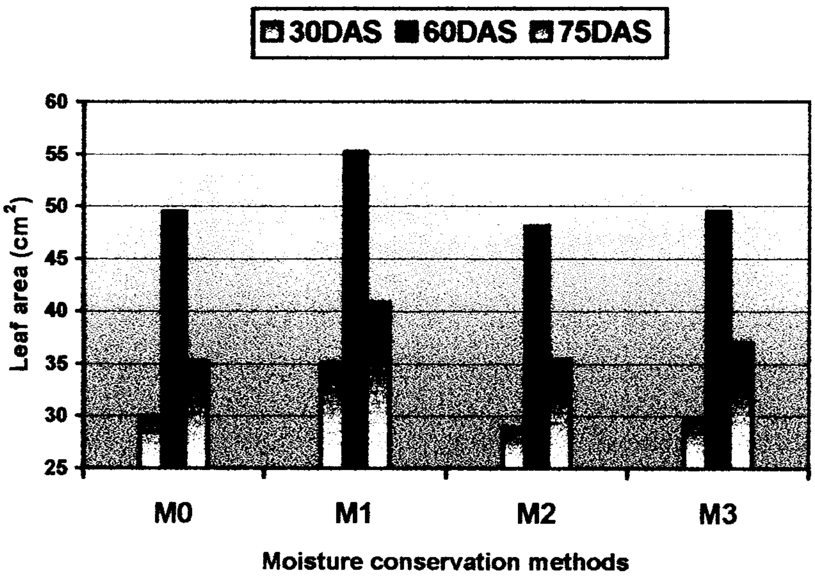


Fig 7. Effect of moisture conservation methods on leaf area

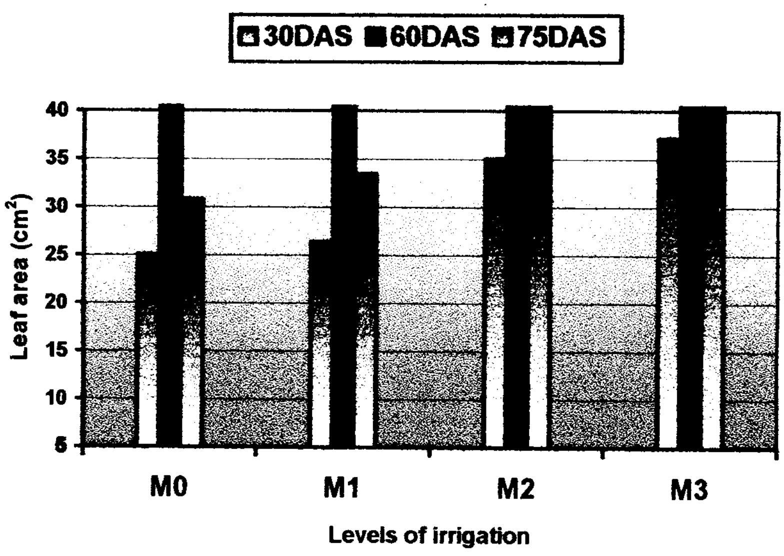


Fig 8. Effect of irrigation on leaf area

dry matter production of control plot was significantly inferior to paddy waste applied plots.

In general the crop growth was better when paddy waste was applied as mulch and in particular when it was applied as surface mulch.

The favourable benefit of moisture conservation method on vegetative growth by paddy waste application might be due to its higher retention of moisture in soil and providing more favourable conditions for plant growth. The better performance of growth attributes due to application of paddy waste observed in the experiment is in conformity with the observation of Corns (1984); Corrales *et al.* (1990); Asoegwu (1991); Khalak and Kumaraswamy (1992); Stang *et al.* (1993); Saravanababu (1994) and Veeraputhiran (1996).

Irrigation exerted a significant influence on the growth attributes like vine length, number of leaves per vine, leaf area, and dry matter production. The treatment which received frequent irrigation (Farmer's practice of daily irrigation) produced significantly the highest length of vine, number of leaves per vine, leaf area, leaf area index and dry matter production. The second best treatment was IW/CPE ratio of 1.4. From the results it is clear that daily irrigations is the best for promoting the vegetative growth of water melon followed by irrigation once in 3-5 days scheduled by the IW/CPE ratio 1.4.

Water deficit is likely to affect two vital processes of growth viz., cell division and cell enlargement and according to Begg and Turner (1976), cell enlargement is more affected resulting in poor growth. This is in agreement with the findings of Flocker *et al.* (1965) in Cantaloups and Yamashita *et al.* (1982) in cucumber.

Changes in leaf area may be due to the changes in leaf number or in leaf size. Leaf number depends on the number of vines, the period during which leaves are produced, the rate of leaf production during the period and the life span of leaves. Leaf size is determined by the number and size of cells by which the leaf is built and is influenced by light, moisture regimes and the supply of nutrients (Arnon, 1975). Both the number of leaves and leaf size are considerably influenced by soil water supply and these attributes were the highest where frequent irrigations were undertaken. The reduction in leaf area with lesser number of irrigations was due to lower number of leaves produced per vine and smaller size of leaves produced. Escobar and Gausman (1974) in Mexican squash, Cummins and Kretchman (1974) in cucumber and Radha (1985) in pumpkin, ashgourd and oriental pickling melon and Veeraputhiran (1996) in cucumber also reported reduction in leaf area in lower level of irrigations.

There was a significant effect of irrigation on drymatter production in water melon. The irrigation treatments receiving larger quantity of water accumulated more dry matter per plant (93.82 g) than other treatments. Water melon requires high soil moisture and its growth is greatly reduced by soil moisture stress (Dimitrov, 1973). Photosynthesis is the basic process for the build up of organic substances by the plant, where by, 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. Therefore, the effectiveness of photosynthesis of the crop determines the dry matter production. The less frequently irrigated plants would produce less dry matter, as reduction in water content brings about a similar reduction in the photsynthetic efficiency (Arnon, 1975). A similar trend was noted by Thomas (1984) in bitter gourd and by Radha (1985) in pumpkin, ash gourd and melon, Veeraputhiran (1996) in cucumber.

At the wider intervals of irrigation (I_1 and I_2) the effect of any of the mulching method did not show very convincing effect over control. But at closer intervals of irrigation (I_3 and I_4) the effect of mulching showed prominent effect or efficiency over control. In the case of irrigation at I_3, the effects of moisture conservation methods were superior to control in the case of length of vines, leaf area, number of leaves per vine, and dry matter production. In the case of leaf area, effects of moisture conservation methods were not superior to M_0. The effect was the maximum with M_1 and dry matter production at I_3, whereas M_3 provided the maximum interaction in the case of leaves per vine.

When the crop was irrigated at I_4, M_2 gave the highest length of vine and dry matter production, whereas for leaf area, M_1 recorded the highest value. While paddy waste mulching had significant effect compared to control on length of vines, dry matter and leaf area there was no interaction in the case of number of leaves per vine.

5.2 Days to first flowering

Moisture conservation methods had no significant influence on the days to first flowering.

In the farmer's practice of daily irrigation, the first female flower emerged in 28 days while in the widest interval of irrigation (I_1) the first female flower opened only on the 33rd day.

Plants receiving higher levels of irrigation (I_4 and I_3) produced female flowers earlier. Larson (1975) stated that a slight water stress can reduce the rate of appearance of female primordia. This was evident in the work of Molnar (1965) in melon. Thomas (1984) noted that there was a trend to hasten flowering at higher levels of irrigation in bitter gourd.

The interaction effect of irrigation and moisture conservation methods was not significant for the days to first flowering.

5.3 Yield attributes

Moisture conservation with paddy waste had a significant influence on the number of fruits per plant and mean weight of fruits (Table 13, Fig. 9), but it did not influence volume of fruit.

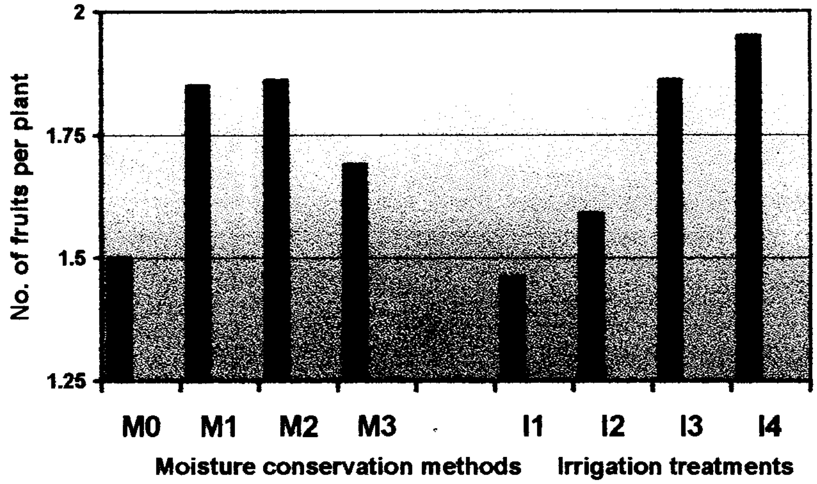


Fig 9. No. of fruits per plant as influenced by moisture conservation methods and levels of irrigation

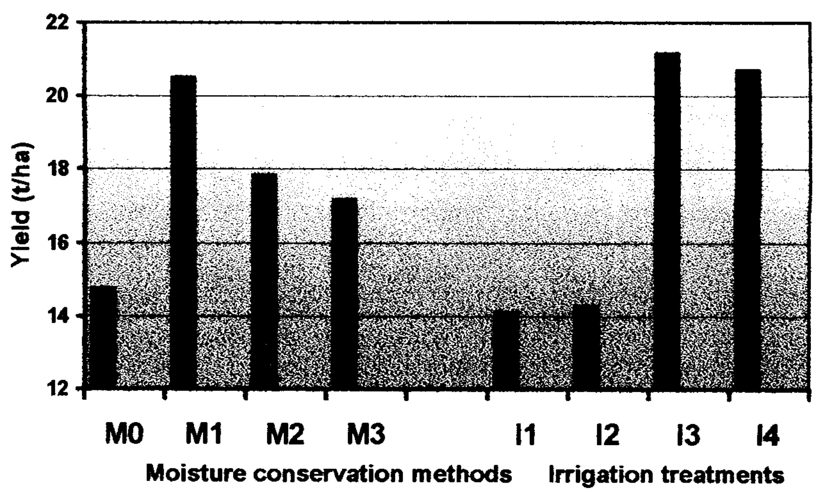


Fig 10. Effect of moisture conservation methods and levels of irrigation on fruit yield (t/ha)

Surface mulching (M_1) produced the highest number of fruits (1.9) per plant closely followed by M_2 and M_3. The above treatments produced 27.8, 26.9 and 16.6 per cent more fruits respectively over control. This might be due to the better growth as a result of higher moisture availability to the plants due to paddy waste mulching.

Surface application of paddy waste (M_1) recorded significantly highest mean weight of fruit (1.66 kg). The effect of M_2 and M_3 were on par and produced significantly higher mean weight of fruit over control. Surface mulching, uniform incorporation and bottom layer application produced fruits which weighed 32.8, 19.5 and 17.9 per cent more than control.

The more frequently irrigated plants produced more number of fruits with higher mean weight than those irrigation less frequently. Over I_1, the percentage increase of number of fruits per plant in I_4, I_3 and I_2 were in the order of 34, 27.5 and 8.9 respectively while the corresponding increase in fruit weight was in the order of 46.9, 59.5 and 4.7 per cent respectively. Frequent irrigation might have made available a favourable soil moisture regime and increased the availability and supply of plant nutrients resulting in better growth and translocation of photosynthates to yield components thereby increasing fruit number and fruit weight. In fruits and vegetables, the fresh weight often confirmed to increase even after the increase in dry weight ceased (Begg and Turner, 1976). Since the size and weight of fruit at this stage depended on plant water potential to a greater extent, water deficit had a strong influence on fruit size and fruit weight, than the dry weight. This view is endorsed by the work of Neil and Zunino (1972), Caro and Linsalata (1977), Doorenbos and Kassan (1979) in melons and Thomas (1984) in bittergourd. A decrease in fruit volume was observed in frequent irrigated plots. When Fruit number increase a general decrease in fruit volume is observed.

5.4 Fruit quality

Moisture conservation methods had no significant influence on the quality of fruits.

The various levels of irrigation exerted significant influence on the total soluble solid content and sugar content of fruit. The plants which received the lowest quantity of irrigation water recorded higher values. With increasing levels of irrigation, there was a continuous downward trend in the total soluble solids and sugar content of the fruit. The highest value of sugar content (13.21%) and T.S.S. (12.27) was recorded by I_1 and lowest sugar content (11.39) and T.S.S. (10.23) were observed in the farmers practice of daily irrigation. The increased sugar content under low water availability may be due to the increased starch hydrolysis with increasing moisture stress (Gater, 1968). Possibly the increase in the net rate of starch hydrolysis with increasing moisture stress results from an increase in the amount of aspargine, because asparagine, which activates the enzyme amylase (Hartt, 1934) was found to increase, with a decrease in moisture content (Petric and Wood, 1938).

The interaction effect of MCM on irrigation did not show significance in the case of mean weight of fruits, sugar content and T.S.S. of fruits.

5.5 Fruit yield

There was significant increase in the fruit yield over control when paddy waste was used as mulch (Table 15 and Fig.10). The highest and significantly superior yield was recorded by surface mulching of paddy waste. The increase in the yield by use of paddy waste as surface mulching, uniform incorporation and bottom layer application over control was 39.2, 21.1 and 16.4 per cent respectively. Better plant growth associated with more moisture retention promoted more number of fruits and higher fruit weight in these treatments. Increase in the yield was due to increase in number of fruits per plant and fruit weight observed in these treatments. This result is in conformity with the findings of Ivonova and Ivonova (1976); Mavrodii (1979), Singh *et al.* (1977); Arunachalan (1987); Anabayan (1988); Athmananthan (1988); Nagarajan *et al.* (1989); Veerabadran (1991); Clark and Moore (1991); Devaraj and Chockalingam (1991); Saravanababu (1994) and Veeraputhiran (1996) who have stated that application of soil conservation materials increased the yield in varying crops.

Irrigation scheduling had a significant influence on fruit yield. The highest yield was recorded by frequent irrigation scheduled by the IW/CPE ratio 1.4. This was closely followed by farmer's practice of daily irrigation which were on par. The yield from irrigation at IW/CPE ratio 0.6 and 1 were at par and significant inferior to IW/CPE ratio 1.4 and farmer's practice of daily irrigation. The increase in yield by irrigation at IW/CPE ratio 1.4 over farmer's practice of daily irrigation, IW/CPE ratio 1 and 0.6 were 5, 48 and 50 per cent respectively. The observed increase in yield with increase in the irrigation is attributed to a more or less similar trend in yield attributes like number of fruits per plant and mean fruit weight. This happens because fruit yield is the sum total of the above parameters.

These findings corroborate reports of Jassal *et al.* (1970), Loomis and Crandall (1977), Kashi (1981), Desai and Patil (1984), Thomas (1984), Radha (1985), Jacob (1985), Thankamani (1987), Prabhakar and Naik (1993), Yinzjajaval and Markmoon (1993), Siby (1993) and Veeraputhiran (1996) who have found that cucurbitaceous crops require frequent irrigation for maximum yield.

Irrigating water melon daily by the farmer's practice has not been found superior to irrigation at IW/CPE ratio of 1.4 (3-6 days interval). The irrigation water applied in I_3 and I_4 are in the order of 330 mm in 10 irrigations and 477 mm in 42 irrigation respectively. Similarly the total quantity of water available for water melon in I_3 was 436.58 mm and that for I_4 being 584.70 mm. The crop has not responded to an irrigation interval above IW/CPE ratio of 1.4 or the excess water applied in I_4 over I_3.Nevertheless the yield at I_4 recorded 41 and 42.8 per cent respectively over I_2 and I_1 which showed the supremacy of daily irrigation over wider intervals of irrigation.

5.6 Chemical composition of leaves

Mulching with paddy waste had significant effect on N content at 30 DAS only. At 75 DAS, control plots recorded highest N content of leaves. Moisture conservation methods had no effect on the P and K content of the leaves at any stages of observation. In general it can be summarised that no convincing change in leaf NPK contents could be brought about by the incorporation of paddy waste.

Higher levels of irrigation increased the N, P and K content of leaves at all stages of observation. The highest leaf N, P and K contents were observed in the farmer's practice of daily irrigation. In the case of N it was significantly superior to all other schedulings except at 75 DAS where it was on par with I_1. The trend of leaf P content was same as that of N. The only variation was that at 75 DAS, wherein the leaf P content in I_4 was at par with I_2. Potash content in leaf at 30 DAS was significantly the highest in I_4. At 60 DAS, K content was on par in all the schedulings. At 75 DAS highest leaf K content was in I_4 closely followed by I_3. This increase in the nutrient uptake with daily irrigation might be due to the creation of a favourable soil moisture regime in the root zone helping better nutrient uptake. This result is in confirmity with the findings of Brown *et al.* (1960) in cotton, Tamaki and Naka (1971) in broad bean, Sharma and Prasad (1973) in bhindi, Singh (1975) in berseem fodder, Cocueci *et al.* (1976) in squash and Thomas (1984) in bitter gourd.

Tanaka *et al.* (1964) pointed out that nutrient absorption by the plant is controlled by nutrient availability in the soil, nutrient absorption power of plant 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 plants to absorb nutrients and the soils capacity to supply them (Black, 1973). Favourable conditions produced by higher levels of irrigation, promoted root growth and rendered nutrients more available.

5.7 Soil moisture studies

Soil moisture content from the moisture conservation materials incorporated plots were higher, after irrigation compared to control at all the depth irrespective of the irrigation treatments (Table 16). This result is in conformity with the findings of Vourinen (1958); Soczek (1958); Lal (1972); Ragothama (1981); Mahey *et al.* (1985); Voorhees (1986); Asoegwu (1991); Kotoky and Bhattarcharya (1991); Ramaswamy and Kothandaraman (1991); Rajendran (1991); Veerabadran (1991); Channappa (1994) and Veeraputhiran (1996) who also observed the increase in the soil moisture content by the addition of paddy straw, paddy husk and other organic materials in various crops. Surface application of paddy waste @ 1/3 pit volume over the pit area (M_1) retained more moisture content than other treatments at 0-15 and 15-30 cm layers at all irrigation levels. Whereas M_2 retained higher moisture at 30-60 cm depth, being the zone where paddy waste was applied as a bottom layer. In the 0-15 cm layer the percentage increase in soil moisture before and after irrigation in M_1 over M_0, M_2 and M_3 were in the order of 43.5, 13.2; 9.96, 2.6 and 14.2, 8.1 respectively. The corresponding increase in soil moisture in 15-30 cm layer in M_1 over M_0, M_2 and M_3 were 17, 5.7; 7.2, 1.2 and 6.5, 2.4 respectively. In the 30-60 cm layer percentage increase in soil moisture before and after irrigation in M_3 over M_0, M_1 and M_2 are in the order of 18.3, 9.3; 9.6, 0.8 and 3.9, 0.4 respectively.

Moisture content at all the depths was the highest when the crop was irrigated at closer intervals viz. daily irrigation and irrigation at IW/CPE ratio of 1.4 due to the frequent replenishments of depleted water.

Maximum depletion of soil moisture was observed from the top 15 cm layer irrespective of the moisture conservation methods and irrigation levels (Table 17 and Fig. 14). Generally moisture depletion decreased with depth. This might be due to the fact that besides transpiration, losses from the soil surface were high and also activity of plant roots were mostly confined to the top surface layers. Another observation was that moisture extraction from the lower layer (15-30 and 30-60 cm) was high under wider intervals of irrigation when compared to closer interval of irrigation. It might be due to proliferation of root system to utilize soil moisture from deeper layers under less irrigated condition. Similar observations were reported by Loomis and Crandall (1977) in cucumber, Thomas (1984) and Thampatti *et al.* (1993) in bitter gourd, Radha (1985) in pumpkin, ash gourd and oriental pickling melon, Siby (1993) in water melon and Veeraputhiran (1996) in oriental pickling melon.

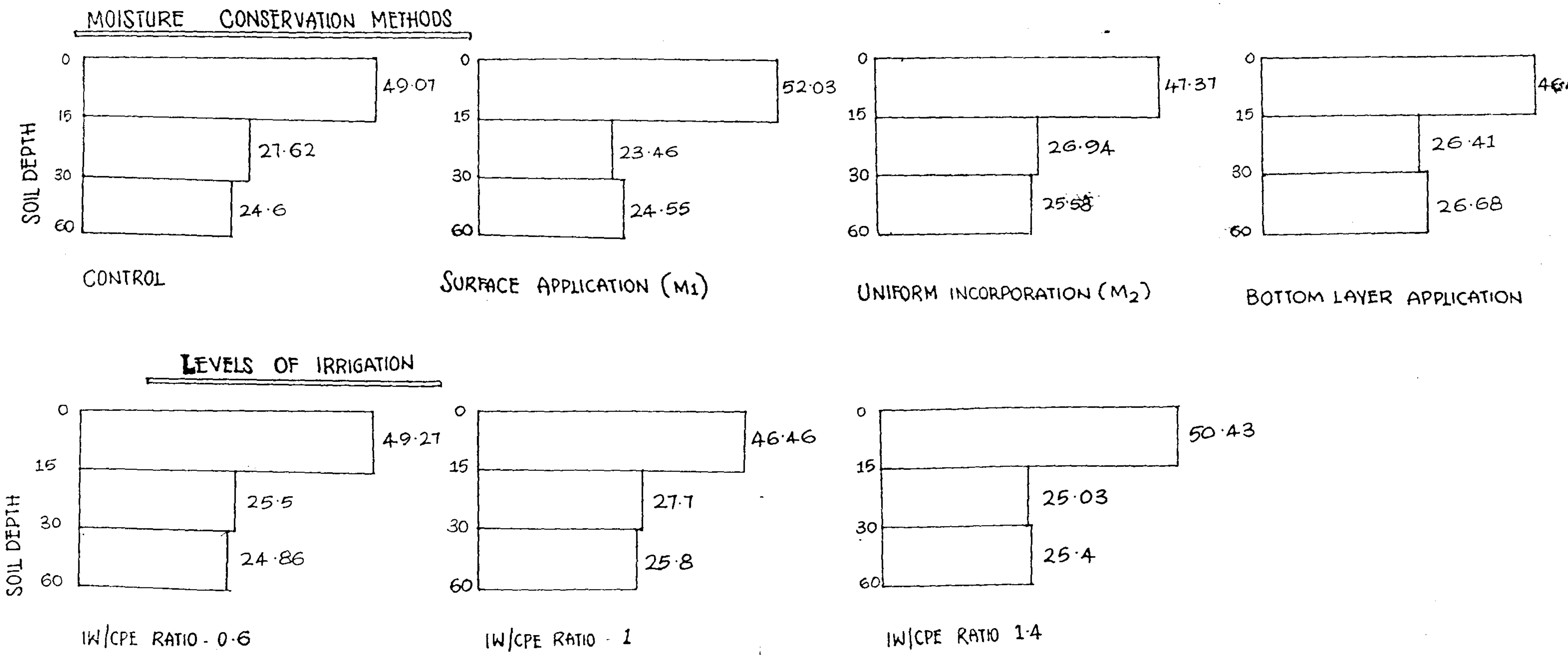
The moisture depletion from 0-15 cm layer was maximum with surface application of paddy waste and was higher by 5, 9.8 and 12 per cent respectively over control, uniform incorporation and bottom layer application. From the middle layer of 15-30 cm the depletion pattern was almost uniform. In the bottom layer of 30-60 cm, moisture depletion was the highest from bottom layer incorporated plots. It was higher by 8.5, 8.7 and 4.3 per cent respectively over control, surface application and uniform incorporation. The trend indicates that maximum depletion of soil moisture coincides with the layer where mulch is applied.

From the surface 0-15 cm layer I_3 depleated 8.5 and 2.4 per cent more moisture over I_1 and I_2 respectively. From 15-30 cm layer I_1 depleated 8.6 and 10.7 per cent more moisture over I_2 and I_3 and from 30–60 cm layer I_1 depleated 3.8 and 1.6 per cent more moisture over I_2 and I_3.

5.7.1 Water use efficiency (WUE)

The data clearly show that addition of moisture conservation materials increased water use efficiency (Table 17 and Fig. 12). The increase in the field

FIG.14. SOIL MOISTURE DEPLETION PATTERN AS INFLUENCED BY MOISTURE CONSERVATION METHODS AND LEVELS OF IRRIGATION



water use efficiency due to the surface mulching, uniform incorporation and bottom layer application of paddy waste were 36.3, 22.5, 17.2 per cent respectively and for crop WUE these were 38.7, 30.2, 20.6 per cent respectively over control. Increase of WUE by addition of paddy straw in maize was reported by Khera *et al.* (1976) and Kalaghat *et al.* (1990) and in cucumber by Veeraputhiran (1996).

The WUE varied between the irrigation schedules. Field WUE as well as crop WUE were the highest and almost equal in irrigations at the IW/CPE ratio of 0.6 (I_1) and 1.4 (I_3). CWUE was the lowest in IW/CPE ratio of 1. Water above the optimum level may be lost in the form excessive evaporation, transpiration or excess as deep percolation. So also the yield in I_4 was less than I_3. Therefore, the excess water applied in I_4 could not find a favourable response in yield. The better WUE observed at I_3 may be due to the fact that water availability might be optimum at this level of irrigation. A higher WUE at IW/CPE ratio of 0.6 may be due to the fact that the crop would have actively tried to maximise the use of water at the minimum critical level. A poor WUE at IW/CPE ratio of 1 (I_2) is due to the fact that crop yield was not better at this level of irrigation than at I_1 eventhough consumptive use as well as total water available for crop growth was more in I_2 than in I_1.

In the case of consumptive use (Table 19 and Fig. 11) among the moisture conservation treatments, the highest consumptive use was recorded from M_2 plots where paddy waste was uniformly incorporated in the pit (376.13 mm) followed by M_3 (368.2 mm). The lowest consumptive use was recorded by the control (354.06). The percentage increase in consumptive use over control due to M_2, M_3 and M_1 are 6.2, 4.0 and 1.7 per cent respectively. The increase in consumptive use by moisture conservation methods might be due to more moisture retention by the mulch material and higher growth attributes like length of vine, number of leaves per vine, leaf area etc.

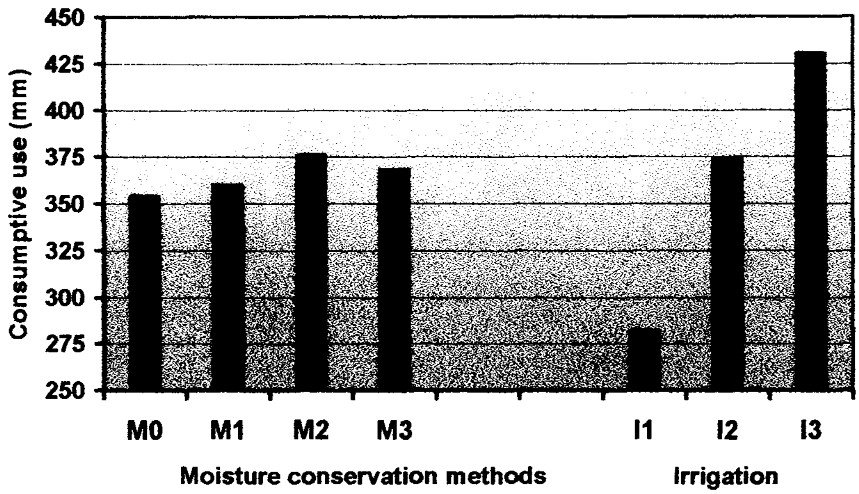


Fig 11. Effect of moisture conservation methods and levels of irrigation on consumptive use of water (mm)

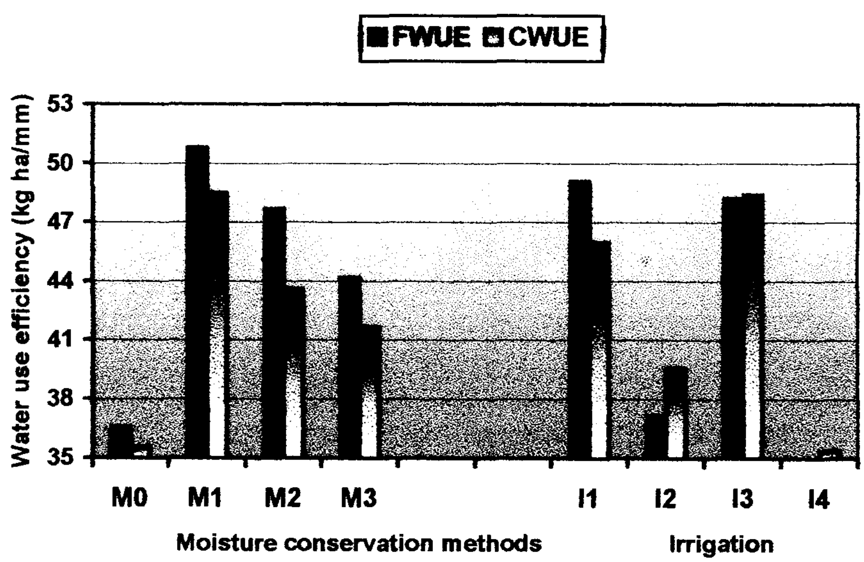


Fig 12. Effect of moisture conservation methods and levels of irrigation on water use efficiency (kg ha mm^{-1})

Consumptive use was always higher in the case of frequent irrigations. The highest value was recorded by I_3 (438.04 mm). Consumptive use could not be estimated from I_4 as it was daily irrigated. The increase in consumptive use in I_3 over I_1 and I_2 were 52.6 and 15.2 per cent respectively. With the increase in frequency of irrigation a favourable condition was created for high evaportranspiration. Similar reports were put forward by Tomitaka (1974); Desai and Patil (1984); Thomas (1984); Radha (1985); Jacob (1988); Thankamani (1987); Siby (1993) and Veeraputhiran (1996).

5.8 Economics of different treatments

The economic analysis clearly indicates that the superiority of incorporation of moisture conservation techniques over control (Table 19 and Fig. 13). The highest net profit was recorded by surface application of paddy waste. The increase in the net profit due to the surface application, uniform incorporation and bottom layer application of paddy waste over control were Rs.27,255 (171%), Rs.12,397 (78%) and Rs.10,842 (68%) respectively. The corresponding increase in net return per rupee invested in the above treatments were in the order of 35.4, 15 and 14 per cent respectively over control. From this it is clear that incorporation of paddy waste is highly useful in the cultivation of water melon and the best method is to spread the paddy waste as surface mulch over the pit area.

Net profit was the highest with scheduling irrigation at IW/CPE ratio of 1.4 (Rs.45,803) followed by farmer's practice of daily irrigation (Rs.29,654). The percentage increase in net income of I_3 over I_1, I_2 and I_4 are in the order of 132, 186 and 54 respectively. In the case of net return per rupee invested, irrigation at IW/CPE ratio of 1.4 recorded the highest value (Rs.1.76) followed by farmers practice of daily irrigation (Rs.1.42). Therefore scheduling irrigation at IW/CPE ratio of 1.4 is the most economic irrigation interval in water melon.

It was noted that, surface mulching of paddy waste was superior to other methods of mulching at all the levels of irrigation.

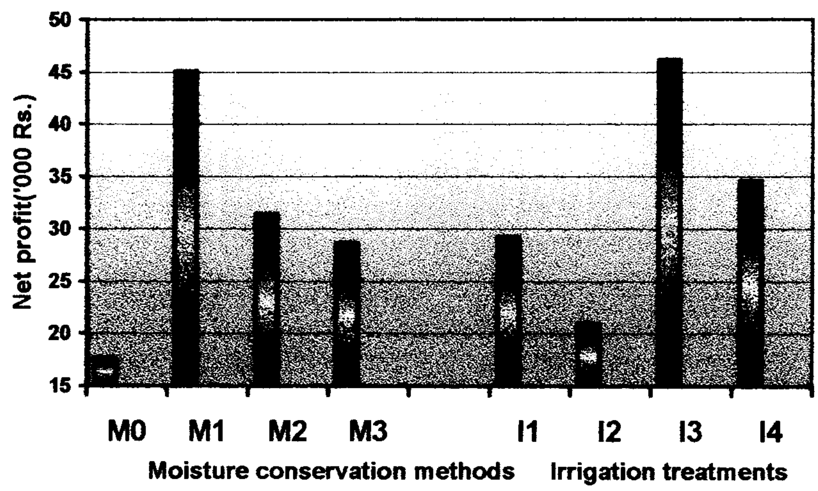


Fig 13. Effect of moisture conservation methods and levels of irrigation on net profit ('000 Rs.)

The net return per rupee invested also showed the similar trend in the combinations of moisture conservation methods and irrigation schedules as that was seen in the case of net profit. Regarding the treatment combinations, the highest net return per rupee invested was observed in the combination of surface mulching of paddy waste and scheduling irrigation at IW/CPE ratio 1.4.

SUMMARY

SUMMARY

A field experiment was carried out at the Agricultural Research Station, Mannuthy, Thrissur during December 1998 to March 1999 to study the effect of "Irrigation scheduling and moisture conservation in water melon [*Citrullus lanatus* (Thumb.) Matsam & Nakai] grown in rice fallows. The soil of the experimental field was sandy clay loam, bulk density 1.3 g m^{-3}, acidic in reaction, medium in organic carbon and available nitrogen, low in available potassium and high in available phosphorus. The weather during the period was almost normal with an average daily pan evaporation of 6.2 mm day^{-1} and there was 23.4 mm rainfall during the last stage of the crop.

. The experiment was laid out in randomized block design with three replications. There were sixteen treatments consisting of combinations of four moisture conservation methods (control, surface application, uniform incorporation and bottom layer application of paddy waste @ 1/3 pit volume) and four levels of irrigation (IW/CPE ratio of 0.6, 1, 1.4 and farmer's practice of daily irrigation @ 20 litres/day). Method of irrigation adopted was pot watering. The water melon variety sugarbaby was used for the experiment.

The salient results obtained during the course of study are summarised below:

1. Length of vine increased by the addition of moisture conservation materials. Significantly higher vine length was observed by paddy waste application over control both at 60 and 75 DAS. Similarly the vine length increased with increase in the frequency of irrigation and significantly the highest value was obtained with farmer's practice of daily irrigation at all the stages of observation.
2. Addition of moisture conservation materials increased the number of leaves per vine. The plants received farmer's practice of daily irrigation and

irrigation at IW/CPE ratio 1.4 produced significantly more number of leaves per vine than that irrigated under other irrigation treatments.

3. Moisture conservation methods had significant influence on the dry matter production and surface application of paddy waste produced the highest dry matter followed by uniform incorporation. The plants that received farmer's practice of daily irrigation produced significantly more dry matter than other intervals.
4. Surface application of paddy waste produced significantly higher leaf area and LAI than other moisture conservation methods. The highest leaf area and LAI was recorded by the farmer's practice of daily irrigation followed by irrigation of IW/CPE ratio of 1.4.
5. The interaction effect shows that significant effect of moisture conservation materials on the growth attributes were pronounced only at closer intervals of irrigation i.e., farmer's practice of daily irrigation and irrigation at IW/CPE ratio of 1.4 at all the stages of observation. At I_3, dry matter production was the maximum for surface application of paddy waste and the number of leaves per vine was high for incorporation of paddy waste.
6. Moisture conservation methods had no significant influence on days taken to first flowering. However, irrigation levels had a significant effect on days to first flowering. Farmer's practice of daily irrigation recorded significantly the lowest number of days to first flowering followed by irrigation at IW/CPE ratio of 1.4.
7. Volume of fruits were significantly higher in control plots than in all other mulched treatments. Similarly the plants irrigated at IW/CPE ratio 0.6 produced significantly the highest volume of fruit.
8. The mean weight of fruits was significantly higher in plots where paddy waste was mulched on the surface. Similarly the plants irrigated at IW/CPE ratio 1.4 recorded the highest mean weight followed by farmer's practice of daily irrigation.

9. Moisture conservation methods had significant influence on the number of fruits produced per plant. Uniform incorporation and surface application of paddy waste produced 27.7 and 26.9 per cent more number of fruits per plant over control. Higher levels of irrigation produced higher number of fruits per plant and plants that received farmer's practice of daily irrigation produced the highest number of fruits per plant.

10. In the case of fruit yield per ha and per plant, the highest yield was produced by surface application of paddy waste. The plants that received surface application of paddy waste produced 39.2 per cent more yield over control. Farmer's practice of daily irrigation and irrigation at IW/CPE ratio of 1.4 resulted the same yield.

11. Incorporation of paddy waste mulch retained more moisture in soil at all the depths than control both before and after irrigation. Among the paddy waste incorporation methods, surface mulching was found superior. Moisture content in soil both at before irrigation and after irrigation increased substantially with increase in frequency of irrigation.

12. Maximum depletion of soil moisture was from the top 15 cm layer irrespective of the moisture conservation methods and irrigation levels. A slight increase in moisture depletion was observed from the bottom layer of 30-60 cm where paddy waste was applied as a bottom layer.

13. Incorporation of moisture conservation material increased the water use efficiency. The increase in the field water use efficiency due to surface mulching, uniform incorporation and bottom layer application of paddy waste were 38.7, 30.2 and 20.6 per cent respectively and for crop WUE the increases were 27.7, 23.8, 14.7 per cent respectively over control. Field water use efficiency as well as crop water use efficiency were the highest and almost equal in irrigations at the IW/CPE ratio of 0.6 (I_1) and 1.4 (I_3).

14. Incorporation of moisture conservation material increased the consumptive use compared to control. The increase of consumptive use over control due to uniform incorporation, bottom layer application and surface mulching of

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paddy waste are 6.2, 4 and 1.7 per cent respectively. Consumptive use increased with increase in the level of irrigation and the plants which received irrigation at IW/CPE ratio 1.4 recorded the highest consumptive use.

15. It was observed that no convincing change in leaf NPK content could be brought about by the incorporation of paddy waste in different ways. Higher levels of irrigation increased the N, P and K content of leaves at all stages of observation.

16. Economic analysis showed that incorporation of paddy waste could increase the net profit. Increase in the net profit due to surface application, uniform incorporation and bottom layer application of paddy waste over control were Rs.27,255 (171%), Rs.12,397 (78%) and Rs.10,842 (68%) respectively. The corresponding increase in net return per rupee invested in the above treatments were in the order of 35.4, 15.3 and 14.0 per cent respectively over control. Net profit as well as net return per rupee invested were the highest with scheduling irrigation at IW/CPE ratio of 1.4 (3-6 days interval). Among the treatment combinations, the best combination was surface application of paddy waste with irrigation at IW/CPE ratio of 1.4 followed by the combination of surface mulching and farmer's practice of daily irrigation.

It may be concluded from the study that water melon grown in summer rice fallows requires frequent irrigation for maximum yield. Scheduling of irrigation with 33 mm water at the IW/CPE ratio 1.4 (3-6 days interval) was the most economic water management practice. Surface applications of paddy waste at the rate of one-third pit volume helps in the conservation of more moisture in soil and greatly influences the growth and yield attributes of water melon. The best net profit and net return per rupee invested were given by the combination of surface application of paddy waste and irrigation at IW/CPE ratio 1.4.

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*Originals not seen

APPENDICES

APPENDIX-I

Abstract of analysis of variance for length of vine

Source	Degree of freedom	Mean squares		
		30 DAS	60 DAS	75 DAS
Replication	2	0.778	605.281	430.289
M	3	2.630	2960.774**	1720.91**
I	3	584.758**	21218.154**	22523.772**
M x I	9	14.640**	1836.624**	1767.692**
Error	30	1.007	150.679	141.683

* Significant at 5% level

** Significant at 1% level

APPENDIX-II

Abstract of analysis of variance for number of leaves per vine

Source	Degree of freedom	Mean squares		
		30 DAS	60 DAS	75 DAS
Replication	2	6.579	0.548	4.036
M	3	9.626*	5.087	10.670
I	3	12.001*	291.448**	305.601**
M x I	9	0.636	27.220**	22.505**
Error	30	2.863	6.329	177.177

* Significant at 5% level

** Significant at 1% level

APPENDIX-III

Abstract of analysis of variance for dry matter production and yield

Sources	Degree of freedom	Mean squares		
		Dry matter production	Yield t ha^{-1}	Yield kg $plant^{-1}$
Replication	2	82.050	73.766	1.584
M	3	96.895**	67.947**	1.685**
I	3	3006.118**	182.209*	4.283**
M x I	9	143.446	14.809	0.336
Error	10	20.745	8.069	0.179

* Significant at 5% level

** Significant at 1% level

APPENDIX-IV

Abstract of analysis of variance for leaf area

Source	Degree of freedom	Mean squares		
		30 DAS	60 DAS	75 DAS
Replication	2	5.633	37.177	67.668
M	3	94.805**	124.067**	80.524**
I	3	446.747**	439.856**	414.588**
M x I	9	74.021**	49.429*	34.469*
Error	30	18.391	17.972	13.790

* Significant at 5% level

** Significant at 1% level

APPENDIX-V

Abstract of analysis of variance for nitrogen content of leaves

Source	Degree of freedom	Mean squares		
		30 DAS	60 DAS	75 DAS
Replication	1	0.001	0.004	0.044
M	3	0.040**	0.003	0.104*
I	3	0.203**	0.216**	0.098*
M x I	9	0.032**	0.019	0.105**
Error	15	0.004	0.009	0.019

* Significant at 5% level

** Significant at 1% level

APPENDIX-VI

Abstract of analysis of variance for phosphorus content of leaves

Source	Degree of freedom	Mean squares		
		30 DAS	60 DAS	75 DAS
Replication	1	0.001	0.001	0.001
M	3	0.001	0.001	0.001
I	3	0.002**	0.002*	0.001
M x I	9	0.001	0.001	0.001
Error	15	0.001	0.001	0.001

* Significant at 5% level

** Significant at 1% level

APPENDIX-VII

Abstract of analysis of variance for potassium content of leaves

Source	Degree of freedom	Mean squares		
		30 DAS	60 DAS	75 DAS
Replication	1	0.002	0.073	0.012
M	3	0.001	0.035	0.001
I	3	0.157**	0.090	0.075**
M x I	9	0.005	0.060	0.009
Error	15	0.003	0.035	0.005

* Significant at 5% level

** Significant at 1% level

APPENDIX-VIII

Abstract of analysis of variance for days to first flowering, volume of fruit and mean weight of fruit and number of fruits per plant

Sources	Degrees of freedom	Mean squares			
		Days to first flowering	Volume of fruit	Mean weight of fruit	No. of fruits per plant
Replication	2	0.064	0.001	0.194	0.086
M	3	0.240	0.001**	0.342**	0.426
I	3	61.188**	0.001**	1.430**	0.644
M x I	9	0.279	0.001	0.069	0.095
Error	30	0.137	0.001	0.033	0.042

* Significant at 5% level

** Significant at 1% level

APPENDIX-IX

Abstract of analysis of variance for sugar content and T.S.S.

Sources	Degrees of freedom	Mean squares	
		Sugar content	T.S.S.
Replication	2	0.995	0.574
M	3	0.182	0.251
I	3	7.238**	9.161**
M x I	9	0.439	0.445
Error	30	0.258	0.320

* Significant at 5% level

** Significant at 1% level

IRRIGATION SCHEDULING AND MOISTURE CONSERVATION IN WATER MELON
(*Citrullus lanatus* [Thumb.] Matsam & Nakai)

By
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ABSTRACT OF THE THESIS

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ABSTRACT

An experiment was conducted at the Agricultural Research Station, Mannuthy, Thrissur during the period from December 1998 to March 1999 to study the influence of levels of irrigation and moisture conservation methods on the growth and yield of water melon (*Citrullus lanatus*) grown in rice fallows.

The experiment was laid out in randomized block design with three replications. The treatments consisted of combinations of four moisture conservation methods (control, application of paddy waste as surface mulch, uniform incorporation and bottom layer application @ 1/3 pit volume) and four levels of irrigation (IW/CPE ratio of 0.6, 1, 1.4 and farmer's practice of daily irrigation @ 20 lit pit^{-1}).

The study revealed that incorporation of moisture conservation materials increased the growth attributes like length of vine, number of leaves per vine, leaf area and dry matter production and yield attributes like weight of fruits and number of fruits per plant. Among moisture conservation methods surface mulch and uniform incorporation of paddy waste were found to be superior in most of the cases.

Watermelon responded very well to irrigation. Biometric characters (length of vine, number of leaves per vine, leaf area and dry matter production) and yield attributing characters (weight of fruits and number of fruits per plant) were favourably influenced by frequent irrigations. The fruit yield increased with increase in frequency of irrigation and was maximum at IW/CPE ratio of 1.4.

Results of soil moisture studies revealed that incorporation of moisture conservation material increased the soil moisture content, consumptive use and water use efficiency. The consumptive use increased with the frequency of irrigation. The top 15 cm of the soil layer accounted for the highest soil moisture

depletion. The depletion was more from the deeper layers in the drier regimes. Field and crop-water use efficiencies were higher in less frequently irrigated treatments.

Higher levels of irrigation increased N, P and K content of leaves. No convincing change in leaf N, P, K content could be brought about by the incorporation of paddy waste.

Economic analysis showed that incorporation of paddy waste could increase the net profit. Net profit as well as net return per rupee invested were the highest with scheduling irrigation at IW/CPE ratio of 1.4. Among the treatment combinations, the best combination was surface application of paddy waste with irrigation at IW/CPE ratio of 1.4 followed by the combination of surface mulching and farmer's practice of daily irrigation.