FERTIGATION AND MULCHING IN ORIENTAL PICKLING MELON (*Cucumis melo* var. *conomon* (L.) Makino) UNDER HIGH DENSITY PLANTING

By
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THESIS

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DECLARATION

I hereby declare that the thesis entitled " **Fertigation and mulching in oriental pickling melon (*Cucumis melo* var. *conomon* (L.) Makino) under high density planting"** is a bonafide record of research work done by me during the course of research and the thesis has not previously formed the basis for the award to me of any degree, diploma, associateship, fellowship or other similar title, of any other university or society.

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CERTIFICATE

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ABBREVIATIONS

CWRDM	:Centre for Water Resources Development and Management
CPE	: Cumulative Pan Evaporation
Ep	: Pan Evaporation
ET	: Evapotranspiration
ETo	: Reference Evaporation
FWUE	: Field Water Use Efficiency
FYM	: Farm Yard Manure
ICAR	: Indian Council of Agricultural Research
KAU	: Kerala Agricultural University
Kc	: Crop Coefficient
LAI	: Leaf Area Index
LDPE	: Low Density Poly Ethylene
MOP	: Muriate of Potash
NS	: Non Significant
PET	: Potential Evapotranspiration
PVC	: Poly -Vinyl- Chloride
RBD	: Randomised Block Design
Sig	: Significant
SSP	: Single Super Phosphate
USWB	: United State Weather Bureau

INTRODUCTION

1. INTRODUCTION

The staggering dependence on imported vegetables and other food items have put Kerala at the bottom of the list of states on the basis of food security. According to estimates, around 1000 crores worth vegetables are imported to Kerala annually. Achieving self sufficiency in vegetable production has an important role in maintaining the health of the population of the state. From an economic point of view also, growing of vegetable crops provides immediate and higher returns to the farmers due to the short term nature as well as higher productivity compared to other crops. There are many cucurbitaceous vegetable crops being cultivated in Kerala. Among them, oriental pickling melon is one of the most important vegetable crops. It is mainly used after cooking in all the countries. In India, it is eaten raw with salt and pepper, as salad with onion and tomato, or as cooked vegetable. They belong to the family cucurbitaceae, the largest group of summer vegetable crops. Cucurbits are good source of carbohydrates, vitamin A, vitamin C and minerals (Yawalkar, 1980).

OP melon is traditionally grown in the summer rice fallows of Kerala. The major limitation for higher productivity in the summer crop is the water scarcity. Since water and nutrients are the two important inputs in agriculture, their efficient management is crucial for economic production and environmental quality. Compared to the traditional pot watering, new technologies like micro irrigation, particularly drip irrigation ensure higher water use efficiency of about 95 per cent as against 60-65 per cent in traditional irrigation methods.

Normal application of fertilizers by soil mixing ensures very low fertilizer use efficiency at 30-50, 20 and 50 per cent respectively in the case of N, P_2O_5 and K_2O. But application of water soluble fertilizers in the root zone of the crop along with irrigation water can increase the fertilizer use efficiency tremendously. Among fertigation methods, drip fertigation has been found to be the best. Drip fertigation is very effective, convenient and a productive method of fertilizer application which can be done as per the requirement of the crop. Water soluble fertilizers can very well be applied through drip irrigation system. Drip fertigation ensures higher nutrient use efficiency and quality of the produce. Uniform application of nutrients and flexibility in nutrient ratio are also possible through drip fertigation. Drip fertigation is able to increase fertilizer use efficiency by 95, 45 and 80 per cent respectively in the case of N, P_2O_5 and K_2O.

The usual spacing of OP melon is 2 x 1.5 m and the productivity under this spacing with pot watering is only 20-25 t ha^{-1}. Studies have revealed the possibility of increasing the productivity of OP melon to 60-70 t ha^{-1} by planting short duration, high yielding and less vigorous varieties like Soubhagya at a close spacing of 1x 0.3 m. This variety matures in about 65 days and was found to be suitable for high density planting. It is a widely accepted variety among vegetable growers in Kerala due its higher yield and small attractive fruits suitable for nuclear families.

Another important constraint in irrigated vegetable production is the high weed growth. Due to increased labour charge in Kerala, the economic production of vegetable crops is difficult in the state as plenty of human labour is required to keep the vegetable field free of weeds. It is known that mulching the field with LDPE (Low Density Poly Ethylene) sheets prevents the germination of weeds and reduce the labour requirement for weeding considerably. Also, this practice was found to increase the productivity of the crop by reducing excessive evaporation and creating suitable microclimate in the root zone of the crop during summer.

A plant population of 33,333 plants per hectare under high density planting was found to be the best for realizing the highest yield. Adequate water and nutrient application is important for realizing the highest productivity of the crop under high density planting. The recommended dose of fertilizer for OP melon is 70: 25:25 kg N, P_2O_5 and K_2O per hectare. The response of oriental pickling melon to increased levels of water and nutrients is also experimentally proven. In previous studies it is found that high density planting of OP melon at 33,333 plants per hectare responded linearly to drip irrigation up to 100 per cent pan evaporation and nutrients up to 200 per cent of recommended dose of NPK under drip fertigation (Ningaraju, 2013). Hence, the requirement of irrigation and fertilizer levels in OP melon under high density planting through drip fertigation is to be standardized under LDPE mulching for realizing the most economic production of the crop.

In this context, the investigation on " Fertigation and mulching in oriental pickling melon (*cucumis melo* var *conomon* (L.) Makino) under high density planting was conducted with following objectives.

1. To standardize the irrigation and fertilizer requirement of oriental pickling melon in fertigation under high density planting and LDPE mulching.
2. To study the relative efficiency of fertigation over conventional irrigation and fertilizer application.
3. To know the effect of LDPE mulch on control of weeds
4. To work out the optimum Benefit : Cost ratio for oriental pickling melon variety Saubhagya with drip fertigation under high density planting

REVIEW OF LITERATURE

2. REVIEW OF LITERATURE

Cucurbits belong to the family Cucurbitaceae which consist of about 118 genera and 825 species, according to the last taxonomic treatment of Jeffrey (1990). They are one among the most important plant families that supply human with edible products and useful fibers. Cucurbits are one of the largest and the most diverse plant families, having a large range of fruit characteristics, and are cultivated worldwide in a variety of environmental conditions. They are associated with the origin of agriculture and human civilizations and also consists of some of the first plant species to be domesticated in both the Old and the New World (Bisognin, 2002) . Cucurbits are the largest group of summer vegetable crops grown in the state of Kerala. They are grown for their ripe and unripe fruits, which are good sources of carbohydrates, vitamin A, vitamin C and minerals (Yawalkar,1980).

Among the agronomic practices, optimum plant population, irrigation and appropriate nutrition of the crop are important parameters to achieve the maximum productivity in cucurbits. Cucurbits are one of the most popular vegetables cultivated in the world. They require more water than grain crops (; Mao *et al,* 2003). Mao *et al.* (2003) found that fresh fruit yields of cucumber were highly affected by the total volume of irrigation water at all growth stages. It is proved that irrigation level has a significant role in controlling the male/female flower ratios in cucurbits, which is a primary factor affecting their yield. The ratio was found to be decreased with increasing levels of N and water. It is also found that yield of cucurbits was not increased by surplus irrigation above an optimum level. Results showed that, irrigation and fertilizer could individually or together significantly improve the cucurbit yield. Several studies have indicated the possibility of increasing the fruit yield of cucurbits by adopting high density planting with suitable irrigation and nutrient management. Although sufficient information on the nutritional requirement of the cucurbits through soil application is available, there is very little information available on its nutritional requirement through fertigation. Plastic film mulching is one of the recent technologies which is being widely used in Kerala especially for vegetable cultivation and high tech farming. Even though many studies have been conducted on these technologies, there is a need to collect detailed information about high density planting and fertigation under LDPE mulching especially in vegetables. Hence the literature related to above mentioned points are reviewed here.

Scheduling irrigation using pan evaporation

The amount of water allocated for agricultural production is being decreased. Therefore, to obtain maximum yield and to avoid excessive water application, the water requirements of the cultivated plants should be accurately determined, and irrigation water should be applied according to the needs of the plants. Crop water consumption (ETc) varies from region to region depending on crop type, stage of growth, soil, and climate conditions. Different evapo transpiration rates may be observed even in different parts of the same region. Considering global warming and climate change in recent years, it is clear that the predicted *ET* values of a year cannot be used safely for upcoming years. Research studies have revealed a linear correlation between crop water consumption and the amount of water evaporated from open water surface. Therefore, irrigation scheduling based on the combination of proper crop-pan coefficient and pan evaporation (Class-A pan) is very important due to both ease of adjustment to the climate changes and ease of application (Ertek, 2011).

Correct establishment of the irrigation moment is very important for plant growth, and finally for yield quantity and quality . At the same time, a correct irrigation scheduling prevents the negative ecological consequences. Irrigation water applied plus rainfall that achieves the corresponding yield can be mostly considered as plant evapotranspiration until deep drainage occurs as in surplus irrigation application. Optimum application water estimated to equal standard evapotranspiration achieves the maximum yield.

As the evaporation is easy to monitor and the necessary equipment is simple and easy to maintain, and also due to the high relationship between water loss from an evaporimeter and potential evapotranspiration, this method of irrigation scheduling is more attractive than others (Doorenbos and Pruitt, 1977).

The two-step crop coefficient (Kc) x reference evapotranspiration (ETo) method has been a successful and dependable means to estimate evapotranspiration (ET) and crop water requirements (Praveen Rao and Raikhelkar, 1994). The method utilizes weather data to estimate ET for a reference condition (ETo) and multiplies that estimate by a crop coefficient (Kc) that represents the relative rate of ET from a specific crop (ETc) and condition to that of the reference. The reference condition is generally ET from a clipped, cool season, well-watered grass (ETo) or from a taller full-cover alfalfa crop (ETr). The calculation of ET from these surfaces has been standardized by FAO group of scientists (Allen *et al.* 1998). The Kc x ETo approach provides a simple, convenient and reproducible way to estimate ET from a variety of crops and climatic conditions (Doorenbos and Pruitt, 1977; Wright, 1982; Allen *et al.* 1998). Developed Kc curves or values represent the ratios of ETc to ETo during various growth stages. Crop coefficient values have been reported for a wide range of agricultural crops (Allen *et al.* 1998 and 2007). The Kc is regarded as generally transferable among regions and climates under the assumption that the ETo accounts for nearly all variation caused by weather and climate.

Evaporation values measured from a standard USWB class A open pan evaporimeter are extensively used for scheduling of irrigation (Vamadevan, 1980). Dastane (1967) defined an evaporimeter as an instrument which integrates the effect of all the different climatic elements furnishing them their natural weightage.

Excess irrigation is detrimental to the crop especially during ripening stage. Musard and Yard (1990) found that Vitreous flesh disorder in melons might be due to too much of water during ripening and they also suggested that irrigation must be reduced to 40-50 per cent of evapotranspiration during the last week before harvest. Philips *et al.* (1996) in a field experiment on scheduling micro-irrigation found that water melon yield were highest for treatments which received the most irrigation water. This indicates that relatively high soil moisture content based on the evapotransiration should be maintained.

Highest fruit yield and water use efficiency in okra was obtained when the crop was drip irrigated at 1.0 Epan and fertilized with 120 kg N per hectare. It could be concluded from another field experiment that, for higher bean yield of castor crop grown during winter season, daily drip irrigation at 0.6 Epan throughout the crop life with a seasonal ETc of 334.5 mm is recommended over conventional check basin method of irrigation.

An increase in yield attributing characters in oriental pickling melon with the increase in the frequency of irrigation was observed by Veeraputhiran (1996). The yield was highest at IW/CPE ratio of 1.2. The peak consumptive use was reached between 36-50 days after sowing for the irrigation intervals of IW/CPE ratio 1.2, 0.8 and 0.4. Leekyaeongbho *et al.* (1999) in a study on the effect of fruit weight and total yield in oriental pickling melon observed that plants irrigated up to 20 days after flowering with 88.8 mm water produced highest yield (11.4 t ha^{-1}) of good quality fruit. A similar study in OP melon conducted by Alemeyhu (2001) revealed that growth, yield and net income increased with increase in level of daily drip irrigation from 50-125 per cent Ep.

Irrigation levels have a significant role on leaf area index (LAI) and leaf chlorophyll content. The highest leaf area index was obtained when water was adequately applied (1.0 ET treatment). High LAI appears to produce the best yields, and early signs of good leaf growth can predict yield. The highest chlorophyll a and b were obtained when adequate amount of irrigation was applied (1.0 ET) within a fertilizer treatment (Amer *et al*., 2009).

A study at Indian Institute of Horticultural Research (IIHR) revealed that irrigation scheduled to replenish 120 per cent of pan evaporation recorded 25 per cent more early harvestable yield (Prabhakar and Nair, 1993). Further, from an irrigation cum fertilizer trial conducted at Thailand, Yingjawal and Markmoon (1993) found that increasing the irrigation rate from 100 to 150 or 200 per cent potential evapotranspiration increased the total yield of cucumber 12 and 13 per cent respectively.

Srinivas *et al*. (1984) tested four levels of evaporation (25, 50, 75 and 100 per cent) in watermelon by replenishment through drip and furrow irrigation. They concluded that replenishment of 25 per cent evaporation losses under drip and 50 to 70 per cent evaporation losses under furrow irrigation were optimum for higher yield.

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

In a recent study conducted by Zhang *et al*. (2011), cucumber plants were subjected to three irrigation levels (I_1, 0.6 Ep; I_2, 0.8 Ep; and I_3, 1.0 Ep). The results showed that the fruit yield increased with the enhancement of irrigation water. But the highest values of IWUE and WUE were obtained from I_2 treatment.

A similar trial was conducted by Chun-Zhi Zeng *et al*. (2011) in musk melon with four different irrigation levels (100, 90, 80 and 70 per cent Ep). It was observed that plant growth, fruit production and quality were significantly affected under different irrigation levels. Plant height, stem diameter and fruit yield decreased from treatment T100 to T70. Fruit quality was the best in T90 treatment. The irrigation water use efficiency (IWUE) values showed that the lower the amount of irrigation water applied, the higher the IWUE obtained.

Under high density planting of op melon at 33,333 plants per hectare against the normal population of 10,000 per hectare, Ningaraju (2013) observed linear increase in yield upto 100 per cent Ep applied through drip irrigation.

2.2 Effect of method of irrigation in cucurbits

It is important to identify the best irrigation practice that will allow the vegetable industry to develop in the future. This means using systems that allow efficient use of water, labour and other resources whilst producing a quality product.

Drip irrigation provides controlled amounts of irrigation water at frequent intervals to the root zone of the plants. In addition to saving water, early reports of field trials in Israel (Anonymous, 1969 ; Goldberg and Schmueli, 1969) claimed that drip irrigation increased yield by 30 per cent or more compared to furrow or sprinkler irrigation.

When Singh and Singh (1978) compared the water application through drip irrigation, overhead sprinkler and furrow irrigation with respect to the yield potential and water use efficiency of long gourd, ridge gourd and water melon, it was found that drip irrigation increased the yield of long gourds by 45 to 47 per cent, ridge gourd by 21 to 38 per cent and water melon by 10 to 22 per cent compared to sprinkler and furrow irrigation.

The foremost reason among the several contributing characters behind the adoption of drip irrigation is the economical use of water, potential to maintain low soil moisture tension in the root zone (Sivanappan and Padmakumari, 1978) and its ability to maximize crop response and yield. Watering through drip irrigation eliminates wide fluctuations of soil moisture.

Balakumaran *et al.* (1982) studied the comparative effect of pitcher irrigation and pot watering in cucumber. They reported that yields were slightly higher in pot watered plants, but water economy was appreciably greater under pitcher irrigation.

Drip systems have a highly non-uniform application pattern on the surface which is smoothed out and becomes quite uniform after water has infiltrated (Wallach 1990). There is a report by Chartzoulakis and Michelakis (1996) that the water use efficiency of cucumber was highest with drip compared to furrow, micro tube drip, porous clay tube and porous plastic tube. In another study conducted by Komamura *et al.* (1990) for evaluating irrigation methods in greenhouse cucumber, it was observed that perforated pipe system maintained adequate soil moisture than drip irrigation.

In a comparative study of drip and sprinkler irrigation for small scale farms by Monynihan and Harman (1992), it was found that water requirement of cucumber was 3-4 times more with less yields and more labour under furrow system than drip irrigation. Azis *et al.* (1998) in a study on the effect of soil conditioning and irrigation on chemical properties of sandy soils of Inshas, Egypt concluded that drip irrigation was the best method for higher yield, water conservation and water use efficiency in cucumber production. Higher yields of cucumber was reported by Limbulkar (1998) with 50 per cent water saving under micro irrigation compared to surface irrigation methods, from a trial at Rahuri.

In a comparative study of drip and sprinkler irrigation for pickling cucumber in Germany, drip irrigation was found to accelerate seedling development, leading to earlier yield and prolonged harvesting periods (Paschold, 1999). The yield under drip was 547 t ha^{-1} with 50 per cent water saving compared to sprinkler with a yield of 400 t ha^{-1} .

Farshi (2001) reported an increased water use efficiency of 5.2 kg m^{-3} from drip irrigated cucumber compared to 1.2 kg m^{-3} under surface irrigation. A higher yield (7.8 t ha^{-1}) was reported by Guler and Ibrikci (2002) from drip irrigated plants compared to furrow irrigated plants (7.2 t ha^{-1}).

From an evaluation study of moisture regime and plant growth of vegetables under drip irrigation and conventional furrow irrigation, Foster (1989) concluded that drip irrigation gave the highest water use efficiency in round guard (5.10 q ha cm^{-1}) and water melon (10.3 q ha cm^{-1}) than furrow irrigation system (3.7 q ha^{-1} cm). It was observed that the yield increase by irrigation was associated with increase in fruit weight.

From an experiment conducted by Reddy and Rao (1983) on the response of bittergourd to pitcher and basin irrigation systems, it was evident that the yields were highest in pitcher filled every 4^{th} day and lowest in basin filled every every fifth day.

From a study conducted by Srinivas *et al.* (1986) on water requirement of water melon using different drip irrigation treatments, it was found that one emitter per two plants gave slightly higher yields (34 t ha^{-1}). In Kerala Agricultural University (1991), a comparative study of bubbler and drip methods of irrigation in bittergourd was undertaken. It was found that an irrigation schedule at 100 per cent evaporation in bubbler gave a yield increment of 28.33 t ha^{-1} with water use of 320 mm compared to drip. A similar study in okra revealed that bubbler works with pressure less than that of sprinkler with uniform distribution and increase in water use efficiency.

A field experiment was conducted in KAU by Gebremedhin (2001) to compare the efficiency of drip irrigation with that of basin irrigation in oriental pickling melon. The study revealed that drip irrigation saved irrigation water by 37 per cent and increased fruit yield by 20 per cent over conventional method.

A field experiment conducted during summer seasons of the years 2010 and 2011 to study the response of vegetable cluster bean (*cyamopsis tetragonaloba)* to fertigation of p and k revealed that higher yield attributes, green pod yield (15.03 t ha^{-1}) and straw yield (17.28 t ha^{-1}) were obtained with irrigation at 100 % CPE along with fertigation of 60 kg phosphorus and 60 kg potash per hectare. It also recorded higher net return (102314 ha^{-1}) and BCR (2.99). While, recommended 20-40 kg NP ha^{-1} through surface irrigation produced only 9.33 t ha^{-1} pod and 10.73 t ha^{-1} straw yields (Patel *et al.* 2013).

Studies by Ningaraju(2013) in op melon under high density planting revealed a FWUE of 203 kg ha-mm-^{1} in drip irrigation at 100 per cent Ep compared to the value of 75 203 kg ha-mm-^{1} under conventional method of pot irrigation. The corresponding yield levels in the above treatments were 66.8 and 52.9 t ha-^{1} respectively.

Recently, a field trial carried out by Iacomi *et al.* (2014) on automated and computer based fertigation in vegetables, it was revealed that using the system it is possible to reduce fertilizers needs by 70-90 per cent. Since most of the fertilizer gets absorbed directly into the plant, fertilizer run-off was virtually eliminated. Fertigation also improved the plant's efficiency in holding water due to an increase in root mass thereby reduced total water needed. The system, in its conception, could save 20-50 per cent of water usage through fertigation (increased uptake efficiency by the plant). It was possible to cut back the watering time by 10 per cent.

However, there are certain disadvantages for drip irrigation, both in agricultural and technical sides. They include clogging of emitters, high maintenance requirements, formation of precipitates, emitter non uniformity, damage by rodents, high initial cost, need for management skill and faulty designs.

Suitability of micro irrigation systems for fertigation

In general, pressurised systems such as sprinklers and drip irrigation can be managed to provide more uniform application, resulting in better control of deep percolation, than that is possible with surface systems. Micro irrigation systems make efficient use of available water to the plant root zone by minimising the losses. There is considerable saving of water in these systems (upto 40-50 per cent) depending upon the climate as soil surface wetted is restricted to root zone both in respect of depth and spread. Also, the drip system is having the minimum evaporation loss (Bruce *et al.* 1980).

Fertigation helps in easy supply of nutrients as they are available to plant roots more quickly than solid fertilizers which are applied to the soil. Therefore, this method saves fertilizers and labour requirement. The major possible disadvatages of fertigation are reported when irrigation systems are improperly designed or when poor quality fertilizer materials are used (Koo, 1980).

The benefits such as saving of water, labour, non - interference with cultural practices and distinct possibility of saving fertilizers when given through these systems can substantiate the initial cost of establishment. Since irrigation and fertilizer applications were regarded as very important among input management practices, enterprising farmers and scientists in the past have attempted to let fertilizers be distributed through irrigation, a concept termed as fertigation (Goldberg and Shumeli, 1970). Particularly for horticultural crops, this approach of supplying fertilizers through drip or sprinklers was developed by scientists in several countries (Bester *et al*, 1977). The area under drip fertigation has increased tremendously due to the potential advantages of the technology.

There are a number of pre - requisites for a fertigation system to be successful. They are a) the system should be designed in such a way that every emitter should deliver the same amount of water. b) the distribution of nutrients should be such that there should not be any blockages or deposits of fertilizers and chemicals and that c) there should be a constant and uniform mixing of plant nutrients with irrigation water and constant water flow throughout the system (Greef, 1975).

Fertilizers are the key inputs in agriculture for obtaining higher productivity. Normally, the use efficiency of fertilizers under conventional methods of application is low. This problem is more severe in the case of nitrogenous fertilizers whose consumption is the highest in most of the crops because of the universal deficiency of nitrogen in Indian soils which makes enormous appetite for nitrogenous fertilizers in our soils. The reason for low nitrogen use efficiency is because of its high mobility and liability to losses by various natural processes like leaching, denitrification and volatalization which are difficult to control particularly when nitrogen is added in bulk. Because of the low mobility of phosphorous in soil, it gets fixed in soil and gets slowly released and is made available to the plants in due course. Mobility of potassium is in between N and P and therefore its use efficiency is not a problem in general. The irrigation system being followed in India is largely flood irrigation, which not only results in huge loss of water, but also nutrients. The fertigation system is having the following advantages, *viz* a) higher water and fertilizer use efficiency, b) minimum loss of nitrogen through leaching, c) optimization of nutrient balance by supplying nutrients directly to the root zone in available form, d) control of nutrient concentration in soil solution for proper supply, e) saving in application cost and f) improvement of soil physical and biological conditions due to proper maintenance of moisture levels. Among the various nitrogenous fertilizers available in market, urea is best suited for fertigation due to its high solubility and inert nature with water to form ions. A higher nitrogen use efficiency of up to 90 per cent compared to 40-60 per cent in conventional systems can be obtained through fertigation. Under conventional system of flood irrigation, the nutrient uptake is affected by drought, lack of light and anaerobic conditions .Moreover, alternate wetting and drying of the soil in the conventional method of flood irrigation may cause denitrification losses, which is particularly absent in fertigation (Greeff, 1975a)

Effect of spacing and population density on growth, flowering and productivity

A decrease in spacing in melon has increased the number of fruits per plant when different spacings such as 30 60 and 90 cm were tested. But, a lower spacing reduced the mean fruit size and weight (Lazin and Simonds, 1982). From a similar study in musk melon, Prabhakar *et al.* (1985) revealed that the highest yield of 45 q ha^{-1} was recorded when plants were placed at 60 x 60 cm compared to other spacings.

Induction of early female flowers and total yield were observed in melons at a closer spacing of 90 x 22.5 cm from a field trial by Singh (1990). A wider spacing of 90 x 45 cm was found to produce more vine length, branches and leaves per plant. From a trial on different spacing in musk melon variety Superstar, Elizabeth and Dennis (1998) reported that the yield and number of fruits per ha generally increased with increase in plant population from 3074 to 10,076 plants per hectare. But the number of fruits per plant and fruit weight decreased linearly with decrease in row spacing. From a further study by Nerson *et al*. (1994), it was found that when plant population was increased from 13,500 to 31,250 plants per hectare, the vegetative growth of plants were increased.

From a trial conducted by Garcia *et al*. (1973), the greatest number of fruits of acceptable size per hectare of pickling cucumber was obtained with a spacing of 40 cm between hills and 3 plants per hill. The plants were planted at 1, 2 and 3 per hill with a spacing of 20, 40 or 60 cm and row width of 1m. In another trial by Mangal and Yadav (1979), maximum yield of cucumber was recorded in plants grown at a spacing of 100x 60 cm compared to 100 x 90 cm.

When cucumber plants were grown at different planting densities, the lowest had the greater values for growth parameters such as vine length and number of flowers. But, it was found that the leaf area was higher at high density planting (Bach and Hruska, 1981).

Burgmans (1981), while studying the effect of spacing on growth and yield of cucumber came to a conclusion that there is an increase in total yield of crop with increase in plant density. A study by Khayer (1982) showed that among the different spacing *viz,* 1.5, 2.0, 2.5 and 3.0 plants per m^2, increase in plant densities increased fruit number and weight per plot.

From a trial conducted by Lower *et al.* (1983) with different hybrids and open pollinated varieties of cucumber, more number of staminate flowers and less number of pistillate flowers were obtained with an increase in plant density.

Staub *et al.* (1992), after studying the effect of plant density on the performance of cucumber, observed that a higher plant density increased the number and weight of fruits per hectare but decreased the fruit weight. In an attempt to study the effects of different spacings, Wann (1993) observed that among the three different spacings such as 38 x 10, 56 x 8 and 84 x 5 cm, plants spaced at 38 x 10 cm produced higher yield compared to other treatments.

Further, studies by Hanna and Adams (1993) showed that high plant population achieved by decreasing row spacing from 12 to 6 inches increased total yield than plants spaced at 18 inches. In a work conducted with cucumber cultivar Japanese Long, Choigounghah *et al.* (1995) reported that maximum yield of 3,80,020 kg per hectare was obtained with a planting density of 45,000 plants per hectare.

Renji (1998) reported the highest yield of slicing cucumber from the highest density of 13,333 plants per hectare. The maximum yield of cucumber was observed from a spacing of 60 x 60 cm with pruning of all primary branches after two nodes (Kanthaswamy *et al.* 2000).

It was observed that when plant spacing decreased from 30 to 20 cm and from 20 to 10 cm, there was an increase in staminate flowers and decrease in pistillate flowers and fruit yield (Hafidh, 2001). Later, a study conducted to determine the effect of plant spacing on yield and quality of cucumber, Paroussi and Saglam (2002) found that, among different within - row spacings (20, 30 and 40 cm) the highest yield was reported from 20 cm compared to 30 and 40 cm.

The highest number of fruits per vine and yield per hectare were recorded in cucumber from a spacing of 1.8 m x 0.40 m. The different spacings tested were 1.8 x 0.3m, 1.80 x 0.45m and 1.8 x 0.60m (Choudri and More, 2002). From an experiment to find out the effect of plant density on fruit growth, Nishimura and Lopezgalvezij (2002) found that an increased plant density decreased the total above ground biomass and the number of fruits, but enhanced the biomass allocation to the vegetative shoots.

Echevarria and Castro (2002) reported that among four plant densities (2, 1.67, 1.43 and 1.25 plants per m^2), yield per plant increased with decrease in spacing. Also, it was found that earliness and quality were not affected by plant density.

A field trial was conducted to study the effects of plant density on the growth and yield of water melon variety Sugar Baby by Bindukala (2000). She came into a conclusion that maximum number of fruits per plot and marketable yield per plant were obtained from the highest planting density of 20,000 plants per hectare.

In an attempt to find out the effect of plant density on growth, development and yield of winter squash, it was found that maximum marketable yield of 18 t ha^{-1} was obtained from a spacing of 1.1 plants per m^2 (Botwright *et al.* ,1998).

From a trial conducted at Punjab Agricultural University by Kulbir Singh *et al.* (1990) on the effect of different plant spacings (3.00 x 0.60 m, 3.00 x 0.75 m and 4.00 x 0.75 m) on growth, yield and quality of pumpkin, it was observed that different spacings did not change the number of fruits per vine, but the yield per plant was increased significantly with increase in intra row spacing from 0.60 m to 0.75 m. The closer spacing of 3.00 m x 0.60 m produced the maximum yield of 108.12 q h^{-1} and the closer spacing induced early formation of female flowers.

A work held to study on the effect of spacing on different varieties of pointed gourd revealed that the maximum yield of 110.32 q h^{-1} was recorded at a spacing of 1.5 m x 1.5 m among the two spacings tested viz. 1.5 m x 1.5 m and 3 m x 1.5 m (Yadav *et al.* ,1979).

Parekh (1990) reported the maximum main vine length and number of primary branches per plant and TSS at wider spacing of 1.5 m x 1.0 m in bittergourd. In another study, when seeds of ridge gourd variety Pusa Nasdar were sown at 12, 9 and 6 plants per bed, the spacing of 9 plants per bed gave the longest plant with highest number of secondary branches and resulted in early appearance of pistillate flowers (Arora and Mallik, 1990).

According to Pandit *et al.* (1997) total number of fruits per plant and length of fruits increased with increase in plant population in pointed gourd.

A study conducted by Jamuna Devi (2003) on the spacing requirement of oriental pickling melon variety Soubhagya revealed that high density planting is necessary in obtaining maximum yield. She came into the conclusion that Soubhagya, a short duration, low spreading variety, when planted at a high population of 33,333 plants ha^{-1} (1.0 x 0.3 m) produced the highest fruit yield of 33.93 t ha^{-1} compared to 11.4 t ha^{-1} with the usual recommended plant population of 10,000 plants ha^{-1} (i.e. 2.0 m x 1.5 m). Similar studies by Rajees (2013) at the Agricultural Research Station, Mannuthy also reported best crop performance by op melon at a plant population of 33,333 ha-^{1}.

Movement of plant nutrients under fertigation

Localized application of fertilizers is possible through fertigation, and this makes the method highly beneficial one. The determining factors of nutrient movement in soil are the cation exchange capacity of the soil, electrostatic charge of the particular nutrient and the water flow through the soil. The movement of charged nutrients such as ammonium, potassium, calcium and magnesium is dependent on the degree of saturation of the exchange complex of the soil and also exchange capacity of this complex, i.e., a sandy soil has less exchange sites than a loamy soil which is lesser than a clayey soil. Therefore nutrient movement in sandy soil occurs more readily than on a loamy or clayey soil. Neutral chemical molecules like urea and negatively charged nutrient ions like nitrate and sulphate primarily move through the profile with the flow of water. Therefore, leaching out of urea and nitrates may occur when irrigation is provided in excess of the plant requirement (Greeff, 1975b).

Occurrence of phosphate fixation in most of the soils was reported by Ralston *et al*. (1974). When conventional practice of broadcasting of fertilizers is practiced, a larger proportion of applied phosphate is found in the surface soil layers. It is reported that fertigation can ensure uniform phosphate gradient in soil and also movement of organic phosphates and glycerophosphate in the soil column.

Effect of fertigation on growth, yield and quality of vegetables

Choudhari *et al*. (1995) reported that number of leaves and number of internodes per plant were significantly influenced by the application of 100 kg N ha^{-1}

through fertigation compared to control. Also, among the two varieties tested, the variety Parbhani Kranti was found to be more vigorous than Selection 2-2.

From an experiment conducted by using three okra varieties (Parbhani Kranthi, Selection 2-2 and Punjab-7) with different doses of fertilizers through fertigation, Soumkuwar *et al.* (1997 reported that application of 75 kg nitrogen per hectare increased the vegetative growth, number and weight of fruits per plant and yield per hectare. Among the three tested varieties, highest yield was recorded for Parbhani Kranthi (77.70 q ha^{-1}) with low incidence of yellow vein mosaic virus and shoot borer.

Pitts *et al.* (1991) studied the effect of flooding against fertigation using staked drip irrigated tomato cv. Sunny, where N and K (about 75per cent of the total rates) were applied as fertigation. It was found that fertigation could reduce the crop damage due to higher water table following heavy rains. But there was no significant difference in the yields produced by fertigation and conventional flood irrigation.

From another study, Ibrahim (1992) reported that fertigation increased the crop yield compared to traditional method of band application in tomato cultivar Ed Cawy. It was also found that the fertigation frequency of 2 days interval produced highest yield.

A study conducted to find out the effect of drip irrigation and different rates of N, P and K fertilizers on yield and quality of tomato cultivar Mountain Pride. It was revealed that application of 1000 lb of 10: 10: 10 NPK fertilizers before planting, in combination with drip irrigation produced yield equal to those with higher rates of fertilizers applied partly before planting and partly through irrigation stream (Mullins *et al.* 1992).

For obtaining high yield and good quality tubers in potato, application of P at a rate of 40 mg l^{-1} along with irrigation water was found suitable among different P levels tested (0, 20, 40 and 60 mg l^{-1}) (Papadopoulos, 1992).

Liquid fertilizers gave highest yields compared to solid fertilizers when two cultivars of tomato were studied (Soliman and Doss, 1992).

In potato, highest tuber yield (15.03 t ha^{-1}) was obtained by soil application of 50 per cent of recommended nitrogen with furrow irrigation and the remaining 50 per cent through drip irrigation at four weekly split applications (Keshvaiah and Kumaraswamy, 1993). The water use efficiency was highest when daily drip irrigation was provided.

Amarananjundeshwara (1997) reported that 100 per cent water soluble fertilizers when applied as fertigation recorded maximum yield, plant height, number of sprouts, higher leaf area and more number of leaves per plant than the conventional method of fertilization in potato.

Thumbere and Nikam (1998) studied the effect of planting and fertigation on growth and yield of green chilli (Capsicum annum). The treatments included recommended doses of fertilizers (100: 50: 50 kg NPK ha^{-1}) at every irrigation (2 days interval) up to 105 days which resulted in a significantly higher yield of 9.30 and 9.06 t ha^{-1} during first and second year respectively. However, it was found on par with fertigation at 4 days intervals up to 105 days.

From another study on the effects of source and levels of fertigation on capsicum hybrid Green Gold under green house condition during winter revealed that maximum productivity was achieved when water soluble fertilizers were applied at a higher dose (120 per cent RDF). Also, the fruits were having excellent quality with a shelf life of 11.36 days. The crop was economically feasible at other levels of fertilizers also (Manohar, 2002).

Prabhakar *et al.* (2002) studied the effects of fertigation and plastic mulching in tomato. The treatment with half NK fertigation and drip with black polythene mulch was found to be good with respect to yield and growth parameters like mean fruit weight, number of fruits per plant and number of clusters per plant. And the yield was 121.3 t ha^{-1}. The highest TSS of 5.3° B (Brix) was observed in treatments with soil application of recommended dose of fertilizers. The treatment half of NK fertigation through Multi K with black polythene mulch reported the highest fruit dry matter content.

Fertigation studies were conducted in cucurbitaceous crops also. The highest yield (29.83 t ha^{-1}) and an increased fruit weight of melons (1.1 kg) were obtained with N at 70 kg, P_2O_5 at 60 kg and K_2O at 90 kg ha^{-1} when applied through irrigation water (Harnandez and Aso, 1991).

Veeranna *et al.* (2002) reported that decreasing the fertilizer levels by 12 per cent than the recommended level especially under fertigated conditions may not affect the yield level in chilli because of the improved fertilize use efficiency at the lower fertilizer dose.

Patel and Rajput (2004), after conducting trial on fertigation reported that the yield of okra under conventional method of fertilization with 100 per cent of recommended dose of fertilizers was on par with that under fertigation with 60 per cent recommended dose of fertilizers. More than 16 per cent increase in yield under fertigation (25.21 per cent) was observed as compared with broadcasting of fertilizers when 100 per cent RDF was applied.

Darwish *et al.* (2003) studied the impact of N fertigation in potato and reported that fertigation with continuous N feeding through drip system based on actual N demand and available N in soil resulted in 55 per cent N recovery. High N input not only increased the N derived from fertilizers but also enhanced soil residual N.

There are reports that irrigation at 100 and 50 per cent ET with fertigation of 100 per cent N and K recorded higher and comparable pod yield of chilli as compared to surface irrigation at 0.9 IW/CPE ratio with entire NPK as soil application (Muralikrishnasamy *et al.* 2006). However, fertigation of 125 per cent of N and K led to marginal decrease in chilli pod yield over fertigation of 100 per cent N and K. Whereas, fertigation of 75, 100 and 125 per cent N and K registered 50.6, 66.8 and 58.6 per cent increase in pod yield respectively over soil application of 100 per cent N and K with surface irrigation.

An experiment was conducted by Mahajan and Singh (2006) in greenhouse grown tomato on different irrigation methods and fertilizer levels. They have found that when the same quantity of water and N was applied through drip fertigation, a significantly higher yield (68.5 t ha^{-1}) was obtained as compared to the yield of 58.4 t ha^{-1} in check basin method. Drip irrigation at 0.5 x Ep along with fertigation of 100 per cent N resulted in increased fruit yield by 59.5 per cent over the control.

According to Shedeed *et al.* (2009), there was a significant increase in growth parameters (like plant height, LAI, fruit dry weight, total dry weight), yield components (number of fruits per plant, mean fruit weight, fruit yield per plant) and total fruit yield in tomato with the application of 100 per cent RDF through fertigation over furrow and drip irrigation and soil application of fertilizers.

Fertigation studies by Bhakare and Fatkal (2008) in onion with 100 per cent recommended dose of fertilizers applied through drip irrigation resulted in 106 per cent increase in water use efficiency, 40 per cent saving of irrigation water and 53 per cent increase in fertilizer use efficiency over 100 per cent recommended dose of fertilizers applied through broadcasting and incorporation along with surface irrigation method.

It was reported that drip irrigation system with 100 per cent RDF is more profitable as compared to furrow irrigation in brinjal due to the increased yield. The highest yield obtained in furrow irrigation with 100 per cent RDF (21 t ha^{-1}) was less than the yield obtained in 60 per cent ET and 50 per cent RDF level under drip irrigation (32 t ha^{-1}) (Basavarajappa *et al.* 2011).

The application of NPK through fertigation was found to influence the vegetative growth, flowering, bunch weight and yield in banana variety Monthan (Banthal). It was also noticed that maximum pseudostem height, stem circumference were found with the application of 75 per cent RDF as NPK in the ratio of 3: 2: 1 at vegetative growth, 1: 3: 2 at flowering stage and 2: 1: 3 at fruit development stage (Dinesh *et al.* 2012).

Prabhaker *et al.* (2012) reported that application of 50 per cent recommended dose of NPK fertilizers through drip irrigation in summer tomato gave higher plant height, number of branches, lesser number of days for flowering, fruiting and higher marketable fruit yield over the conventional soil application of fertilizers to the tune of 10.75 to 20.69 per cent. When 50 per cent recommended dose of N : K was applied through fertigation using conventional fertilizers, the highest net income and B: C ratio were obtained.

A recent study by Pandey *et al.* (2013) revealed that there is a significant increase in yield and net income by the adoption of drip irrigation in chilli as compared to flood irrigation. It was found that when the crop was irrigated through drip, the yield was increased by 60.30 per cent. It also resulted in maximum water saving, minimization of weeds, diseases and total time for irrigation.

An experiment was conducted by Chattoo *et al.* (2013) in radish variety Japanese White Long to compare the efficiency of different irrigation levels and fertilizer doses for fertigation. He found the superiority of drip irrigation and fertigation practices in terms of yield, water and fertilizer use efficiency over conventional methods. It was also reported that the treatment combination of 75 per cent ET through drip with 75 per cent recommended dose of fertilizers was significantly superior over conventional method. The advantages include 68.9 per cent yield enhancement, 46.2 q ha^{-1}-cm water use efficiency and 4.78 q ha^{-1}-kg P and K fertilizer use efficiency.

Fertigation in cucurbits

Several studies have been conducted to evaluate the effect of fertigation in cucurbitaceous crops. Important among them are discussed below.

A trial conducted in two cucumber cultivars Uniflora B and Sporu for a period of two years by Kretschmer and Zengerle (1973) revealed that higher yield of 6.8 per cent was obtained from application of N, P and K fertilizers through overhead sprinkler compared to soil application.

From a study of Bhella and Wilcox (1987) on the N use efficiency of musk melon under drip irrigation, it was revealed that there was a significant increase in stem growth, early maturity and total yields with increasing pre-plant nitrogen fertilization rates. The plants were found to be more responsive to increasing N fertigation in the case of plant growth without the application of fertilizers. Fertigation responses were reduced in regimes that received 67 or 100 kg N per hectare.

An increased fruit weight of melons (1.1 kg) were obtained with N at 70 kg, P_2O_5 at 60 kg and K_2O at 90 kg ha^{-1} when they are applied through irrigation water (Harnandez and Aso, 1991).

Pinto *et al.* (1993) studied the efficiency of trickle irrigation in Eldorado melons by applying N either daily or three times a week at eight different growth periods up to 55 days after germination. In the control, 55 per cent of total N and 100 per cent of K as potassium chloride were applied at planting and the remaining 45 per cent of N was applied 30 days later, but K was applied at different periods up to 42 days after germination in other treatments. They came into a conclusion that the highest yield were obtained with daily fertigation.

A fertigation trial on the growth and yield of gherkins was held by Raman *et al.* (2000) where the treatments consisted of four fertigation with different soluble fertilizer combinations at two levels (100 and 75 per cent NPK) compared with recommended dose of solid fertilizers applied through band application in soil. The results showed that, application of 75 per cent of recommended dose of NPK with soluble fertilizers through drip irrigation system gave higher yields, resulting in 25 per cent saving of fertilizers, than band application.

From a field trial conducted in pickling cucumber, it was reported that treatments with total amount of nitrogen 110 kg ha^{-1} resulted in the lowest yield whereas the highest N supply (170 kg ha^{-1}) gave the highest yield. The use of all nutrients in fertigation had no significant effect on yield, in comparison with giving only N and K. Finally, it was concluded that 120-140 kg per ha nitrogen is enough for producing better yield (Soujala *et al.* , 2006).

According to Shinde and Malunjkar (2010), 100 per cent recommended dose of nitrogen (100 kg ha^{-1}) through fertigation with 8 splits in cucumber cultivar Himangi were recorded higher number of fruits (2.166 kg per plant), yield (255.03 q ha^{-1}) and also showed lower values of water requirement with an increased water use efficiency.

Ruby *et al.* (2012) reported that the parameters like fruit weight, fruit length, and average fruit weight per vine in pointed gourd were highest under 100 per cent fertigation with mulch. These values were on par with 80 per cent fertigation with mulch. Also, the highest yield of 15.78 t ha^{-1} was recorded by 100 per cent fertigation with mulch.

An experiment to study the effect of optimal daily fertigation on migration of water and salt in soil, root growth and fruit yield of cucumber (*Cucumis sativus* L.) in solar-greenhouse was carried out in China. The treatments included conventional interval fertigation, optimal interval fertigation and optimal daily fertigation. The results suggested that optimal daily fertigation is a beneficial practice for improving crop yield and the water and fertilizers use efficiency in solar greenhouse (Xinshu *et al.* ,2014).

A field experiment was conducted by Ningaraju (2013) at the Kerala Agricultural University during December 2012 to March 2013 to standardize drip fertigation under high density planting in summer grown oriental pickling melon. The treatments consisted of combinations of four irrigation levels (50, 75 and 100 % Ep through drip irrigation and farmers practice of pot irrigation @ 10 litres per plant on alternate days from flowering to maturity and half of this quantity from 10 DAS to flowering) and three fertilizer levels (100, 150 and 200 % as recommended by the KAU, PoP). Growth parameters like length of vine, number of leaves per vine, number of branches per vine, leaf area index and shoot dry matter production at harvest increased significantly with increase in drip irrigation level from 50 to 100 per cent Ep and with increase in fertilizer levels from 100 to 200 per cent RDF. Among the treatment combinations, maximum yield (72.4 t $ha^{-1)}$ was recorded at 100 % Ep given through drip system with 200 % RDF.

Water and nutrient interaction

Since most of the nutrients are taken up by the plants through mass flow, the nutrient absorption is affected directly by soil moisture content. At the same time, nutrient uptake is affected indirectly by the effect of water on the metabolic activity, the degree of soil aeration and salt concentration of the soil solution. Generally, P and K uptake is highly affected by soil moisture depletion compared to N uptake. Under drought conditions, in addition to reduced uptake of soluble N, the mineralization of N is also reduced. It is evident that fertilizer N will not increase yield without sufficient plant available water. At the same time, increased stored soil moisture by conservation practices will not increase the production without adequate nitrogen (Jackson *et al.* , 1983).

It is well known that yield response to P and other nutrients are mainly affected by water availability. Lower the rainfall , greater the response to P. The same relationship is commonly observed with K also. Response of crops to K in wet soil can be related to the effect of reduced aeration or respiration in wet soil where oxygen availability is less compared to dry soil. Nutrient and water interactions under irrigated systems are similar to that of dry land systems, except the interactions operate at higher yield levels under the first case. Soil fertility is one of the important factors influencing water use in irrigated soils. When N is deficient, increasing N fertilization will increase the yield, total water use, and WUE. Generally, when water is non limiting, the crop response to N is much greater under irrigation (Thorne *et al.* , 1979).

Effect of nutrient doses on growth, yield and quality of vegetable crops

Meena *et al.* (2008) after conducting a trial to assess the suitable dose of nitrogen (among 40, 80 and 120 kg N) with and without bio fertilizer (Azotobacter) in okra cv. Arka Anamika, reported that 120 kg N ha^{-1} along with Azotobacter application gave significantly highest yield.

Singh *et al.* (2008) conducted a trial during kharif seasons of 2007 and 2008 to ascertain the effect of nitrogen (at 0, 80, 120 and 140 kg ha^{-1}) under varying plant spacing (50 x 30 and 50 x 40 cm) on the growth and yield attributes of okra. The study revealed that vegetative growth in terms of height and diameter of plant, number of leaves and nodes and leaf area increased with N application 140 kg ha^{-1}, followed by 120 and 80 kg ha^{-1} during both years. In the case of phosphorous also, similar trend was seen. Highest level of yield attributes was observed from 100 kg P_2O_5 ha^{-1}.

A field experiment was conducted by Verma and Batra (2001) at Haryana, during spring-summer season of 1997 and 1998 on sandy loam soil to study the response of spring okra to irrigation and N levels. It was found that 150 and 200 Kg N applied in three splits (basal, 30 and 45 days after sowing) increased the N uptake linearly with the increase in the intensity of irrigation. But, excess irrigation showed a detrimental effect on yield. Highest fruit yield was obtained with moderate intensity of irrigation.

From a study conducted at Bangalore, Karnataka, India to investigate the effect of different doses of fertilizers (NPK at 125:75:60, 150:100:75 and 175:125:100 kg ha^{-1}) on bindhi varieties Arka Anamika, Varsh and Vishal by Gowda *et al.* (2002) revealed that highest nutrient uptake and accumulation in leaves and fruits were reported from highest level of fertilizers irrespective of the varieties.

Kushwaha *et al.* (2008) conducted a field experiment to obtain the optimum dose of nitrogen and phosphorous. Results showed that each increment in nitrogen dose up to 150 kg ha^{-1} significantly increased the plant height, number of fruits per plant, pod length, pod weight, dry weight of 100 gm fresh pod and crop yield. Also the phosphorus levels up to 80 kg ha^{-1} increased all the above parameters except pod weight and yield.

Role of application of organic manures along with chemical fertilizers was studied by Ashish *et al.* (2006) at Bihar in okra. The highest nutrient uptake with respect to N, P and K and net return was recorded with the treatments supplied with 25 per cent of the recommended rate of nutrients through farm yard manure. The combination of inorganic fertilizers in same proportion followed the same. It was also found that in terms of net returns, application of 18 kg N ha^{-1} was more beneficial compared to the full dose of inorganic fertilizers.

Singh *et al*. (2007) conducted a field trial to determine the effect of N (50, 100 and 150 kg ha^{-1}), Cu (500, 1000 and 2000 ppm) in okra cultivar Pusa Sawani. The result revealed that maximum plant height, stem diameter, leaf length and width, fresh pod weight and green pod yield etc were obtained with 100 kg N ha^{-1}, 1000 ppm Cu and 1000 ppm Fe.

To evaluate the effect of NPK fertilizer rates and method of application on growth and yield of okra, an experiment was conducted by Omotoso and Shittu (2007). They have tested three levels of NPK fertilizer rates (0, 150 and 300 kg NPK ha^{-1}) and two methods of fertilizer application (ring and band method). It was found that levels of fertilizer significantly increased growth parameters like plant height, leaf area, root length and number of leaves. They have concluded that the optimum yield of okra was obtained from the use of 150 kg NPK ha^{-1} and ring method of application.

Effect of plastic film mulching in crops

Mulching is the process or practice of covering the soil or ground to make more favorable conditions for plant growth, development and efficient crop production. Plastic mulching – covering soil with polyethylene (PE) plastic films – is being established worldwide as a method in agriculture to increase crop production (Berger, 2013). Use of mulches for early crop offers great scope in such a situation because of conserving moisture and improving soil temperature (Hooda *et al*., 1999). Plastic mulches are used in many horticultural crops to raise soil temperature, suppress weeds and conserve soil water (Brault *et al*., 2002).

In many regions of the world, over the last 20 years, vegetable production has shown significant yield increases (Krug, 1999). Plasticulture techniques such as plastic film mulch and drip irrigation have undoubtedly contributed considerably to these increases in production (Lamont, 1993). When compared to other mulches, plastic mulches are completely impermeable to water, therefore prevents direct evaporation of moisture from the soil and thus limits the water losses and soil erosion over the surface. In this manner it plays a positive role in water conservation. The suppression of evaporation also has a supplementary effect as it prevents the rise of water containing salt, which is important in countries with high salt content water resources.

Effect of plastic film mulching on soil moisture conservation

From a study conducted by Gutal *et al.* (1992) to find out the effects of mulching in on the yield of tomato, it was evident that polythene film mulch has a significant effect on the growth of tomato by conserving 23 per cent more soil moisture compared to control treatment. During the same year (1992), Chandraputhiran *et al.* reported an increase in soil moisture level of 10.4 per cent under straw mulch and 29.6 per cent under polythene mulch over control treatment.

It was found that mulched soil contained approximately 2 to 40 per cent more moisture in ploughing depth than unmulched soils (Putra *et al.*, 1993). According to Uthaiah *et al.* (1993), both natural and synthetic mulches improved the growth by conserving soil moisture in the root zone of coconut .

In a field trial conducted by Ckakrabarthy and Sadhu (1994), greater soil moisture conservation was observed in treatments mulched with polythene sheets. At the same time, the ability of rice straw mulch or water hyacinth mulch in conserving soil moisture was significantly lower than that of polythene mulch.

A study conducted by Srinivas and Hedge (1994) in Robusta banana to find out the effect of different mulches and cover crops revealed that the water use was lowest under the polythene mulch, followed by straw mulch, and was highest when banana was raised with cover crops. The evapotranspiration under polythene mulch decreased by 8 per cent and 14 per cent compared with that under straw mulch and no mulch treatments. Also the water use efficiency was highest under polythene mulch, mainly due to higher yield and lower evapotranspiration.

In cabbage, it was reported that sowing and simultaneously covering the rows with perforated plastic strips increased the soil moisture in the top soil by up to 14.5 per cent and soil temperature by 0.5 to 1.6°C. This improved soil micro climate, and shortened the crop growing period by 21 to 24 days compared with the use of transplants (Mikhov *et al.* 1995).

The effect of plastic mulching and drip irrigation in capsicum was investigated by Yoon *et al.* (1995) in four areas of Korean Republic. They found that mulching increased the soil water content and yield compared with controls. The highest yield (2778 kg ha^{-1}) was observed from the black polythene and rice hull treatments.

Studies by Gebremedhin (2001) at the Agricultural Research Station, Mannuthy using different mulching materials in op melon revealed 7 to 8.2 per cent more moisture retention in the root zone depth of the crop under black LDPE mulching than control plots. Paddy straw mulching could increase the same by 2.2 to 4.2 per cent.

Effect of plastic film mulching on soil temperature

Plastic mulches alter the crop micro climate by changing the soil energy balance (Liakatas *et al.* 1986; Tarara, 2000), resulting in changes in soil temperature that may positively affect plant growth and yield (Cooper, 1973; Lamont, 2005).

In temperate regions, black plastic mulch is very effective when used with cucurbits because it absorbs heat, warms the soil, and maintains good soil moisture levels. The plastic can be installed when the soil is in good planting condition, any time from a few days to 2-3 weeks before planting. This will speed harvest since the soil will be very warm when the seeds and transplants are planted (Lerner and Dana, 2001).

The effect of soil mulching with black plastic sheets on soil temperature and tomato yield was evaluated in the temperate region of Uttarakhand. Highest soil temperature was obtained under the black plastic mulch during the early growth season due to less shade on the surface. The difference in temperature between mulched and bare soil was 2.2 to 3.4°C. Black plastic mulch significantly affected the tomato yield. The yield increased with black plastic mulch from 20.7 to 29.8 per cent as compared to bare soil (Singh and Kamal, 2008).

In a trial conducted to compare the black and silver coloured plastic muiches, Carlos (2002) found that the percentage of photosynthetically active radiation (PAR) reflected from the mulches was highest in silver mulches and lowest in black mulches. The mean root zone temperature under the plastic mulch decreased with increasing percentages of reflected PAR. In the fall season, during the first 28 days after transplanting, plant growth attributes were among the highest in silver mulches and the lowest in black mulches. Both marketable and total yields were higher on silver mulches.

Among the various mulches tried in vegetables, superiority of plastic mulches has been well accepted. Polythene mulching and drip irrigation has shown to improve early and total yields (Abdul- Baki *et al.*, 1992); increase water and nutrient efficiency (Halsey, 1985); improves yield and quality (Vani *et al.* 1989) and control weeds (Halsey, 1985). One of the most important advantages of polythene mulch cum drip irrigation is the higher BC ratio of 13 which may go up to 32 when water saving is also taken into consideration. This figures are substantially higher than surface methods of irrigation, which are having a BC ratio between 1.8 to 3.9 (Narayanamoorthy, 1997).

In an experiment conducted by Gutal *et al.* (1992) with polythene mulches, it was observed that coloured polythene mulch films increased soil temperature by 5-7 °C which facilitated faster germination and better root proliferation. At the same time, weed growth was checked and soil moisture was retained preserving soil structure. It was further observed that CO_2 around the plants was increased.

A three year experiment with 25μ LDPE film as mulch resulted in a conclusion that the yield of tomato could be increased by 55 per cent and weed growth was reduced by 90 per cent and soil moisture conserved was 28 per cent more than the control without mulch.

Gupta and Acharya (1994) reported that the use of black polythene mulch was superior to transparent polythene. The beneficial effect of transparent polythene due to rise in soil temperature during initial stages was counteracted during fruiting stage by reducing the yield due to higher soil temperature. Whereas black polythene raised the soil temperature by 2 to 3°C during night over unmulched soil and did not alter the day temperature.

Gebremedhin (2001) using different mulching materials in op melon revealed increase in soil temperature by 2 ^{0} C at 15 cm soil depth at 15 cm radius from the emitter under black LDPE mulching and drip irrigation. The study was conducted at the at the Agricultural Research Station, Mannuthy.

Effect of plastic film mulching on weed control

Mulching with plastic film controls the weeds as in the case of all other mulches used in agriculture. This is possible by reducing the bare soil surface area for the weeds to grow. Hundred per cent weed control is possible for the surface which is covered by plastic mulch, which cannot be applicable to any other mulches.

It was reported that among the different mulching materials such as smooth paper, bark straw, and black polythene, the later is having good weed control per cent ground cover (Davies *et al.* 1993). They have also explained that a clean ground was left following the removal of polythene mulch and weed population remained low throughout the next crop season.

From a study conducted by Ashworth and Harrison (1983) to determine the effect of organic and synthetic mulches on weed control, water conservation and soil temperature, they found that the opaque synthetic mulches like black polythene remained intact throughout the summer and thus provided the most effective weed control. And the worst weed problem was identified in straw mulch.

Chakraborthy and Sadhu (1994) reported hundred per cent weed control in plots mulched with black polythene. Whereas, clear polythene allowed considerable weed growth, and the fresh and dry weights of weeds which was as high as that under rice-straw mulched plots.

Selders *et al.* (1994) conducted a study on different mulching materials and came into a conclusion that shredded and chopped newspaper mulches can provide good weed control, help retain soil moisture, suitable soil temperature, reduce some disease problems and increase yields and quality of fruits. It was also reported that, black polythene mulch suppressed weed growth whereas white polythene mulch encouraged weed growth (Gupta and Acharya, 1994).

A weed control of 98 per cent was reported from a combination of black polythene mulch and drip irrigation in tomato crop (Srivastava *et al.*1994). In a similar study, (Anonymous, 1989) it was reported that black plastic mulch and sugarcane trash mulch could reduce the weed growth to the tune of 91 per cent and 89 per cent respectively.

According to a trial conducted by Monks *et al.* (1997) using shredded news paper (2.5, 7.6, 12.7, and 17.8 cm depth), chopped newspaper (2.5 and 7.6 cm), wheat straw (15.3 cm), black plastic and plastic landscape fabric as mulching materials during 1993 and 1994 in West Virginia for their effect on soil temperature, soil moisture, weed control and yield in tomato, a high newspaper mulching rates reduced soil temperature as compared to black plastic and bare ground. Chopped newspaper controlled weeds more consistently than other treatments. At least 7.6 cm of chopped newspaper mulch was required to give 90 per cent control. Wheat straw was not as effective in controlling weeds. Generally mulches applied at 0, 2 or 4 weeks after transplanting resulted in weed control similar to the chemical treatment.

Successful control of weed growth in op melon was achieved by mulching with black LDPE(Gebremedhin, 2001). The dry matter production of weeds observed in op melon in control, straw mulched plots and black LDPE mulched plots were in the order of 228.7, 130.4 and 0.0 g m^{-2} respectively.

Effect of plastic film mulch on growth and yield

There are several experimental reports regarding the positive effects of plastic film mulching on germination, growth and yield of many crops.

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

In pickling cucumbers mulching with polythene was found to increase the yield, vine length, leaf number and main root length by 149, 183, 163 and 128 per cent respectively (Carne, 1984). In a similar experiment conducted by Iapichino and Gagliand (1984), it was found that the growth of water melon was higher in polythene mulched plots. Also, They have seen to produce female flowers earlier than control plots.

According to Djigma and Diemkouma (1986), the yield of brinjal cultivar Longue Violette was 33.8 t ha^{-1} with 100 μm black polythene mulch compared to 10.07 t ha^{-1} with no mulch. The corresponding yields in Heinz-1370 tomatoes were 110.9 t ha^{-1} and 47.6 t ha^{-1} respectively. In a similar experiment conducted in the same crop using pine needle, black plastic and newspaper as mulching material, it was revealed that in a year of abundant rainfall, mulching did not influence growth and yield of crop. But in years of limited rainfall, black plastic mulching increased earliness and yield of brinjal and this as well as pine needle mulching conserved soil moisture and controlled weeds more effectively than other mulches (Carter and Johnson, 1988).

There are also reports on the effect of plastic mulching on the reduction of some plant diseases. Vani *et al.* (1989) observed that use of yellow polythene, transparent polythene and straw mulch reduced the levels of mosaic disease incidence in muskmelon and increased the plant growth and yield by 36, 74 and 51 per cent respectively.

In salad cucumber and watermelon grown inside a greenhouse, Salman *et al.* (1990) observed that the features like plant height, number of leaves and leaf area were increased irrespective of mulch colour that is, transparent in the case of cucumber and black in the case of water melon.

From a trial conducted in tomato, it was evident that higher and early marketable yields of 4.7, 4.5 and 4.3 t ha^{-1} were obtained when it was grown over aluminium or black coloured mulch than from those grown over white mulch which produced 2.3 t ha^{-1}. It was also observed that total marketable yield was higher in plants grown over green or aluminium mulch than that grown over black or white mulch (Brown *et al.* 1992).

Studies revealed that the harvesting time of cucumber could be brought forward by 7 days by mulching either with red or black plastic mulch. The red plastic mulch treatment produced the best yield of 60.27 t ha^{-1} against 47.03 t ha^{-1} with black plastic mulch and 42.33 t ha^{-1} with no mulch (Aranjo *et al.*, 1992).

In a field trial to investigate the effect of polythene mulch colour on the fruiting response of strawberry, Albregts and Chandler (1993) used black , white, blue, brown, green, orange, red and yellow coloured mulches. They have found that an early high yield was obtained in all three seasons by using yellow mulch compared to black mulches. The soil temperature was the highest for blue coloured mulch and lowest with white and yellow coloured mulch.

The yield of musk melon was higher under plastic sheet mulching compared to bare soil (Taber, 1993). An experiment was conducted to study the effect of different mulch types and colours on the growth and yield of tomato. It revealed that polythene mulches, irrespective of colour improved the growth and yield over rice straw mulch (Chakraborthy and Sadhu, 1994).

In another field trial conducted by Farghali (1994), capsicum plants were mulched with black or white polythene applied before planting. Compared with unmulched control, mulching resulted in earlier flowering and fruiting, increased plant height and greater number of branches. The white mulch resulted in slightly higher yields than black mulch.

Saravanababu (1994) reported that the mean plant height, leaf area, number of flowers per plant, mean number of branches per plant, root length, dry matter production and yield of brinjal were highest in plants grown with banana trash mulch at a rate of 15 t ha^{-1} compared to other mulches and without-mulch control.

In the case of cucumber, it was well evident that fruit number and yield are higher for mulched plots (Farias *et al.*, 1994). Siwek *et al.* (1994) studied the effects of mulching on changes in microclimate and on the growth and yield of sweet pepper grown in plastic tunnels. White and black polythene sheets were applied as mulch. The black polythene mulch resulted in a 10.3 per cent increase and the white polythene mulch resulted in only 6.1 per cent increase in the yield over the bare tunnel soil. Fruits were larger with either mulch than no- mulch.

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

From a study conducted to observe the effects of mulch on tomato production, Rubeiz and Freiwal (1995), it was concluded that early and total yields were highest with mulching and lowest with raw covers. The largest fruits were produced under black mulch.

A field experiment was conducted by Lourduraj *et al.* (1996) for four years in okra and for two years on tomato at Tamil Nadu Agricultural Unuversity, Coimbatore. Results showed the beneficial effects of mulching. In the case of tomato, mulching with black LDPE recorded a yield of 12.74 kg ha^{-1}, thus registering 28.4 per cent yield enhancement over unmulched control. In okra, the same treatment resulted in 50 per cent yield increment compared with control.

Studies by Gebremedhin (2001) at the Agricultural Research Station, Mannuthy in OP melon revealed significant increase in number of vines per plant, length of vines, number of leaves per vine, leaf area, LAI, number of fruits per plant, fruit yield per hectare, length of fruits, girth of fruits and fruit volume under black LDPE mulching than control and straw mulching. The increase in LAI, number of fruits per plant, average fruit weight and yield under LDPE mulching over control were in the order of 30, 27, 13 and 43 per cent respectively.

Similar studies by Anoop (2009) at the same research station in op melon also recorded similar results. Here also significant increase in number of vines per plant, length of vines, number of leaves per vine, leaf area, LAI, number of fruits per plant, fruit yield per hectare, length of fruits, girth of fruits and fruit volume were observed under black LDPE mulching than control. The increase in branches per plant, length of vine, LAI, number of fruits per plant, average fruit weight and yield under LDPE mulching over control were in the order of 27, 07, 21, 25, 01 and 28 per cent respectively.

MATERIALS AND MEHODS

5

3. MATERIALS AND METHODS

The investigation entitled "Fertigation and mulching in oriental pickling melon *(Cucumis melo* var. *conomon*) under high density planting" was carried out at College of Horticulture, Vellanikkara, Thrissur, Kerala. The field experiment was conducted during December 2014 to March 2015 at the Agricultural Research Station, Mannuthy under Kerala Agricultural University. The details of materials used and techniques adopted during the course of investigation are presented below.

3.1. Location

The experimental area is situated at 12° 32' N latitude and 74° 20' E longitude at an altitude of 22.5 m above mean sea level. The climate of the area is typical warm humid tropical.

3.2. Cropping history

The site used for experiment is a double cropped paddy wet land in which a semi dry sown crop from April – September and a transplanted wet crop from September – December are cultivated. The land is usually kept fallow during summer season. Soil type of the experimental field is sandy clay loam. The soil characteristics of the experimental field are given in Table 1.

3.3. Crop and variety

Oriental pickling melon *(Cucumis melo* var. *conomon*) variety Saubhagya developed at the Department of Olericulture, College of Horticulture, Vellanikkara was utilized for the study. Fruits of Saubhagya are small to medium in size and oblong in shape. The developing fruits are green with light green lines and they turn to attractive golden yellow colour on ripening. The variety matures in 60-65 days. Low spreading nature and small to medium sized attractive fruits are its other advantages which make them suitable for use in nuclear families.

3.4. Season

Experiment was conducted in the summer rice fallow from December 2014 to February 2015. Meteorological data during the cropping period are presented in Table 2and Table 3

Table1. Soil characteristics of the experimental field

Particulars	Value	Procedure adopted
1) Mechanical composition		
Coarse sand (%)	27.1	Robinson's international pipette method (Piper, 1950)
Fine sand (%)	23.9	
Silt (%)	22.8	
Cay (%)	26.2	
Textural class	Sandy clay loam	I.S.S.S system (ISSS,1992)
2) Physical constants of the soil		
Field capacity(% at 0.3 bars)	21.82	Pressure plate apparatus (Richard, 1947)
Permanent wilting point (% at15 bars)	9.34	Core method (Blake, 1965)
Bulk density (g cm^{-3})		
0 - 30 cm	1.34	Pycnometer method (Blake, 1965)
30 - 60 cm	1.36	
Particle density (g cm^{-3})	2.16	

3) Chemical properties		
Organic Carbon (%)	0.63	Chromic acid wet digestion method (Walkley and Black, 1934)
Available Nitrogen (kg/ha)	210.8	Alkaline permanganate method (Subbiah and Asija, 1956)
Available Phosphorus (kg/ha)	29.5	Bray and Kurtz method(Bray and Kurtz, 1945)
Available Potassium (kg/ha)	88	Neutral normal ammonium acetate extract using flame photometer (Jackson, 1958)
Soil reaction (p^H)	5.45	1:2.5 soil: water suspension using p^H meter (Jackson, 1958)
Electrical conductivity (dS/m)	1.35	Supernatant of 1:2.5 soil : water suspension using EC bridge (Jackson,1958)

3.5. Experimental details

3.5.1 Layout

The layout plan of experiment is given in Fig.2 and in Plate 1. Other details of the experiment are given below:

Design	: Randomized Block Design (RBD)
Number of treatments	: 10
Number of replications	: 3
Total number of plots	: 30
Plot size	: 4 m x 3 m
Spacing	: 1.0 m x 0.3 m
Number of plants per plot	: 40
Date of sowing	: 27th December 2014
Date of harvest	: 28th February 2015

3.5.3. Treatments

The treatments consisted of combinations of three levels of drip irrigation and three doses of NPK as drip fertigation with LDPE mulching. The treatment details are given below.

3.5.2.1. Irrigation levels

I_1 – Drip irrigation at 75 % Ep

I_2 – Drip irrigation at 100 % Ep

I_3 – Drip irrigation at 125 % Ep

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3.5.2.2. Fertilizer levels

F_1- 200 % of RDF (Recommended Dose of Fertilizer)

F2- 250 % of RDF

F3- 300 % of RDF

3.5.2.3. Mulching details

Mulching with LDPE sheet which is ash coloured on the upper surface and black in the lower surface was done for all treatments except control.

3.5.2.4. Treatment combinations

T_1 (I_1F_1)	T_2 (I_1F_2)	T_3 (I_1F_3)	With LDPE mulch
T_4 (I_2F_1)	T_5 (I_2F_2)	T_6 (I_2F_3)	
T_7 (I_3F_1)	T_8 (I_3F_2)	T_9 (I_3F_3)	

3.5.2.5. Control (T_{10})

- Irrigation on alternate days with 2 cm water during flowering and fruiting and 1 cm water during initial stages (Germination and Seedling)
- Fertilizers as per PoP (Package of Practices) recommendations of KAU (Kerala Agricultural University) (100 % RDF ; 70:25:25 Kg N: P_2O_5 : K_2O ha^{-1})
- No mulch

3.6. Cultural practices

3.6.1. Land preparation

The land was ploughed twice with a cultivator and harrowed once to bring the soil to a fine tilth. Stubbles were then removed and the experimental plot was laid out according to the plan. Channels were taken at the spacing mentioned above to a depth of 30 cm and width of 50 cm. After the FYM application, and incorporation into the soil by digging, soil was heaped over the channels to form raised ridges. After that, basal P fertilizer was applied and a pre - sown irrigation was given uniformly to all the ridges. Ash coloured LDPE sheet was spread over the ridges and sides were sealed with soil. Holes for seeding were made on the sheet at every 30 cm interval using PVC pipe. A total of 30 plots (10 treatments × 3 replications) were made with boundaries of width 1m on all sides of the plots. A view of the experimental plot after land preparation is provided in Plate 1.

3.6.2. Manure and fertilizer application

Farmyard manure at the rate of 25 t ha^{-1} was applied uniformly in all the channels as basal dose. After thorough mixing with top soil by digging, channels were filled and converted to ridges and then uniformly irrigated using hose. Entire P (Super phosphate) was applied as basal soil incorporation. Fertilizers applied were urea, single super phosphate (SSP) and muriate of potash (MOP). Nitrogen and Potassium were applied as fertigation in 6 split doses at weekly interval from 10 DAS to 40 DAS in treatment plots. In control plots, soil incorporation of fertilizers was done as per PoP recommendations of KAU.

3.6.3. Sowing

Two seeds were uniformly sown at each point inside shallow holes on each ridge. Gap filling was done on 6^{th} day after sowing and thinning was done on 10^{th} day after sowing by retaining only one plant in each point.

3.6.4. Irrigation

A pre-sowing irrigation was given uniformly to all the treatments. After sowing, uniform irrigation was given to all the channels up to 9 days using rose can. Daily drip irrigation was based on the pan evaporation values of the previous day and the amount of water was fixed as per the treatments.

Three sets of water tanks (two tanks each) of 200 litre capacity were used for storing water. The tanks were kept on raised platforms to a height of 2 m above the ground. The tanks were connected to main irrigation lines consisting of rigid PVC pipes having 2 inch diameter by suitable bends and pipes. At the beginning of each main line a PVC valve was provided. From the main lines, laterals made of LDPE having 16 mm internal diameter were connected at 1m intervals in rows in the plots. Drippers were inbuilt in the main laterals at 30 cm apart. The discharge rate from each dripper was calculated as 1.3 L hr^{-1}. The required amount of water was applied according to the treatments through single dripper per plant.

Constant filling of the tanks were assured by connecting them to the pumping line. A wire mesh filter was provided in the pumping line to prevent soil and other impurities in the irrigation water from entering into the storage tanks. Separate control valves were provided for each laterals.

3.6.5. Aftercare

There was no weed problem in the plots due to LDPE mulching. But there were few weeds near the base of the plant and at the inter – ridged area. At the same time, control plots were highly affected with weeds. Hand weeding was done three weeks after sowing.

3.6.6. Plant protection

Minor attack of red pumpkin beetle was there during early seedling stages. Confidor (Imidachloprid) was sprayed at a rate of 0.5 ml l^{-1} at 18 DAS for the control of minor sucking pests and red pumpkin beetle, and also during the fruit development stage for the control of fruit flies.

3.6.7. Harvesting

Fruits were harvested when they were fully ripe (when they got attractive golden yellow stripes from stalk end to pedicel end). Staggered harvesting was done. Control plots were harvested one week after the harvest of the drip fertigated plots.

3.7. Biometric observations

Growth and yield parameters were recorded for understanding the effects of treatments on growth and development of the crop. The following attributes were recorded from randomly selected four plants per plot and the average was worked out.

3.7.1. Length of vines (cm)

The length of vines was observed and measured from the base to the tip of the plant at final harvest.

3.7.2. Number of leaves per vine

Total number of leaves per vine was recorded from four plants per plot at harvest.

3.7.3. Number of primary and secondary branches per plant

The number of primary and secondary branches was counted from four sample plants in a plot before harvest.

3.7.4. Leaf area index

Leaf Area Index (LAI) was found out by dividing the total leaf area by the land area occupied by the plant (Watson, 1947). Leaf area was measured by leaf area meter on 45^{th} day after sowing.

3.7.5. Shoot dry matter production at harvest

Shoots of ten plants were taken from each plot and the average was taken to get the fresh weight. After that it was dried in oven up to constant weight to find out the dry weight.

3.7.6. Days to first flowering (male and female)

Number of days taken for first blooming of both male and female flowers in every plot was recorded in all the four observational plants and average worked out.

3.7.7. Days to harvest

The treatment plots were harvested in the last week of February 2015. It took exactly 63 days and 68 days respectively to harvest the treatment plots and control plots.

3.7.8 .Mean volume of fruits (cm^3)

Volume of fruits from each plot was found from the selected sample fruits having mean weight using water displacement method.

3.7.9. Mean weight of fruits (g)

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

3.7.10. Number of fruits per plant

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

3.7.11. Yield of fruits per plot

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

3.7.12. Percentage loss of fruits on storage

Six fruits from each treatment were kept for four months after harvest for storage studies. And the percentage loss of fruits on storage was calculated.

3.8. Uptake of NPK at harvest

The concentration of N, P and K in shoots and fruits were analysed and multiplied with total dry matter yield of shoots and fruits respectively at harvest to obtain uptake of these nutrients, which is expressed as kg ha^{-1}

3.9. Field water use efficiency

The economic yield (kg) per unit of water used is referred as water use efficiency. It was calculated using the given formula:

$$\text{FWUE (kg ha - mm}^{-1}\text{)} = \frac{\text{Fruit yield (kg ha}^{-1}\text{)}}{\text{Water used (ha mm)}}$$

3.10. Incidence of pests and diseases

Attack of red pumpkin beetles was severe during the initial stages of crop growth. Fruit fly attack was found in the fruit development stages. Both of them were brought under control by appropriate spraying of insecticides. Powdery mildew was observed during harvesting stage. But it was not severe enough to affect the yield.

3.11. Soil properties of the experimental field after the trial

3.11.1. Soil p^H

1:2.5 ratio of soil: water suspension was prepared and p^H was measured by using p^H meter (Jackson, 1958).

3.11.2. Electrical conductivity ($dS\ m^{-1}$)

A supernatant of 1:2.5 ratio soil : water suspension was prepared and the electrical conductivity was measured using EC bridge (Jackson, 1958).

3.11.3. Soil moisture content

Determination of soil moisture content was done by gravimetric method. For this, soil samples were collected from three depths *viz.* 0-15 cm, 15-30 cm and 30-45 cm using a screw auger after the harvest of the crop.

3.11.4. Nutrient status of the soil after the trial

3.11.4.1. Available Nitrogen (kg ha^{-1})

The available nitrogen content of soil was determined by alkaline permanganate method (Subbiah and Asija, 1956).

3.11.4.2. Available phosphorus (kg ha^{-1})

The available phosphorus content of soil was determined by Bray and Kurtz method (Bray Kurtz, 1945).

3.11.4.3. Available potassium (kg ha^{-1})

The available potassium of soil was extracted by neutral normal ammonium acetate and the content was estimated using flame photometer (Jackson, 1958).

3.12. Plant analysis

Leaf samples were collected at 45 days after sowing. Whole plant samples were collected at the time of harvest. Samples were oven dried, ground and used for N, P and K analysis.

3.12.1. Nitrogen content

The plant samples were digested by using con. H_2SO_4 and distillation was done by micro kjeldahl method (Jackson, 1958). The content was estimated by titration.

3.12.2. Phosphorus content

The plant samples were digested by diacid digestion (Jackson, 1973). Spectrophotometer was used for reading the colour intensity developed by Vanado - molybdate yellow colour method.

3.12.3. Potassium content

The potassium contents of samples were determined with diacid extract and the content was read in an EEL flame photometer (Jackson, 1973).

3.13. Economics of production

The economics of production was worked out based on the input costs, labour charges and the price at which the local sellers accepted the fruits of OP melon at the time of harvest. Input costs were taken as the actual cost of the materials at the time of conduct of the experiment. Labour charges considered were the prevailing labour wages of the locality at the time of conduct of the experiment. Cost of installation of drip irrigation system for the experiment was taken as the one fifth of the total cost of materials as it is assumed that a unit of drip irrigation can be used at least for five consecutive crops. Based on this, the total cost of production and return was worked out. From this the net income and the net profit per rupee invested was calculated.

3.14. Statistical analysis

Analysis of variance was done separately for all the characters at different stages as per the statistical design of RBD with two factor combinations and significance was tested by 'F' test (Snedecor and Cochran, 1967).

Plate 1(a). View of experimental field after land preparation

Plate 1(b). View of the experimental field after seedling establishment

Plate 2 (a). View of experimental field after installation of drip system

Plate 2(b). View of experimental field at peak vegetative

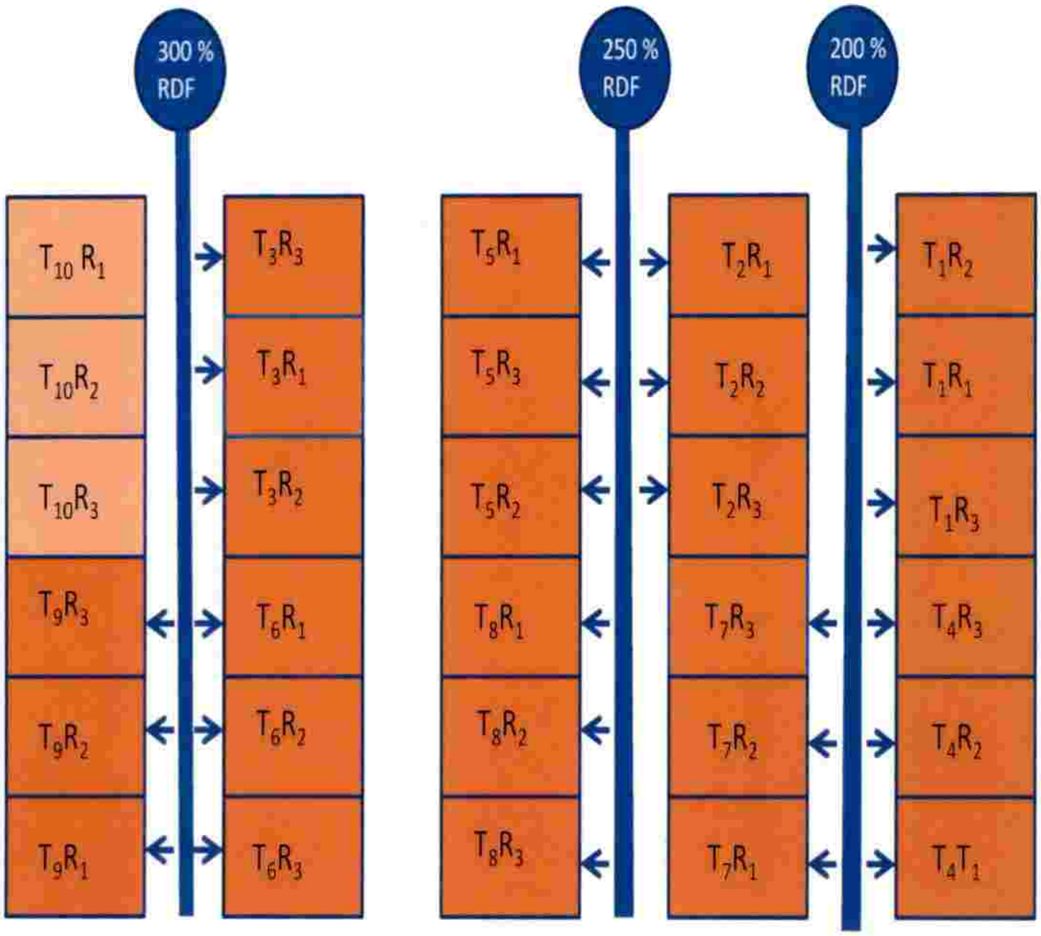

Fig.1. Lay out of the experimental field

Spacing = 1.0 m x 0.3 m

Distance between plots = 1m

Fertigation plots with LDPE mulch

Cotrol plots

Table 2. Mean weekly weather factors during cropping period (December 2014 to March 2015)

Std week	Date	Temperature		Relative Humidity (%)		Wind speed (Km/hr)	Evaporation (mm)	Soil temperature at 15 cm depth (^{0}C)	
		Max	Min	Morning (07-22 hrs)	Evening (14-22 hrs)			Morning	Evening
52	24/12 to 31/12	23.3	23.3	078	052	3.9	3.5	27.5	32.2
1	01/01 to 07/01	32.5	21.5	090	047	2.7	3.2	27.5	33.2
2	8/01 to 14/01	32.0	21.3	072	039	5.7	4.5	27.5	32.4
3	15/01 to 21/01	32.4	22.1	066	041	5.9	4.5	27.7	32.4
4	22/01 to 28/01	32.9	23.0	073	038	7.1	5.1	28.4	32.4
5	29/01 to 04/02	32.9	23.7	066	040	8.6	6.0	28.8	33.3
6	05/02 to 11/02	33.6	23.2	069	036	7.5	5.9	29.0	33.6
7	12/02 to 18/02	35.2	23.5	083	037	4.0	4.6	30.2	35.2
8	19/02 to 25/02	35.0	35.0	066	030	5.1	6.1	29.9	34.8
9	26/02 to 04/03	34.6	34.6	086	049	3	4.3	30.5	35.5

Table 3. Mean weekly weather factors for five years from 2011

Std week	Date	Temperature		Relative Humidity (%)		Wind speed (Km/hr)	Evaporation (mm)	Soil temperature at 15 cm depth (^{0}C)
		Max	Min	Morning (07-22 hrs)	Evening (14-22 hrs)			Morning
52	24/12 to 31/12	32.1	22.27	072	046	5.57	34.50	29.76
1	01/01 to 07/01	32.75	22.32	082	046	4.85	31.52	31.90
2	8/01 to 14/01	33.42	22.57	072	042	5.20	34.65	32.30
3	15/01 to 21/01	32.92	21.60	065	036	5.72	36.90	32.05
4	22/01 to 28/01	32.95	22.44	064	034	8.27	44.50	31.85
5	29/01 to 04/02	33.45	22.82	065	032	7.25	45.05	32.27
6	05/02 to 11/02	34.75	22.36	075	033	4.70	37.90	33.25
7	12/02 to 18/02	34.30	22.84	083	038	4.20	32.92	33.17
8	19/02 to 25/02	34.57	22.64	071	041	4.56	38.10	32.75
9	26/02 to 04/03	35.2	23.04	076	032	4.56	40.40	33.80

Table 4. Total quantity of water used for the different irrigation treatments

Treatments	Irrigation interval	Quantity of water used (mm)				Total water applied (mm)
		Pre sowing irrigation (mm)	Irrigation as per treatment from 1 to 9 DAP (mm)	Irrigation as per treatment from 10 DAP to 1 day prior to harvest (mm)	Effective rainfall (mm)	
I1	Daily	40	30	212	0	282
I2	Daily	40	30	283	0	353
I3	Daily	40	30	354	0	424
Control	Once in two days	40	30	400	0	560

RESULT

4. RESULTS

The results obtained from the experiment on "Fertigation and mulching in oriental pickling melon under high density planting" are furnished in this chapter.

4.1 Growth parameters

4.1.1 Number of primary branches

The data on number of primary branches per plant are given in Table 5 and the Analysis of variance in Appendix 1.

Levels of irrigation did not influence the primary branches significantly. It varied from 2.1 to 2.4 per plant. Number of primary branches per plant also was not significantly influenced by the levels of fertilizer. The interaction between irrigation and fertilizer levels did not influence the number of primary branches per plant significantly. Treatments were not effective than the control in promoting more primary tiller production as evidenced by the non significance of F test.

4.1.2. Number of secondary branches per plant

The data on number of secondary branches per plant are given in Table 5 and the Analysis of Variance in Appendix 1.

Levels of irrigation significantly influenced the number of secondary branches per plant. Maximum number of secondary branches per plant (6.9) was observed at the irrigation level I_3 and was significantly superior to other levels.I_2 was significantly superior to I_1. Fertilizer levels also significantly influenced the number of secondary branches per plant. Maximum number of secondary branches per plant (6.7) observed at F_3 was significantly superior to F_1 and F_2. The effects of F1 and F2 were on par. The interaction between irrigation and fertilizer levels was not significant. Treatments were found to be effective in producing more secondary branches compared to the control as evidenced by significance of the F test.

4.1.3. Length of vine

The data on average length of vines at the time of harvest are given in Table 5 and the Analysis of Variance in Appendix 1.

Levels of irrigation significantly influenced the length of vines. Highest length of vines (166.1 cm) was observed at the irrigation level I_3 and was significantly superior to I_1 and I_2 .. I_2 was significantly superior to I_1. Fertilizer levels also significantly influenced the length of vine. Among the fertilizer levels, F3 recorded the highest length of vine (166.5 cm). F3 was significantly superior to F1 and F2. But the difference between F1 and F2 was not significant. The interaction between irrigation and fertilizer levels was not significant. Treatments were effective in comparison with control on promoting the length of vine as evidenced by the significance of F test.

4.1.4 Number of leaves per vine

The data on average number of leaves per vine at the time of harvest are given in Table 5 and the Analysis of Variance in Appendix 1.

Number of leaves per vine was significantly influenced by the levels of irrigation up to I_3. Highest number of leaves per vine (44) was observed at the irrigation level I_3 and was significantly superior to I_1 and I_2. I_2 was significantly superior to I_1.Fertilizer levels also significantly influenced the number of leaves per vine. Highest number of leaves per vine (40.7) was observed with F_3 and it was significantly superior to F_1 and F_2. F_2 was significantly superior to F_1. The interaction between irrigation and fertilizer was not significant. Treatments were found to be effective in comparison with the control in increasing the number of leaves per vine as evidenced by significance of F test.

4.1.5. Leaf Area Index (LAI)

The data on Leaf Area Index (at 45 DAS) are shown in Table 5 and the Analysis of Variance in Appendix 1.

Leaf Area Index was significantly influenced by the levels of irrigation. Highest Leaf Area Index of 2.0, observed at I_3 level of irrigation was significantly superior to I_1, but at par with I_2. I_2 was on par with I_1. Fertilizer levels also significantly influenced the Leaf Area Index. Leaf Area Index increased significantly up to F_3 . Highest Leaf Area Index (2.16) observed at F_3 was significantly superior to F_1 and F_2. F_2 was significantly superior to F_1 . The interaction between fertilizer and irrigation levels was not significant. Teatments were effective in comparison with the control, in promoting the Leaf Area Index as evidenced by the significance of F test.

4.2. Number of days to flowering

4.2.1. Days to male flowering

The data on number of days taken for the appearance of male flowers in oriental pickling melon Variety Saubagya as influenced by irrigation and fertilizer level are given in Table 5 and the Analysis of Variance in Appendix 1.

The effect of irrigation, fertilizer and their interaction on days taken for male flowering was not significant. Days, taken to male flowering remained constant at about 21 days in all the treatments.Control took significantly more days (24.7) compared to treatments (20.3) for male flowering as evidenced by significance of F test.

4.2.2 Days to female flowering

The data on number of days taken for the appearance of female flowers in oriental pickling melon Variety Saubagya as influenced by irrigation and fertilizer level are given in Table 5 and the Analysis of Variance in Appendix 1.

Irrigation, fertilizer and their interaction did not affect days taken for female flowering in a significant way. On an average, the days taken to female flower opening remained between 24.3 to 26.0. Control took significantly more days (29.3) compared to treatments (25.7) to female flower opening as evidenced by the significance of F test.

Table 5; Influence of irrigation and fertilizer levels on vegetative growth and days to flowering

Treatments	Length of vine (cm)	No. of leaves per vine	LAI	No . of primary branches	No. of secondary branches	Days to first male flower	Days to first female flower
Irrigation							
I_1	146.2	31.3	1.87	2.1	5.1	20.6	25.4
I_2	152.4	34.3	1.93	2.1	5.9	20.8	25.6
I_3	166.1	44	2.00	2.4	6.9	20.8	25.7
C.D (0.05)	4.90	1.79	0.07	NS	0.79	NS	NS
SEm±	1.62	0.59	0.023	0.67	0.26	0.15	0.13
Fertilizer							
F_1	146.8	33.3	1.77	2.1	5.3	20.6	25.3

F_2	151.4	35.7	1.87	2.1	5.9	20.7	25.7
F_3	166.5	40.7	2.16	2.4	6.7	20.9	26.0
C.D (0.05)	4.90	1.79	0.07	NS	0.79	NS	NS
SEm±	1.62	0.59	0.023	0.67	0.26	0.15	0.13
Interaction	NS	NS	NS	NS	NS	NS	NS
C.D (0.05)	NS	NS	NS	NS	NS	NS	NS
SEm±	1.62	0.59	0.023	0.67	0.26	0.15	0.13
Control	126.5	24.0	0.96	2	2.7	24.7	29.3
Treatments	154.9	36.5	1.93	2.2	6.0	20.7	25.7
Control Vs Treatments (F 0.05)	8.20*	7.77*	30.32**	NS	4.6*	9.49**	11.84**

4.3. Yield and yield attributes

4.3.1. Number of fruits per plant

The data on number of fruits per plant are presented in Table 6 and the analysis of variance in Appendix 1.

Levels of irrigation did not influence the number of fruits per plant significantly. Fertilizer levels had significant effects on number of fruits per plant. Highest number of fruits per plant (2.85) observed at I_2 was significantly superior to I_1 and at par with I_3 . I_1 and I_3 were on par. The interaction between levels of irrigation and fertilizer was not significant. Treatments were effective in increasing the number of fruits per plant (2.82) over the control (1.82) as evidenced by the significance of F test.

4.3.2 . Average weight of fruits

The data on average weight of fruits are presented in Table 6 and the analysis of variance in Appendix 1.

Levels of irrigation, fertilizer and their interaction had no significant effect on the average weight of fruits. Nevertheless, the treatments (656 g) were superior to control (398 g) in increasing the average weight of fruits as evidenced by the significance of F test.

4.3.3. Average volume of fruits

The data on average fruit volume are furnished in Table 6 and the analysis of variance in Appendix 1.

As in the case of average fruit weight, average fruit volume also was not significantly influenced by the levels of irrigation, fertilizer and their interaction.

Treatments were effective in increasing the fruit volume (676 cm^3) over the control (407 cm^3) as evidenced by the significance of F test.

4.3.4. Fruit yield (kg /plant)

The data on average fruit yield (kg /plant) are furnished in Table 6 and the analysis of variance in Appendix 1.

Levels of irrigation had no significant influence on the mean fruit yield per plant. But, per plant yield was slightly higher at I_2 level of irrigation than at I_1 and I_3.

Fertilizer levels influenced the average fruit yield per plant significantly. Highest fruit yield per plant (1.927 kg) observed at F_2 level of Fertilizer was significantly superior to F_1 and F_3, whose effects were on par.

The interaction between irrigation and fertilizer levels was significant with regard to the average fruit yield per plant. In all irrigation levels , average fruit yield per plant increased with increase in fertilizer levels up to F_2 and then decreased. At I_1, I_2 and I_3 irrigation levels, F_2 level of fertilizer recorded significantly higher fruit yield per plant over F_1 level. The decrease in fruit yield per plant with F_3 fertilizer level over F_2 level was not significant at I_2 and I_3 levels of irrigation. In F_1 fertilizer level, fruit yield per plant remained same without significant change with all the three levels of irrigation. But in F_2 level of fertilizer, fruit yield per plant increased significantly upto I_2 and then decreased. In F_3 fertilizer level, highest yield was obtained with I_2 level of irrigation and the lowest yield with I_3 level of irrigation. I_2F_3 was significantly superior to I_3F_3. Among the combinations, I_2F_2 recorded the highest fruit yield per plant (1.973 kg) and was significantly superior to all the combinations except I_3F_2(1.940 kg).

All the treatments were effective in increasing the fruit yield per plant (1.850 kg) over the control (0.717 kg) as evidenced by the significance of F test.

4.3.5. Fruit yield

The data on fruit yield are presented in Table 6 and the analysis of variance in Appendix 1.

Levels of irrigation did not affect fruit yield significantly. Nevertheless, fruit yield was the highest (64.2 t/ha) at I_2 level of irrigation compared to I_1 (60.8 t/ha) and I_3 (61.8 t/ha).

Fertilizer levels influenced the fruit yield significantly. Highest fruit yield was observed at F_2 level of fertilizer application (64.2 t ha $^{-1}$) and was significantly superior to F_1 (60.1 t ha^{-1}) and F_3 (60.7 t ha^{-1}). F_1 and F_3 were on par in terms of fruit yield.

The interaction between irrigation and fertilizer levels was significant on fruit yield per ha. In all irrigation levels, fruit yield per ha increased with increase in fertilizer levels up to F_2 and then decreased. At I_1, I_2 and I_3 irrigation levels, F_2 recorded significantly higher fruit yield over F_1 level. The decrease in fruit yield with F_3 fertilizer level over F_2 level was not significant at I_1 level of irrigation, but significant at I_2 and I_3 levels of irrigation. In F_1 fertilizer level, fruit yield remained same without significant change with all the three levels of irrigation. But in F_2 level of fertilizer, fruit yield increased significantly up to I_2 and then decreased. In F_3 fertilizer level, highest fruit yield was obtained with I_2 level of irrigation and the lowest with I_3 level. I_2F_3 was significantly superior to I_3F_3. Among the combinations, I_2F_2 recorded the highest fruit yield per ha (65.8 t ha^{-1}) and was significantly superior to all the other combinations Except I_3F_2 (64.7 t ha^{-1}).

Treatments were highly superior to control in increasing fruit yield per ha (61.7 t/ha) over control (23.9 t ha^{-1}) as evidenced by the significance of F test.

4.3.6. Days to harvest

The number of days to harvest was not significantly influenced by levels of drip irrigation or fertilizer. However, harvest was delayed by five days in control plots and the difference was significant as per the F test.

Table 6: Influence of irrigation and fertilizer levels on yield and yield attributes

Treatment	No. of fruits per plant	Avg. weight of fruits(g)	Avg. volume of fruits (cm^3)	Yield per plant(kg)	Yield ($t\ ha^{-1}$)	Days to harvest
Irrigation						
I_1	2.81	651	670	1.824	60.8	63
I_2	2.85	657	677	1.873	62.4	63
I_3	2.80	661	681	1.853	61.8	63
C.D (0.05)	NS	NS	NS	NS	NS	NS
SEm±	0.02	7.50	7.75	0.0147	0.4849	0.5052
Fertilizer						
F_1	2.76	653	673	1.803	60.1	63
F_2	2.85	664	684	1.927	64.2	63
F_3	2.80	652	672	1.821	60.7	63
C.D (0.05)	0.06	NS	NS	0.04	1.45	NS
SEm±	0.0196	7.50	7.75	0.0147	0.4849	0.5052
Interaction	NS	NS	NS	S	S	NS
CD (0.05)	NS	NS	NS	0.08	2.50	NS
SEm±	0.02	7.50	7.75	0.0147	0.4849	0.5052
Control	1.82	398	407	0.717	23.9	68
Treatments	2.8	656	676	1.850	61.7	63
Control Vs Treatments(F 0.05)	38.6**	15.56**	16.87**	86.70**	88.2**	16.25**

Table 6 (a). Interaction between irrigation and fertilizer levels on yield (t ha^{-1})

Treatments	I_1	I_2	I_3
F_1	59.2	59.7	61.4
F_2	62.2	65.8	64.7
F_3	61.0	61.8	59.2

CD (0.05) =2.50

Table 6 (b). Interaction between irrigation and fertilizer levels on average fruit yield per plant (kg)

Treatments	I_1	I_2	I_3
F_1	1.777	1.790	1.843
F_2	1.867	1.973	1.940
F_3	1.830	1.857	1.777

CD (0.05) = 0.076

4.4. Shoot and fruit dry matter production

4.4.1. Shoot dry matter production

The data on the effect of irrigation and fertilizer levels on the shoot dry matter production at harvest are presented in Table 7 and the analysis of variance in Appendix 1.

Shoot dry matter production was significantly influenced by the levels of irrigation. Highest shoot dry matter production was recorded by I_3 level of irrigation (1528.7 kg ha^{-1}) which was significantly superior to I_1(1443.3 kg ha^{-1}). The effects of I_1 and I_2 were on par.

There was significant influence of fertilizer levels on the shoot dry matter production. The highest shoot dry matter production was with F_3 level of fertilizer (1576.7 kg ha^{-1}) which was significantly superior to both F_1 (1400.7 kg ha^{-1}) and F_2 (1486.0 kg ha^{-1}) levels. Effect of F_2 was superior to that of F_1.

Interaction between irrigation and fertilizer did not show any significant effect on shoot dry matter production.

All the treatments were effective in increasing the shoot dry matter production of op melon compared to the control, as evidenced by the significance of F test.

4.4.2. Fruit dry matter production

The data pertaining the effect of irrigation and fertilizer levels on fruit dry matter production are given in Table 7 and the analysis of variance in Appendix 1.

There was an increase in fruit dry matter production with increase in irrigation level up to I_2 and then the trend was reverse up to I_3. But the effects were not significant.

At the same time, increase in fertilizer levels significantly reflected in fruit dry matter production up to F_2 and then decreased. There was significant difference between the effects of all the fertilizer levels. The maximum fruit dry matter production (5464 kg ha^{-1}) was with F_2 level of fertilizer.

The interaction between irrigation and fertilizer levels also significantly influenced the fruit dry matter production. In all irrigation levels, fruit dry matter production increased with increase in fertilizer levels up to F_2 and then decreased. Similarly in all fertilizer levels, fruit dry matter production increased with increase in irrigation level up to I_2 and then decreased. The maximum fruit dry matter production was recorded with I_2F_2 (5590.7 kg ha^{-1}) which was significantly superior to all other treatment combinations except I_3F_2 (5500.0 kg ha^{-1}).

All the treatments showed their superiority in increasing fruit dry matter production compared to control as evidenced by significance of F test.

Table 7 . Influence of irrigation and fertilizer levels on shoot and fruit dry matter production at harvest

Treatment	Shoot dry matter production (kg ha $^{-1}$)	Fruit dry matter production (kg ha $^{-1}$)
Irrigation		
I_1	1443.3	5172
I_2	1491.3	5306
I_3	1528.7	5250
C.D (0.05)	64.9	NS
SEm±	21.6409	40.9416
Fertilizer		
F_1	1400.7	5108
F_2	1486.0	5464
F_3	1576.7	5157
C.D (0.05)	64.9	122.7
SEm±	21.64	40.9416
Interaction	NS	S
CD (0.05)	NS	212.6
SEm±	21.6409	40.9416
Contol	948	1864
Treatments	1488	5243
Control Vs Treatments F (0.05)	10.59**	111.4**

Table 7(a). Interaction between irrigation and fertilizer levels on fruit dry matter production

Treatments	I_1	I_2	I_3
F_1	5029.3	5071.7	5222.0
F_2	5301.0	5590.7	5500.0
F_3	5185.3	5256.0	5029.3

CD (0.05) = 212.6

4.5. NPK content of leaf at 45 DAS

4.5.1. Nitrogen content

The data showing effects of irrigation and fertilizer levels on nitrogen composition of leaves at 45 DAS is provided in Table 8 and the analysis of variance in Appendix 1.

Levels of irrigation significantly influenced the nitrogen content of leaves at 45 DAS. Highest N level (3.94%) was observed with I_3 level of irrigation, which was significantly superior to other two levels. In general, N content increased with increase in irrigation level.

Fertilizer levels also showed a similar trend on the nitrogen composition of leaves. With increase in fertilizer level, N content also increased. Highest Nitrogen composition of leaves at 45 DAS (4.16%) was observed with F_3 level of fertilizer, which was significantly superior to all other levels.

The interaction between irrigation and fertilizer levels didn't show any significant influence on the N content of leaves at 45 DAS.

In general, all the treatments recorded significantly higher N content than the control which was evidenced by the significance of F test.

4.5.2. Phosphorus content

The data on P composition of leaves at 45 DAS are given in Table 8 and the analysis of variance in Appendix 1.

Levels of irrigation significantly influenced the leaf P content at 45 DAS . With increase in irrigation levels, P content also increased. Highest leaf P content (0.35%) was observed with I_3 level of irrigation, which was significantly superior to all other levels.

Similarly, there was a significant effect of fertilizer levels on the leaf P content of OP melon at 45 DAS. Leaf P content increased with increase in fertilizer levels. The highest value (0.38%) was observed with F_3 level of fertilizer, which was significantly superior to F_1 and F_2 levels.

The interaction between irrigation and fertilizer levels was not significant on the leaf P content at 45 DAS. In general, all the treatments were significantly superior to control.

4.5.3. Potassium content

The data on K composition of leaves at 45 DAS are given in Table 8 and the analysis of variance in Appendix 1.

It was found that, with increase in irrigation levels the content of K content in leaves also increased, but the effect was not significant.

With increase in fertilizer levels, there was an increase in K content of leaves. The highest K content of leaves observed at 45 DAS with F_3 level of fertilizer (1.95 %) was significantly superior to all other levels.

There was no significant effect by the interaction of irrigation and fertilizers on the leaf composition at 45 DAS.

All the treatments were superior to the control as evidenced by the significance of F test.

Table 8. Influence of irrigation and fertilizer levels on NPK content of leaf at 45 DAS

Treatment	N(%)	P(%)	K(%)
Irrigation			
I_1	3.63	0.32	1.87
I_2	3.79	0.34	1.88
I_3	3.94	0.35	1.90
CD (0.05)	0.06	0.01	NS
SEm±	0.0212	0.0019	0.0097
Fertilizer			
F_1	3.47	0.30	1.81
F_2	3.74	0.33	1.89
F_3	4.16	0.38	1.95
SEm±	0.0212	0.0019	0.0097
Interaction	NS	NS	NS
CD (0.05)	NS	NS	NS
SEm±	0.0212	0.0019	0.0097
Contol	3.03	0.22	1.58
Treatments	3.79	0.34	1.88
Control Vs Treatments F (0.05)	222.01**	37.00**	17.80**

4.6. NPK content of shoot at harvest

4.6.1. Nitrogen content

The data on N composition of shoot at harvest are given in Table 9 and the analysis of variance in Appendix 1.

The levels of irrigation significantly influenced N content of shoot at harvest. The N content was found increasing with increase in irrigation level. The highest N content observed at I_3 level of irrigation (1.24%) was significantly superior to other two levels.

Fertilizer levels also showed significant influence on the shoot N content. The highest N content of shoot was observed with F_3 level of fertilizer, which was significantly superior to all other levels. Generally, there was a proportionate increase in shoot N content with increase in fertilizer levels.The interaction among irrigation and fertilizer levels was not significant in creating any effect on shoot N content.

In general, all the treatments recorded significantly higher N content in the shoot at harvest than the control, which was evidenced by the significance of F test.

4.6.2. Phosphorus content

The data on the effect of irrigation and fertilizer levels on the shoot P content at harvest are presented in Table 9 and the analysis of variance in Appendix 1.

There was a significant increase in shoot P content with increase in irrigation levels. The highest content of (0.30%) was observed with I_3 level of irrigation, which was significantly superior to other two levels.

Almost similar trend was expressed by the shoot P content with increase in fertilizer levels also. The highest shoot P content (0.31%) was observed with F_3 level of fertilizer, which was significantly superior to all other levels.

At the same time, interaction between irrigation and fertilizer levels didn't show any significant effect on shoot P content at harvest.

There was a significant increase in shoot P content in all the treatments compared to control.

4.6.3. Potassium content

The data on the effect of irrigation and fertilizer levels on the shoot K content at harvest are presented in Table 9 and the analysis of variance in Appendix 1.

The shoot K content at harvest showed a similar trend as expressed by shoot N and P. With increase in irrigation level, shoot K content also increased. The highest content recorded with I_3 level of irrigation (0.92%), was significantly superior to other two levels. Similarly, with increase in fertilizer levels, K content in shoot at harvest also increased. All the treatments created significantly different results. The highest content (0.96%) was recorded with F_3 level of fertilizer.

The interaction between irrigation and fertilizer did not make any significant effect on shoot K content.

All the treatments showed significant superiority over the control in increasing shoot K content, which was evidenced by the significance of F test.

Table 9. Influence of irrigation and fertilizer levels on NPK content of shoot at harvest (%)

Treatment	N(%)	P(%)	K(%)
Irrigation			
I_1	1.19	0.27	0.89
I_2	1.22	0.28	0.91
I_3	1.24	0.30	0.92
CD (0.05)	0.014	0.006	0.008
SEm±	0.0047	0.0021	0.0028
Fertilizer			
F_1	1.16	0.25	0.86
F_2	1.23	0.28	0.90
F_3	1.26	0.31	0.96
CD (0.05)	0.014	0.006	0.006
SEm±	0.0047	0.0021	0.0028
Interaction	NS	NS	NS
CD (0.05)	NS	NS	NS
SEm±	0.0047	0.0021	0.0028
Control	1.00	0.19	0.76
Treatments	1.21	0.28	0.90
Control Vs Treatments F (0.05)	13.90**	25.00**	28.50**

4.7. Fruit NPK content at harvest

4.7.1. Fruit Nitrogen content

The data on the effect of irrigation and fertilizer levels on the fruit N content at harvest are presented in Table 10 and the analysis of variance in Appendix 1.

Compared to the nutrient composition of leaf and shoot, the nutrient composition of fruit remained same without any significant difference with the changes made in irrigation and fertilizer levels.

Fruit N content did not vary significantly among the irrigation and fertilizer levels tried. The interaction between irrigation and fertilizer levels also didn't show any significant difference on fruit N content at harvest. So also there was no significant difference between the treatments and control on fruit N content at harvest.

4.7.2. Fruit Phosphorus content

The data on the effect of irrigation and fertilizer levels on the fruit P content at harvest are presented in Table 10 and the analysis of variance in Appendix 1.

Fruit P content did not vary significantly among the irrigation and fertilizer levels tried. The interaction between irrigation and fertilizer levels also didn't show any significant difference on fruit P content at harvest. So also there was no significant difference between the treatments and control on fruit P content at harvest.

4.7.3. Fruit Potassium content

The data on the effect of irrigation and fertilizer levels on the fruit K content at harvest are presented in Table 10 and the analysis of variance in Appendix 1.

In spite of increase in irrigation levels, all the treatments showed same content of Potassium in fruit at harvest. The same result repeated in the case of variation in fertilizer levels also. None of the treatments showed significant variation in fruit K content.

Similarly, the interaction between irrigation and fertilizer levels also didn't make any significant effect on the fruit K content at harvest.None of the treatments showed significant superiority over the control in increasing the fruit K content.

Table 10. Influence of irrigation and fertilizer levels on fruit NPK content at harvest

Treatment	N (%)	P (%)	K (%)
Irrigation			
I_1	1.30	0.29	1.11
I_2	1.31	0.30	1.11
I_3	1.30	0.30	1.11
CD (0.05)	NS	NS	NS
SEm±	0.0029	0.0031	0.0040
Fertilizer			
F_1	1.30	0.30	1.11
F_2	1.30	0.30	1.11
F_3	1.30	0.30	1.11
CD (0.05)	NS	NS	NS
SEm±	0.0029	0.0031	0.0040
Interaction	NS	NS	NS
SEm±	0.0029	0.0031	0.0040
Control	1.30	0.30	1.11
Treatments	1.30	0.30	1.11
Control Vs treatments F (0.05)	NS	NS	NS

4.8. Total NPK uptake at harvest

4.8.1. Total Nitrogen uptake at harvest

The data on the effect of irrigation and fertilizer levels on the total N uptake by the crop at harvest are given in Table 11 and the analysis of variance in Appendix 1.

Levels of irrigation significantly influenced the N uptake by the crop at harvest. With increase in irrigation levels, N uptake increased significantly up to I_2 and then decreased. The effect created by I_2 and I_3 were on par and significantly superior to I_1.

All the three fertilizer levels gave significantly different results on the total nitrogen uptake by the crop at harvest. The total nitrogen uptake by the crop at harvest increased with increase in fertilizer levels up to F_2 and then decreased.F2 was significantly superior to F1 and F3. F3 was significantly superior to F1.

The interaction between irrigation and fertilizer levels didn't make any significant effect on the character.

In general, all the treatments were significantly superior in the total nitrogen uptake at harvest (86.4 kg) than the control(33.6 kg) as evidenced by the significance of F test.

4.8.2. Total Phosphorus uptake at harvest

The data on the effect of irrigation and fertilizer levels on the total P uptake by the crop at harvest are given in Table 11 and the analysis of variance in Appendix 1.

Levels of irrigation significantly influenced the P uptake by the crop. With increase in irrigation levels, P up take increased significantly up to I_2 and then decreased. The effect created by I_2 and I_3 were on par.

Similar was the result with fertilizer levels. With increase in fertilizer levels, the P uptake by the crop increased up to F3. Both F2 and F3 were on par and significantly superior to F1. The interaction between irrigation and fertilizer levels could not make any significant effect on P uptake by the crop.

All the treatments (19.7 kg) were significantly superior to the control (7.3 kg) as evidenced by the significance of F test.

4.8.3. Total Potassium uptake

The data on the effect of irrigation and fertilizer levels on the total K uptake by the crop at harvest are given in Table 11 and the analysis of variance in Appendix 1.

Levels of irrigation significantly influenced the K uptake by the crop. With increase in irrigation levels, K uptake increased significantly up to I_2 and then decreased. The effect created by I_2 and I_3 were on par and significantly superior to I1.

All the three fertilizer levels produced significantly different results on the total K uptake by the crop at harvest. Total K uptake increased with increase in fertilizer levels up to F_2 and then decreased. F2 was significantly superior to F1 and F3. F3 was significantly superior to F1.

The interaction between irrigation and fertilizer levels didn't show any significant influence on total K up take. Compared to the control, all the treatments (71.6 kg) were significantly superior to the control (27.8 kg) in increasing the total K uptake by the crop, which was evidenced by the significance of F test.

Table 11 ; Influence of irrigation and fertilizer levels on total NPK uptake by the crop at harvest (kg ha^{-1})

Treatments	N(k ha^{-1})	P(kg ha^{-1})	K(kg ha^{-1})
Irrigation			
I_1	84.4	18.9	70.1
I_2	87.6	20.0	72.4
I_3	87.2	20.2	72.1
CD (0.05)	2.00	0.67	1.64
SEm±	0.6753	0.2241	0.5472
Fertilizer			
F_1	82.8	18.7	68.6
F_2	89.3	20.2	74.0
F_3	87.1	20.3	72.1
CD (0.05)	2.00	0.67	1.64
SEm±	0.6753	0.2241	0.5472
Interaction	NS	NS	NS
CD (0.05)	NS	NS	NS
SEm±	0.6753	0.2241	0.5472
Control	33.6	7.3	27.8
Treatments	86.4	19.7	71.6
Control Vs Treatments F (0.05)	99.0**	54.0**	105.5**

4.9. Available NPK in soil after harvest

4.9.1. Available Nitrogen in soil after harvest of the crop

The data on the effect of irrigation and fertilizer levels on the available N in soil after harvest of the crop are provided in Table 12 and the analysis of variance in Appendix 1.

When the nutrient analysis of the soil was conducted, the available N in the soil after the harvest of the crop was found decreasing with increase in irrigation levels. But the effect was not significant.

With increase in fertilizer levels from I_1 to I_3, the available N in soil also increased significantly. But the interaction between irrigation and fertilizer levels couldn't make any significant effect on the available N in soil after harvest of the crop.

Soils in all the treatments recorded significantly higher values of available N after the harvest of the crop (200.7kg) than the control (158.8 kg) as evident from the F test.

4.9.2. Available Phosphorus in soil after harvest of the crop

The data on the effect of irrigation and fertilizer levels on the available N in soil after harvest of the crop are provided in Table 12 and the analysis of variance in Appendix 1.

The result on available N in soil after harvest repeated in the case of available P also. With increase in irrigation levels, available P in soil decreased significantly from I_1 to I_3. The highest available P in soil (38.9 kg ha^{-1}) was observed with I_1 level of irrigation and the lowest (36.5 kg ha^{-1}) with I_3 level. I_1 was significantly superior to I_2 and I_3.All the levels produced significantly different values of available P in soil.

Increase in fertilizer level, available P in soil after harvest also increased significantly from F1 to F3. The highest value (42.3%) was observes at F_3 level of fertilizer, which was significantly superior over F_1 and F_2 levels. The interaction between irrigation and fertilizer was not significant.

Compared to the control all treatment plots recoded higher values of available P in soil (37.8kg), over control (24.2 kg) as evidenced by the significance of F test.

4.9.3. Available potassium in soil after harvest of the crop

The data on the effect of irrigation and fertilizer levels on the available K in soil after harvest of the crop are provided in Table 12 and the analysis of variance in Appendix 1.

With increase in irrigation levels, available K in soil after harvest of op melon decreased significantly from I_1 to I_3. The highest K content (120.3 kg ha^{-1}) was observed with I_3 level of irrigation, which was significantly superior to both I_1 and I_2 levels.

As in the case of available N and P, available K in soil after harvest also increased significantly from F_1 to F_3 levels of fertilizers. The highest value (126.6 kg ha^{-1}) was recorded with F_3 level of fertilizer, which was significantly superior to both F_1 and F_2 levels.The interaction between irrigation and fertilizer didn't make any significant effect on the available K in soil after harvest.

In general, all the treatments recorded significantly higher values of available K in soil after harvest of the crop (120.1 kg) over the control (106.6 kg) as evident from the significance of F test.

Table 12. Influence of irrigation and fertilizer levels on available NPK in soil after harvest (kg ha^{-1})

Treatments	N(kg ha^{-1})	P(kg ha^{-1})	K(kg ha^{-1})
Irrigaion			
I_1	202.2	38.9	121.8
I_2	201.0	37.9	120.3
I_3	198.9	36.5	118.0
CD (0.05)	NS	1.34	1.85
SEm±	1.2822	0.4484	0.6169
Fertilizer			
F_1	194.8	32.9	113.5
F_2	201.5	38.2	120.2
F_3	205.8	42.3	126.4
CD (0.05)	3.8	1.34	1.85
SEm±	1.2822	0.4484	0.6169
Interaction	NS	NS	NS
CD (0.05)	NS	NS	NS
SEm±	1.2822	0.4484	0.6169
Control	158.8	24.2	106.6
Treatments	200.7	37.8	120.1
Control Vs Treatments F (0.05)	17.2**	16.8**	8.8**

4.10. Soil moisture content after the cropping period

The moisture content of cropped area was found immediately after the harvest of the crop from three different sampling depths viz., 0-15 cm, 15-30 cm and 30-45 cm. The values are shown in Table 13.

In all the treatments and control, soil moisture content was the highest in the surface layer of 0-15 cm and the lowest in the bottom most layer of 30-45 cm. The decrease in soil moisture content from surface to the bottom most layer was gradual. In each layer, moisture content increased with increase in drip irrigation level from 75 % Ep to 125 % Ep. The moisture content in each layer was more in the control plot as it received more moisture through flood irrigation. In each layer the variation in moisture content was negligible within every level of drip irrigation due to the influence of varying levels of fertilizers. The average soil moisture content in the 0-15 cm layer in I_1, I_2, I_3 levels of drip irrigation and control were in the order of 15.1, 16.4, 17.4 and 19.6 percentage respectively. In the middle layer of 15-30 cm, the corresponding moisture contents were in the order of 13.5, 14.5, 15.6 and 17.7 per cent respectively. In the bottom most layer of 30-45 cm the moisture content in the respective irrigation levels were in the order of 12.6 %, 13.6 %, 14.4 % and 16.3% respectively.

Table 13: Soil moisture content(%) at harvest

	Depth of sampling		
Treatments	0-15 cm	15-30 cm	30-45 cm
I_1F_1	15.1	13.4	12.5
I_1F_2	15.3	13.4	12.9
I_1F_3	14.9	13.6	12.5
I_2F_1	16.3	14.4	13.5
I_2F_2	16.5	14.7	13.5
I_2F_3	16.4	14.5	13.7
I_3F_1	17.4	15.8	14.4
I_3F_2	17.2	15.6	14.3
I_3F_3	17.5	15.5	14.4
Control	19.6	17.7	16.3

4.11. Field water use efficiency

The data related to field water use efficiency are given in Table 14.

Table 14: Influence of irrigation and fertilizer levels on field water use efficiency

Treatment	Field water use efficiency (kg ha-mm^{-1})
Irrigation	
I_1	215.6
I_2	176.8
I_3	145.8
Fertilizer	
F_1	170.3
F_2	181.9
F_3	171.9
Control	42.7

The field water use efficiency was influenced by the levels of irrigation. With increase in drip irrigation quantity from 75 to 125 per cent Ep, field water use efficiency decreased from 215.6 (kg ha-mm^{-1}) to 145.8 (kg ha-mm^{-1}). Highest field water use efficiency was reported by F_2 level of fertilizer (181.9 kg ha-mm^{-1}) . In control, field water use efficiency was very much reduced to 42.7 kg ha-mm^{-1}.

4.12. Chemical properties of soil

4.12.1. pH of soil after harvest

Soil pH was observed after the harvest of the crop and there was no significant variation in soil pH due to various levels of irrigation or fertilizer doses. Soil pH remained constant between 5.37 and 5.54 irrespective of the treatments. The values are shown in the table 15.

4.12.2. EC of the soil after the harvest

Electrical conductivity of the soil was observed after the harvest of OP melon and the values are furnished in Table 15. There were no appreciable changes in the values of EC due to various irrigation and fertilizer levels. Nevertheless EC values increased slightly with increase in fertilizer levels.

Table 15. pH and EC values of the soil after harvest of the crop

Treatment	pH	Electrical Conductivity (dSm^{-1})
I_1F_1	5.49	1.43
I_1F_2	5.37	1.50
I_1F_3	5.54	1.58
I_2F_1	5.53	1.46
I_2F_2	5.37	1.54
I_2F_3	5.46	1.58
I_3F_1	5.48	1.51
I_3F_2	5.43	1.55
I_3F_3	5.47	1.58
Control	5.54	1.56

4.13. Economics of production

The data pertaining to the economics of production of OP melon under different treatments in terms of total cost of production, total return, net profit per hectare and net income per rupee invested as influenced by the treatment combinations are presented in Table 11 and Appendix 16.

All the drip fertigation treatments were far superior to control on increasing the net profit per hectare. In all the irrigation treatments F2 fertilizer level increased the net profit per hectare in a significant way. Among the treatment combinations I2F2 recorded the highest net return of Rs 531581 per hectare followed by I_3F_2 of Rs 513651.Among the treatment combinations also I_2F_2 recorded the highest net income of Rs 2.06 per rupee invested followed by 1.95 by both I_3F_2 and I_1F_2.

Table 16.Economics of production of oriental pickling melon as influenced by combination of irrigation and fertilizer levels

Treatments	Total cost of production per ha (Rs)	Yield (t ha^{-1})	Total income (Rs ha^{-1})	Net profit per ha (Rs)	Net income per rupee invested
I_1F_1	250819	59.2	710400	459581	1.83
I_1F_2	252883	62.2	746400	493517	1.95
I_1F_3	254978	61	732000	477022	1.87
I_2F_1	255917	59.7	716400	460483	1.80
I_2F_2	258019	65.8	789600	531581	2.06
I_2F_3	260114	61.8	741600	481486	1.85
I_3F_1	260639	61.4	736800	476161	1.83
I_3F_2	262741	64.7	776400	513651	1.95
I_3F_3	264836	59.2	710400	445564	1.68
Control	208259	23.9	286800	78541	0.40

4.14. Percentage loss of fruits on storage

The harvested fruits were observed for 45 days after harvest to examine its keeping quality. During this period, none of the fruits in any of the treatments rotted. Therefore, keeping quality of the fruits is not affected by irrigation or fertilizer levels up to 45 days after harvest.

4.15. Incidence of pests and diseases

There were minor incidence of pests such as red pumpkin beetles, leaf minors, fruit flies at various growth stages. These were controlled effectively with two sprays of pesticide (Confidor : Imidachloprid @ 6ml/9l.). Also, some diseases like powdery mildew and leaf spots were observed at the final stage of the crop. Therefore, no control measures were needed. These pests or diseases didn't make any negative impact on the growth or yield of the crop.

DISCUSSION

5. DISCUSSION

The results of the investigation on " Fertigation and mulching in oriental pickling melon (*cucumis melo* var.*conomon*(L.) Makino) under high density planting " are discussed below based on the effects of levels of irrigation and fertilizer levels on various parameters under high density planting and polythene mulching.

5.1.Growth parameters

The study results shows that the application of fertilizers along with irrigation water (fertigation) with polythene mulch significantly increased growth attributes such as average length of vines, number of primary branches per vine, number of secondary branches per vine, number of leaves per vine, shoot dry matter production at harvest and leaf area index, compared to the control (Table 5 and Figures 2-6).

Length of vine, number of leaves per vine, number of secondary branches per vine, leaf area index and shoot dry matter production at harvest showed significant increase with increase in drip irrigation levels from 75 per cent Ep to 125 per cent Ep. Irrigation with pot watering on alternate days with 2 cm water during flowering and fruiting and 1 cm water during initial stages was inferior to all the three levels of drip irrigation, on these characters. Number of primary branches per vine and days to first male and female flower appearance didn't show any significant effect with various drip irrigation levels.

The results indicated the necessity for higher level of drip irrigation at 125 % Ep for enhancing vegetative growth of OP melon under high density planting of 33,333 plants per hectare under LDPE mulching. Shoot dry matter production and LAI which reflect the overall impact of vegetative growth increased by 95, 101 and 108 per cent and 52, 57 and 61 per cent respectively in I_1, I_2 and I_3 levels of drip irrigation over conventional irrigation. Drip irrigation studies by Ningaraju (2013) in

OP melon with the same variety and location also reported high water requirement of the crop even above 100 % Ep under high density planting.

Similarly, under high density planting and polythene mulching, the length of vine, number of leaves per vine and number of secondary branches per vine increased linearly with increase in fertilizer levels from 200 per cent to 300 per cent of recommended dose applied through drip irrigation. This indicates the necessity of a higher level of fertilizers at 300 per cent RDF under situations of high density planting at 3.3 times more plant population than normal plant population and LDPE mulching to induce best vegetative growth.

The shoot dry matter production and leaf area index, which are having direct impact on the yield of the plants, were also found to increase with increase in fertilizer levels from 200 per cent to 300 per cent of RDF. In the trial, per ha shoot dry matter production increased by 148, 157 and 166 per cent and LAI by 184, 195 and 225 per cent respectively in F_1 ,F_2 and F_3 levels of fertilizer over normal recommended dose of fertilizer. Similar result have been reported by Alphonse and Saad (2000) and Jaksungnaro *et a.l,* (2001) in vegetable crops and Alemayeophu (2001) and Ningaraju (2013) in OP melon.

The interaction between irrigation and fertilizer levels was not significant in any of the characters viz., length of vine, number of leaves per vine, number of primary and secondary branches per vine, shoot dry matter production and LAI. This indicates that the major growth inducing factors like water and nutrients acted independently up to the levels tried in this experiment.

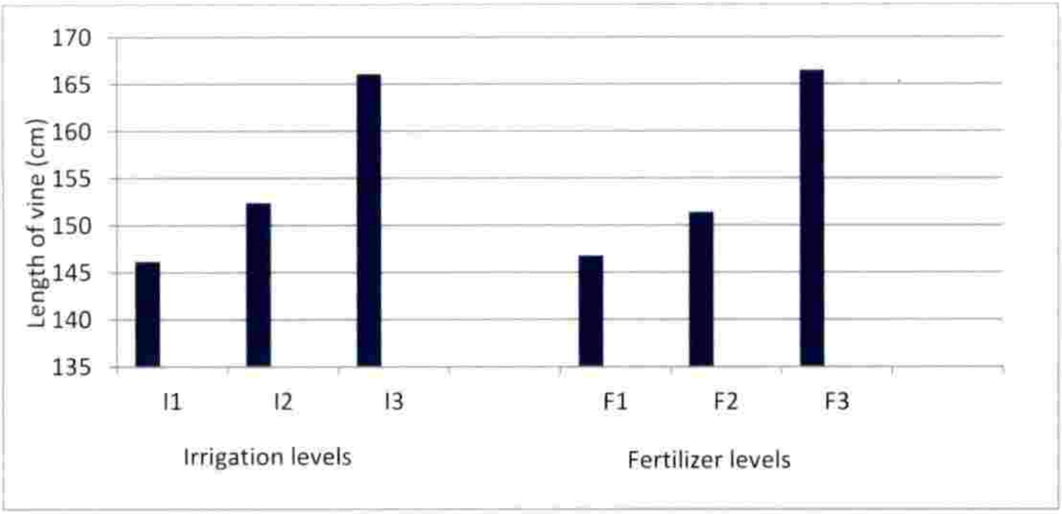

Fig. 2. Effect of drip fertigation levels on length of vines

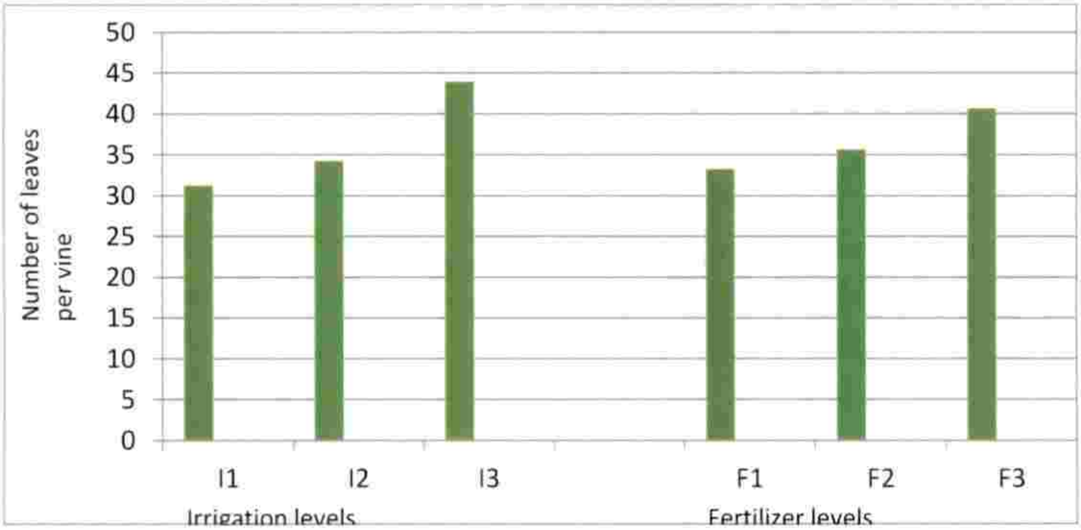

Fig. 3. Effect of drip fertigation levels on number of leaves per vine

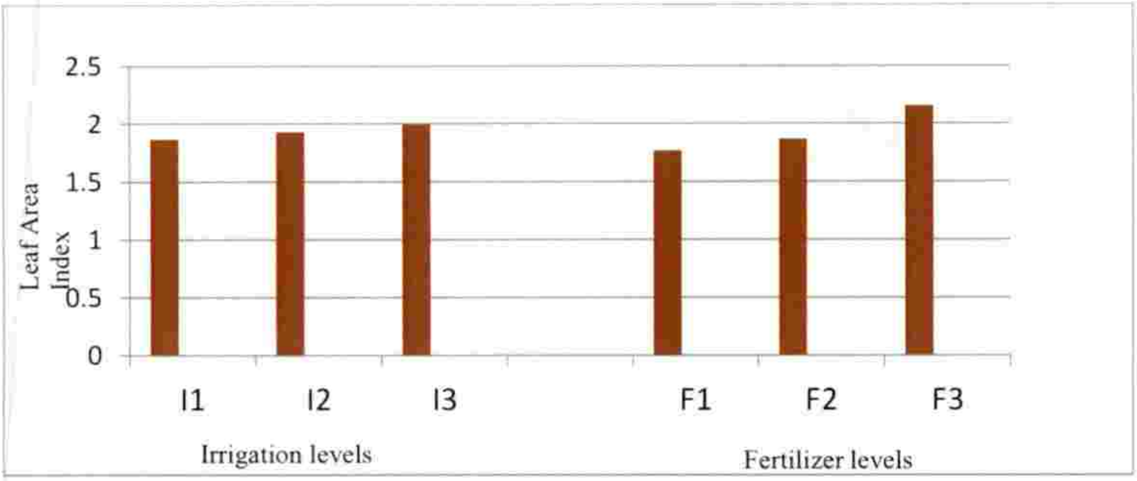

Fig. 4. Effect of drip fertigation levels on Leaf Area Index

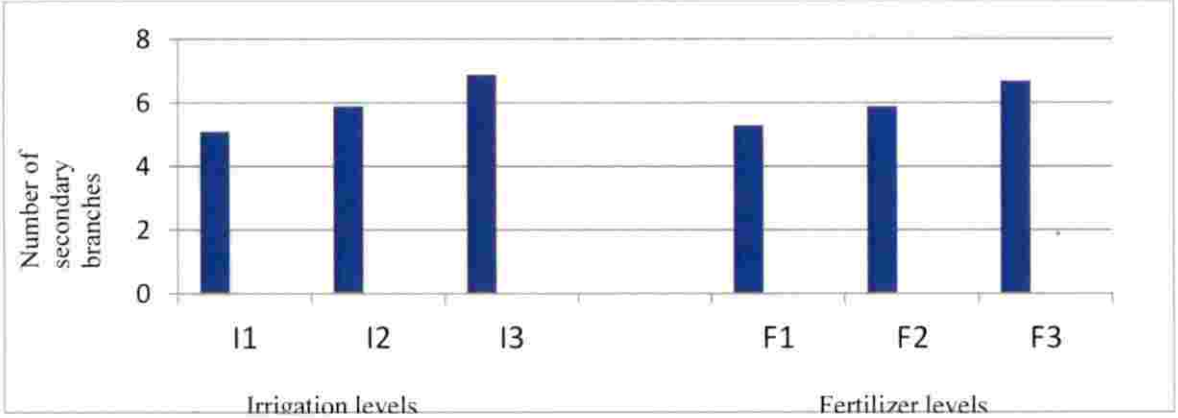

Fig. 5.. Effect of drip fertigation levels on number of secondary branches

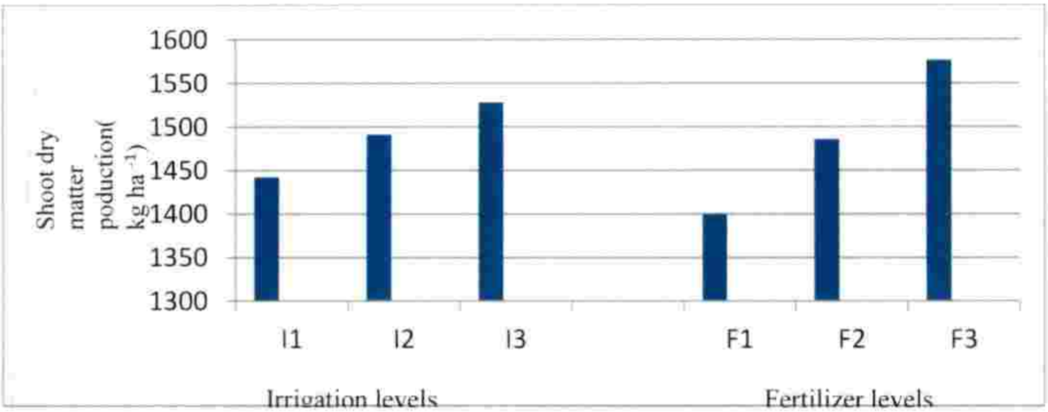

Fig.6. Effect of drip fertigation on shoot dry matter production at harvest

5.2. Yield and yield attributes

Yield attributes like number of fruits per plant, average fruit weight, average volume of fruit, fruit yield per plant and per hectare yield of op melon were not affected significantly by various irrigation levels. Nevertheless, all the yield parameters like number of fruits per plant, average fruit weight, average volume of fruit, fruit yield per plant and fruit yield per ha recorded maximum value at 100 per cent Ep and the value declined gradually when irrigation level was increased to 125 per cent Ep. Thus it appears that drip irrigation at 100 % Ep is better than that at 75 and 125 % Ep. Number of fruits per plant at drip irrigation of 100 % Ep was more by 1.4 and 1.8 % respectively over 0.75 and 1.25 % respectively. Similarly, drip irrigation at 100% Ep produced 1.6t and 0.6t more per hectare over 0.75 and 1.25 % respectively. Results thus indicate the superiority of 100 % Ep over 75 and 125 % Ep for drip irrigation of op melon at high density planting and mulching. Even though growth parameters increased significantly with increase in the level of drip irrigation from 75 to 125 % of Ep, such an increase did not support the yield attributes and yield of the crop.

Number of fruits per plant, fruit yield per plant and per hectare yield of fruit showed significant increase with increase in fertilizer level from 200 per cent to 250 per cent of recommended dose of fertilizer and then decreased significantly when the fertilizer level was increased to 300 % RDF. There was an increase in crop yield by 4.2 t ha^{-1} with 250 per cent RDF over 200 per cent RDF. Similarly, the yield recorded at 250 % RDF over 300 % RDF is more by 3.5 tonnes per hectare. The study thus proves the requirement of 250 % RDF for high density planting of op melon under LDPE mulching. Among the fertilizer levels, the average weight and volume of fruits were not significantly affected by the levels of fertilizer doses.

The interaction between irrigation and fertilizer levels was not significant on the number of fruits per plant and average weight and volume of fruits. But, the interaction between irrigation and fertilizer levels was significant on characters like fruit yield per plant and per hectare. Highest fruit yield per plant and per ha were recorded at I_2F_2. I_2F_2 recorded the highest fruit yield of 65.8 t ha^{-1} followed by 64.7 t ha^{-1} recorded by I_3F_2. These two treatment combinations were significantly superior to all the other combinations. Between these two treatment combinations I_2F_2 appears to be the better one. A higher level of irrigation through either drip system over 100 % Ep or through farmer's practice did not interact favourably with fertilizer levels above 250 per cent RDF under high density panting and LDPE mulching.

A positive interaction between irrigation and fertilizer levels on enhancing fruit yield in various vegetables has been reported by Alemeyu (2001), Jamuna Devi (2003) ,Yingjavawal *et al.* (1993), Harnandez and Aso (1991), Raman *et al.* (2000), Shinde and Malunjkar (2010), Meena *et al.* (2008), Hafidh (2001) and Soltani *et al.* (2007) and Ningaraju (2013).

The interaction between irrigation and fertilizer levels was not significant over I_2F_2 in increasing fruit yield per plant or per hectare. The study points out that the optimum combination of irrigation with 100 per cent Ep and fertilizer at 250 per cent of RDF as drip fertigation should be applied to realize maximum yield of op melon under high density planting and polythene mulching.

The number of days to harvest was not significantly influenced by levels of drip irrigation or fertilizer. However, harvest was delayed by five days in control plots compared to drip fertigation treatments and the difference was significant as per the F test.

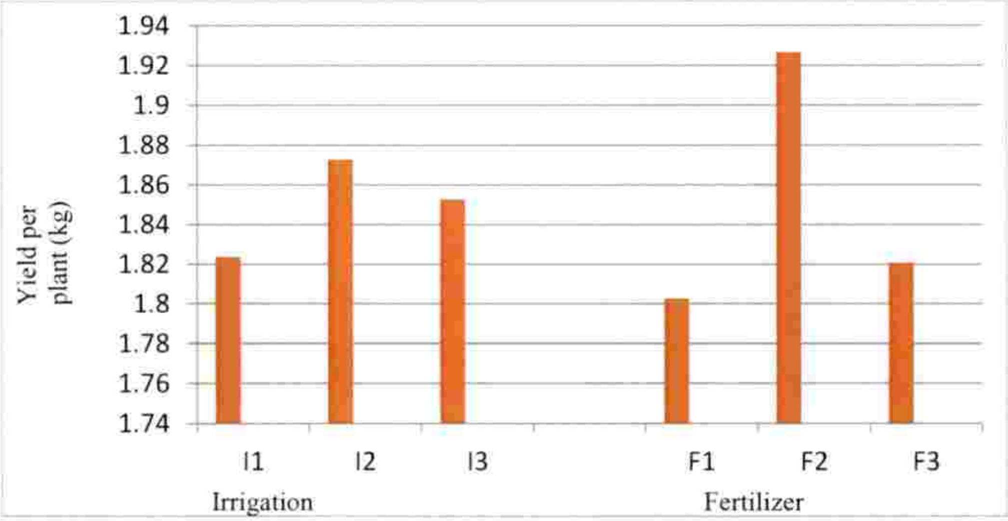

Fig. 7. Effect of drip fertigation levels on yield per plant

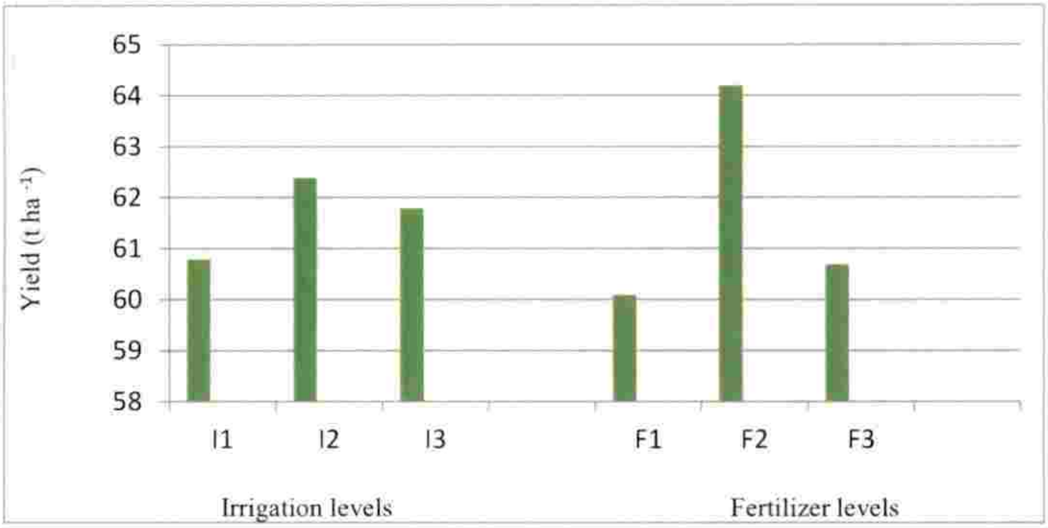

Fig. 8. Effect of drip fertigation levels on yield per hectare

5.3. Days to flowering and harvest

Number of days taken for the appearance of flowers and the number of days taken for harvest did not show significant variation under various levels of irrigation and fertilizer. The interaction between irrigation and fertilizer levels was also non significant on these characters. In general, days to first flowering were 21 for male flowers in all the drip fertigation treatments. And the days taken for first female flower appearance remained between 25 and 26. At the same time, pot irrigation without mulching took 24 and 29 days respectively for the appearance of male flower and female flower. Days to harvest were early in drip irrigated plots than pot irrigated plots. Generally, it took 63 days for the drip fertigated treatments and 68 days for control for the harvest. Thus the influence of excess water in delaying the maturity of the crop is evident from the study.

5.4. Fruit dry matter production

There was an increase in fruit dry weight with increase in irrigation levels from 75 per cent Ep to 100 per cent Ep and then it declined with further increase in irrigation level to 125 per cent Ep. A high irrigation level by pot irrigation was inferior to both 75 , 100 and 125 per cent Ep through drip irrigation under high density planting. The highest fruit dry weight was observed with 100 per cent Ep under drip irrigation in op melon by Ningaraju (2013) also in the same variety and at the same location under high density planting.

In op melon, under high density planting and polythene mulching, the highest fruit dry matter production was recorded with 250 per cent of RDF compared to both 200 and 300 per cent of RDF. It indicates that under high density planting and mulching, the optimum level of fertilizer is 250 per cent of RDF and a level above or below this is either insufficient or excess for a crop with 33,333 plats per ha. The interaction between irrigation and fertilizer levels was also significantly influenced the fruit dry matter production. The maximum was observed with a combination of irrigation with 100 per cent Ep and fertilizer with 250 per cent RDF.

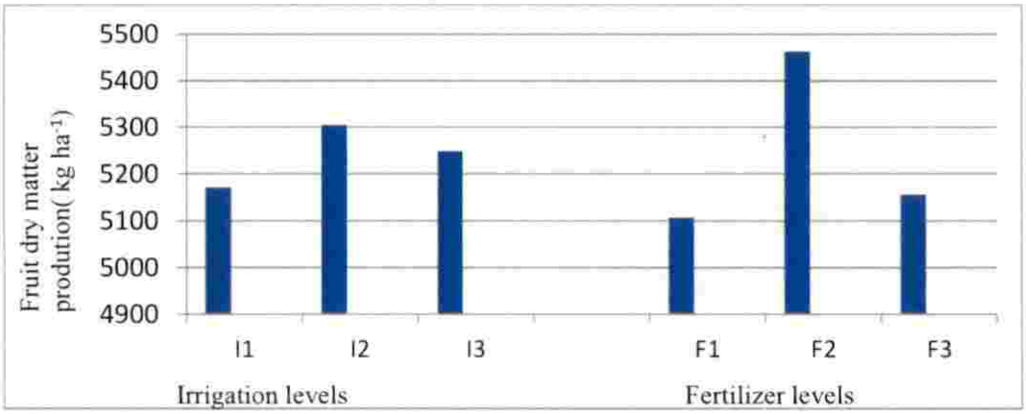

Fig.9. Effect of drip fertigation levels on fruit dry matter production

5.5. Nutrient composition of leaves at 45 DAS

Both nitrogen and phosphorus contents of leaves increased significantly with increase in irrigation levels from 75 per cent to 125 per cent Ep under drip irrigation.This is ue to the increased nutrient uptake by the crop at this stage. But the increase in potassium content with increase in irrigation levels was non significant. This may be due to less availability of potassium at this stage. A high irrigation level with pot irrigation (around 560 mm) was inferior to all the tested levels under fertigation. The result indicates that a low irrigation and excess irrigation are not conducive for higher contents of primary nutrients in op melon. The high content of NPK in leaves by 45 DAS observed above 100 per cent Ep was not effectively utilized for a higher yield. An experiment in water melon showed that daily irrigation with 100 per cent Ep resulted in highest N, P, K, Ca and Mg concentration and uptake (Srinivasa *et al.*,1986).

Under high density planting and polythene mulching, the content of nitrogen, phosphorus and potassium in leaves of op melon increased significantly with increase in fertilizer levels from 200 per cent RDF to 300 per cent RDF. This shows that, there is a trend to absorb and accumulate more and more nutrients in the leaves of op melon with an increase in the level of nutrients applied into the root zone of the crop by drip fertigation. However, the excess content of NPK in the leaves over that of 250 per cent RDF had no impact on improving the yield of the crop. Excess nutrients are believed to be stored in the leaf vacuoles. This result is in conformity with that of Al-Sahaf and Al-Khafagi (1990) , Tunacy *et al.* (1999) and Ningaraju (2013).

The interaction between the tested irrigation and fertilizer levels did not show any significant effect on the content of primary nutrients in leaves of op melon AT 45 DAS.

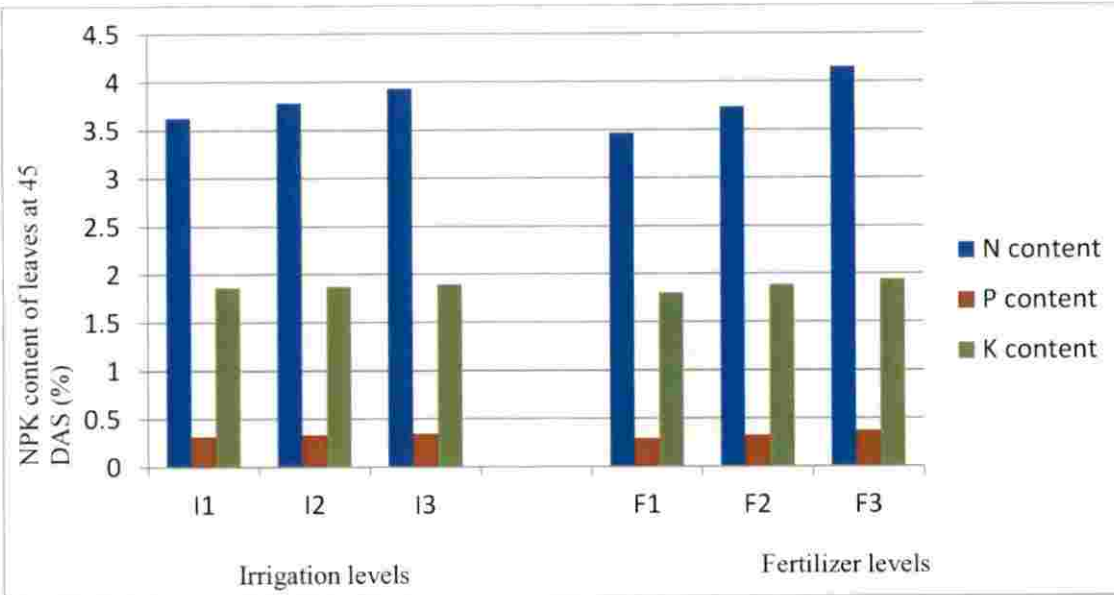

Fig.10. Effect of drip fertigation levels on NPK content of leaves at 45 DA

5.6 Nitrogen content of fruit and shoot at harvest and nitrogen uptake

Nitrogen content of shoot was found to be increasing with increase in irrigation levels from 75 per cent Ep to 125 per cent Ep. A higher irrigation level with 560 mm by pot irrigation was inferior to all the tested levels of drip irrigation. Increase in water availability in the root zone through drip method is thus congenial for the uptake of more nitrogen by the crop.

At high density planting and mulching, nitrogen content of shoot increased linearly with increase in fertilizer levels from 200 per cent to 300 per cent of RDF. It indicates that plants try to accumulate more and more nitrogen as long as it is available in soil. But the higher content of nitrogen at 300 per cent RDF has not contributed to enhanced production of fruits.

The fruit nitrogen level at harvest remained constant with slight variation, with the different levels of irrigation and fertilizers. At the same time, the interaction between any of the tested irrigation and fertilizer levels did not make any significant effect on shoot and fruit nitrogen content at harvest.

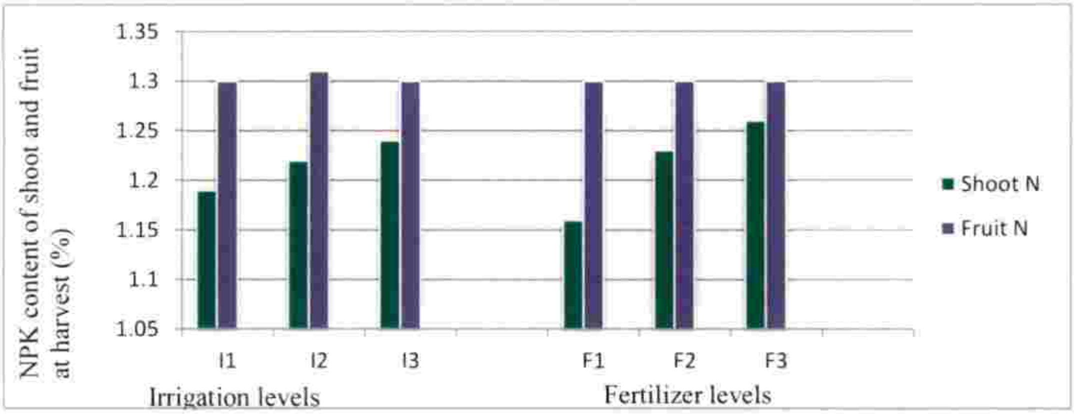

Fig. 11. Effect of drip fertigation levels on shoot and fruit N content at harvest

Levels of irrigation significantly influenced the N uptake by the crop. Uptake of nitrogen was highest at 100 per cent Ep. And it decreased with further increase in irrigation level. This is due to the reduction in yield and dry matter production at drip irrigation above 100 per cent Ep.

Similar was the trend by fertilizer levels also. The uptake of nitrogen increased when fertilizer level increased from 200 per cent to 250 per cent and then decreased at 300 per cent RDF. This indicates that a higher dose of fertilizer above 250 percent is adversely affecting the yield, which may be due to excess accumulation of the nutrient in plants than an optimum level.

The drip fertigation treatments in general increased nitrogen uptake by the crop(86.4 kg ha^{-1}) by 157 per cent as compared to the control (33.6 kg ha^{-1}) due to increase in higher vegetative and fruit yield and better higher concentration of nutrients in plant parts. The interaction between irrigation and fertilizer levels didn't make any significant effect on the total N uptake as they acted independently

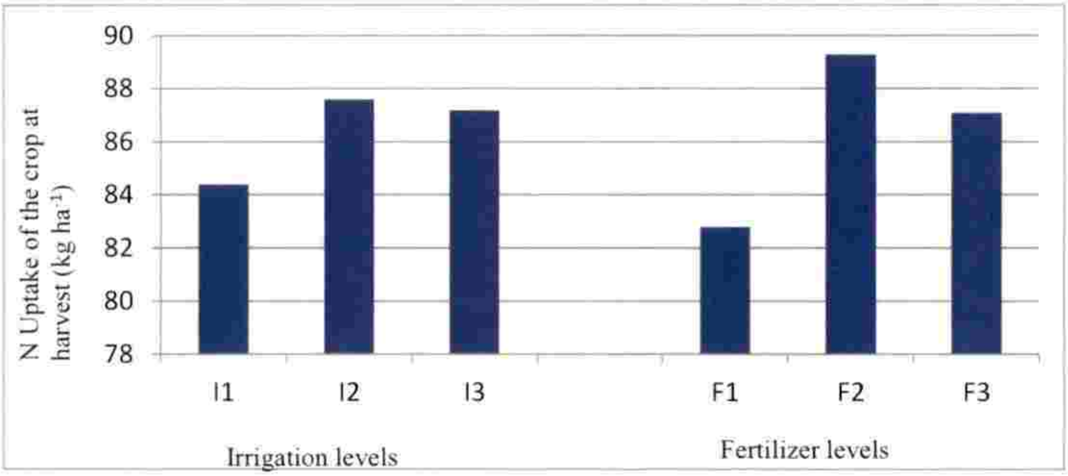

Fig.12. Effct of drip fertigation levels on N uptake of the crop at harvest

5.7 Phosphorus content of shoot and fruit at harvest and phosphorus uptake

Phosphorus content of shoot at harvest of op melon was found increasing with increase in drip irrigation levels from 75 per cent Ep to 125 per cent Ep. Increase in water availability in the root zone through drip method is thus congenial for the uptake of more phosphorus by the crop.

But an excess amount of moisture by flooding in the root zone is not favouring a high removal of phosphorus by the crop. The high irrigation level by pot irrigation with 560 mm was inferior to all the tested levels of drip irrigation in promoting phosphorus content of shoot in op melon.

An increased application of phosphorus through fertilizers reflected in the shoot P concentration also. The character expressed a linear increase with increase in fertilizer levels. This indicates that there is an increased uptake of phosphorus by the crop as its availability increases in soil.

At the same time, the fruit phosphorus content at harvest was not significantly affected by an increased application of phosphorus in soil. This shows that even if the plants absorb and accumulate the nutrient in shoot and leaves, it is not getting accumulated in the fruits.

None of the combinations between irrigation and fertilizer levels showed significant superiority in increasing either shoot or fruit phosphorus content in op melon.

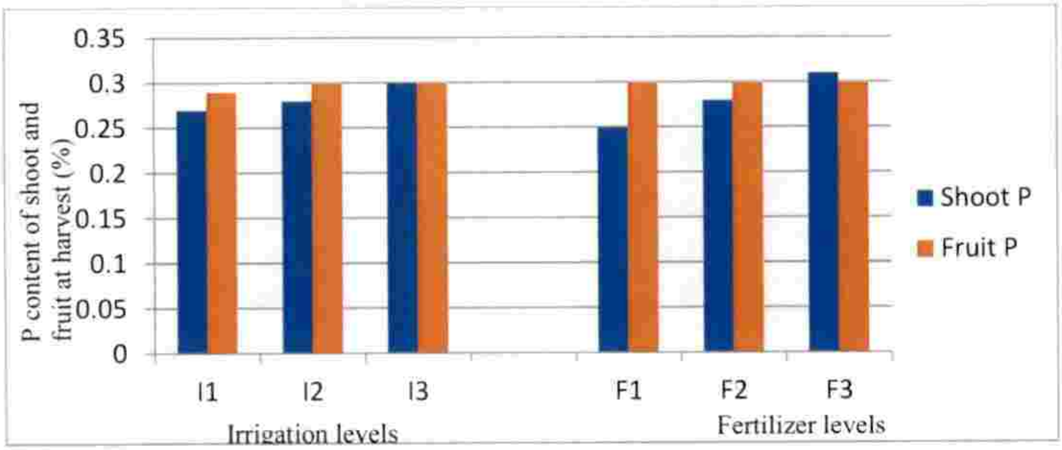

Fig.13. Effect of drip fertigation levels on P content of shoot and fruit at harvest

The drip fertigation treatments in general increased phosphorus uptake by the crop (19.7 kg/ha) by 170 per cent as compared to the control (7.3 kg/ha) due to increase in higher vegetative and fruit yield and better higher concentration of nutrients in plant parts.

Uptake of phosphorus by the crop also showed similar trend of that of nitrogen. P uptake was highest at an irrigation level of 100 per cent Ep. And a level above or below this was either insufficient or excess for the crop. P uptake by op melon increased when fertilizer level was increased from 200 per cent to 250 per cent, but decreased when the level was further increased to 300 per cent.

This indicates the necessity of optimization of irrigation and fertilizer level at 100 per cent Ep and 200 per cent RDF respectively in order to ensure better phosphorus uptake and best yield.

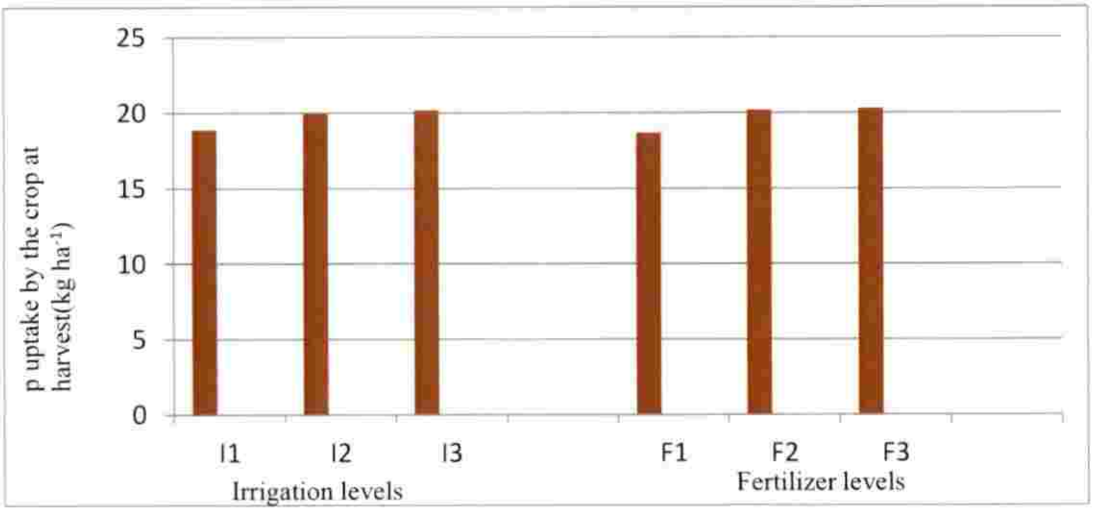

Fig.14. Effect of drip fertigation levels on P uptake by the crop

5.8 Potassium content of shoot and fruit at harvest and potassium uptake

Irrigation and fertilizer levels significantly influenced the potassium content of shoot at harvest, but not the content of fruit. Highest potassium concentration in shoot was recorded with irrigation level of 125 per cent Ep and highest shoot K with a fertilizer level of 300 per cent RDF indicating that K removal by op melon at high density planting at 33,333 plants per hectare is proportional to the content of soil moisture and potassium availability in the root zone.But the higher potassium content in the plant at harvest above that at 100 per cent Ep and 250 per cent RDF through drip fertigation did not contribute to realizing more fruit yield.

Fruit potassium concentration remained constant with different irrigation and fertilizer levels.

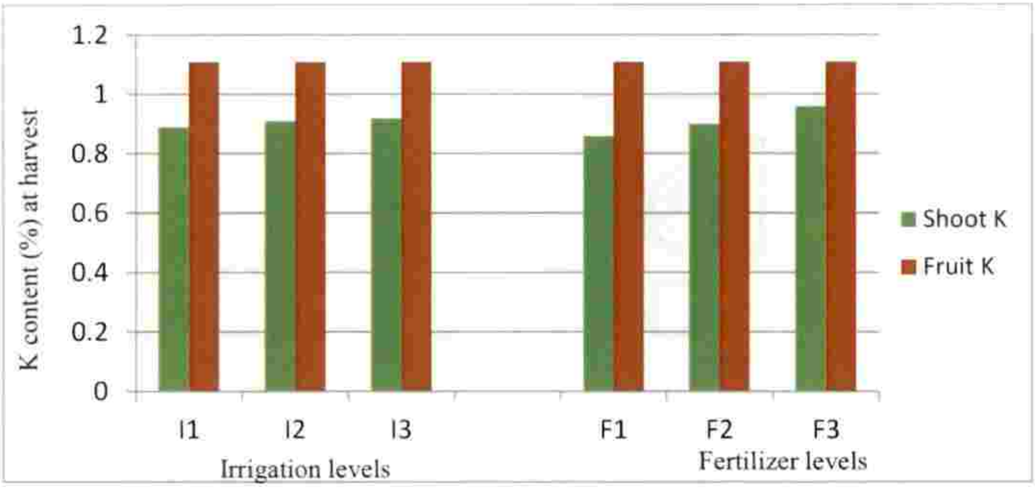

Fig.15. Effect of drip fertigation levels on shoot and fruit K content at harvest

The drip fertigation treatments in general increased potassium uptake by the crop (71.6 kg/ha) by 157 per cent as compared to the control(27.8 kg/ha) due to increase in higher vegetative and fruit yield and better higher concentration of nutrients in plant parts.

Levels of irrigation significantly influenced the total K uptake by the crop. With increase in irrigation levels, P up take increased significantly up to I_2 (100 per cent Ep) and then decreased. Similarly, total K uptake was the highest at 250 per cent RDF because of the highest fruit yield and a level above and below this reduced the total K uptake. The interaction between irrigation and fertilizer levels didn't show any significant influence on total K up take. A combination of 100 per cent Ep and 250 per cent RDF is effective in promoting better potassium uptake and obtaining best yield.

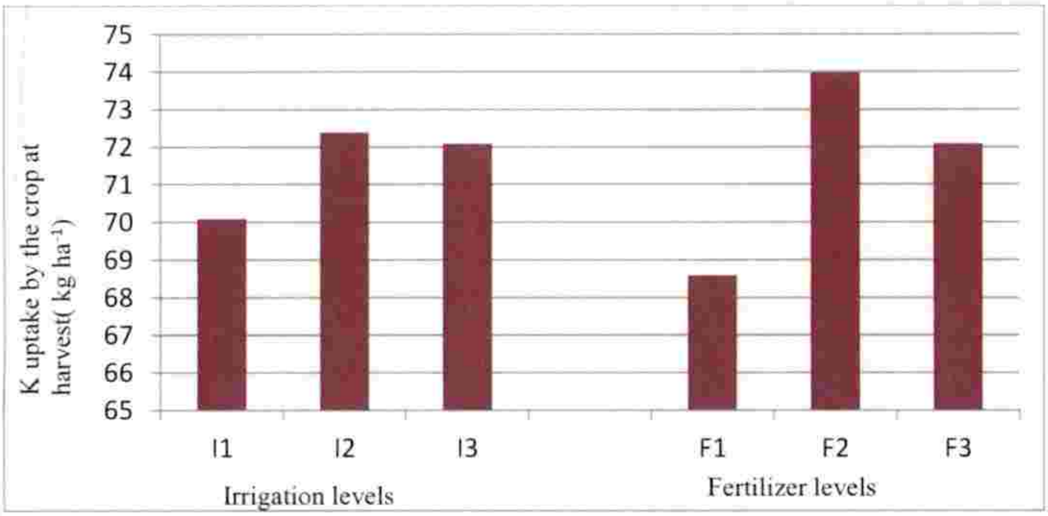

Fig. 16. Effect of drip fertigation levels on K uptake by the crop at harvest

5.9. Soil moisture studies

In all the treatments and control, soil moisture content was the highest in the surface layer of 0-15 cm and the lowest in the bottom most layer of 30-45 cm. This may be the influence of LDPE mulching on reducing the evaporation loss from the soil surface. The decrease in soil moisture content from surface to the bottom most layer was gradual. In each layer, moisture content increased with increase in drip irrigation level from 75 % Ep to 125 % Ep due to the availability of more moisture from the drip with increase in water application rate. The moisture content in each layer was more in the control plot as it received more moisture through flood irrigation. In each layer the variation in moisture content was negligible within every level of drip irrigation due to the influence of varying levels of fertilizers. It means that fertilizer levels did not influence the moisture extraction pattern by the crop. The average soil moisture content in the 0-15 cm layer in I_1, I_2, I_3 levels of drip irrigation and control were in the order of 15.1, 16.4, 17.4 and 19.6 percentage respectively. In the middle layer of 15-30 cm, the corresponding moisture contents were in the order of 13.5, 14.5, 15.6 and 17.7 per cent respectively. In the bottom most layer of 30-45 cm the moisture content in the respective irrigation levels were in the order of 12.6, 13.6 14.4 and 16.3 respectively.

5.10. The field water use efficiency

Field water use efficiency decreased with increase in drip irrigation quantity from 75 to 125 per cent Ep. It decreased from 215.6 (kg ha-mm^{-1}) to 145.8 (kg ha-mm^{-1}) when water level was increased from 75 to 125 per cent Ep. The increase in FWUE in I_1, I_2 and I_3 over control was in the order of 405, 314 and 241 per cent respectively. Thus, high water application through drip is found to be decreasing the FWUE. Among the fertilizer levels, highest field water use efficiency was reported by F_2 level of fertilizer (181.9 kg ha-mm^{-1}) . However, the variation in FWUE among the fertilizer levels was not as significant as that observed in irrigation treatments. High level of irrigation in the control practice reduced FWUE in a significant way and was the lowest at 42.7 kg ha-mm^{-1}.

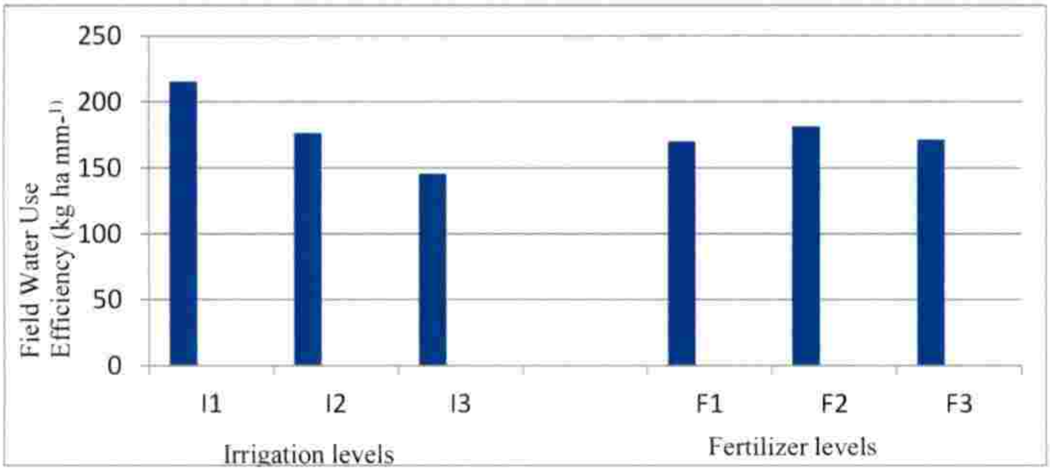

Fig. 17. Effect of drip fertigation levels o FWUE

5.10 Chemical properties of soil

Soil chemical properties such as pH and Electrical Conductivity didn't show appreciable variation due to the various levels of irrigation and fertilizer. This indicates that chemical properties of soil are not likely to be influenced by short term managements like irrigation and fertilizer application. There can be probable variation in the chemical properties of soil if the same cropping practice is continued for a long period.

5.11. Available NPK in soil after harvest

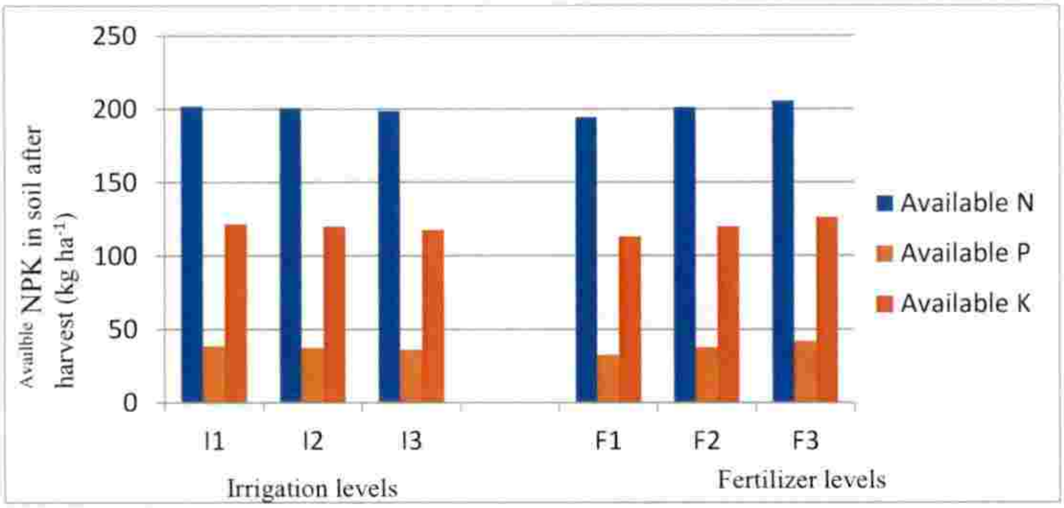

Fig. 18. Effect of drip fertigation levels on available NPK in soil after harvest

5.11.1. Available N in soil

When the nutrient analysis of the soil was conducted, the available N in the soil after the harvest of the crop was found decreasing with increase in irrigation levels. But the effect was not significant. The lowest N level was observed in pot irrigation treatment which is probably due to the leaching out of N with excess irrigation water. The decrease in available N in soil with increase in irrigation from 75 to 125 per cent Ep can be substantiated by the increased dry matter production and uptake of nutrient from soil.

With increase in fertilizer levels from I_1 to I_3, the available N in soil also increased significantly. The result indicates favorable influence of increasing dosed of applied nitrogen on available N in soil at different growth stages of crop. The interaction between irrigation and fertilizer levels couldn't make any significant effect on the available N in soil after harvest of the crop.

5.11.2. Available P in soil

The result on available N in soil after harvest repeated in the case of available P also. With increase in irrigation levels, available P in soil decreased significantly from I_1 to I_3. The highest available P in soil (38.9 kg ha^{-1}) was observed with I_1 level of irrigation and the lowest (36.5 kg ha^{-1}) with I_3 level. The decrease in available P in soil can be correlated with the increase in dry matter production with increased levels of irrigation.

Increase in fertilizer level, available P in soil after harvest also increased significantly from F1 to F3. The highest value (42.3%) was observes at F_3 level of fertilizer, which was significantly superior over F_1 and F_2 levels. This indicates the direct effect of applied phosphorus, which in turn is available to the crops. The interaction between irrigation and fertilizer was not significant.

5.11.3. Available K in soil

With increase in irrigation levels, available K in soil after harvest of OP melon decreased significantly from 75 to 125 per cent Ep. The highest K content (120.3 kg ha^{-1}) was observed with I_3 level of irrigation, which was due to the reduced production of shoot and fruit dry matter.

As in the case of available N and P, available K in soil after harvest also increased significantly from F_1 to F_3 levels of fertilizers. The highest value (126.6 kg ha^{-1}) was recorded with F_3 level of fertilizer, which was significantly superior to both F_1 and F_2 levels. The interaction between irrigation and fertilizer didn't make any significant effect on the available K in soil after harvest.

5.11. Economics of production

All the drip fertigation treatments were far superior to control on increasing the net profit per hectare and also the net income per rupee invested. In all the irrigation treatments F_2 fertilizer level increased the net profit per hectare as well as net income per rupee invested in a significant way as the increase in fertilizer level above F_2 had negative effect on crop yield. Among the treatment combinations I_2F_2 recorded the highest net return of Rs. 531581 per hectare followed by I_3F_2 of Rs 513651. Among the treatment combinations also I_2F_2 recorded the highest net income of Rs 2.06 per rupee invested followed by 1.95 by both I_3F_2 and I_1F_2.

The study may be concluded by stating that for the most profitable production of op melon in the summer rice fallows of Kerala, high yielding, less spreading varieties like Saunhagya should be planted at a high density of 33,333 plants per hectare and managed by drip fertigation at 100 per cent Ep and 250 per cent RDF with LDPE mulching. This has produced the highest net profit per hectare and net income per rupee invested.

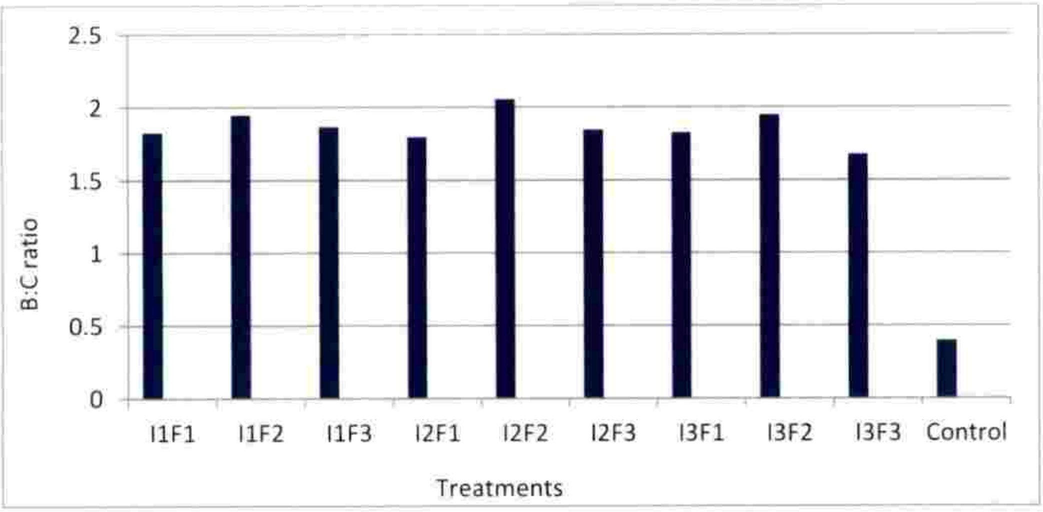

Fig. 19. Effect of drip fertigation levels on B:C ratio of the crop

5.12. Keeping quality of the fruit

Keeping quality of the fruits was not affected by irrigation or fertilizer levels up to 45 days after harvest. It means that high levels of water and nutrients through drip fertigation is not harmful to the keeping quality of the fruits under high density planting with mulching, where the nutrient requirement of the crop is higher due to the increased plant population. Even a three fold increase in fertilizer dose may be just sufficient for the high density planting.

5.13. Incidence of pests and diseases

Due to the application of higher doses of irrigation and fertilizer, more pests and diseases were expected for the crop. But, there were only some minor pests such as red pumpkin beetles, fruit flies and leaf miner which were appeared in the initial stages of the crop in few parts. All the pests were controlled by appropriate pesticide sprays. Also, diseases like powdery mildew and leaf spots were appeared during final stage when the crop was almost ready to harvest. The less occurrence of pests and diseases even with increased levels of irrigation and fertilizer can be substantiated by the increased requirement of these inputs due to three fold increase in plant population than normal practice.

5.12. Conclusion

From the discussion furnished above, it can be concluded that , under high density planting and polythene mulching, oriental pickling melon variety Saubhagya has shown a linear increase in vegetative parameters upto 125 per cent Ep. But yield parameters like number of fruits per plant, average fruit weight and fruit yield per plant and hectare was not significantly influenced by the drip irrigation levels from 75 to 125 per cent Ep. But yield parameters and yield varied significantly between drip fertigation levels and control. Vegetative parameters like number of primary and secondary branches, number of leaves per branch, length of vine and LAI increased linearly from 200 to 300 per cent RDF. But yield parameter like number of fruits per plant and fruit yield per plant and hectare were significantly the maximum in F_2 level of fertilizer (250 per cent of RDF) through fertigation. The fruit yield at F2 was significantly higher by 4.1 and 3.5 tonnes per hectare respectively over F_1 and F_3 levels of fertilizers. The other yield parameters like average weight and volume of fruits were also the highest in F2, though there was no significant difference between the drip fertigated plots. There was significant reduction in the yield parameters and yield at F_3 (300 per cent RDF) compared to F_2(250 per cent RDF) level of fertilizers.

Among the treatment combinations, I_2F_2 recorded the highest fruit yield per ha (65.8 t/ha) and was significantly superior to all the other combinations Except I_3F_2 (64.7 t ha^{-1}).The increase in fruit yield in I_2F_2 over other combinations was remarkable as can be seen from the data given in bracket(I_1F_1= 59.2 t, I_1F_2= 62.2 t, I_1F_3= 61.0t, I_2F_1= 59.7t, I_2F_2= 65.8 t, I_2F_3= 61.8 t, I_3F_1= 61.4 t, I_3F_2= 64.7 t and I_3F_3= 59.3 t). Among the treatment combinations I_2F_2 recorded the highest net return of Rs. 531581 per hectare followed by I_3F_2 of Rs 513651. Among the treatment combinations also I_2F_2 recorded the highest net income of Rs 2.06 per rupee invested followed by 1.95 by both I_3F_2 and I_1F_2.

For the most profitable production of op melon in the summer rice fallows of Kerala, high yielding, less spreading varieties like Saubhagya planted at a high density of 33,333 plants per hectare requires drip fertigation at 100 per cent Ep and 250 per cent RDF with LDPE mulching.

5.13. Future line of work

The experiment should be repeated for 2-3 seasons since only one season data is considered in this trial to reach a conclusion. Also the trial can be extended to other cucurbitaceous crops to explore the possibility of increased productivity.

SUMMARY

6. SUMMARY

A study on the effect of " Fertigation and mulching in oriental pickling melon (*Cucumis melo* var *conomon* (L.) Makino) under high density planting" was conducted by means of a field experiment held in the summer rice fallows at Agricultural Research Station , Mannuthy, followed by nutrient analysis at Agronomy lab of College of Horticulure, Vellanikkara.

The experimental field was an open rice fallow with sandy clay loam soil having a bulk density of 1.34 g cm^{-3} . Soil was acidic in reaction, medium in organic carbon (0.63 %), available N (210.8 kg ha^{-1}), phosphorus (29.5 kg ha^{-1}), and potassium (88 kg ha^{-1}). The crop started from December 2014 to February 2015. The weather during the trial was hot and humid with an average daily pan evaporation of 5.34 mm, relative humidity (morning 73 and afternoon 36.89 per cent),and wind speed (6.01 km h^{-1}).

Since it was a field experiment with 9 treatment combinations and one control and due to the easiness of preparing of homogenous blocks in the area, the model chosen for experiment was Randomised Block Design (RBD). There were 3 replications for each treatment. The treatments consisted of combinations of 3 levels of irrigation (75, 100 and 125 per cent of Ep) and 3 levels of fertilizers (200 , 250 and 300 per cent RDF) and a control.

The variety used was Saubhagya, which is a short duration, less spreading high yielding variety suitable for high density planting. It is having small sized fruits.

The salient findings and conclusions drawn out from the investigation are summarised below.

1. Levels of irrigation and fertilizer levels did not influence the primary branches significantly. It varied from 2.1 to 2.4 per plant. The interaction between irrigation and fertilizer levels also didn't make any influence on the number

of primary branches per plant significantly. The difference between treatments and control also was not significant.

2. Levels of irrigation significantly influenced the number of secondary branches per plant. Maximum number of secondary branches per plant (6.9) was observed at the irrigation level I_3 and was significantly superior to other levels. Fertilizer levels also significantly influenced the number of secondary branches per plant. The maximum number of secondary branches per plant (6.7 observed at F_3 was significantly superior to F_1 and F_2. The interaction between irrigation and fertilizer levels was not significant. The difference between treatments and control also was highly significant.

3. Levels of irrigation significantly influenced the length of vines. Highest length of vines (166.1 cm) was observed at the irrigation level I_3 and was significantly superior to I_1 and I_2.. I_2 was significantly superior to I_1. Fertilizer levels also significantly influenced the length of vine. Among the fertilizer levels, F_3 (166.5 cm) recorded the highest length of vine . The interaction between irrigation and fertilizer levels was not significant. The difference between treatments and control also was highly significant.

4. Number of leaves per vine was significantly influenced by the levels of irrigation up to I_3. Highest number of leaves per vine (44) was observed at the irrigation level I_3. Fertilizer levels also significantly influenced the number of leaves per vine. Highest number of leaves per vine (40.7) was observed with F_3 and it was significantly superior to F_1 and F_2. The difference between treatments and control was highly significant.The interaction between irrigation and fertilizer was not significant.

5. Leaf Area Index was significantly influenced by the levels of irrigation. Highest Leaf Area Index of 2, observed at I_3 level of irrigation was significantly superior to I_1, but at par with I_2. Fertilizer levels also significantly influenced the Leaf Area Index. Leaf Area Index increased significantly up to F_3 . Highest Leaf Area Index (2.16) observed at F_3. The difference between treatments and control was highly significant.Interaction between fertilizer and irrigation levels was not significant.

6. The effect of irrigation, fertilizer and their interaction on days taken for male flowering was not significant. Days taken to male flowering remained constant at about 21 days in all the drip fertigation treatments. The difference between treatments and control was highly significant. While drip fertigation treatments took 21 days for first male flower appearance, control took 25 days.

7. Irrigation , fertilizer and their interaction did not affect days taken for first female flowering significantly. The difference between treatments and control was highly significant. On an average, the days taken to female flower opening remained at 26 days in drip fertigation treatments. Control took significantly more days (29.3) compared to drip fertigation treatments.

8. Levels of irrigation did not influence the number of fruits per plant significantly. Nevertheless number of fruits per plant the the highest in I_2.Fertilizer levels had significant effects on number of fruits per plant. Highest number of fruits per plant (2.85) was observed at F_2. The interaction between levels of irrigation and fertilizer was not significant. The difference between treatments and control was highly significant.While control plots

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produced 1.6 fruits per plant, the average fruit number per plant in the drip fertigation plots was 2.8.

9. Levels of irrigation , fertilizer and their interaction had no significant effect on the average weight of fruits. The difference between treatments and control was highly significant.The average fruit weight of 398 g in control plot increased to 656 g in drip fertigation plots.

10. As in the case of average fruit weight, average fruit volume also was not significantly influenced by the levels of irrigation, fertilizer and their interaction. The difference between treatments (676 cm^3) and control (407 cm^3) was highly significant.

11. Levels of irrigation had no significant influence on the mean fruit yield per plant. Fertilizer levels influenced the average fruit yield per plant significantly. Highest fruit yield per plant (1.927 kg) observed at F_2 level of Fertilizer was significantly superior to both F1 and F2. The interaction between irrigation and fertilizer levels was significant with regard to the average fruit yield per plant. In all irrigation levels , average fruit yield per plant increased with increase in fertilizer levels up to F_2 and then decreased. Among the combinations, I_2F_2 recorded the highest fruit yield per plant and was significantly superior to all the combinations except I_3F_2. The difference between treatments and control was highly significant. The average fruit yield of 717 g in control plot increased to 1850 g in drip fertigation plots.

12. Levels of irrigation did not affect fruit yield significantly. But I_2 produced 1.6 and 0.6 tonnes more fruit per hectare than I_1 and I_3 respectively. But, fertilizer levels influenced the fruit yield significantly. Highest fruit yield was

observed at F_2 level of fertilizer application (64.2 t/ha). The interaction between irrigation and fertilizer levels was significant on fruit yield per ha. Among the combinations, I_2F_2 recorded the highest fruit yield per ha (65.8 t/ha) and was significantly superior to all the other drip fertigation combinations except I_3F_2 (64.7 t/ha). These two treatment combinations were significantly superior to all the other combinations. Between these two treatment combinations I_2F_2 appears to be the better one as it demanded less water and nutrients.The difference between treatments and control was highly significant. The average fruit yield of 23.9 t/ha in control plot increased to 71.6 t/ha in drip fertigation plots.

13. The number of days to harvest was not significantly influenced by levels of drip irrigation or fertilizer. However, harvest was delayed by five days in control plots compared to drip fertigation treatments and the difference was significant as per the F test.

14. Shoot dry matter production was significantly influenced by the levels of irrigation. Highest shoot dry matter production was recorded by I_3 level of irrigation (1528.7 kg ha^{-1}). There was significant influence of fertilizer levels on the shoot dry matter production. The highest shoot dry matter production was with F_3 level of fertilizer (1576.7 kg ha^{-1}) . Interaction between irrigation and fertilizer did not show any significant effect on shoot dry matter production. The difference between treatments and control was highly significant

15. There was an increase in fruit dry matter production with increase in irrigation level upto I_2 and then the trend was reverse up to I_3. But the effects were not significant. At the same time, increase in fertilizer levels significantly

reflected in fruit dry matter production up to F_2 and then decreased. The interaction between irrigation and fertilizer levels also significantly influenced the fruit dry matter production. In all irrigation levels, fruit dry matter production increased with increase in fertilizer levels up to F_2 and then decreased. Similarly in all fertilizer levels, fruit dry matter production increased with increase in irrigation level up to I_2 and then decreased. The difference between treatments and control was highly significant.

16. Levels of irrigation significantly influenced the nitrogen concentration of leaves at 45 DAS. Highest N level (3.94%) observed with I_3 level of irrigation was significantly superior to other lower levels. Fertilizer levels also showed a similar trend on the nitrogen content of leaves. With increase in fertilizer level, N content also increased and significantly the highest content was observed at F_3 fertilizer level. The interaction between irrigation and fertilizer levels didn't show any significant influence on the N content of leaves at 45 DAS. The difference between treatments (3.79 per cent) and control (3.03) was highly significant.

17. Levels of irrigation significantly influenced the leaf P content at 45 DAS . With increase in irrigation levels, P content also increased significantly upto I_3. Highest leaf P content (0.35%) was observed with I_3 level of irrigation. Similarly there was a significant effect of fertilizer levels on the leaf P content of OP melon at 45 DAS. Leaf P content increased significantly with increase in fertilizer levels upto F_3. The interaction between irrigation and fertilizer levels was not significant on the leaf P content at 45 DAS. The difference between treatments (0.34 per cent) and control (0.22 per cent) was highly significant.

18. It was found that, with increase in irrigation levels the content of K content in leaves also increased, but the effect was not significant. With increase in fertilizer levels, there was an increase in K content of leaves. The highest K content observed with F_3 level of fertilizer was significantly the highest. There was no significant effect by the interaction of irrigation and fertilizers on the leaf content of K at 45 DAS. The difference between treatments (1.88 per cent) and control (1.58) was highly significant.

19. The levels of irrigation significantly influenced N content of shoot at harvest. The content was found increasing with increase in irrigation level. The highest N content observed at I_3 level of irrigation (1.24%) was significantly the highest. Fertilizer levels also showed significant influence on the shoot N content. The highest N content of shoot observed with F_3 level of fertilizer also was significantly the highest. The interaction among irrigation and fertilizer levels was not significant in creating any effect on shoot N content. The difference between treatments (1.21 per cent) and control(1.00 per cent) was highly significant.

20. There was a significant increase in shoot P content with increase in irrigation levels. Significantly the highest content (0.30%) was observed with I_3 level of irrigation. Almost similar trend was expressed by the shoot P content with increase in fertilizer levels also. The highest shoot P content (0.31%) was observed with F_3 level of fertilizer and was significantly the highest. At the same time, interaction between irrigation and fertilizer levels didn't show any significant effect on shoot P content at harvest. The difference between treatments(0.28 per cent) and control(0.19) was highly significant

21. The shoot K content at harvest showed a similar as expressed by shoot N and P. With increase in irrigation level, shoot K content also increased. The

highest content was recorded with I_3 level of irrigation (0.92%), which was significantly superior to other two levels. Similarly, with increase in fertilizer levels, K content in shoot at harvest also increased. The interaction between irrigation and fertilizer didnt make any significant effect on shoot K composition. The difference between treatments (0.90 per cent)and control(0.76 per cent) was highly significant

22. Compared to the nutrient content of leaf and shoot, the nutrient content of fruit (NPK) remained same without any significant difference with the changes made in irrigation and fertilizer levels. The interaction between irrigation and fertilizer levels also didn't show any significant on fruit NPK content at harvest. It is worth to note that the difference between the treatments and control also was non- significant on fruit NPK concentration.

23. Levels of irrigation significantly influenced the N uptake by the crop. With increase in irrigation levels, N uptake increased significantly up to I_2 and then decreased. I_2 and I_3 were at par. All the three fertilizer levels gave significantly different results on the total nitrogen uptake by the crop at harvest. The total nitrogen uptake by the crop at harvest increased with increase in fertilizer levels upto F_2 and then decreased. F_2 was significantly superior to F_1 and F_3. The interaction between irrigation and fertilizer levels didn't make any significant effect on the character. The difference between treatments(86.4 kg /ha) and control (33.6 kg/ha) was highly significant.

24. Levels of irrigation significantly influenced the P uptake by the crop. With increase in irrigation levels, P uptake increased up to I_3. But I_2 and I_3 were at par and significantly superior to I_1. Similar was the result with fertilizer levels. With increase in fertilizer levels, the P uptake by the crop also increased up to F_3. But F_2 and F_3 were at par and significantly superior to F_1.

The interaction between irrigation and fertilizer levels could not make any significant effect on P uptake by the crop. The difference between treatments(19.7 kg ha^{-1}) and control (7.3 kg ha^{-1}) was highly significant.

25. Levels of irrigation significantly influenced the K uptake by the crop. With increase in irrigation levels, K uptake increased significantly up to I_2 and then decreased. But I_2 and I_3 were at par and significantly superior to I_1. All the three fertilizer levels produced significantly different results on the total K uptake by the crop at harvest. Total K uptake increased with increase in fertilizer levels up to F_2 and then decreased. F_2 was significantly superior to F_1 and F_3. The interaction between irrigation and fertilizer levels didn't show any significant influence on total K up take. The difference between treatments(71.6 kg ha^{-1}) and control (27.8 kg ha^{-1}) was highly significant.

26. When the nutrient analysis of the soil was conducted, the available N in the soil after the harvest of the crop was found decreasing with increase in irrigation levels. But the effect was not significant. With increase in fertilizer levels from F_1 to F_3, the available N in soil also increased significantly. But the interaction between irrigation and fertilizer levels couldn't make any significant effect on the available N in soil after harvest of the crop. Treatments retained significantly more available N in soil after harvest(200.7 kg ha^{-1}) than control(158.8 kg ha^{-1}).

27. The result on available N in soil after harvest was repeated in the case of available P also. With increase in irrigation levels, available P in soil decreased significantly. The highest available P in soil (38.9 kg ha^{-1}) was observed with I_1 level of irrigation. With increase in fertilizer level, available P in soil after harvest also increased significantly. The highest value (42.3%) was observes at F_3 level of fertilizer, which was significantly superior over F_1

and F_2 levels. The interaction between irrigation and fertilizer was not significant. Treatments retained significantly more available P in soil after harvest(37.8 kg ha^{-1}) than control(24.2 kg ha^{-1}).

28. With increase in irrigation levels, available K in soil after harvest of op melon decreased significantly. The highest K content (120.3 kg ha^{-1}) was observed with I_1 level of irrigation, which was significantly superior to both I_2 and I_3 levels. As in the case of available N and P, available K also increased significantly with increase in fertilizer levels. The highest value (126.6 kg ha^{-1}) was recorded with F_3 level of fertilizer. The interaction between irrigation and fertilizer didn't make any significant effect on the available K in soil after harvest. Treatments retained significantly more available K in soil after harvest(120.1 kg ha^{-1}) than control(106.6 kg ha^{-1}).

29. With increase in drip irrigation from 75 to 125 per cent Ep field water use efficiency decreased from 215.6 (kg ha mm^{-1}) to 145.8 (kg ha mm^{-1}) .The increase in FWUE in I_1, I_2 and I_3 over control was in the order of 405, 314 and 241 per cent respectively. Among the fertilizer levels, highest field water use efficiency was reported by F_2 level of fertilizer (181.9 kg ha mm^{-1}) . However, the variation in FWUE among the fertilizer levels was not as significant as that observed in irrigation treatments. High level of irrigation in the control practice reduced FWUE in a significant way and was the lowest at 42.7 kg ha mm^{-1}.

30. In all the treatments and control, soil moisture content was the highest in the surface layer of 0-15 cm and the lowest in the bottom most layer of 30-45 cm. The decrease in soil moisture content from surface to the bottom most layer was gradual. In each layer, moisture content increased with increase in drip irrigation level from 75 % Ep to 125 % Ep. The moisture content in each layer

was more in the control plot as it received more moisture through flood irrigation. In each layer the variation in moisture content was negligible within every level of drip irrigation due to the influence of varying levels of fertilizers.

31. Soil p^H was observed after the harvest of the crop and there was no significant variation in soil p^H due to various levels of irrigation or fertilizer doses. Soil p^H remained constant between 5.37 and 5.54 irrespective of the treatments.

32. There were no appreciable changes in the values of EC due to the various irrigation and fertilizer levels. No noticeable trend was observed on this character due to the treatments.

33. Keeping quality of the fruits was not affected by irrigation or fertilizer levels up to 45 days after harvest. It means that high levels of water and nutrients through drip fertigation is not harmful to the keeping quality of the fruits under high density planting with mulching.

34. All the drip fertigation treatments were far superior to control on increasing the net profit per hectare and also the net income per rupee invested. In all the irrigation treatments F_2 fertilizer level increased the net profit per hectare as well as net income per rupee invested in a significant way as the increase in fertilizer level above F_2 had negative effect on crop yield. Among the treatment combinations I_2F_2 recorded the highest net return of Rs. 531581 per hectare followed by I_3F_2 of Rs 513651. Among the treatment combinations also I_2F_2 recorded the highest net income of Rs 2.06 per rupee invested followed by 1.95 by both I_3F_2 and I_1F_2.

35. The study may be concluded by stating that the most profitable production of OP melon in the summer rice fallows of Kerala with high yielding, less spreading varieties like Saubhagya planted at a high density of 33,333 plants per hectare requires drip fertigation at 100 per cent Ep and 250 per cent RDF with LDPE mulching. This has produced the highest net profit per hectare and net income per rupee invested.

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*Original not seen

APPENDICES

Appendix I

a) Anova table for length of vine

Source	Degrees of freedom	Mean square
Replication	2	40.929
Irrigation	2	934.703
Fertilizer	2	957.296
Interaction (I x F)	4	22.234
Error	16	23.851

b) Anova table for number of leaves per vine

Source	Degrees of freedom	Mean square
Replication	2	5.33
Irrigation	2	394.333
Fertilizer	2	126.333
Interaction (I x F)	4	0.833
Error	16	3.208

c) Anova table for Leaf Area Index

Source	Degrees of freedom	Mean square
Replication	2	0.002
Irrigation	2	0.041
Fertilizer	2	0.365
Interaction (I x F)	4	0.001
Error	16	0.005

d) Anova table for number of primary and secondary branches per vine

Source	Degrees of freedom	Mean square	
		No. of primary branches	No. of secondary branches
Replication	2	0.444	0.704
Irrigation	2	0.333	7.148
Fertilizer	2	0.333	4.037
Interaction (I x F)	4	0.000	0.315
Error	16	0.153	0.620

e) Anova table for days to first flowering

Source	Degrees of freedom	Mean square	
		Days to first male flower	Days to first female flower
Replication	2	0.259	0.111
Irrigation	2	0.148	0.444
Fertilizer	2	0.259	1.000
Interaction (I x F)	4	0.204	0.111
Error	16	0.218	0.153

f) Anova table for number of fruits per plant

Source	Degrees of freedom	Mean square
Replication	2	0.009
Irrigation	2	0.006
Fertilizer	2	0.122
Interaction (I x F)	4	0.004
Error	16	0.003

g) Anova table for average weight of fruits

Source	Degrees of freedom	Mean square
Replication	2	833.370
Irrigation	2	266.259
Fertilizer	2	372.148
Interaction (I x F)	4	913.481
Error	16	507.454

h) Anova table for average volume of fruits

Source	Degrees of freedom	Mean square
Replication	2	870.314
Irrigation	2	301.344
Fertilizer	2	407.114
Interaction (I x F)	4	956.130
Error	16	540.371

i) Anova table for yield per plant

Source	Degrees of freedom	Mean square
Replication	2	0.009
Irrigation	2	0.005
Fertilizer	2	0.040
Interaction (I x F)	4	0.006
Error	16	0.002

j) Anova table for yield t ha $^{-1}$

Source	Degrees of freedom	Mean square
Replication	2	10.781
Irrigation	2	6.168
Fertilizer	2	44.834
Interaction (I x F)	4	6.964
Error	16	2.117

k) Anova table for number of days to harvest

Source	Degrees of freedom	Mean square
Replication	2	0.00
Irrigation	2	0.00
Fertilizer	2	0.00
Interaction (I x F)	4	0.00
Error	16	0.00

l) Anova table for shoot and fruit dry matter production at harvest

Source	Degrees of freedom	Mean square	
		Shoot dry matter production	Fruit dry matter production
Replication	2	3468.444	83353.370
Irrigation	2	16469.333	40928.037
Fertilizer	2	69717.333	335249.148
Interaction (I x F)	4	841.333	48023.093
Error	16	4214.944	15085.912

m) Anova table for NPK content of leaf (%) at 45 DAS

Source	Degrees of freedom	Mean square		
		N (%)	P (%)	K(%)
Replication	2	0.008	0.000	0.001
Irrigation	2	0.218	0.001	0.003
Fertilizer	2	1.081	0.013	0.047
Interaction (I x F)	4	0.002	0.000	0.000
Error	16	0.004	0.000	0.001

n) Anova table for NPK content of shoot (%) at harvest

Source	Degrees of freedom	Mean square		
		N (%)	P (%)	K(%)
Replication	2	0.001	0.000	0.000
Irrigation	2	0.005	0.002	0.002
Fertilizer	2	0.022	0.008	0.023
Interaction (I x F)	4	0.000	0.000	0.000
Error	16	0.000	0.000	0.000

0) Anova table for fruit NPK content at harvest (%)

Source	Degrees of freedom	Mean square		
		N (%)	P (%)	K(%)
Replication	2	0.000	0.000	0.000
Irrigation	2	0.000	0.000	0.000
Fertilizer	2	0.000	0.000	0.000
Interaction (I x F)	4	0.000	0.000	0.000
Error	16	0.000	0.000	0.000

p) Anova table for total NPK uptake by the crop at harvest (kg ha^{-1})

Source	Degrees of freedom	Mean square		
		N uptake	P uptake	K uptake
Replication	2	19.018	0.430	17.365
Irrigation	2	26.669	3.952	14.431
Fertilizer	2	97.482	7.035	66.353
Interaction (I x F)	4	7.408	0.592	5.350
Error	16	4.104	0.452	2.695

q) Anova table for available NPK in soil after harvest (kg ha^{-1})

Source	Degrees of freedom	Mean square		
		Available N	Available P	Available K
Replication	2	126.749	2.149	4.699
Irrigation	2	24.223	13.863	32.416
Fertilizer	2	276.813	197.936	372.686
Interaction (I x F)	4	1.123	0.224	1.409
Error	16	14.797	1.809	3.426

Appendix II

a) Cost of drip system per hectare

Sl no.	Materials required	Quantity	Unit cost (Rs)	Total cost (Rs)
1	Water tank (1000 L capacity)	6	3200	19200
2	2'' PVC pipe	38m	38	1444
3	12 mm lateral	3350 m	4	13400
4	4 mm extension tube	33333m	1.75	58333
5	Drippers(2 Lhr^{-1})	33333 No.	5	166665
6	Belt wash	180 No.	13	2340
7	Pin connector	33333 No.	1.1	36666
8	2''PVC end cap	3 No.	12	36
9	2'' MTA	3 No.	10	30
10	2 ''FTA	3 No.	14.5	43.5
11	2'' Bend	3 No.	12	36
12	2'' Coupling	3 No.	10	30
13	2'' Valve	3 No.	350	1050
14	Screen filters	3 No.	1850	5550
15	Installation cost		4000	4000
	Total	**308823**		

a) Cost of cultivation per hectare

Sl No.	Particulars	Quantity	Unit cost (Rs)	Total cost (Rs)
1	Ploughing by tractor	3 hr	600	1800
2	Digging of corners and trimming of bund	5 men	415	2075
3	Pit/ channel preparation	115 men	415	47725
4	Transportation and application of FYM	26 women	315	8190
5	Incorporation of FYM and filling	44 men	415	18260
6	Basal fertilizer application	18 women	315	5670
7	Spreading of polythene mulch on the ridges	10 men and 10 women	415 315	4150 3150
8	Sowing of seeds	20 women	315	6300
9	Pot watering upto 10 DAS (5	25 women	315	7875

	times)			
9	Thinning and gap filling	9 women	315	2835
10	Weeding interspaces	10 men	415	4150
11	Top dressing of fertilizer (to control)	2 women	315	630
12	Raking and earthing up (to control)	1 man	415	415
13	Imidachloprid spray (2 times)	4 men	415	1660
14	Harvesting and transportation	4 men 4 women	415 315	1660 1260
	Total	**117805**		

b) Labour cost for irrigation and cost of electricity

Sl No.	Treatments	Quantity	Unit cost (Rs)	Total cost (Rs)
1	I_1 (Drip irrigation at 75 % Ep) - Labour cost - Electricity cost	27 men 108 units	415 3	11205 324
2	I_2(Drip irrigation at 100 % Ep) - Labour cost - Electricity cost	30 men 162 units	415 3	12450 486
3	I_3 (Drip irrigation at 125 % Ep) - Labour cost - Electricity cost	34 men 216 units	415 3	14110 648
4	Pot watering - Labour cost - Electricity cost	80 women 156 units	315 3	25200 468
	Total	**64891**		

c) Cost of inputs per hectare

Sl No.	Input	Quantity	Unit cost (Rs)	Total cost (Rs)
1	Seed	1.67 kg	1000	1670
2	FYM (t)	25	1000	25000
3	Urea F_1 F_2 F_3 Control	 304 kg 380 kg 456 kg 152 kg	 6 6 6 6	 1824 2280 2736 912
4	MOP F_1 F_2 F_3 Control	 312 kg 390 kg 468 kg 156 kg	 17 17 17 17	 5304 6630 7956 2652
5	SSP F_1 F_2 F_3 Control	 83 kg 104 kg 125 kg 42 kg	 16 16 16 16	 1328 1664 2000 672
6	Imidachloprid	300 ml	Rs. 300 per 100 ml	900
	Total	F_1 : 35126 F_2 : 38144 F_3 : 40262 Control : 31806		

FERTIGATION AND MULCHING IN ORIENTAL PICKLING MELON

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

UNDER HIGH DENSITY PLANTING

By

ASHLY P.

(2013-11-143)

ABSTRACT OF THE THESIS

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COLLEGE OF HORTICULTURE

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ABSTRACT

A field experiment was conducted to study the effects of 'Fertigation and mulching in oriental pickling melon (*Cucumis melo var.*conomon (L.) Makino) under high density planting and LDPE mulching in the summer rice fallow at the Agricultural Research Station (ARS) , Mannuthy from December 2014 to February 2015. High density planting of short duration less spreading high yielding variety of op melon at 33,333 plants per hectare was found to increase the yield of op melon more than double the yield at the recommended population of 10,000 plants per hectare. Under high density planting there is a proportionate increase in the demand of water and nutrients, which are crucial for the balanced growth, development and yield of the crop. The purpose of this experiment was to find out an optimum level of irrigation, fertilizer which will be supplied as drip fertigation for the highest yield and quality of fruits under polythene mulched condition.

There were nine drip fertigation combinations with three levels of irrigation (75, 100 and 125 per cent Ep) and 3 levels of fertilizers (200, 250 and 300 per cent of RDF), and one control which were laid out in Randomized Block Design with three replications.

There was a significant increase in the characters like length of vine, number of leaves per vine, number of secondary branches per vine, leaf area index and shoot dry matter production at harvest with increase in irrigation levels from 75 per cent Ep to 125 percent Ep. At the same time, other growth attributes such as number of primary branches per vine and days to first male and female flower appearance didn't show any significant effect with various drip irrigation levels.

Similarly, under high density planting and polythene mulching, the length of vine, number of leaves per vine, number of secondary branches per vine, LAI and shoot dry matter production at harvest increased linearly with increase in fertilizer levels from 200 per cent to 300 per cent of recommended dose. But increase in fertilizer level did not make any significant effect on the number of primary branches of OP melon. It remained constant around 2 in all levels of irrigation and fertilizer.

The interaction between irrigation and fertilizer levels was not significant in any of the characters viz., length of vine, number of leaves per vine, number of primary and secondary branches per vine and LAI and shoot dry matter production at harvest.

Per hectare yield of crop as well as various yield attributes like number of fruits per plant, average fruit weight, average volume of fruit and fruit yield per plant were not affected significantly by various irrigation levels. However, the average weight and volume of fruits increased slightly and non significantly with increase in irrigation levels from 75 per cent Ep to 125 per cent Ep. All other parameters like number of fruits per plant, yield of fruits per plant and

fruit yield per ha recorded maximum value at 100 per cent Ep and the value declined gradually when irrigation level was increased to 125 per cent Ep.

Even though the weight and volume of individual fruits were maximum at 125 per cent Ep, the number of fruits per plant was less in this treatment, which ultimately resulted in a reduction in per ha yield of the crop.

Number of fruits per plant, fruit yield per plant and per hectare yield of fruit showed significant increase with increase in fertilizer level from 200 per cent to 250 per cent of recommended dose of fertilizer. But a further increase in fertilizer level affected the above characters negatively.So also, among the fertilizer levels, the average weight and volume of fruits were highest at 250 per cent RDF even though the effect was non- significant.

The interaction between irrigation and fertilizer levels was not significant on the weight of fruits per plant and average weight and volume of fruits. But, there was significant effect of interaction between irrigation and fertilizer levels on characters like fruit yield per plant and per ha. Highest fruit yield per plant and highest per ha fruit yield were recorded at I_2F_2 which was significantly superior to all the other combinations except I_3F_2.. So, there was positive interaction up to 100 per cent Ep and 250 per cent of recommended dose of fertilizer level when applied together as drip fertigation with LDPE mulching.

Number of days taken for the appearance of flowers and the number of days taken for harvest did not show significant variation under various levels of drip fertigation. The interaction between irrigation and fertilizer levels was also non- significant on these characters. In general, days to first male flowering and female flowering were 21 and 26 respectively in drip fertigation treatments, while they were 25 and 29 respectively in control. Fruits were harvested 63 and 68 days after planting in drip fertigation treatments and control plots respectively.

There was an increase in fruit dry weight with increase in irrigation levels from 75 per cent Ep to 100 per cent Ep and then it declined with further increase in irrigation level to 125 per cent Ep and the highest fruit dry matter production was recorded with 250 per cent of RDF compared to both 200 and 300 per cent of RDF. The interaction between irrigation and fertilizer levels also significantly influenced the fruit dry matter production. The maximum was observed at a combination of irrigation with 100 per cent EP and fertilizer with 250 per cent RDF.

Both nitrogen and phosphorus content of leaves at 45 DAS increased significantly with increase in irrigation levels from 75 per cent to 125 per cent Ep under drip irrigation. But the increase in potassium content with increase in irrigation levels was non- significant. But the concentration of nitrogen, phosphorus and potassium in leaves of op melon increased significantly with increase in fertilizer levels from 200 per cent RDF to 300 per cent RDF. This shows the tendency of op melon to absorb and accumulate more and more NPK in their leaves with an increase in their availability in the root zone. The interaction between the tested irrigation and fertilizer levels did not show any significant effect on the content of primary nutrients in leaves of op melon at 45 DAS.

Nitrogen content of shoot at harvest increased significantly with irrigation levels from 75 per cent Ep to 125 per cent Ep and fertilizer level from 200 per cent to 300 per cent of RDF. The fruit nitrogen level at harvest remained constant with slight variation, with the different levels of irrigation and fertilizers. At the same time, the interaction between any of the tested irrigation and fertilizer levels did not make any significant effect on shoot and fruit nitrogen content at harvest.

Levels of irrigation significantly influenced the total N uptake by the crop at harvest. With increase in irrigation levels, N uptake increased significantly up to I_2 and then decreased. I_2 and I_3 were at par. The total nitrogen uptake by the crop at harvest increased with increase in fertilizer levels upto F_2 and then decreased. F2 was significantly superior to F_1 and F_3. The interaction between irrigation and fertilizer levels didn't make any significant effect on the character.

Phosphorus content of shoot at harvest of op melon was found increasing significantly with increase in drip irrigation levels from 75 per cent Ep to 125 per cent Ep and fertilizer from F_1 to F_3 levels. At the same time, the fruit phosphorus content at harvest was not significantly affected by an increased application of phosphorus in soil.Fruit P content at harvest was not influenced by levels of irrigation and fertilizers. None of the combinations between irrigation and fertilizer levels showed significant superiority in increasing either shoot or fruit phosphorus content in OP melon.

Levels of irrigation significantly influenced the P uptake by the crop. With increase in irrigation levels, P uptake increased up to I_3. But I_2 and I_3 were at par and significantly superior to I_1. With increase in fertilizer levels, the P uptake by the crop also increased up to F_3. But F_2 and F_3 were at par and significantly superior to F_1. The interaction between irrigation and fertilizer levels could not make any significant effect on P uptake by the crop.

Irrigation and fertilizer levels significantly influenced the potassium content of shoot at harvest, but not the content of fruit. Significantly the highest potassium content in shoot was recorded at irrigation level of 125 per cent Ep and fertilizer level of 300 % RDF(F_3). The fruit potassium content remained constant with different irrigation and fertilizer levels. Levels of irrigation significantly influenced the total K uptake by the crop. With increase in irrigation levels, K uptake increased significantly up to I_2 (100 per cent Ep) and then decreased. Similarly, total K uptake also increased significantly upto 250 per cent RDF and then decreased. The interaction between irrigation and fertilizer levels didn't show any significant influence on total K up take.

With increase in drip irrigation from 75 to 125 per cent Ep field water use efficiency decreased from 215.6 (kg ha-mm^{-1}) to 145.8 (kg ha-mm^{-1}) . Among the fertilizer levels, highest field water use efficiency was reported by 200 per cent RDF (181.9 kg ha-mm^{-1}) . However, the variation in FWUE among the fertilizer levels was not as significant as that observed in irrigation treatments. High level of irrigation in the control practice reduced FWUE in a significant way and was the lowest at 42.7 kg ha-mm^{-1}.

Soil chemical properties such as pH and Electrical Conductivity didn't show appreciable variation due to the various levels of irrigation and fertilizer. This indicates that chemical properties of soil are not likely to be influenced by short term management practices like irrigation and fertilizer application.

In all the treatments and control, soil moisture content was the highest in the surface layer of 0-15 cm and the lowest in the bottom most layer of 30-45 cm. The decrease in soil moisture content from surface to the bottom most layer was gradual. In each layer, moisture content increased with increase in drip irrigation level from 75 % Ep to 125 % Ep. The moisture content in each layer was more in the control plot as it received more moisture through flood irrigation. In each layer the variation in moisture content was negligible within every level of drip irrigation due to the influence of varying levels of fertilizers.

Keeping quality of the fruits was not affected by irrigation or fertilizer levels up to 45 days after harvest under high density planting with LDPE mulching.

All the drip fertigation treatments were far superior to control on increasing the net profit per hectare and also the net income per rupee invested. In all the irrigation treatments F_2 fertilizer level increased the net profit per hectare as well as net income per rupee invested in a significant way as the increase in fertilizer level above F_2 had negative effect on crop yield. Among the treatment combinations I_2F_2 recorded the highest net return of Rs. 531581 per hectare followed by I_3F_2 of Rs 513651. Among the treatment combinations also I_2F_2 recorded the highest net income of Rs 2.06 per rupee invested followed by 1.95 by both I_3F_2 and I_1F_2.

The study may be concluded by stating that for the most profitable production of op melon in the summer rice fallows of Kerala, high yielding less spreading varieties like Saunhagya should be planted at a high density of 33,333 plants per hectare and managed by drip fertigation at 100 per cent Ep and 250 per cent RDF with LDPE mulching. This has produced the highest net profit per hectare and net income per rupee invested.