FERTIGATION IN ORIENTAL PICKLING MELON

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

UNDER HIGH DENSITY PLANTING

By

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(2011-11-171)

THESIS

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DECLARATION

I hereby declare that the thesis entitled **"Fertigation 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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ABBREVIATIONS

CWRDM	: Centre for Water Resources Development and Management
CPE	: Cumulative Pan Evaporation
DMRT	: Duncan's Multiple Range Testing
Ep	: Pan Evaporation
ET	: Evapotranspiration
ET_0	: Reference Evapotranspiration
FWUE	: Field Water Use Efficiency
FTA	: Female Threaded Adapter
FYM	: Farm Yard Manure
ICAR	: Indian Council of Agricultural Research
KAU	: Kerala Agricultural University
Kc	: Crop Coefficient
LAI	: Leaf Area Index
LDPE	: Low Density Polythene
MOP	: Muriate of Potash
MTA	: Male Threaded Adapter
NS	: Non significant
PET	: Potential Evapotranspiration
PVC	: Polyvinyl- Chloride
RBD	: Randomised Block Design
RDF	: Recommended Dose of Fertilizer
Sig	: *Significant*
SSP	: Single super phosphate
USWB	: United State Weather Bureau

Introduction

1. INTRODUCTION

Water and nutrients are the two most critical inputs in agriculture and their efficient management is important not only for higher productivity but also for maintaining environmental quality. Among the various methods used for water application, micro irrigation systems (MIS) particularly, drip irrigation method seems most efficient and increasingly adopted worldwide.

Fertigation is a new concept that is being adopted recently in several horticultural crops. Inorganic fertilizers were probably the first chemicals to be injected into the trickle irrigation system (Goldberg and Shmueli, 1970). Fertigation, means fertilizer combined with irrigation, is one of the most effective and convenient means of supplying nutrients and water, according to the specific requirements of the crop, whenever required, resulting in higher productivity and better quality produce. Fertigation also ensures high efficiency of fertilizer application, uniform and proper distribution of irrigation water in the soil, flexibility of nutrient ratio and avoids nitrogen volatilization from soil surface.

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

The higher plant population or density of planting is an important practice, necessary for realising maximum productivity. The yield realised in the conventional watering of oriental pickling melon at the recommended spacing of 2 m x 1.5 m is between 20-25 tonnes per hectare. Studies revealed the possibility of increasing the productivity of oriental pickling melon to about 60-70 tonnes per hectare by high density planting with less vigorous growing, high yielding varieties and good management.

Oriental pickling melon variety Saubhagya is a short duration less vigorous high yielding variety maturing in 65-70 days. It is suitable for high density planting. It has other good qualities like concentrated fruiting and small attractive fruits. Saubhagya has gained wide acceptance among the vegetable growers of Kerala state.

The main constraint for oriental pickling melon production during summer in the rice fallows is scarcity of water for irrigation. In order to ensure sufficient water to the irrigated oriental pickling melon cultivated in summer, efficient irrigation systems such as drip irrigation as well as schedule of irrigation and other water saving management practices are to be experimentally found out so that water saved can be utilized for growing oriental pickling melon in additional area. Such efficient systems can save not only considerable irrigation water but also substantially improve the productivity of the crop. Combining fertilizer with irrigation water (fertigation) improves the water as well as fertilizer use efficiencies. Under higher density planting, fertigation is sure to give better results than separate application of water and fertilizer. Among fertigation techniques, fertigation through drip irrigation is more popular.

Under this context, an investigation on the "Fertigation in oriental pickling melon (*Cucumis melo* var. *conomon* (L.) Makino) under high density planting" was conducted with the following objectives:

1. To standardize the fertigation requirement of oriental pickling melon under high density planting.
2. To study the relative efficiency of fertigation over conventional irrigation and fertilizer application.
3. To work out optimum benefit: cost ratio for oriental pickling melon variety Saubhagya with drip irrigation and different fertilizer levels under high density planting.

Review of Literature

2. REVIEW OF LITERATURE

Cucurbits are the largest group of summer vegetable crops grown in the state of Kerala. They belong to the family cucurbitaceae and are grown for their ripe and unripe fruits. Cucurbits are good sources of carbohydrates, vitamin-A, vitamin-C and minerals (Yawalkar, 1980). Among the agronomic practices, water application and an appropriate nutrition of the crop are important parameters to achieve the maximum productivity. 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 cucurbits through soil application is available, there is very little information available on its nutritional requirement through fertigation. Hence the literature related to application of major nutrients through fertigation on growth and yield of cucurbits and other related crops are reviewed here.

2.1. Scheduling of irrigation using pan evaporation

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

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

Rekha *et al.* (2005) found that highest fruit yield and water use efficiency were obtained when bhendi crop was drip irrigated at 1.0 Epan and fertilized with 120 kg N *per hectare.*

Veeraputhiran (1996) observed an increase in yield attributing characters in oriental pickling melon with the increase in the frequency of irrigation and it was maximum 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. In a study on the effect of irrigation on fruit weight and total yield, in oriental pickling melon Leekyaeongbho *et al.* (1999) observed that plants irrigated up to 20 days after flowering (88.8 mm) produced highest yield (11.4 t/ha) of good quality fruit. Similar study in oriental pickling melon revealed that growth, yield and net income increased with increase in level of daily drip irrigation from 50 -125 per cent Ep and reached maximum at 125 per cent Ep Alemeyhu (2001).

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

Studies in water melon by Srinivas *et al.* (1984) with four level of evaporation (25, 50, 75 and 100 %) and replenishment under drip and furrow irrigation indicated that replenishment of 25 per cent evaporation losses under drip and 50 to 70 per cent evaporation losses under furrow irrigation were optimum for 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, Varanasi. Results indicated that for maximum number of fruits per plant, fruit weight, and fruit yield, drip irrigation should be scheduled in tomato at 100 per cent ET_0. Similar studies conducted by Sharda *et al.* (2006) in onion also revealed that higher plant height, number of leaves and yield of onion were obtained when irrigation was scheduled at 1.0 x Epan.

2.2. Effect of methods of irrigation in cucurbits

Out of several contributing characters for the adoption of drip irrigation foremost is the economical use of water and its potential to maintain low soil moisture tension in the root zone (Sivanappan and Padmakumari, 1978) and its ability to maximise crop response and yield. Watering through drip irrigation eliminates wide fluctuations of soil moisture resulting in better growth and yield.

The comparative effect of pitcher irrigation and pot watered in cucumber was studied by Balakumaran *et al.* (1982). They reported that yields were slightly higher in pot watering plants, but water economy was appreciably greater under pitcher irrigation. Chartzoulakis and Michelakis (1996) reported that water use efficiency for cucumber was highest with drip compared to furrow, micro tube drip, porous clay tube and porous plastic tube. In a study on effect of irrigation method on green house cucumber, Komamura *et al.* (1990) found that perforate pipe system maintained adequate soil moisture than drip irrigation.

Monynihan and Harman (1992) compared drip and furrow irrigation system for small-scale farms and found that water requirement for cucumber was 3-4 times more with less yields and more labour under furrow system than drip irrigation. Aziz *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 water management for higher yield, water conservation and water use efficiency in cucumber production. From a trial at Rahuri on yield response of cucumber to micro irrigation, Limbulkar (1998) reported higher yield with 50 per cent water saving under drip irrigation than surface irrigation method.

From a comparative study of drip and sprinkler irrigation for pickling cucumber in Germany, Kunzelmann and Paschold (1999) observed that drip irrigation accelerate seedling development leading to earlier yield and prolonged harvesting periods. Yield under drip was 547 tonnes per hectare with 50 per cent water saving compared to sprinkler with an yield of 400 tonnes per hectare.

Farshi (2001) reported an increased WUE of 5.2 kg m^{-3} from drip irrigated cucumber compared to 1.2 kg m^{-3} in surface irrigation. Guler and Ibrikci (2002) reported higher yield (7.8 t ha^{-1}) from drip irrigated plant compared to furrow irrigated plant (7.2 t ha^{-1}).

Foster (1989) evaluated moisture regime and plant growth of vegetable under drip irrigation and conventional furrow irrigation. The results showed greater water savings and higher yields under drip. Drip irrigation gave highest water use efficiency in round guard (5.10 q ha^{-1} cm) and water melon (10.3 q ha^{-1} cm) than furrow irrigation system (3.70 q ha^{-1} cm). The yield increase by irrigation was associated with increase in fruit weight.

Reddy and Rao (1983) worked on the response of bitter gourd to pitcher and basin systems of irrigation. Yields were highest in pitcher filled every 4^{th} day and lowest in basin filled every fifth day.

Srinivas *et al.* (1986) while working on water requirement of water melon reported that among two different drip irrigation treatments one emitter per two plants recorded slightly higher yields (34 t ha^{-1}). In a comparison of bubbler and drip methods in bitter gourd (KAU, 1999) an irrigation schedule at 100 per cent evaporation in bubbler gave increased yield of 28.33 kg ha^{-1} with water use of 320 mm compared to drip. Similar studies in okra revealed that bubbler works with the pressure less than that of sprinkler with uniform distribution and increase in water use efficiency.

Field experiment conducted in oriental pickling melon by Gebremedhin (2001) drip irrigation saved irrigation water by 37 per cent and increased fruit yield by 20 per cent over conventional basin method of irrigation.

However, certain disadvantages, both agricultural and technical have restricted the field level application of drip irrigation. Agricultural problems under drip irrigation were that the localized water application causes development of limited root mass. Technical problems include precipitates, growth of biological organisms, emitter non uniformity, damage by rodents, high initial cost, need for management skill and faulty designs.

2.3. Studies on micro irrigation systems for fertigation

Micro irrigation systems make efficient use of the available water resources, as frequent application of water to the plant root zone minimises losses through seepage. There is considerable saving of water in these systems (up to 40-50%) depending upon the climate, as soil surface wetted is restricted to root zone both in respect of spread and depth. The evaporation is also reduced (Bruce *et al.*, 1980)

Fertigation helps in saving fertilizer and labour cost. This method facilitates easy supply of nutrients as they are already available to plant roots more quickly than solid fertilizers supplied to soil surface. The possible disadvantages of fertigation are when irrigation systems are improperly designed or when poor quality fertilizer materials are used (Koo, 1980).

Though the initial cost of establishing a micro irrigation system could be high, benefits in saving water, labour, non-interference with cultural practices and distinct possibility of saving fertilizers when given through these systems are very important. Since irrigation and fertilizer applications were regarded as very important input management practices, enterprising farmers and scientists in the past have attempted to let fertilizers be distributed through irrigation a concept termed as fertigation with yield advantages (Goldberg and Shmueli, 1970). Subsequently, this approach of supplying fertilizers through drip or sprinklers particularly for horticultural crops was developed by scientists in several countries (Bester *et al.*, 1977). In view of the potential advantages of this technology, area under drip irrigation has increased tremendously.

For a fertigation system to be successful, a number of pre-requisites like 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, have been indicated by Greeff (1975a).

Fertilizer is a key input for increasing crop productivity. Normally its use efficiency under conventional method of application is low. This problem is more acute with nitrogenous fertilizers whose consumption is also highest as compared to the major nutrients. Nitrogen consumption is highest in most of the crop plants because Indian soils are universally deficient in nitrogen and crops have an enormous apettite for nitrogenous fertilizers. Nitrogen use efficiency is generally low because it is highly mobile and liable to be lost by various natural processes like leaching, denitrification and volatilisation which are difficult to control particularly when nitrogen is added in bulk in the field. Phosphorous being not mobile, applied phosphorous gets fixed in soil and gets slowly released and is made available to the plants in due course. Potassium is in between N and P, and its use efficiency is not a serious problem. Conventional system of irrigation followed in India is largely the flooding method, which not only results in huge loss of water but also nutrients. The water and fertilizer use efficiency could be increased, substantially through fertigation, as it enjoys several advantages, *viz.*, a) higher use efficiency of both water and fertilizers, b) minimum loss of nitrogen through leaching , c) optimisation of nutrient balance by supplying nutrients directly to the root zone in available form, d) control of nutrient concentration in soil solution to effect proper supply, e) saving in application cost and f) improvement of soil physical and biological conditions due to proper maintenance of soil moisture levels. Among the nitrogenous fertilizers, urea is best suited for fertigation as it is highly soluble and does not react with water to form ions. The nitrogen use efficiency could be as high as 90 per cent compared to 40-60 per cent in conventional method of application. The uptake is affected by drought, lack of light and anaerobic conditions in the conventional method of flood irrigation. Alternate wetting and drying of the soil in the conventional method of flood irrigation also leads to greater denitrification loss, which is practically absent with fertigation (Greeff, 1975a).

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

According to Lazin and Simonds (1982) melons when spaced at 30, 60 and 90 cm within rows, decreased in spacing increased the number of fruits per plant but decreased mean fruit size and weight. Similar study by Prabhakar *et al.* (1985) revealed that in muskmelon highest yield of 45 q ha^{-1} was recorded when plants were spaced at 60 x 60 cm compared to other spacings.

Singh (1990) observed induction of early female flowers and total yield at a closer spacing of 90 x 22.5 cm. A wider spacing 90 x 45 cm produced more vine length, branches and leaves per plant in melons. From a spacing trial in muskmelon variety Superstar, Elizabeth and Dennis (1998) reported that the yield and number of fruits per ha generally increased with increasing plant population from 3074 to 10,076 plants, but number of fruits per plant and fruit weight decreased linearly with decreased in row spacing. Further studies by Nerson *et al.* (1994) revealed an increase in vegetative growth with increase in population from 13, 500 to 31,250 plants per hectare in muskmelon.

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

Cucumber when planted at different densities, the low density had greater values for growth parameters such as vine length and number of flowers. But leaf area alone was increased at high density planting (Bach and Hruska, 1981). In an experiment to study the effect of spacing on growth and yield of cucumber, Burgmans (1981) found an increase in total yield with increase in plant density (1, 26, 000 plants ha^{-1}). Studies by Khayer (1982) revealed that among the deferent spacing 1.5, 2.0, 2.5, and 3.0 plants m^{-2}, increase in plant densities increased fruit number and weight per plot. In an experiment with hybrids and open pollinated varieties of cucumber, Lower *et al.* (1983) found more staminate flowers and less pistillate flowers with an increase in plant density.

In an attempt to study the effect of plant density on performance of cucumber, Staub *et al.* (1992) observed that increased plant density increased the number and weight of fruits per hectare but decreased the fruit weight. Wann (1993) observed that among three different spacings 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) revealed that high plant population achieved by decreasing with in row spacing from 12 to 6 inches increased total yield than plant spaced at 18 inches. In a work with cucumber cv. Japanese, Choigounghah *et al.* (1995) found maximum yield of 3,80,020 kg per hectare with a planting density of 45,000 plants per hectare.

In an experiment with the slicing cucumber, (Renji, 1998) reported highest yield from the highest density of 13,333 plants per hectare. Kanthaswamy *et al.* (2000) observed maximum yield of cucumber (125.82 t/ha) at 60 x 60 cm spacing with pruning off all primary branches after two nodes.

Hafidh (2001) observed significant increase in staminate flowers and decrease in pistillate flowers and fruit yield when plant spacing decreased from 30 to 20 cm and 20 to 10 cm. Further studies to determine the effect of plant spacing on yield and quality of pickling cucumber, Paroussi and Saglam (2002) observed that among different within row spacing (20, 30 and 40 cm) highest yield was recorded with 20 cm compared to 30 and 40 cm.

Choudri and More (2002) reported that among three spacings (1.8 m x 0.3 m, 1.80 m x 0.45m, 1.80 m x 0.60 m), highest number of fruits per vine and yield per hectare, were recorded in 1.80 m x 0.40 m in cucumber. In an experiment to find out the effect of plant density on fruit growth when cucumber was grown with a density of 1.8 and 2.3 plants/m^2, Nishimura and Lopezgalvezij (2002) found that increased 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) observed that among four plant densities (2, 1.67, 1.43 and 1.25 plants m^{-2}), production per plant increased with decrease in spacing (6.6, 19.2, 19.7 and 20.7 kg $plant^{-1}$). Earliness and quality were not influenced by plant density.

In a study on the effect of plant density on growth and yield of watermelon var. Sugarbaby, Bindukala, (2000) found maximum fruits per plot and marketable yield per plant at highest density of 10,000 plants per hectare.

In an attempt to study the effect of plant density on growth, development and yield of winter squash, Botwright *et al.* (1998) found maximum marketable yield of 18 tonnes per hectare at 1.1 plants/m^2.

Effect of the plant spacings (3.00 m x 0.60 m, 3.00 m x 0. 75 m and 4.00 m x 0.75 m) on growth, yield and quality of pumpkin was studied by Kulbir Singh *et al.* (1990) in the loamy sand soils of Punjab Agricultural University. The different spacings did not change the number of fruits per vine but the fruit 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 ha^{-1} and the closer spacing induced early female flowers.

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

Parekh (1990) observed maximum main vine length and number of primary branches/plant and TSS at wider spacing of 1.5 m x 1.0 m in bitter gourd. Arora and Mallik (1990), in a work on ridge gourd variety Pusa Nasdar, observed that when seeds were sown at 12, 9 and 6 plants per bed, the spacing of nine plants per bed gave the long plant with highest secondary branches and resulted in early appearance of pistilate flowers. According to Pandit *et al.* (1997) total number of fruits per plant and fruit length increased with decrease in plant spacing in pointed gourd cv. Damodarpandit.

Jamuna Devi (2003) studied the spacing requirement of short duration oriental pickling melon variety Saubhagya, and reported that high density planting was needed to obtain maximum yield. She found that Saubhagya, at a high population density of 33,333 plants per hectare (1.0 x 0.3 m) gave the highest fruit yield of 33.93 tonnes per hectare compared to the fruit yield of 11.4 tonnes per hectare at the recommended population density of 10,000 plants per hectare (2.0 m x 1.5 m).

2.5. Studies on fertigation in cucurbits

Kretschmer and Zengerle (1973) conducted a trial for two years in cucumber cvs. Uniflora B and Sporu. Plants were given the same amounts of N, P and K applied either to the soil or via overhead sprinkler, the latter method gave 6.9 per cent higher yields.

Singh and Singh (1978) evaluated the relative merits of water application by 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. Drip irrigation increased the yield of long gourds by 45-47 per cent, ridge gourd by 21-38 per cent and water melon by 10-22 per cent compared to sprinkler and furrow irrigation.

Bhella and Wilcox (1986) studied the N-use efficiency of muskmelon under trickle irrigation. The significant increase in stem growth, early maturity and total yields were obtained with pre-plant N fertilization rates. The plants were more responsive to increasing N fertigation in the case of plants growth without the application of fertilizers. Fertigation responses were reduced in regimes that received 67 or 100 kg N per hectare.

Highest yield (29.83 t/ha) and 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 per hectare when applied through irrigation water (Harnandez and Aso, 1991).

Valenzuela *et al.* (1992) reported that in a greenhouse fertigation trial with musk melon cv. Gelia, there were 24 treatments involving NO_3^-, NH_4^+, P_2O_5 and K_2O. The results revealed that leaf Mg concentrations were not markedly affected by different N, P and K rates. The relationship between P supply and SO_4^{-2} content was unusual in that the lowest P dose was associated with the lowest SO_4^{-2} content. K was mobile, being translocated from the start of leaf maturation and especially to developing fruits.

Pinto *et al.* (1993) applied urea via trickle irrigation to Eldorado melons, 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 the total N (90 kg/ha) and 100 per cent of K (100 kg/ha) 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. The highest yields of 26.4 and 25.89 tonnes per hectare were obtained with daily fertigation up to 42 and 55 days after germination, respectively.

Raman *et al.* (2000) reported the effect of fertigation on growth and yield of gherkins where the treatments consisted of four fertigation with different soluble fertilizer combinations at two levels (100 and 75% NPK) compared with recommended dose of solid fertilizers applied through band application in soil. 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.

Soujala *et al.* (2006) revealed that fertigation in pickling cucumber with total amount of nitrogen 110 kg/ha resulted in the lowest yield. The highest nitrogen supply 170 kg/ha gave the highest yield and use of all nutrients in fertigation had no effect on the yield, in comparison with giving only N and K and finally states that 120-140 kg/ha of nitrogen is enough for producing a good yield.

Shinde and Malunjkar (2010) reported that 100 per cent recommended dose of nitrogen (100 kg N/ha) through fertigation with 8 splits in cucumber (cv. Himangi) were recorded higher number of fruits (2.166 kg/plant), yield (255.03 q/ha) and also showed lower values of water requirement with an improvement in water use efficiency (10.13 g ha- cm^{-1}).

Ruby *et al.* (2012) reported that highest fruit weight (38.50 g), fruit length (10.55 cm) and average fruit weight per vine (6.31 kg) of pointed gourd were recorded by 100 per cent fertigation with mulch. This was statistically at par with 80 per cent fertigation with mulch. Likewise highest yield of 15.78 tonnes per hectare was recorded by 100 per cent fertigation with mulch.

2.6. Studies on movement of plant nutrients under fertigation

Greeff (1975b) reported that application of fertilizers through fertigation is highly beneficial as it ensures localised application. Movement of the nutrients in the soil is largely determined by the cation exchange capacity of the soil and electrostatic change of the particular nutrient, the water flow was through the soil and uptake of nutrients was better. The movement of the charged nutrient ion, i.e., 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 and a loamy soil lesser than a clayey soil. Therefore, nutrient movement in sandy soils occurs more readily than on a loamy or clayey soil. Neutral chemical molecules like urea and negatively charged nutrient ions such as nitrate and sulphate primarily move in to the profile with the flow of the water. Thus irrigation in excess of the plant moisture requirement could lead to leaching of urea and nitrates.

Rolston *et al.* (1974) reported that phosphate fixation occurs in most soils. High concentration of phosphates is to be found in the surface soil layers when conventional broadcasting of fertilizers is the practice. With fertigation more uniform phosphate gradient in the soil is evident, movement of organic phosphate and glycerophosphate in the soil columns has been reported.

2.7. Effect of fertigation on growth, yield and quality of vegetables

Plant height, number of leaves and number of internodes per plant were significantly influenced by application of 100 kg nitrogen per hectare as compared to control. The variety Parbhani Kranti was found to be more vigorous than selection 2-2 (Chaudhari *et al.*, 1995).

Soumkuwar *et al.* (1997) reported that application of 75 kg nitrogen per hectare increased the vegetable growth, number and weight of fruit per plant and yield per hectare in okra varieties Parbhani Kranthi, Selection 2-2 and Punjab-7. Among these tested varieties Parbhani Kranthi recorded higher yield (77.70 q/ha) with low incidence of yellow vein mosaic virus and shoot borer. For okra cultivation, 75 kg nitrogen per hectare can be applied to variety Parbhani Kranthi under black soil of Vidarbha.

The effect of flooding against fertigation was studied using staked drip irrigated tomato cv. Sunny where N and K (about 75% of the total rates) were applied via the irrigation stream. Fertigation reduced the risk of crop damage due to high water table following heavy rains, but flooding and drip irrigation treatments did not affect the total yield (Pitts *et al.*, 1991).

Studies of Ibrahim (1992) indicated that fertigation increased crop yield as compared to traditional method of band application and more so with high frequency fertigation (*i.e.*, 2 days) in tomato cv. Ed Cawy.

Studies on effects of drip irrigation and different rates of N, P and K fertilizers on fruit yield and quality of cultivar Mountain Pride tomato revealed that application of 1000 lb of 10: 10: 10 NPK fertilizers before planting, in combination with drip irrigation produced yields equal to those with higher rates of fertilizers applied partly before planting and partly through irrigation stream (Mullins *et al.*, 1992).

An experiment was conducted during the summer by Meena *et al.*, 2008, in Lucknow, Uttar Pradesh, India, in randomised block design to access the suitable dose (40, 80 and 120 kg N) of nitrogen with and without bio fertilizer (Azotobacter) in okra cv. Arka Anamika. The results show that 120 kg / ha of nitrogen along with Azotobacter application gave significantly highest yield in okra crop.

Singh *et al.* (2008) conducted a field experiment during the kharif seasons of 2007 and 2008 to ascertain the effect of N (at 0, 80, 120 and 140 kg/ha) and P (0, 120 and 140 kg/ ha) under varying plant spacing (50 x 30 and 50 x 40 cm) on the growth and yield attributes of okra at Kanpur, Uttar Pradesh, India. The vegetative growth in height and diameter of plant, number of leaves and nodes and leaf area increased with N application at 140 kg/ha, followed by 120 and 80 kg per hectare, during both years. The highest level of P (100 kg/ha) promoted these attributes, followed by 80 kg per hectare.

Verma and Batra (2001) conducted a field experiment in Haryana, during spring-summer season of 1997 and 1998 on sandy loam soil to study the response of spring okra to irrigation and nitrogen. 150 kg nitrogen and 200 kg nitrogen applied in 3 times (basal, 30 and 45 days after sowing) they observed that the nitrogen uptake increased with increase in intensity of irrigation and level of nitrogen supply. The highest fruit yield could be ensured with moderate intensity of irrigation.

A study was conducted by Gowda *et al.* (2002) in Bangalore, Karnataka, India, to investigate the effects of different fertilizer levels (N:P:K at 125:75:60, 150:100:75 and 175:125:100 kg/ha) on okra Anamika, Varsh and Vishal. The highest nutrient uptake and accumulation in leaves and fruits was recorded at the highest level of fertilizer (175:125:100 kg/ha) in all the varieties.

Kushwaha *et al.* (2008) conducted a field experiment to assess the optimum dose of nitrogen and phosphorus fertilizers on hybrid summer okra. Results revealed that each incremental dose of nitrogen up to 150 kg per hectare significantly increased the plant height, number of fruits per plant, pod length, pod girth, pod weight, dry weight of 100 gm fresh pod and crop yield. Phosphorus levels up to 80 kg per hectare also significantly increased in all the above parameters except pod weight and yield.

Field studies were conducted at Bangalore, Karnataka, India, by Sajjan *et al.* (2002) to evaluate the effect of sowing date (15 June, 15 July (kharif), and 15 November and 15 December (rabi), spacing (60 x 20, 60 x 30 and 60 x 40 cm) and nitrogen rates (100, 125 and 150 kg/ha) on the yield attributes and seed yield of okra cv. Arka Anamika during the 1998 kharif season and 1998-99 rabi season. Sowing on 15 July coupled with 60 x 30 cm spacing and 150 kg N/ha recorded the highest yield attributes *viz*, branches per plant, fruits per plant, 100-seed weight, length and girth of fruits, processed seed recovery and processed yield (1139.7 kg/ha) in the kharif season. However, for the 15 November sowing, with the same spacing (60 x 30 cm) and nitrogen rate (150 kg N/ha), the higher seed yield of 745.3 kg per hectare was recorded.

Ashish *et al.* (2006) conducted field experiment at Bihar, during 2001 kharif season, to determine the response of okra to the application of organic and inorganic fertilizers. The highest nutrient uptake with respect to nitrogen (N), phosphorus (P) and potassium (K) yielded and net return in okra was recorded from the treatment supplied with 25% of the recommended rate of nutrients through farmyard manure. It was closely followed by the combination of inorganic fertilizers in same proportion. Application of 18 kg nitrogen per hectare was more beneficial in terms of net returns compared to the full rate of inorganic fertilizers.

Singh *et al.* (2007) conducted field experiment at Meerut, Uttar Pradesh to determine the effect of N (50, 100 and 150 kg/ha), Cu (500, 1000 and 2000 ppm) on the growth and yield of okra cv. Pusa Sawani. The maximum plant height, stem diameter, leaf length, leaf width, fresh pod weight and green pod yield, including the earliest number of days to emergence was obtained with 100 kg nitrogen per hectare, 1000 ppm Cu and 1000 ppm Fe.

A study was conducted by Omotoso and shittu, (2007) to determine the effect of NPK fertilizer application rates and method of application on growth and yield of okra (*Abelmoschus esculentus* L.) with three levels of NPK fertilizer rates (0, 150 and 300 kg NPK /ha) and two methods of fertilizers application (ring and band method). The results indicated that the fertilizer NPK significantly increased growth parameters (plant height, leaf area, root length and number of leaves), and yield components with optimum yield of okra obtained at 150 NPK kg per hectare and ring method of application seems appropriate for okra production.

Potato cultivar 'Spunta' showed that irrigation water supplied with 130 and 120 mg/l of N and K respectively, and among P levels of 0, 20, 40, 60 mg/l, the application of 40 mg/l of P resulted in no accumulation of P in deep layers of soil profile. This level of P was recommended for obtaining high yield with good quality of tubers (Papadopoulos, 1992).

Liquid fertilizers gave higher yields as compared to solid fertilizers in two cultivars of tomato (Soliman and Doss, 1992).

Highest tubers yield (15.03 t/ha) was obtained by soil application of 50 per cent of recommended nitrogen with furrow irrigation and the remaining 50 per cent N was through drip irrigation at four weekly split applications. The water use efficiency was highest when drip irrigation was provided daily in potato (Keshvaiah and Kumaraswamy, 1993).

Maximum plant height, number of branches, fruit volume, fruit girth, fresh weight of green fruits (128 g), fresh yield of fruit (637.5 g / plant) were recorded in sweet pepper at the higher fertilizer level of 150: 200: 200 kg NPK per hectare (Shrivastava *et al.*, 1993).

Carbello *et al.* (1994) studied the effect of drip irrigation with various rates and timings of N and K application on bell pepper fruit quality. They found that higher fertilizers rate (266-309 kg/ha of N and K, respectively) increased the yield of class I fruits in the first harvest and reduced the total discards. The low fertilizers rate (70-81 kg/ha of N and K) increased the yields of class I fruits in the first harvest and mid or late season fertigation produced more of second harvest yields and less discards than the first harvest.

According to Amarananjundeshwara (1997), 100 per cent water soluble fertilizer through fertigation recorded maximum plant height, more number of sprout, higher leaf area, more number of leaves per plant, higher fresh and dry weight of plants and marketable tuber yield, than the conventional method of fertilization in potato.

High levels of N and P recorded higher fruit weight (80.90 g) when fruit characters of sweet pepper cv. California Wonder were studied by Maya *et al.*, (1997).

The effect of planting and fertigation on growth and yield of green chilli (*Capsicum annum*) was studied. The treatments included fertigation of recommended dose of fertilizer (100: 50: 50 kg NPK/ha) at every irrigation (2 days interval) up to 105 days which resulted in significantly higher yield of green chilli of 9.30, and 9.06 tonnes per hectare during first and second year respectively. However, it was on par with fertigation at alternate irrigation (4 days intervals) up to 105 days (8.62 and 8.00 t / ha) (Tumbere and Nikam, 2004).

Studied on effect of source and levels of fertigation on capsicum hybrid 'Green Gold' under greenhouse during winter revealed that, water soluble fertilizers at higher level (120% of RDF) resulted in maximum productivity (13.72 kg/m^2) of excellent quality fruits having shelf-life of 11.36 days. It was economically feasible (B : C ratio of 1.387) that the other sources and levels of fertigation. Among the growing conditions, greenhouse grown crop had maximum vegetative growth and earliness in flowering, fruit set and harvesting (about 18 days) with maximum cumulative yield (13.85 kg/m^2 from both the season) (Manohar, 2002).

The treatment with half of NK fertigation and drip with black polythene mulch was found to be good with respect to tomato yield and growth parameters like mean fruit weight (64.5 g), number of fruits per plant (7.7) and number of clusters per plant (12.3) and the yield of 121.3 tonnes per hectare. The highest TSS of 5.3^0 B (brix) was observed in treatments with soil application of recommended levels of fertilizers. The fruit dry matter content (41.2%) was highest in the treatments half of NK fertigation through Multi K with block polythene mulch (Prabhakar *et al.*, 2002).

Decreasing the fertilization levels by 12 per cent than the recommended level especially under fertigated conditions may not affect the yield level in chilli because of improved fertilizer use efficiently at the lower fertilizers dose. Irrigation method produced significantly higher water use efficiency over furrow method even with the same level and method of normal fertilizers application (Veeranna *et al.*, 2002).

Highest yield (29.83 t/ha) and 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 per hectare when applied through irrigation water (Harnandez and Aso, 1991).

According to Patel and Rajput (2004), the yield of okra under conventional method of fertilization with 100 per cent of recommended dose of fertilizers and under fertigation with 60 per cent of recommended dose of fertilizers was not significantly different (23.0 t/ha and 23.1 t/ha in the year 2000 and 23.56 t/ha and 23.35 t/ha in the year 2001). More than 16 per cent increase in yield under fertigation (25.21% in the year 2000 and 16.59% in the year 2001) was observed as compared with broadcasting method of fertilizer application when 100 per cent recommended dose of fertilizers 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 the soil resulted in 55 per cent N recovery; and for spring potato crop in this treatment, 44.8 per cent N need was met from the soil N and 21.8 per cent from the irrigation water. Higher N input increased not only the N derived from fertilizers, but also the residual soil N.

Muralikrishnasamy *et al.* (2006) reported that irrigation at 100 per cent ET with fertigation of 100 per cent N and K and, 50 per cent ET with fertigation of100 per cent N and K recorded higher and comparable pod yield of chilli as compared to surface irrigation at 0.90 IW/CPE ratio with entire NPK as soil application. 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. 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.

Mahajan and Singh (2006) found that in green house grown tomato when the same quantity of water and N was applied through drip irrigation a significantly higher tomato yield (68.5 t/ha) was obtained as compared to the yield of 58.4 and 43.1 tonnes per hectare in check basin method of irrigation when the crop was sown both inside and outside the greenhouse, respectively. Drip irrigation at 0.5 x E pan along with fertigation of 100 per cent N resulted in increased fruit yield by 59.5 per cent and 116.2 per cent over the control with recommended practices inside and outside the greenhouse, respectively.

Shedeed *et al.* (2009) observed significant increase in growth parameters (plant height, LAI, fruit dry weight, total dry weight), yield components (number of fruits /plant, mean fruit weight, fruit yield / plat) 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 conducted 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 percent increase of fertilizer use efficiency over 100 percent recommended dose of fertilizers applied through surface incorporation under conventional surface application of water.

Basavarajappa *et al.* (2011) reported that drip irrigation system with 100 per cent RDF was more profitable as compared to furrow irrigation due to the increase in yield of brinjal. The highest yield obtained in furrow irrigation with 100 per cent RDF (21.00 t/ha) was less than the yield obtained in 60 per cent ET and 50 per cent RDF level under drip irrigation which recorded 32 tonnes per hectare and that 51.4 per cent saving of water was achieved over furrow irrigation and 50 per cent saving of RDF.

Dinesh *et al.* (2012) reported that application of NPK through fertigation influenced the vegetative growth, flowering, enhanced the bunch weight and yield by 8.29 and 8.31 per cent respectively in banana variety Monthan (Banthal). Maximum pseudo stem height, stem circumference were recorded with the application of 75 per cent RDF with application of N: P: K in the ratio of 3: 2: 1 at vegetative growth, 1: 3: 2 at flowering stage and 2: 1: 3 at fruit development stage.

Pandey *et al.* (2013) revealed that the method of drip irrigation had significantly increased yield (10.50 kg/m^2) and net income (60.30 Rs/m^2) of chilli as compared to flood irrigation. The crop yield improved by 60.30 per cent in chilli when the crop was irrigated through drip irrigation. Maximum water saving minimized weeds, diseases and total time of irrigation were found in drip irrigation.

Application of 50 per cent recommended dose of N: P: K fertilizer through drip irrigation in summer tomato gave higher plant height, number of branches, less 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. Highest net income and B: C ratio were obtained with the treatment that received 50 per cent of recommended dose of N: K using conventional fertilizers supplied through fertigation (Prabhakar *et al.*, 2012).

Chattoo *et al.* (2013) found that superiority of drip irrigation and fertigation practices in terms of yield, water and fertilizer use efficiency over conventional method of irrigation and fertilizer application in radish var. Japanese white long.

The treatment combination of 75 per cent ET through drip with 75 per cent recommended NPK was found to be significantly superior with 68.9 per cent yield enhancement, 46.2 q /ha-cm water use efficiency, 4.78 q/ha-kg N, 7.17 q/ha-kg P and K fertilizer use efficiency respectively over conventional method.

2.8. Water and nutrient interaction

Nutrient absorption is affected directly by soil moisture content, and indirectly by the effect of water on the metabolic activity, the degree of soil aeration, and salt concentration of the soil solution. N uptake is reduced in dry soils; it is usually not reduced as much as P and K uptake. Under drought conditions, N mineralisation is reduced, in addition to reduced uptake of soluble N. Fertilizer N will not increase yield without sufficient plant available water and increasing stored soil water by conservation practices will not increase production without adequate nitrogen (Jackson *et al.*, 1983).

Crop yield response to P and other nutrients varies depending on water availability. The lower the rain fall, the greater the response to P. the same relationship is commonly observed with K. Crop response to K in wet soils can be related to the effect of reduced aeration on respiration. Plant roots respire to obtain energy to absorb nutrients and respiration requires O_2 (adequate K enhances respiration). Nutrient and water interactions under irrigated systems are similar to dry land systems, except the interactions operate at higher yield levels. Fertility is one of the important controllable factors influencing water use in irrigated soils. When N is deficient, increasing N fertilization will increase yield, total water use, and WUE. Generally, the crop response to N is much greater under irrigation, where water is non limiting (Thorne *et al.*, 1979).

Materials and Methods

3. MATERIALS AND METHODS

Investigation on "Fertigation in oriental pickling melon (*Cucumis melo* var. *conomon* (L.) Makino) under high density planting" was carried out at the college of Horticulture, Vellanikkara Thrissur, Kerala. Field experiment was conducted during December 2012 to February 2013 at Agricultural Research Station, Kerala Agricultural University, Mannuthy Thrissur. The details of materials used and techniques adopted during the course of investigation are presented below.

3.1. Location

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

3.2. Cropping history

The experimental site is a double crop paddy wet land in which a semi dry sown crop (April - September) and a transplanted wet crop (September - December) was regularly cultivated. The land is left 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* (L.) Makino) variety Saubhagya developed at the Department of Olericulture, College of Horticulture, Vellanikkara was utilized for the study. Its fruits are small to medium in size with uniform oblong shape. The developing fruits are green with light green lines and turns attractive golden yellow on ripening. Specific advantage of the variety is its short duration (60-65 days), less vegetative growth and small to medium sized attractive fruits.

Table 1. Soil characteristics of the experimental field

Procedure adopted	Value	Particulars
		1) Mechanical composition
Robinson's international pipette method (Piper, 1950)	27.1	Coarse sand (%)
	23.9	Fine sand (%)
	22.8	Silt (%)
	26.2	Clay (%)
I.S.S.S. system (ISSS, 1992)	Sandy clay loam	Textural class
		2) Physical constants of the soil
Pressure plate apparatus (Richard, 1947)	21.82	Field capacity (0.3 bars)
Core method (Blake, 1965)	9.34	Permanent wilting point (15 bars)
		Bulk density (g cm^{-3})
Pycnometer mehod (Blake, 1965)	1.34	0-30 cm
	1.36	30-60 cm
	2.16	Particle density (g cm^{-3})
		3) Chemical properties
Chromic acid wet digestion method (Walkley and Black, 1934)	0.62	Organic carbon (%)
Alkaline permanganate method (Subbiah and Asija, 1956)	225.79	Available nitrogen (kg ha^{-1})
Bray and Kurtz method (Bray and Kurtz, 1945)	31.3	Available phosphorus (kg ha^{-1})
Neutral normal ammonium acetate extract using flame photometer (Jackson,1958)	90	Available potassium (kg ha^{-1})
1:2.5 soil : water suspension using p^H meter (Jackson, 1958)	5.43	Soil reaction (p^H)
Supernatant of 1:2.5 soil : water suspension using EC bridge (Jackson, 1958)	1.25	Electrical conductivity (dS/ m)

3.4. Season

Experiment was conducted from 10th December 2012 to 15th February 2013. Meteorological data during the cropping period are presented in Table.2 and Fig.1and 1(a).

3.5. Experimental details

3.5.1 Layout

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

Design	: Randomised Block Design (RBD)
Replications	: 3
Number of treatments	: 12
Total number of plots	: 36
Plot size	: 4 m X 3 m
Spacing	: 1.0 m X 0.3 m
Number of plants per plot	: 40
Date of sowing	: 10th December, 2012
Date of harvest	: 15th February, 2013

3.5.2 Treatments

The treatments consisted of combinations of four irrigation levels and three fertilizer levels. The details are given below.

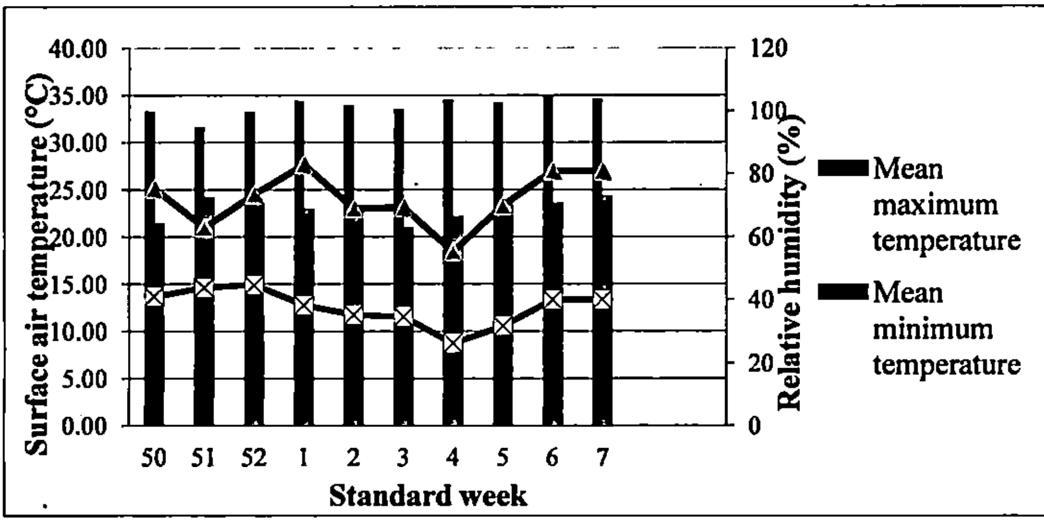

Fig 1. Mean weekly weather data of temperature and relative humidity

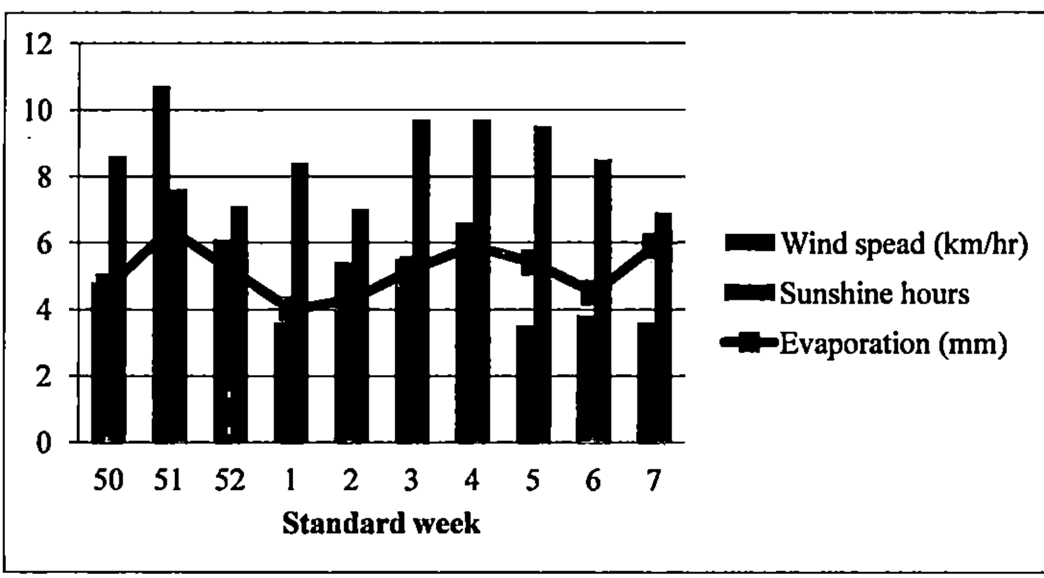

Fig 1(a). Mean weekly weather data of wind speed, air temperature and evaporation

3.5.2.1 Irrigation levels

I_1 - Drip irrigation at 50% Ep

I_2 - Drip irrigation at 75% Ep

I_3 - Drip irrigation at 100% Ep

I_4 - Pot irrigation @ 10 litres plant^{-1}on alternate days from flowering to maturity and half of this quantity from 10 DAS to flowering.

3.5.2.2 Fertilizer levels

F_1- 100% NPK (PoP)

F_2- 150% NPK (PoP)

F_3- 200% NPK (PoP)

3.5.2.3 *Treatment combinations*

I_1F_1 I_2F_1 I_3F_1 I_4F_1

I_1F_2 I_2F_2 I_3F_2 I_4F_2

I_1F_3 I_2F_3 I_3F_3 I_4F_3

3.6 Cultural practices

3.6.1. Land preparation

The land was ploughed using tractor drawn disc plough to break the soil. Then cultivator was passed over to crush the clods and to bring the soil to a fine tilth. Thereafter stubbles were removed and the experimental plots were laid out as per the plan. Channels and pits were opened at the spacing mentioned above to a depth of 40 cm and width of 60 cm. Each plot was surrounded by bunds of width 1m on all the four sides.

3.6.2. Manure and fertilizer application

Farmyard manure at the rate of 25 t ha^{-1} was applied uniformly in all the channels and pits as basal dose. After thorough mixing with top soil, channels/pits were partially filled and irrigated using hose. Entire dose of phosphorus was applied basal and incorporated into the soil. Nitrogen and potassium were applied through drip in six split doses at weekly interval from 10 DAS to 40 DAS. Fertilizers were applied as per treatment in the form of SSP, urea and muritae of potash.

3.6.3. Sowing

Two seeds were uniformly sown at a point in each channel. Gap filling was done on 09^{th} day and thinning on 12^{th} day after sowing by retaining only one plant at a point.

3.6.4. Irrigation

A uniform irrigation was given to all the channels up to 9 DAS. Operation of drip system started from the 10^{th} day after sowing. Daily drip irrigation was based on the evaporation values of the previous day and the rate was fixed as per the treatment. Under pot irrigation, plots were irrigated by using a mud pot, amount of water used for irrigation is shown in table3.

Nine water tanks of 200 litre capacity were kept on a platform of 2 m height above the ground. The tank was connected to main line made of rigid PVC pipe having 2 inch diameter. The main line laterals made of LDPE having 12 mm internal diameter were connected at 1m intervals in rows. Drippers were inbuilt in the main lateral 30 cm apart. From each dripper, the discharge rate was 2 litres per hour. Required amount of water was provided through single dripper per plant.

The tanks were constantly kept filled with water by connecting to the pumping line. Wire mesh filter was provided in the pumping line to prevent impurities entering into the drip system. Each line was provided with separate control valves at the beginning.

3.6.5. Aftercare

Hand weeding was done on 11th day after sowing. Raking and earthing up was done on 15th day after sowing. During fertilizer applications, gentle raking was given to the soil with the help of hand fork in pot irrigated plots. Earthing up was given to drip irrigated plots by using spade. After the second weeding, the interspace was mulched uniformly in all the plots with dried coconut fronds.

3.6.6. Plant protection

Imidacloprid 30.5% SL sprayings were given on 20th and 30th days after sowing to control the attack of red pumpkin beetle, serpentine leaf minor and other small sucking pests like jassids and white fly.

3.6.7. Harvesting

Fruits were harvested at 67 days after sowing when they were fully matured (they got attractive golden yellow stripes from stalk end to pedicel end).

3.7 Biometric observations

For understanding the effects of treatments on growth, development and yield of the crop, growth and yield attributes were recorded from randomly selected six plants per plot and the average was worked out.

3.7.1. Number of branches per vine

The number of branches per vine was counted from six plants per plot before harvest.

3.7.2. Length of vines (cm)

The length of vines were observed and measured from the base to the tip at final harvest from six observational plants.

3.7.3. Number of leaves per vine

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

3.7.4. Leaf area index

Leaf area index 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.

Leaf area index is defined as leaf area of assimilatory surface per unit land area (Sestak *et al.*, 1971). The Leaf area index was measured by LI-COR: LAI-2000 plant canopy analyzer (Welles and Norman, 1990).

3.7.5. Shoot dry matter production at harvest

Shoots of all the plants were taken from each plot at harvest and dried in oven at about 80^0 C to a constant weight to find out the dry weight.

3.7.6. Days to first flowering

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

3.7.7. Days to harvest

The crop was harvested on 15^{th} February 2013. It took 67 days to harvest the crop.

3.7.8. Volume of fruits (cm^3)

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

3.7.9. Weight of fruits (g)

The mean weight of a fruit was calculated from total fruit yield and total number of fruits harvested 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 hectare

Total weight of fruits harvested from each plot was recorded and the yield in kg/ plot and yield in tones / hectare were worked out.

3.8 Uptake of NPK at harvest

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

3.9 Field water use efficiency

The weight of economic yield per unit of water used is referred to as water use efficiency and was calculated by using the formula by

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

3.10 Incidence of pests and diseases

Serpentine leaf minor, red pumpkin beetles, white flies and jassids were seen from the initial stages of crop growth. All of them where brought under control by appropriate spraying of insecticides. No diseases were observed during cropping period.

3.11. Soil properties during (15, 30 and 45 DAS) and after the experiment

3.11.1. Soil p^H

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

3.11.2. Electrical conductivity (dS / m)

Supernatant of 1:2.5 soil : water suspension was prepared and measured EC by using EC bridge (Jackson, 1958).

3.11.3. Moisture content of soil

Soil moisture determination was done using gravimetric method. Soil samples were drawn with the help of screw auger from 0-15, 15-30 and 30-60 cm soil depth. In all the treatments soil samples were collected before sowing and 15, 30 and 45 DAS.

3.12 Nutrient status of soil during (15, 30 and 45 DAS) and after the experiment

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

The available nitrogen content of soil was determined by alkaline permanganate method (Subbiah and Asija, 1956) at 15, 30, 45 DAS and after harvest the crop.

3.12.2. Available Phosphorus (kg ha^{-1})

The available phosphorus content of soil was determined by Bray and Kurtz method (Bray and Kurtz, 1945) at 15, 30, 45 DAS and after harvest the crop.

3.12.3. Available Potassium (kg ha^{-1})

The available potassium content of soil was determined by neutral normal ammonium acetate extract using flame photometer (Jackson, 1958) at 15, 30, 45 DAS and after harvest the crop

3.13 Plant analysis

Leaf samples were collected at two stages of crop growth *viz,* 30 and 60 days after sowing and shoot samples at the time of harvest. Samples were oven dried, ground and used for N, P and K analysis.

3.13.1. Nitrogen content

The plant samples were digested by micro kjeldahl method (Jackson, 1958). Estimation was done by distillation and titration.

3.13.2. Phosphorus content

The plant samples were digested by diacid digestion (Jackson, 1958). Spectrophotometer was used for reading the colour intensity developed by Vanado-molybdate yellow colour method.

3.13.3. Potassium content

The potassium content of samples was determined with diacid extract, and reading in an EEL flame photometer (Jackson, 1958).

3.14. Economics of production

The economics of production was worked out based on the input costs, labour charges and the price at which the local sellers accepted the fruits of cucumber at the time of harvest. Input costs were taken as the actual cost of the materials at the time of conduct of the experiment. Labour charges considered were the prevailing labour wages of the locality at the time of conduct of the experiment. Cost of drip irrigation system used for the experiment was taken as one fifth of the total cost of material 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 total returns were worked out. From this the net income and the net profit per rupee invested were calculated.

3.15. Statistical analysis

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

Distance between plots=1m   Plot size=4m X 3m   Distance between fertigation plots and pot irrigated plots = 4m   Spacing=1m X 0.3m

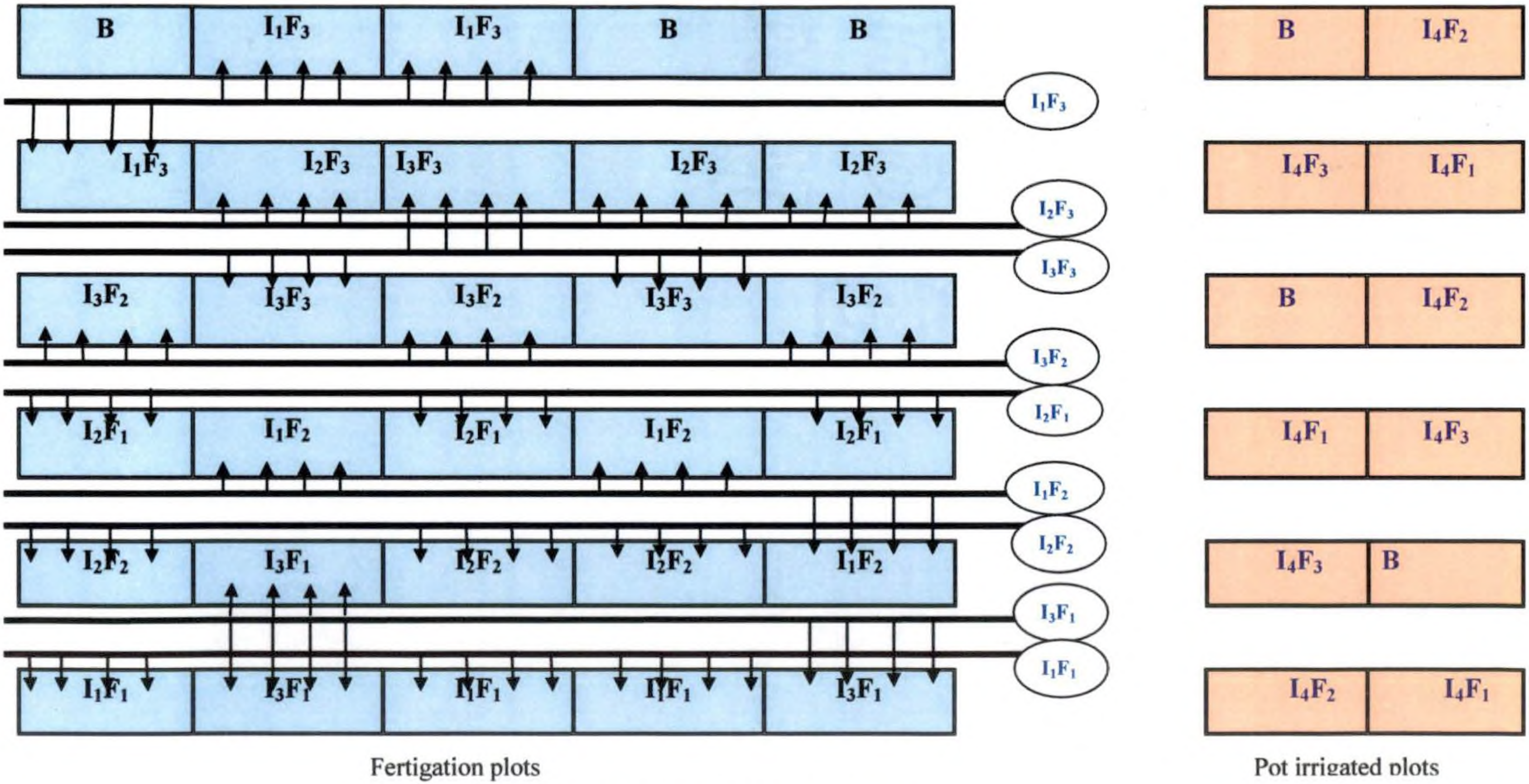

Fig. 2 Experimental plot lay out

Table2. Mean weekly weather factors during cropping period (December 2012 to February 2013)

Std week	Date	Temperature (°C)		Humidity (%)		Wind speed (Km/hr)	Sunshine (Hrs)	Evaporation (mm)	Soil temperature at 15cm depth (°C)	
		Max	Min	Morning (07-22 hrs)	Evening (14-22 hrs)				Morning	evening
50	Dec. 10-16	33.3	21.5	75.4	41.1	4.8	8.6	4.7	27.0	31.3
51	Dec. 17-23	31.6	24.2	63.1	43.9	10.7	7.6	6.4	26.6	30.9
52	Dec. 24-31	33.2	23.6	73.6	44.8	6.1	7.1	5.2	27.9	31.4
1	Jan. 01-07	34.4	23.0	83	38.3	3.6	8.4	4.0	27.5	32.3
2	Jan. 08-14	33.9	23.0	69.1	35.3	5.4	7.0	4.3	27.8	31.9
3	Jan. 15-21	33.5	21.0	69.4	34.7	5.5	9.7	5.2	27.0	32.0
4	Jan. 22-28	34.5	22.2	55.4	26.3	6.6	9.7	5.9	27.9	32.5
5	Jan.29-Feb. 04	34.2	23.5	70	31.7	3.5	9.5	5.4	28.3	32.6
6	Feb. 05-11	35.0	23.6	81.1	40	3.8	8.5	4.5	29.9	34.3
7	Feb. 12-18	34.6	24.4	81	40.1	3.6	6.9	5.9	29.7	33.5

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

Treatments	Irrigation interval	Quantity of water used			Total quantity of water applied (mm)
		Pre-sowing irrigation (mm)	Irrigation as per treatment (mm)	Effective rainfall (mm)	
I_1	Daily	40.0	144.6	-	184.6
I_2	Daily	40.0	216.9	-	256.9
I_3	Daily	40.0	289.2	-	329.2
I_4	Once in 2 days	40.0	666.1	-	706.1

Plate 1. View of experimental plot

Plate 1(a). View of fertigation tanks.

Results

4. RESULTS

The results obtained from the experiment on fertigation in oriental pickling melon (*Cucumis melo* var. *conomon* (L.) Makino) under high density planting are furnished in this chapter.

4.1 Growth components

4.1.1 Length of vine (cm)

The data on average length of vines at the time of harvest are given in Table 4 and the analysis of variance in Appendix I.

Levels of irrigation significantly influenced the length of vine. Maximum length of vine (135.6 cm) was observed at the irrigation level I_3 and was significantly superior to all other irrigation levels.

Fertilizer levels also significantly influenced length of vine. Highest length of vine (133.6 cm) 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 level was significant as regards length of vine. In all irrigation levels, length of vine increased with increasing fertilizer levels (Table 4[a]).

With I_1, I_3 and I_4, the increase in length of vine with increase in fertilizer was significant over all the fertilizer levels, in I_2 level of irrigation, there was significant increase in length of vine up to F_2. In all the fertilizer levels, length of vine increased significantly with increase in irrigation levels up to I_3 and then decreased. From among the treatment combinations I_3F_3 recorded significantly the highest length of vine (142.3 cm) and the lowest length of vine by I_1F_1.

4.1.2 Number of leaves per vine

The data on average number of leaves per vine at the time of harvest are given in Table 4 and the analysis of variance in Appendix I.

Levels of irrigation significantly influenced the number of leaves per vine. Maximum number of leaves per vine (18.3) was observed at the irrigation level I_3 and was significantly superior to all other irrigation levels.

Fertilizer levels also significantly influenced number of leaves per vine. Highest number of leaves per vine (18.4) 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 level was significant as regards number of leaves per vine. In all irrigation levels, number of leaves per vine increased with increasing fertilizer levels (Table 4[b]).

With I_1, I_2 and I_3, the increase in number of leaves per vine with increase in fertilizer was significant over all the fertilizer levels. As regards I_4 level of irrigation, there was significant increase in number of leaves per vine up to F_2. In all the fertilizer levels, number of leaves per vine increased significantly with increase in irrigation levels up to I_3 and then decreased. From among the treatment combinations, I_3F_3 recorded significantly the highest number of leaves per vine (19.9) and the lowest number of leaves per vine by I_1F_1.

4.1.3 Number of branches per vine

The data on number of branches per vine at harvest are given in Table 4 and the analysis of variance in Appendix I.

Levels of irrigation significantly influenced the number of branches per vine. Maximum number of branches per vine (3.6) was observed at the irrigation level I_3 and was significantly superior to all other irrigation levels.

Fertilizer levels also significantly influenced number of branches per vine. Highest number of branches per vine (3.2) 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 level was significant as regards number of branches per vine. In all irrigation levels number of branches per vine increased with increasing fertilizer levels (Table 4[c]).

With I_1, I_2, I_3 and I_4, the increase in number of branches per vine with increase in fertilizer was significant over all the fertilizer levels. In all the fertilizer levels, number of branches per vine increased significantly with increase in irrigation levels up to I_3 and then decreased. From among the treatment combinations, I_3F_3 recorded significantly the highest number of branches per vine (4.5) and the lowest number of branches per vine by I_1F_1.

4.1.4 Leaf area index (LAI)

The data related to leaf area index taken at 45 DAS are given in Table 4 and the analysis of variance in Appendix I. Plates II, III and IV show leaf coverage of land.

Levels of irrigation significantly influenced the LAI. Maximum LAI (2.08) was observed at the irrigation level I_3 and was significantly superior to all other irrigation levels.

Fertilizer levels also significantly influenced LAI. Highest LAI (2.00) was observed with F_3 and it was significantly superior to F_1 and F_2.

The interaction between irrigation levels and fertilizer levels was significant as regards LAI. In all irrigation levels LAI increased with increasing fertilizer levels (Table 4[d]).

With I_2, I_3 and I_4, the increase in LAI with increase in fertilizer was significant over all the fertilizer levels. As regards the lowest level of irrigation, there was significant increase in LAI up to F_2. In all the fertilizer levels, LAI increased significantly with increase in irrigation levels up to I_3 and then decreased. From among the treatment combinations, I_3F_3 recorded significantly the highest LAI of 2.4, and the lowest LAI by I_1F_1.

4.1.5 Days to flowering

The data on days taken to flowering of oriental pickling melon var. Saubhagya as influenced by irrigation and fertilizer are given in the table 4 and the analysis of variance in Appendix I.

The effect of irrigation and fertilizer levels and their interaction on days taken for flowering was not significant. Days taken to flowering remained constant at 23 days in almost all the treatments.

Table 4. Influence of irrigation and fertilizer levels on days to flowering and vegetative growth

Treatment	Days to flowering	Length of vine (cm)	Number of leaves per vine	Number of branches per vine	Leaf Area Index
Irrigation					
I_1	23.0^{b}	114.9^{d}	15.1^{c}	2.3^{c}	1.48^{c}
I_2	23.0^{b}	133.1^{b}	17.5^{ab}	2.8^{b}	1.78^{b}
I_3	23.0^{b}	135.6^{a}	18.3^{a}	3.6^{a}	2.08^{a}
I_4	24.0^{a}	122.3^{c}	17.3^{b}	2.2^{c}	1.81^{b}
Fertilizer					
F_1	23.25^{a}	119.0^{c}	15.6^{c}	2.3^{b}	1.58^{c}
F_2	23.25^{a}	126.9^{b}	17.2^{b}	2.6^{b}	1.78^{b}
F_3	23.25^{a}	133.6^{a}	18.4^{a}	3.2^{a}	2.00^{a}
SEm $\pm$	0	1.13	0.18	0.06	0.02
Interaction	NS	Sig	Sig	Sig	Sig

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

Table 4(a). Length of vine as influenced by combination of irrigation and fertilizer levels

Treatment	I_1	I_2	I_3	I_4
F_1	110.0^{f}	125.8^{c}	128.5^{c}	111.5^{ef}
F_2	114.3^{e}	136.8^{b}	136.0^{b}	120.4^{d}
F_3	120.3^{d}	136.8^{b}	142.3^{a}	135.0^{b}

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

Table 4(b). Number of leaves per vine as influenced by combination of irrigation and fertilizer levels

Treatment	I_1	I_2	I_3	I_4
F_1	13.5^{g}	15.7^{ef}	16.9^{d}	16.0^{e}
F_2	15.3^{f}	17.9^{c}	18.1^{c}	17.6^{c}
F_3	16.7^{d}	18.8^{b}	19.9^{a}	18.2^{c}

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

Table 4(c). Number of branches of vine as influenced by combination of irrigation and fertilizer levels

Treatment	I_1	I_2	I_3	I_4
F_1	2.1^{fg}	2.4^{e}	2.9^{c}	2.0^{g}
F_2	2.4^{e}	2.7^{cd}	3.3^{b}	2.2^{f}
F_3	2.6^{de}	3.3^{b}	4.5^{a}	2.6^{de}

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

Table 4(d). Leaf area index as influenced by combination of irrigation and fertilizer levels

Treatment	I_1	I_2	I_3	I_4
F_1	1.28^{e}	1.61^{d}	1.80^{c}	1.62^{d}
F_2	1.55^{d}	1.75^{c}	2.05^{b}	1.80^{c}
F_3	1.60^{d}	1.99^{b}	2.40^{a}	2.02^{b}

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

4.2 Yield and yield attributes

4.2.1 Number of fruits per plant

The data on number of fruits per plant are presented in Table 5 and the analysis of variance in Appendix I.

Levels of irrigation significantly influenced the number of fruits per plant. Maximum number of fruits per plant (2.8) was observed at the irrigation level of I_3 and was significantly superior to all other irrigation levels.

Fertilizer levels also significantly influenced number of fruits per plant. Highest number of fruits per plant (2.7) 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 levels and fertilizer levels was non significant as regards number of fruits per plant. From among the treatment combinations, I_3F_3 recorded the maximum number of fruits per plant (3.0) and the lowest by I_1F_1.

4.2.2 Average weight of one fruit (g)

The data on average weight of fruit are presented in Table 5 and the analysis of variance in Appendix I.

Levels of irrigation significantly influenced the average weight of fruit. Maximum average weight of fruit (710.2 g) was observed at the irrigation level of I_3 and was significantly superior to all other irrigation levels.

Fertilizer levels also significantly influenced average weight of fruit. Highest average weight of fruit (666.7g) 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 levels and fertilizer levels was non significant as regards average weight of fruit. From among the treatment combinations, I_3F_3 recorded the highest average weight of fruit (727.9 g) and the lowest recorded by I_1F_1.

4.2.3 Volume of fruit (cm^3)

The data on volume of fruit are presented in Table 5 and the analysis of variance in Appendix I.

Levels of irrigation significantly influenced the volume of fruit. Maximum volume of fruit (724.4 cm^3) was observed at the irrigation level I_3 and was significantly superior to all other irrigation levels.

Fertilizer levels also significantly influenced volume of fruit. Highest volume of fruit (680.0 cm^3) 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 levels and fertilizer levels was non significant as regards volume of fruit. From among the treatment combinations, I_3F_3 recorded the highest volume of fruit (742.4 cm3) and the lowest recorded by I_1F_1.

4.2.4 Mean fruit yield (t/ha)

The data on fruit yield are presented in Table 5 and the analysis of variance in Appendix I.

Levels of irrigation significantly influenced the fruit yield. Maximum fruit yield (66.8 t/ha) was observed at the irrigation level of I_3 and was significantly superior to all other irrigation levels.

Fertilizer levels also significantly influenced fruit yield. Highest fruit yield (62.0 t/ha) 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 level was significant as regards fruit yield. In all irrigation levels, fruit yield increased with increasing fertilizer levels (Table 5 [a]). With I_1, I_2, I_3 and I_4, the increase in fruit yield with increase in fertilizer levels was significant over all fertilizer levels. In all the fertilizer levels fruit yield increased significantly with increase in irrigation level up to I_3 and then decreased. From among the treatment combinations, I_3F_3 recorded significantly the highest fruit yield of 72.4 tonnes per hectare and the lowest fruit yield by I_1F_1.

4.2.5 Days to harvest

The data on days to harvest of oriental pickling melon var Saubhagya as influenced by irrigation and fertilizer levels are given in Table 5 and the analysis of variance in Appendix I.

Levels of irrigation did not influence days to harvest. Fertilizer levels also did not influence days to harvest.

The interaction between irrigation and fertilizer levels was also non significant with regard to days to harvest. Days taken to harvest were 65 days in drip irrigation and 67 days in pot irrigation, it shows early maturity in drip irrigation.

Table 5. Influence of Irrigation and fertilizer levels on fruit characters, yield and days to harvest

Treatment	No. of fruits per plant	Average weight of one fruit (g)	Volume of one fruit (cm^3)	Mean fruit yield (t/ha)	Days to harvest
Irrigation					
I_1	2.3^{d}	624.9^{b}	637.3^{b}	49.1^{d}	65.0^{b}
I_2	2.7^{b}	638.9^{b}	652.8^{b}	58.3^{b}	65.0^{b}
I_3	2.8^{a}	710.2^{a}	724.4^{a}	66.8^{a}	65.0^{b}
I_4	2.5^{c}	626.8^{b}	639.3^{b}	52.9^{c}	67.0^{a}
Fertilizer					
F_1	2.4^{c}	638.7^{b}	652.2^{b}	52.3^{c}	65.50^{a}
F_2	2.6^{b}	645.4^{b}	658.2^{b}	56.0^{b}	65.50^{a}
F_3	2.7^{a}	666.7^{a}	680.0^{a}	62.0^{a}	65.50^{a}
SEm ±	0.039	9.31	9.71	0.479	0
Interaction	NS	NS	NS	Sig	NS

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

Table 5(a). Mean fruit yield (t ha^{-1}) as influenced by combination of irrigation and fertilizer levels

Treatment	I_1	I_2	I_3	I_4
F_1	44.9^{g}	53.5^{e}	61.9^{c}	48.9^{f}
F_2	48.4^{f}	56.7^{d}	66.0^{b}	52.8^{e}
F_3	53.9^{e}	64.7^{b}	72.4^{a}	57.1^{d}

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

4.3 Effect of irrigation and fertilizer levels on dry matter production

4.3.1 Shoot dry matter production at harvest (kg ha^{-1})

The data on shoot dry matter production at harvest (kg ha^{-1}) are presented in Table 6 and the analysis of variance in Appendix I.

Levels of irrigation significantly influenced the shoot dry matter production at harvest. Maximum shoot dry matter production at harvest (1642.0 kg ha^{-1}) was observed at the irrigation level of I_3 and was significantly superior to all other irrigation levels.

Fertilizer levels also significantly influenced shoot dry matter production at harvest. Highest shoot dry matter production at harvest (1515.0 kg ha^{-1}) 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 levels was significant as regards shoot dry matter production at harvest. In all irrigation levels shoot dry matter production increased with increasing fertilizer levels (Table 6[a]).

With I_1, I_2, I_3 and I_4 the increases in shoot dry matter production with increase in fertilizer levels were significant. In all the fertilizer levels shoot dry matter production increased significantly with increase in irrigation level up to I_3 and then decreased. From among the treatment combinations I_3F_3 recorded significantly the highest shoot dry matter production at harvest (2043.0 kg ha^{-1}). The lowest shoot dry matter production at harvest was recorded by I_4F_1.

43.2 Fruit dry matter production (kg ha^{-1})

The data on fruit dry matter production after harvest (kg ha^{-1}) are presented in Table 6 and the analysis of variance in Appendix I.

Levels of irrigation significantly influenced the fruit dry matter production. Maximum fruit dry matter (6010.0 kg ha^{-1}) was observed at the irrigation level of I_3 and was significantly superior to all other irrigation levels.

Fertilizer levels also significantly influenced fruit dry matter production. Highest dry matter of fruits (5584.0 kg ha^{-1}) 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 levels and fertilizer levels was non significant as regards fruit dry matter production.

Table 6. Influence of Irrigation and fertilizer levels on shoot and fruit dry matter production (kg ha^{-1})

Treatment	Shoot dry matter production at harvest (kg ha^{-1})	Fruit dry matter production (kg ha^{-1})
Irrigation		
I_1	1059.0^{d}	4414.0^{d}
I_2	1353.0^{b}	5248.0^{b}
I_3	1642.0^{a}	6010.0^{a}
I_4	1144.0^{c}	4757.0^{c}
Fertilizer		
F_1	1100.0^{c}	4707.0^{c}
F_2	1284.0^{b}	5031.0^{b}
F_3	1515.0^{a}	5584.0^{a}
SEm $\pm$	17.68	61.90
Interaction	Sig	NS

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

Table 6(a). Shoot dry matter production as influenced by combination of irrigation and fertilizer levels

Treatment	I_1	I_2	I_3	I_4
F_1	988.3^{i}	1176.0^{f}	1288.0^{e}	947.7^{i}
F_2	1043.0^{h}	1400.0^{d}	1596.0^{b}	1096.0^{gh}
F_3	1146.0^{fg}	1484.0^{c}	2043.0^{a}	1388.0^{d}

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

4.4 Nutrient composition in leaf

4.4.1 Nitrogen content of leaf

The data on leaf nitrogen content (%) at 30 and 60 DAS are given in Table 7 and the analysis of variance in Appendix I.

Levels of irrigation significantly influence the nitrogen content (%) of leaf at 30 and 60 DAS. Maximum nitrogen content of leaf at 30 and 60 DAS (3.93 and 1.81%) respectively was observed at the irrigation level of I_3 and was significantly superior to all other irrigation levels.

Fertilizer levels also significantly influenced nitrogen content of leaf at 30 and 60 DAS. Highest nitrogen content of leaf at 30 and 60 DAS (3.94 and 1.81%) respectively 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 level was significant as regards nitrogen content of leaf at 30 DAS. In all irrigation levels, nitrogen content of leaf at 30 DAS increased with increasing fertilizer levels (Table 7[a]).

With I_1, I_2, I_3 and I_4, the increase in nitrogen content of leaf at 30 DAS with increase in fertilizer level was significant up to F_3. In all the fertilizer levels, nitrogen content of leaf increased significantly with increase in irrigation level up to I_3 and then decreased. From among the treatment combinations, I_3F_3 recorded significantly the highest nitrogen content of leaf at 30 DAS (4.10 %) and the lowest by I_1F_1.

The interaction between irrigation and fertilizer level was non significant as regards nitrogen content of leaf at 60 DAS.

Table7. Influence of irrigation and fertilizer levels on leaf nitrogen content (%)

Treatment	30 DAS	60 DAS
Irrigation		
I_1	3.48^c	1.58^d
I_2	3.75^b	1.75^b
I_3	3.93^a	1.81^a
I_4	3.69^b	1.64^c
Fertilizer		
F_1	3.49^c	1.58^c
F_2	3.71^b	1.69^b
F_3	3.94^a	1.81^a
SEm ±	0.023	0.019
Interaction	Sig	NS

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

Table 7 (a). Leaf nitrogen content (%) at 30 DAS as influenced by combination of irrigation and fertilizer levels

Treatment	I_1	I_2	I_3	I_4
F_1	3.23^{h}	3.54^{f}	3.73^{e}	3.47^{fg}
F_2	3.40^{g}	3.75^{de}	3.96^{b}	3.74^{e}
F_3	3.82^{cd}	3.98^{b}	4.10^{a}	3.86^{c}

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

4.4.2 Phosphorus content of leaf

The data on phosphorus content of leaf at 30 and 60 DAS are given in Table 8 and the analysis of variance in Appendix I.

Levels of irrigation significantly influenced the phosphorus content (%) of leaf at 30 and 60 DAS. Maximum phosphorus content of leaf observed at 30 and 60 DAS (0.37 and 0.28 %) respectively at the irrigation level of I_3 and was significantly superior to all other irrigation levels.

Fertilizer levels also significantly influenced phosphorus content of leaf at 30 and 60 DAS. Highest phosphorus content of leaf at 30 and 60 DAS (0.39 and 0.29 %) respectively were 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 level was significant as regards phosphorus content of leaf at 30 and 60 DAS. In all irrigation levels phosphorus content of leaf at 30 and 60 DAS increased with increasing fertilizer levels up to F_3 (Table 8[a] & 8[b]).

With I_1, I_2, I_3 and I_4, the increase in phosphorus content of leaf at 30 and 60 DAS with increase in fertilizer level was significant up to F_3. In all the fertilizer levels, phosphorus content of leaf increased significantly with increase in irrigation level up to I_3 and then decreased. From among the treatment combinations, I_3F_3 recorded significantly the highest phosphorus content of leaf at 30 and 60 DAS (0.44 and 0.33 %) respectively and the lowest by I_1F_1.

Table 8. Influence of irrigation and fertilizer levels on leaf phosphorus content (%)

Treatment	30 DAS	60 DAS
Irrigation		
I_1	0.32^{c}	0.21^{c}
I_2	0.35^{b}	0.26^{ab}
I_3	0.37^{a}	0.28^{a}
I_4	0.31^{c}	0.24^{bc}
Fertilizer		
F_1	0.29^{c}	0.20^{c}
F_2	0.33^{b}	0.24^{b}
F_3	0.39^{a}	0.29^{a}
SEm $\pm$	0.0076	0.0061
Interaction	Sig	Sig

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

Table 8 (a). Leaf Phosphorus (%) at 30 DAS as influenced by combination of irrigation and fertilizer levels

Treatment	I_1	I_2	I_3	I_4
F_1	0.27^{g}	0.29^{f}	0.32^{e}	0.26^{g}
F_2	0.32^{e}	0.35^{d}	0.35^{d}	0.31^{ef}
F_3	0.35^{cd}	0.40^{b}	0.44^{a}	0.37^{c}

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

Table 8 (b). Leaf Phosphorus (%) at 60 DAS as influenced by combination of irrigation and fertilizer levels

Treatment	I_1	I_2	I_3	I_4
F_1	0.17^{g}	0.20^{f}	0.22^{e}	0.20^{f}
F_2	0.20^{f}	0.27^{cd}	0.27^{c}	0.23^{e}
F_3	0.25^{d}	0.30^{b}	0.33^{a}	0.28^{c}

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

4.4.3 Potassium content of leaf

The data on potassium content of leaf at 30 and 60 DAS are given in Table 9 and the analysis of variance in Appendix I.

Levels of irrigation significantly influenced the potassium content (%) of leaf at 30 and 60 DAS. Maximum potassium contents of leaf at 30 and 60 DAS (2.27 and 1.24 %) respectively were observed at the irrigation level I_3 and were significantly superior to all other irrigation levels.

Fertilizer levels also significantly influenced potassium content of leaf at 30 and 60 DAS. Highest potassium content of leaf at 30 and 60 DAS (2.22 and 1.30%) respectively 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 level was significant as regards potassium content of leaf at 30 and 60 DAS. In all irrigation levels, potassium content of leaf at 30 and 60 DAS increased with increasing fertilizer levels (Table 9[a] & 9[b]).

With I_1, I_2, I_3 and I_4, the increase in potassium content of leaf at 30 DAS with increase in fertilizer level was significant up to F_3. In all the fertilizer levels potassium content of leaf increased significantly with increase in irrigation level up to I_3 and then decreased. From among the treatment combinations, I_3F_3

recorded significantly the highest potassium content of leaf at 30 DAS (2.38%) and the lowest by I_1F_1.

With I_1, I_2, I_3 and I_4, the increase in potassium content of leaf at 60 DAS with increase in fertilizer level was significant up to F_3. In F_1 and F_2 fertilizer levels, potassium content of leaf at 60 DAS did not show significant increase with increase in irrigation level. Leaf content of potassium under F_3 at 60 DAS increased significantly with increase in irrigation level up to I_3 and then decreased. From among the treatment combinations, I_3F_3 recorded significantly the highest potassium content of leaf at 60 DAS (1.38%) and the lowest by I_1F_1.

Table 9. Influence of irrigation and fertilizer levels on leaf potassium content (%)

Treatment	30 DAS	60 DAS
Irrigation		
I_1	1.94^c	1.16^b
I_2	2.11^b	1.20^b
I_3	2.27^a	1.24^a
I_4	1.99^c	1.19^b
Fertilizer		
F_1	1.94^c	1.08^c
F_2	2.08^b	1.20^b
F_3	2.22^a	1.30^a
SEm $\pm$	0.0138	0.0075
Interaction	Sig	Sig

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

Table 9 (a). Leaf Potassium (%) at 30 DAS as influenced by combination of irrigation and fertilizer levels

Treatment	I_1	I_2	I_3	I_4
F_1	1.78^{g}	1.95^{e}	2.16^{c}	1.86^{f}
F_2	1.96^{e}	2.09^{d}	2.28^{b}	1.99^{e}
F_3	2.08^{d}	2.27^{b}	2.38^{a}	2.14^{cd}

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

Table 9 (b). Leaf Potassium (%) at 60 DAS as influenced by combination of irrigation and fertilizer levels

Treatment	I_1	I_2	I_3	I_4
F_1	1.04^{f}	1.07^{ef}	1.11^{e}	1.12^{e}
F_2	1.19^{d}	1.20^{cd}	1.22^{cd}	1.20^{cd}
F_3	1.26^{c}	1.32^{b}	1.38^{a}	1.26^{c}

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

4.5 Nutrient contents of shoot, fruit and total uptake at harvest

4.5.1 Nitrogen content (%) of shoot and fruits at harvest

The data on nitrogen content of shoot and fruit are given in Table 10 and the analysis of variance in Appendix I.

Levels of irrigation significantly influenced the nitrogen content of shoot and fruit at harvest. Maximum nitrogen contents of shoot and fruit (1.28 and 1.46 %) respectively were observed at the irrigation level I_3 and was significantly superior to I_1 and I_2 in the case of shoot and I_1 and I_4 in the case of fruit.

Fertilizer levels also significantly influenced nitrogen content of shoot and fruit. Highest nitrogen content of shoot and fruit (1.31 and 1.45 %) respectively 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 level was non significant as regards nitrogen content of fruits. In all irrigation levels, nitrogen content of fruits increased with increasing fertilizer levels. In all the fertilizer levels nitrogen content of fruits increased significantly with increase in irrigation level up to I_3 and then decreased. From among the treatment combinations, I_3F_3 recorded significantly the highest nitrogen content (1.47 %) and the lowest by I_1F_1 and I_4F_1 (Table 10 [a]).

4.5.2 Total uptake of nitrogen (kg ha^{-1})

The data on total nitrogen uptake at harvest are given in table 10 and the analysis of variance in Appendix I.

Levels of irrigation significantly influenced the total uptake of nitrogen by the crop. Maximum nitrogen uptake (116.50 kg ha^{-1}) was observed at the irrigation level of I_3 and was significantly superior to all other irrigation levels.

Fertilizer levels also significantly influenced total uptake of nitrogen. Highest uptake of nitrogen (108.8 kg ha^{-1}) was observed with F_3 and it was significantly superior to F_1 and F_2.

The interaction between irrigation and fertilizer level was significant as regards total uptake of nitrogen. In all irrigation levels, uptake of nitrogen increased significantly with increasing fertilizer levels. In all the fertilizer levels, uptake of nitrogen increased significantly with increase in irrigation level up to I_3 and then decreased. From among the treatment combinations, I_3F_3 recorded significantly the highest nitrogen uptake (136.4 kg ha^{-1}) and the lowest by I_1F_1 (Table 10 [b]).

Table 10. Influence of irrigation and fertilizer levels on nitrogen content and uptake at harvest

Treatment	Nitrogen (%) of shoot at harvest	Nitrogen (%) of fruit at harvest	Total Nitrogen uptake at harvest (kg ha^{-1})
Irrigation			
I_1	1.10^{c}	1.43^{b}	78.23^{d}
I_2	1.25^{b}	1.45^{a}	98.20^{b}
I_3	1.28^{a}	1.46^{a}	116.50^{a}
I_4	1.28^{a}	1.43^{b}	86.40^{c}
Fertilizer			
F_1	1.14^{c}	1.43^{c}	82.65^{c}
F_2	1.23^{b}	1.44^{b}	93.03^{b}
F_3	1.31^{a}	1.45^{a}	108.8^{a}
SEm ±	0.011	0.002	0.289
Interaction	NS	Sig	Sig

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

Table 10 (a). Nitrogen content of fruits (%) as influenced by combination of irrigation and fertilizer levels

Treatment	I_1	I_2	I_3	I_4
F_1	1.42^{e}	1.44^{bcd}	1.45^{bc}	1.43^{de}
F_2	1.43^{cde}	1.45^{bc}	1.45^{b}	1.43^{cde}
F_3	1.45^{bc}	1.46^{ab}	1.47^{a}	1.44^{bcd}

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

Table 10 (b). Total uptake of N by crop as influenced by combination of irrigation and fertilizer levels

Treatment	I_1	I_2	I_3	I_4
F_1	69.30^{k}	85.97^{h}	99.53^{d}	75.80^{j}
F_2	76.80^{i}	96.73^{f}	113.5^{b}	85.10^{h}
F_3	88.60^{g}	111.9^{c}	136.4^{a}	98.30^{e}

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

4.5.3 Phosphorus content of shoot and fruit at harvest

The data on phosphorus content of shoot and fruits are given in Table 11 and the analysis of variance in Appendix I.

Levels of irrigation significantly influenced the phosphorus content of shoot and fruit. Maximum phosphorus contents of shoot and fruit (0.22 and 0.3%) respectively observed at the irrigation level of I_3, and were significantly superior to all other irrigation levels.

Fertilizer levels also significantly influenced phosphorus content of shoot and fruit. Highest phosphorus contents of shoot and fruit (0.22 and 0.30%) respectively were 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 levels was non significant as regards both shoot and fruit phosphorus content.

4.5.4 Total uptake of phosphorus (kg ha^{-1})

The data on phosphorus uptake at harvest are given in Table 11 and the analysis of variance in Appendix I.

Levels of irrigation significantly influenced the total uptake of phosphorus by the crop. Maximum phosphorus uptake (21.52 kg ha^{-1}) was observed at the irrigation level of I_3 and was significantly superior to all other irrigation levels.

Fertilizer levels also significantly influenced total uptake of phosphorus. Highest uptake of phosphorus (20.31kg ha^{-1}) 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 levels was non significant as regards total uptake of phosphorus.

Table 11. Influence of irrigation and fertilizer levels on phosphorus content and uptake at harvest

Treatment	Phosphorus (%) of shoot at harvest	Phosphorus (%) of fruit at harvest	Total Phosphorus uptake at harvest (kg ha^{-1})
Irrigation			
I_1	0.17^{c}	0.29^{b}	14.60^{d}
I_2	0.20^{b}	0.29^{b}	18.16^{b}
I_3	0.22^{a}	0.3^{a}	21.52^{a}
I_4	0.20^{b}	0.29^{b}	16.17^{c}
Fertilizer			
F_1	0.17^{c}	0.28^{b}	15.28^{c}
F_2	0.20^{b}	0.29^{b}	17.25^{b}
F_3	0.22^{a}	0.30^{a}	20.31^{a}
SEm ±	0.0038	0.002	0.4424
Interaction	NS	NS	NS

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

4.5.5 Potassium content of shoot and fruits at harvest

The data on potassium content of shoot and fruit are given in Table 12 and the analysis of variance in Appendix I.

Levels of irrigation significantly influenced the potassium content of shoot and fruit. Maximum potassium contents of shoot and fruit (0.97 and 1.13%) respectively were observed at the irrigation level of I_3 and were significantly superior to all other irrigation levels in the case of shoot and at par with I_1 and I_2 levels of irrigation in the case of fruit.

Fertilizer levels also significantly influenced potassium content of shoot and fruit. Highest potassium contents of shoot and fruit (1.0 and 1.13%) respectively were observed with F_3. In the case of shoot, F_3 was significantly superior to F_1 and F_2 and in the case of fruit; F_3 was at par with F_2.

The interaction between irrigation and fertilizer levels was non significant as regards both shoot and fruit potassium content.

4.5.6 Total uptake of potassium (kg ha^{-1})

The data on total potassium uptake at harvest are given in Table 12 and the analysis of variance in Appendix I.

Levels of irrigation significantly influenced the total uptake of potassium by the crop. Maximum potassium uptake (84.56 kg ha^{-1}) was observed at the irrigation level of I_3 and was significantly superior to all other irrigation levels.

Fertilizer levels also significantly influenced total uptake of potassium. Highest uptake of potassium (79.59 kg ha^{-1}) 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 levels was non significant as regards total uptake of potassium.

Table 12. Influence of irrigation and fertilizer levels on potassium content and uptake at harvest

Treatment	Potassium (%) of Shoot at harvest	Potassium (%) of fruit at harvest	Total potassium uptake (kg ha^{-1})
Irrigation			
I_1	0.85^c	1.12^a	58.85^c
I_2	0.93^b	1.12^a	72.06^b
I_3	0.97^a	1.13^a	84.56^a
I_4	0.91^b	1.11^b	63.98^c
Fertilizer			
F_1	0.83^c	1.11^b	61.58^c
F_2	0.91^b	1.12^{ab}	68.42^b
F_3	1.00^a	1.13^a	79.59^a
SEm $\pm$	0.0108	0.0022	1.7073
Interaction	NS	NS	NS

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

4.6 Field water use efficiency (kg ha-mm^{-1})

The data related to field water use efficiency (kg ha-mm^{-1}) are given in Table 13 and the analysis of variance in Appendix I.

Levels of irrigation significantly influenced the field water use efficiency. Maximum field water use efficiency (266.1 kg ha-mm^{-1}) was observed at the irrigation level of I_1 and was significantly superior to all other irrigation levels. There was a tremendous decrease in field water use efficiency under pot watering due to excessive irrigation.

Fertilizer levels also significantly influenced field water use efficiency. Highest water use efficiency (211.3 kg ha-mm^{-1}) was observed with F_3 and it was significantly superior to F_1 and F_2.

The interaction between irrigation and fertilizer levels was significant as regards field water use efficiency. In all irrigation levels field water use efficiency increased significantly with increasing fertilizer levels. In all the fertilizer levels field water use efficiency decreased significantly with increase in irrigation levels. From among the treatment combinations I_1F_3 recorded significantly the highest field water use efficiency (292.1 kg ha-mm^{-1}) and the lowest by I_4F_1 (Table 13 [a]).

Table 13. Influence of irrigation and fertilizer levels on field water use efficiency

Treatment	Field water use efficiency (kg ha-mm^{-1})
Irrigation	
I_1	266.1[a]
I_2	227.1[b]
I_3	202.9[c]
I_4	74.9[d]
Fertilizer	
F_1	177.4[c]
F_2	189.6[b]
F_3	211.3[a]
SEm ±	1.618
Interaction	Sig

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

Table 13(a). Field water use efficiency (kg ha-mm^{-1}) as influenced by combination of irrigation and fertilizer levels

Treatment	I_1	I_2	I_3	I_4
F_1	243.7^{d}	208.4^{f}	188.1^{h}	69.2^{k}
F_2	262.4^{b}	220.7^{e}	200.5^{g}	74.8^{j}
F_3	292.1^{a}	252.2^{c}	220.2^{e}	80.8^{i}

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

4.7 Nutrient status of soil

4.7.1 Available nitrogen in soil (kg ha^{-1})

The data related to available nitrogen in soil (kgha^{-1}) at different growth stages of the crop are presented in Table 14 and the analysis of variance in Appendix I.

Levels of irrigation significantly influenced the available nitrogen at different growth stages of the cropping period and after harvest. With increasing irrigation level there was decreasing of available nitrogen content of soil at all the stages. Maximum available nitrogen in soil was observed with the lowest level of irrigation level (I_1). Lowest nitrogen content in soil was observed at the highest level of irrigation (I_4) at all the stages. The available nitrogen content in soil was almost similar in I_3 and I_4 and these two treatments had significantly lower available nitrogen in soil than I_1 and I_2.

Fertilizer levels also significantly influenced available nitrogen in soil. Highest available nitrogen at all the cropping period and at harvest was observed with F_3 and it was significantly superior to F_1 and F_2. Available nitrogen content in soil increased to the maximum by 30 DAS and there after decreased.

The interaction between irrigation and fertilizer level was significant as regards available nitrogen content of soil at 15 DAS, 45 DAS and at harvest but remained non significant at 30 DAS.

At 15 DAS, at all irrigation levels, available nitrogen in soil increased significantly with increase in fertilizer levels. In the fertilizer levels, available nitrogen in general increased with increasing irrigation level up to I_2 and then decreased. From among the treatment combinations, I_1F_3 recorded the highest available nitrogen content in soil (308.3 kg ha^{-1}) and the lowest by I_3F_1 and I_4F_1 (Table 14[a]).

At all the irrigation levels, available nitrogen in soil at 45 DAS increased significantly with increase in fertilizer levels. In all the fertilizer levels, available nitrogen in soil decreased significantly with increasing irrigation levels. From among the treatment combinations, I_1F_3 recorded significantly the highest available nitrogen at 45 DAS (313.8 kg ha^{-1}) and the lowest by I_4F_1 (Table 14[b]).

At all the irrigation levels, available nitrogen at harvest increased with increase in fertilizer levels. In I_1 and I_2, the increases were significant up to F^3. In all the fertilizer levels, available nitrogen decreased with increasing irrigation levels significantly up to I_3. From among the treatment combinations, I_1F_3 recorded significantly the highest available nitrogen in soil at harvest (268 kg ha^{-1}) and the lowest by I_4F_1 (Table 14[c]).

Table 14. Influence of irrigation and fertilizer levels on available nitrogen in soil (kg ha^{-1})

Treatment	15 DAS	30 DAS	45 DAS	Harvest
Irrigation				
I_1	294.3^{ab}	320.4^{a}	295.0^{a}	255.8^{a}
I_2	295.4^{a}	316.7^{a}	281.4^{b}	230.8^{b}
I_3	292.3^{c}	310.7^{b}	268.5^{c}	207.7^{c}
I_4	292.9^{bc}	307.9^{b}	257.4^{d}	206.8^{c}
Fertilizer				
F_1	281.6^{c}	294.6^{c}	262.2^{c}	218.6^{c}
F_2	293.5^{b}	313.5^{b}	276.3^{b}	226.8^{b}
F_3	306.1^{a}	333.7^{a}	288.4^{a}	230.5^{a}
SEm $\pm$	0.8669	2.0863	1.0955	1.223
Interaction	Sig	NS	Sig	Sig

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

Table 14 (a). Available nitrogen in soil at 15 DAS as influenced by combination of irrigation and fertilizer levels (kg ha^{-1})

Treatment	I_1	I_2	I_3	I_4
F_1	282.2^{fg}	283.9^{f}	280.1^{g}	280.1^{g}
F_2	292.3^{de}	296.2^{c}	291.1^{e}	294.2^{cd}
F_3	308.3^{a}	306.2^{ab}	305.6^{ab}	304.3^{b}

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

Table 14 (b). Available nitrogen in soil at 45 DAS as influenced by combination of irrigation and fertilizer levels (kg ha^{-1})

Treatment	I_1	I_2	I_3	I_4
F_1	272.3^{f}	267.0^{g}	261.0^{h}	248.3^{j}
F_2	299.0^{b}	281.7^{d}	267.0^{g}	257.4^{i}
F_3	313.8^{a}	295.6^{c}	277.5^{e}	266.5^{g}

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

Table 14 (c). Available nitrogen in soil at harvest as influenced by combination of irrigation and fertilizer levels (kg ha^{-1})

Treatment	I_1	I_2	I_3	I_4
F_1	242.0^{c}	222.1^{f}	205.7^{hi}	204.6^{i}
F_2	257.4^{b}	232.3^{e}	210.3^{g}	207.1^{ghi}
F_3	268.0^{a}	238.1^{d}	207.0^{ghi}	208.7^{gh}

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

4.7.2 Available phosphorus in soil (kg ha^{-1})

The data related to available phosphorus in soil (kg ha^{-1}) are presented in Table 15 and the analysis of variance in Appendix I.

Levels of irrigation significantly influenced the available phosphorus in soil at cropping period and after harvest. With increasing irrigation level, there was decreasing of available phosphorus of soil. The decrease in available phosphorus in soil was significant up to I_3 at 45 DAS and after harvest. I_4 recorded more available phosphorus in soil than I_3 at 30 and 45 DAS and after harvest.

Fertilizer levels also significantly influenced available phosphorus in soil. Highest available phosphorus in soil at all the cropping period and at harvest was observed with F_3 and it was significantly superior to F_1 and F_2. Available phosphorus in soil decreased gradually from 15 DAS to harvest both under irrigation and fertilizer levels.

The interaction between irrigation and fertilizer levels was non significant as regards available phosphorus in soil at 15, 30 and 45 DAS. But interaction between irrigation and fertilizer levels was significant as regards available phosphorus in soil at harvest (Table 15[a]).

In all the irrigation levels, available phosphorus in soil increased with increase in fertilizer levels. But the increase was significant only at I_1 level. In all the fertilizer levels, available P in soil decreased significantly with increase in irrigation level up to I_3 and then increased under I_4. From among the treatment combinations I_1F_3 recorded significantly the highest available phosphorus in soil at harvest (47.03 kg ha^{-1}) and the lowest by I_3F_3.

Table 15. Influence of irrigation and fertilizer levels on available phosphorus in soil (kg ha^{-1})

Treatment	15 DAS	30 DAS	45 DAS	Harvest
Irrigation				
I_1	74.08^{a}	73.86^{a}	60.09^{a}	45.34^{a}
I_2	74.07^{a}	72.80^{b}	57.84^{b}	41.96^{b}
I_3	72.81^{b}	72.07^{b}	54.71^{c}	38.62^{c}
I_4	72.30^{b}	72.31^{b}	58.29^{b}	42.42^{b}
Fertilizer				
F_1	63.53^{c}	63.79^{c}	53.00^{c}	41.08^{b}
F_2	73.78^{b}	72.98^{b}	58.00^{b}	42.45^{a}
F_3	82.64^{a}	81.52^{a}	62.20^{a}	42.72^{a}
SEm ±	0.3952	0.4842	0.4129	0.4213
Interaction	NS	NS	NS	Sig

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

Table 15 (a). Available phosphorus in soil at harvest as influenced by combination of irrigation and fertilizer levels (kg ha^{-1})

Treatment	I_1	I_2	I_3	I_4
F_1	43.27^{c}	41.20^{e}	38.17^{f}	41.70^{de}
F_2	45.73^{b}	42.43^{cde}	39.10^{f}	42.53^{cde}
F_3	47.03^{a}	42.23^{cde}	38.60^{f}	43.03^{cd}

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

4.7.3 Available potassium in soil (kg ha^{-1})

The data related to available potassium in soil (kg ha^{-1}) are presented in Table 16 and the analysis of variance in Appendix I.

Levels of irrigation significantly influenced the available potassium in soil at all the cropping period and after harvest. With increasing irrigation level there was decreasing of available potassium in soil at all the stages of observation. The decrease was significant up to I_3 at 30 and 45 DAS and after harvest. After harvest, I_4 recorded more available potassium in soil then I_3.

Fertilizer levels also significantly influenced available potassium in soil at all the cropping period and after harvest. Highest available potassium in soil at all the cropping period was observed with F_3 and it was significantly superior to F_1 and F_2. Available potassium in soil decreased gradually from 15 DAS to harvest both under irrigation levels and fertilizer levels.

The interaction between irrigation and fertilizer level was significant as regards available potassium of soil at 15 DAS, 30 DAS, and 45 DAS and at harvest.

With I_1, I_2, I_3 and I_4, the increase in available potassium in soil at 15 DAS with increase in fertilizer was significant. In all the fertilizer levels available potassium in soil decreased slightly with increase in irrigation levels. From among the treatment combinations I_1F_3 recorded significantly the highest available potassium in soil at 15 DAS (123.9 kg ha^{-1}) and the lowest by I_4F_1 (Table 16 [a]).

With I_1 and I_2 the increase in available potassium in soil at 30 DAS with increase in fertilizer was significant up to F_3 and in I_3 and I_4 up to F_2. In all the fertilizer levels available potassium in soil at 30 DAS decreased significantly with increase in irrigation levels up to I_3 and I_3 and I_4 remained at par. From among the treatment combinations I_1F_3 recorded significantly the highest available potassium in soil at 30 DAS (121.4 kg ha^{-1}) and the lowest by I_3F_1 (Table 16[b]).

With I_1 and I_2 the increase in available potassium in soil at 45 DAS with increase in fertilizer was significant up to F_3 and in I_3 and I_4 up to F_2. In all the fertilizer levels available potassium in soil at 45 DAS decreased with increase in irrigation levels. The decrease was significant in F_1 up to I_4 and up to I_3 in F_2 and F_3. From among the treatment combinations I_1F_3 recorded significantly the highest available potassium in soil at 45 DAS (115.7 kg ha^{-1}) and the lowest by I_4F_1 (Table 16[c]).

With I_1 and I_2 the available potassium in soil at harvest increased significantly with fertilizer up to F_2 and then remained at par under F_3. Under I_3 and I_4, the available potassium decreased slightly with increase in fertilizer level. In all the fertilizer levels available potassium in soil at harvest decreased significantly with increase in irrigation level up to I_3 and then increased. From among the treatment combinations I_1F_3 recorded significantly the highest available potassium in soil at harvest (104.3 kg ha^{-1}) and the lowest by I_3F_3 (Table 16[d]).

Table 16. Influence of irrigation and fertilizer levels on available potassium in soil (kg ha^{-1})

Treatment	15 DAS	30 DAS	45 DAS	Harvest
Irrigation				
I_1	119.6^{a}	116.9^{a}	111.0^{a}	101.3^{a}
I_2	118.3^{b}	112.3^{b}	101.6^{b}	86.12^{b}
I_3	117.9^{bc}	107.5^{c}	92.27^{c}	71.93^{d}
I_4	117.4^{c}	108.2^{c}	91.89^{c}	80.54^{c}
Fertilizer				
F_1	113.8^{c}	107.7^{c}	95.5^{c}	83.4^{b}
F_2	118.8^{b}	111.9^{b}	100.2^{b}	85.8^{a}
F_3	122.3^{a}	114.0^{a}	101.8^{a}	85.7^{a}
SEm ±	0.4123	0.8301	0.5215	0.8349
Interaction	Sig	Sig	Sig	Sig

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

Table 16 (a). Available potassium in soil at 15 DAS as influenced by combination of irrigation and fertilizer levels (kg ha^{-1})

Treatment	I_1	I_2	I_3	I_4
F_1	115.1^{e}	114.7^{ef}	113.6^{f}	112.0^{g}
F_2	119.9^{c}	118.8^{cd}	118.8^{cd}	117.9^{d}
F_3	123.9^{a}	121.6^{b}	121.6^{b}	122.4^{b}

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

Table 16 (b). Available potassium in soil at 30 DAS as influenced by combination of irrigation and fertilizer levels (kg ha^{-1})

Treatment	I_1	I_2	I_3	I_4
F_1	112.7^{c}	108.4^{d}	104.5^{e}	105.4^{e}
F_2	116.4^{b}	112.6^{c}	107.9^{d}	110.6^{cd}
F_3	121.4^{a}	115.8^{b}	110.3^{cd}	108.5^{d}

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

Table 16 (c). Available potassium in soil at 45 DAS as influenced by combination of irrigation and fertilizer levels (kg ha^{-1})

Treatment	I_1	I_2	I_3	I_4
F_1	105.6^{c}	98.03^{e}	90.27^{g}	88.33^{h}
F_2	111.6^{b}	102.2^{d}	93.43^{f}	93.73^{f}
F_3	115.7^{a}	104.7^{c}	93.10^{f}	93.60^{f}

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

Table 16 (d). Available potassium in soil at harvest as influenced by combination of irrigation and fertilizer levels (kg ha^{-1})

Treatment	I_1	I_2	I_3	I_4
F_1	97.07^{b}	83.00^{d}	72.47^{f}	81.33^{de}
F_2	102.6^{a}	87.10^{c}	72.49^{f}	80.93^{de}
F_3	104.3^{a}	88.27^{c}	70.83^{f}	79.37^{e}

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

4.8 Soil moisture content during cropping period (%)

Soil moisture content observed from 15 DAS to 45 DAS from three depths 0-15cm, 15-30cm and 30-60cm, at 15 days interval are shown in Table 17.

Soil moisture content increased with increase in irrigation level from I_1 to I_4 in all the layers *viz.* 0-15, 15-30 and 30-60 cm at 15, 30 and 45 DAS. In each irrigation level there was no commendable change in soil moisture between fertilizer levels in all the three layers.

In I_1, increase in soil moisture was observed only at 45 DAS that too in the surface layer of 0-15 cm. Middle and bottom layers did not express any significant change in soil moisture during 15, 30 and 45 DAS.

In I_2, there was increase in soil moisture in the surface layer of 0-15cm during 30 DAS and further increase at 45 DAS. Middle layer of 15-30 cm also recorded increase in soil moisture during 30 DAS and still higher value at 45 DAS. But in the lower layer of 30-60 cm, soil moisture remained unchanged during 15, 30 and 45 DAS.

In I_3, soil moisture content increased in all the three layers during 30 and 45 DAS compared to 15 DAS. In all the three stages, maximum content of soil moisture was observed in the surface layer of 0-15 cm.

In I_4 also soil moisture content increased in all the three layers during 30 and 45 DAS compared to 15 DAS. In all the three stages of 15, 30 and 45 DAS, maximum content of soil moisture was observed in the surface layer of 0-15 cm.

Table 17. Soil moisture content during cropping period (%)

Duration	15 DAS			30 DAS			45 DAS		
Depth (cm)	0-15	15-30	30-60	0-15	15-30	30-60	0-15	15-30	30-60
I_1F_1	12.5	11.2	12.3	13.6	11.9	12.8	14.4	13.1	12.4
I_1F_2	12.4	11.1	13.0	13.9	11.4	13.0	14.1	12.8	13.1
I_1F_3	12.9	11.4	12.6	13.7	11.7	12.3	14.2	12.6	12.7
I_2F_1	13.5	11.4	12.1	14.3	13.8	12.0	15.7	14.3	12.1
I_2F_2	13.9	11.8	12.3	15.8	13.9	12.1	16.7	15.0	12.0
I_2F_3	13.8	12.0	12.2	15.1	12.9	12.0	16.4	14.7	12.0
I_3F_1	14.2	12.0	11.6	16.4	16.0	13.9	17.5	16.5	14.2
I_3F_2	14.0	12.4	12.1	16.9	15.8	14.2	17.0	16.4	14.8
I_3F_3	14.4	13.3	13.0	16.8	15.5	14.4	17.2	16.4	15.0
I_4F_1	16.1	13.2	13.0	18.0	16.8	15.1	19.0	17.5	16.4
I_4F_2	16.8	13.4	12.8	18.3	17.7	17.0	19.5	17.8	16.1
I_4F_3	15.9	13.5	13.2	17.9	17.6	16.8	19.6	16.9	16.4

4.9 Chemical properties of soil

4.9.1 pH of soil

Soil pH was observed from 15 DAS to harvest at 15 days interval and the data are shown in Table 18. There was no appreciable change in soil pH due to levels of irrigation or fertilizer doses.

Table 18. pH of soil at cropping period and after harvest

Treatment	15 DAS	30 DAS	45 DAS	Harvest
I_1F_1	5.45	5.60	5.63	5.55
I_1F_2	5.45	5.65	5.65	5.60
I_1F_3	5.50	5.70	5.72	5.67
I_2F_1	5.39	5.52	5.60	5.56
I_2F_2	5.44	5.57	5.64	5.68
I_2F_3	5.45	5.61	5.65	5.63
I_3F_1	5.5	5.63	5.70	5.62
I_3F_2	5.55	5.70	5.72	5.66
I_3F_3	5.60	5.74	5.76	5.60
I_4F_1	5.44	5.55	5.60	5.58
I_4F_2	5.50	5.62	5.65	5.62
I_4F_3	5.53	5.64	5.68	5.65

4.9.2 EC of soil (dSm^{-1})

EC of soil was observed from 15 DAS to harvest at 15 days interval and the data are shown in Table 19. There was no appreciable change in soil EC due to irrigation levels. A slight increase in soil EC was observed with increase in fertilizer levels at all the stages of observation *viz.* 15, 30 and 45 DAS and at harvest.

Table 19. EC of soil at cropping period (dSm^{-1}) and after harvest

Treatment	15 DAS	30DAS	45DAS	Harvest
I_1F_1	1.26	1.30	1.43	1.49
I_1F_2	1.38	1.43	1.60	1.65
I_1F_3	1.49	1.53	1.70	1.72
I_2F_1	1.24	1.30	1.38	1.58
I_2F_2	1.32	1.36	1.45	1.70
I_2F_3	1.38	1.46	1.65	1.76
I_3F_1	1.12	1.18	1.24	1.42
I_3F_2	1.32	1.35	1.39	1.54
I_3F_3	1.38	1.40	1.42	1.59
I_4F_1	1.20	1.23	1.28	1.38
I_4F_2	1.23	1.28	1.32	1.44
I_4F_3	1.30	1.32	1.33	1.49

4.10 Economics of production

The data pertaining to the economics of production of oriental pickling melon under different treatments in terms of total cost, total return, net profit and net return per rupee invested as influenced by combinations of irrigation and fertilizer levels are given in Table 20 and in Appendix II.

Results of irrigation and fertilizer levels indicated that, in all the irrigation treatments fertilizer levels tremendously increased net profit over the recommend dose of fertilizer (F_1). F_3 fertilizer level (200 per cent RDF) was better than F_2 and F_1 fertilizer levels, in all the treatments at high density planting.

Among the treatment combinations, I_3F_3 recorded the highest net profit of Rs. 5,02,523 per hectare and was followed by I_3F_2 (Rs. 4,40,581 per hectare). Third best combination was I_2F_3 (Rs. 4, 29,880). Two hundred per cent RDF was highly effective in increasing the net income per rupee invested in all irrigation levels. Among the treatment combinations, the highest net income per rupee invested was recorded by I_3F_3 (2.26) and the lowest by I_1F_1 (1.14).

Table 20. Economics of oriental pickling melon production as influenced by combinations of irrigation and fertilizer levels

Treatments	Total cost of production per hectare (Rs)	Gross income ha^{-1}		Net profit per hectare (Rs)	Net income per rupee invested
		Yield (t ha^{-1})	Value (Rs)		
I_1F_1	208951	44.9	449000	240049	1.14
I_1F_2	211006	48.4	484000	272994	1.29
I_1F_3	213064	53.9	539000	325936	1.52
I_2F_1	213007	53.5	535000	321993	1.51
I_2F_2	215062	56.7	567000	351938	1.63
I_2F_3	217120	64.7	647000	429880	1.97
I_3F_1	217364	61.9	619000	401636	1.85
I_3F_2	219419	66.0	660000	440581	2.00
I_3F_3	221477	72.4	724000	502523	2.26
I_4F_1	180599	48.9	489000	308401	1.70
I_4F_2	182654	52.8	528600	345946	1.89
I_4F_3	184712	57.1	571000	386288	2.09

Discussion

5. DISCUSSION

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

5.1 Crop growth

The results of the study show that application of fertilizer with irrigation increased growth attributes such as average length of vines, number of branches per vines, number of leaves per vine, shoot dry matter production at harvest and leaf area index (Table 4-6 and Fig. 3-7).

Length of vine at harvest, 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 per cent Ep to 100 per cent Ep. A high irrigation level with pot watering totaling 706.1 mm was inferior to both 75 per and 100 per cent Ep through drip irrigation. The results indicated the necessity for higher level of drip irrigation (100% Ep) to enhance growth factors under high density planting. The study reveals the necessity for trying higher levels of drip irrigation over 100 per cent Ep also.

Under high density planting, length of vine, number of leaves per vine and number of branches per vine increased linearly with increase in fertilizer level from 100 percent to 200 percent. It indicates that under high density planting which has 33,333 plants per hectare needs a fertilizer dose more than 200 per cent of the recommended dose for the normal population of 10,000 plants per hectare.

Maximum per hectare dry matter production of vegetative growth and LAI were obtained from F_3 level of fertilizer. In the trial, per hectare vegetative growth increased by 129 and 179 percent and LAI by 124 and 150 percent respectively in F_2 and F_3 levels of fertilizer over the normal recommended dose of fertilizer. Similar results have been reported by Alphonse and Saad (2000) and Jaksungnaro *et al*, (2001) and Alemeyhu, (2001) in vegetable crops.

Interaction between irrigation and fertilizer level was significant on length of vine, number of leaves per vine, number of branches per vine, LAI and shoot dry matter production. In all the growth parameters, I_3F_3 recorded significantly the highest length of vine, number of leaves per vine, number of branches per vine, LAI and shoot dry matter production. So there was positive interaction up to 100 per cent Ep through drip irrigation and 200 per cent of fertilizer level. A very high level of irrigation through farmers practice did not respond favourably to increasing doses of fertilizers as observed under I_2 and I_3 in promoting the growth parameters like length of vine, number of leaves per vine, number of branches per vine, LAI and shoot dry matter production of oriental pickling melon.

While the interaction between irrigation levels of 75 and 100 per cent Ep through drip irrigation and fertilizer levels up to 200 per cent responded positively on growth parameters, such a positive interaction could not be seen at the lowest level of drip irrigation with 50 per cent Ep or at the highest level of irrigation (706.1 mm) with pot watering. The results obtained in this study are in conformity with the results of Bach and Hruska (1981), Parekh (1990), Arora and Mallik (1990), Bikramjit Singh (1990), Singh and Singh (1978), Bahadur *et al.* (2006) and Sharda *et al.* (2006) in different vegetables.

The study made it clear that for best interaction between water and nutrients, both should be present at optimum levels in soil. Growth and development of the crop is best expressed at a favourable interaction between irrigation and nutrients. The study also indicates the necessity for trying a level of drip irrigation above 100 per cent Ep and fertilizer level above 200 per cent of the dose recommended for the normal crop of oriental pickling melon under high density planting.

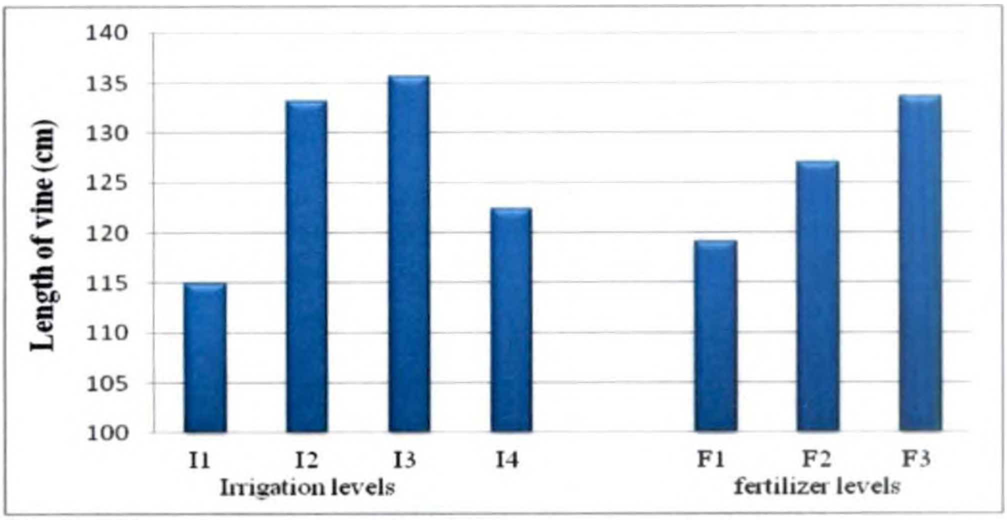

Fig. 3. Effect of irrigation and fertilizer levels on length of vines

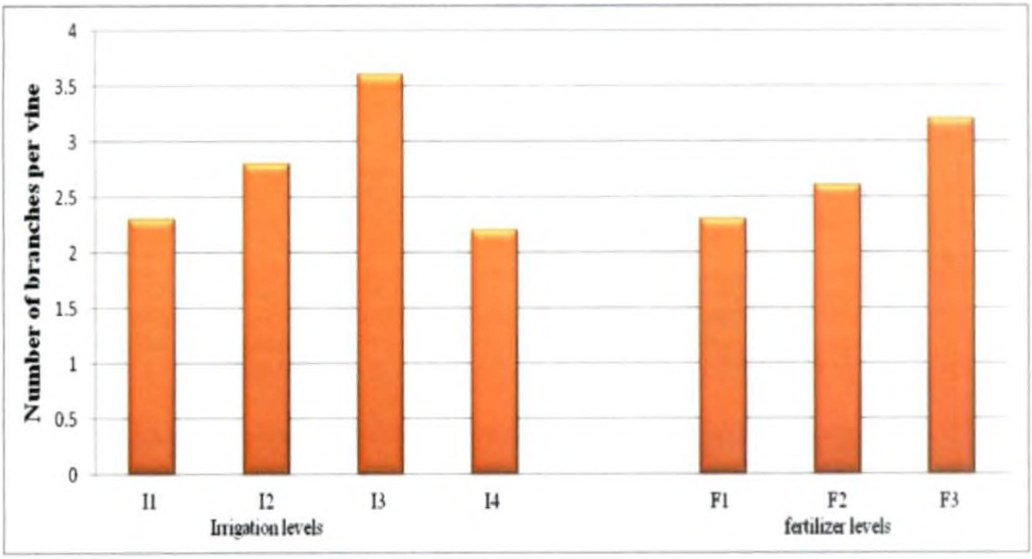

Fig. 4. Effect of irrigation and fertilizer levels on number of branches per vine

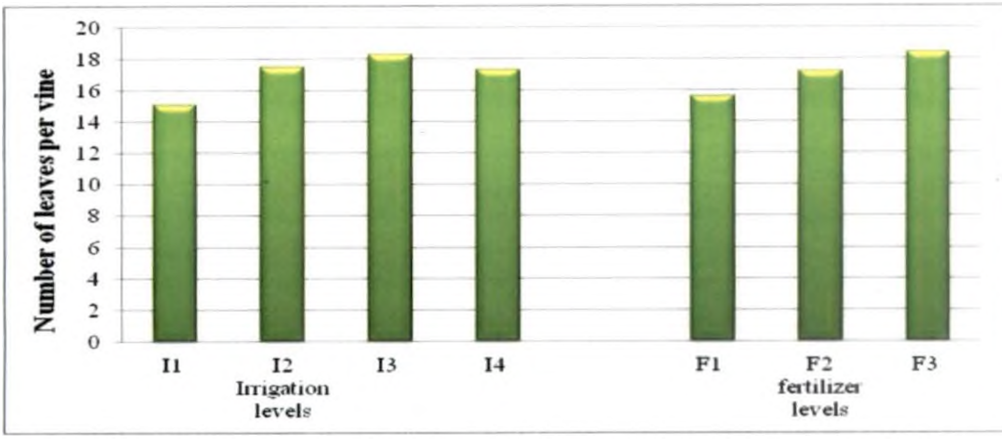

Fig.5. Effect of irrigation and fertilizer levels on number of leaves per vine

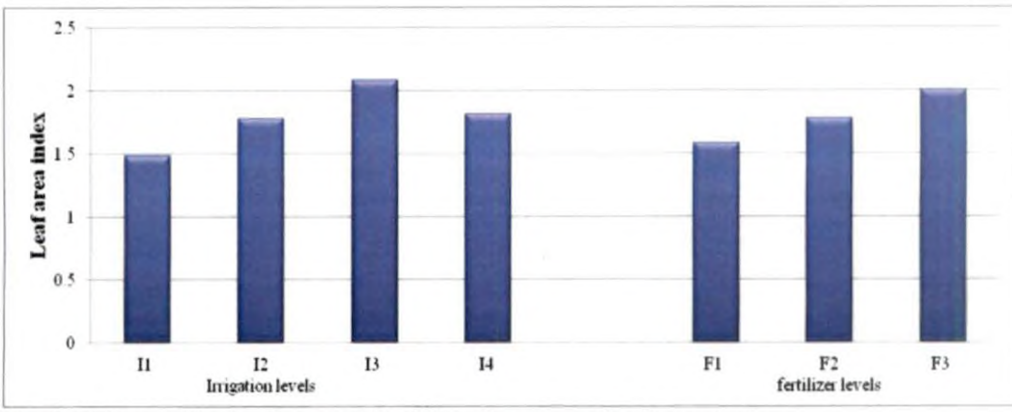

Fig.6. Effect of irrigation and fertilizer levels on leaf area index

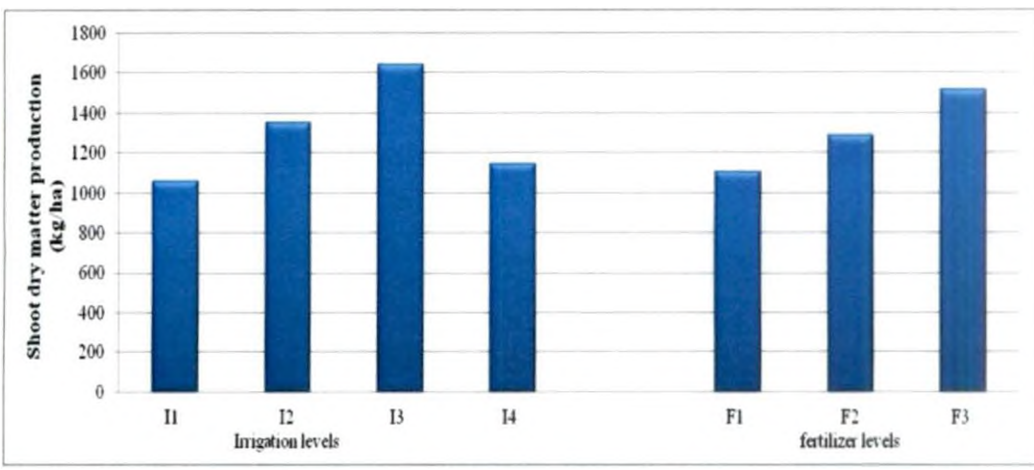

Fig.7. Effect of irrigation and fertilizer levels on shoot dry matter production

5.2 Yield and yield attributes

Yield attributes like number of fruits per plant, average weight of fruit, mean volume of fruit and fruit yield increased significantly with increase in drip irrigation level from 50 per cent Ep to 100 per cent Ep. A high irrigation level of pot irrigation totalling 706.1 mm was inferior to both 75 and 100 per cent Ep through drip irrigation. (Table 5 and Fig 8-11). The results indicated the necessity for higher levels of drip irrigation (100 % Ep) to enhance yield and yield attributes under high density planting. As there was linear increase in yield and yield attributes due to increasing level of drip irrigation, higher levels of Ep above 100 per cent needs to be tried under higher density planting. Lower levels of drip irrigation with 50 per cent Ep as well as higher level of pot irrigation (706.1 mm) are not beneficial to promote yield and yield attributes on the growth parameters.

Mean fruit yield per hectare increased significantly with increase in irrigation level up to I_3 and then decreased. The increases in per hectare fruit yield over I_1 at I_2 and I_3 were in the order of 18.7 and 36.0 per cent respectively. Better growth expressions under I_2 and I_3 were responsible for more fruit yield under these treatments. I_4 which is farmer's practice of irrigation recorded significantly lower fruit yield than I_2 and I_3 because of lower production of number of fruits per plant, average fruit weight, nutrient uptake and growth parameters were lesser.

LAI is an important factor that affects crop performance and fruit yield, as it reflects the combined effect of all the growth parameters. The highest LAI of 2.08 recorded with I_3 level of irrigation under high density planting was instrumental for getting the highest fruit yield with that treatment.

Number of fruits per plant and mean fruit yield increased significantly with increase in fertilizer level from 100 to 200 per cent. Increase of fruit yield per hectare at F_2 over F_1 was 3.7 tonnes and at F_3 over F_1 was 9.7 tonnes. As the response to fertilizer level is linear in nature, it indicates that under high density planting which has 33,333 plants per hectare, a fertilizer dose more than 200 per cent of the recommended dose for the normal population of 10,000 plants per hectare is needed.

Among the fertilizer levels average weight of fruit and volume of fruit increased in F_3 but the difference between F_1 and F_2 was not significant.

Interaction between irrigation and fertilizer level was significant on mean fruit yield. I_3F_3 recorded the highest fruit yield. So there was positive interaction up to 100 per cent Ep through drip irrigation and 200 per cent of fertilizer level. Higher level of irrigation through farmers practice and lower level of drip irrigation with 50 per cent Ep did not interact favourably with fertilizer levels under high density planting.

The positive interaction between irrigation and fertilizer level on enhancing the fruit yield in various vegetables has been reported by Alemeyhu (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).

Interaction between irrigation and fertilizer levels was not significant in the case of number of fruits per plant, average weight of one fruit, and volume of fruit. The study points out the necessity to try higher levels of drip irrigation with water above 100 per cent Ep and fertilizer level above 200 per cent under high density planting.

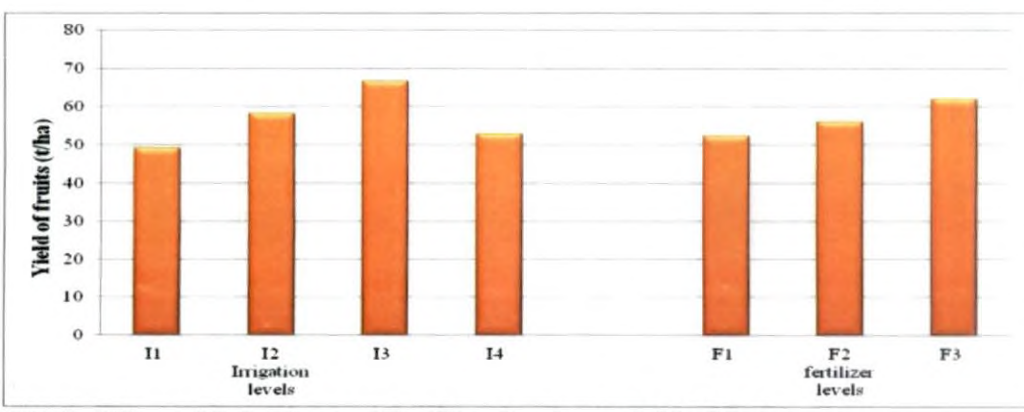

Fig.8. Effect of irrigation and fertilizer levels on yield of fruits

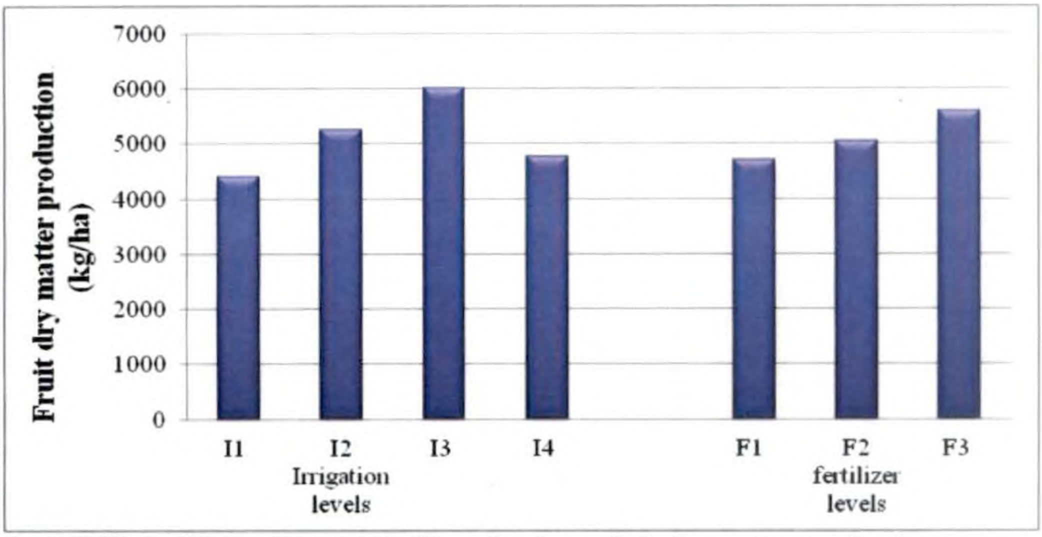

Fig.9. Effect of irrigation and fertilizer levels on fruit dry matter production

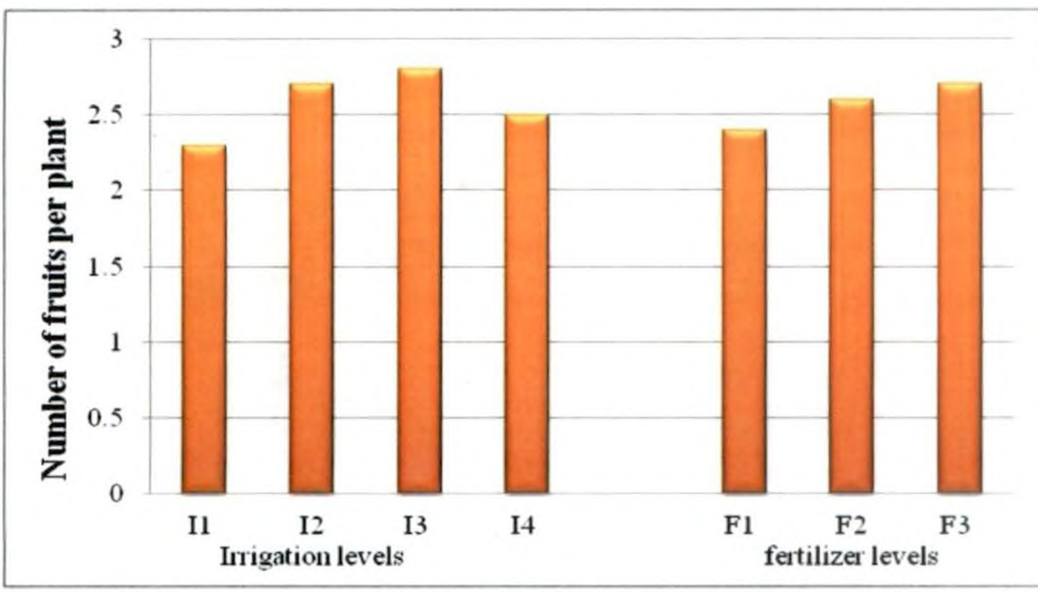

Fig.10. Effect of irrigation and fertilizer levels on number of fruits per plant

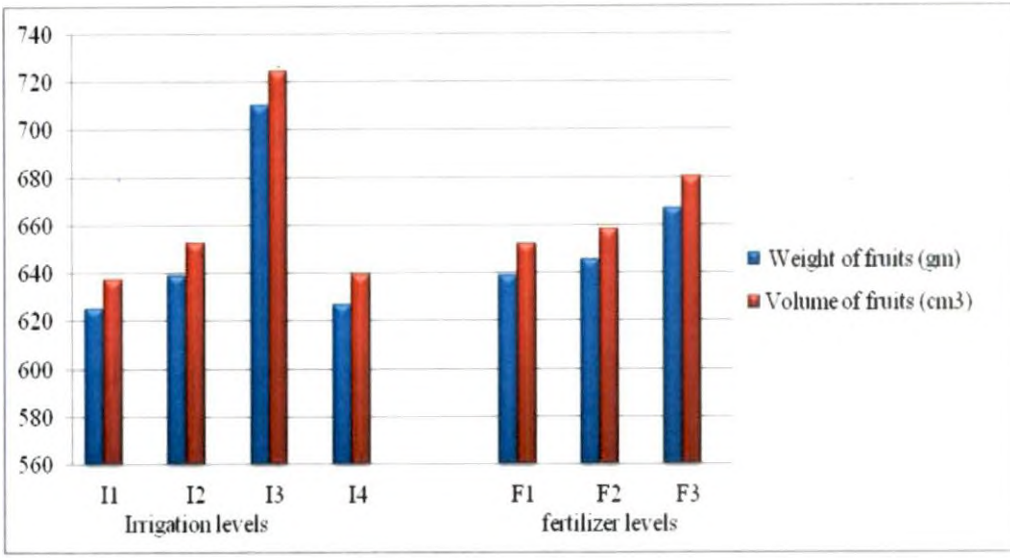

Fig.11. Effect of irrigation and fertilizer levels on weight of fruits and volume of fruits

5.3 Days to first flowering and harvest

These two parameters did not show much variation under irrigation or fertilizer levels (Table 4 and 5). The interaction between them was also non significant. In general, days to first flowering were 23 days in case of drip irrigation and 24 days in pot irrigation. Days to harvest were early in drip irrigated plots than pot irrigated plots. Early maturity was noticed in drip irrigated plots; generally days to harvest in drip and pot irrigation were 65 days and 67 days respectively. The results indicate the influence of excess water on delaying the maturity of the crop.

5.4 Fruit dry weight

Fruit dry weight increased significantly with increase in drip irrigation level from 50 per cent Ep to 100 per cent Ep (Table 6. Fig. 9). A high irrigation level by pot irrigation was inferior to both 75 and 100 per cent Ep through drip irrigation under high density planting.

Under high density planting, dry matter production of fruit increased linearly with increase in fertilizer level from 100 per cent to 200 per cent. It indicates that under high density planting which has 33,333 plants per hectare, a fertilizer dose more than 200 per cent of the recommended dose for the normal population of 10,000 plants per hectare is needed. Fruit dry weight was proportionate to the fruit yield in various treatments. Interaction between irrigation and fertilizer level was not significant on fruit dry weight.

5.5 Chemical compositions of leaves

Chemical compositions of leaves like nitrogen, phosphorus and potassium increased significantly with increase in drip irrigation level from 50 per cent Ep to 100 per cent Ep both at 30 and 60 DAS. A high irrigation level by pot irrigation totaling 706.1mm was inferior to both 75 per cent Ep and 100 per cent Ep through drip irrigation both at 30 and 60 DAS (Table 7-9. Fig.12-14) under high density planting. The result indicates that low irrigation and excess irrigation are not conducive for higher nitrogen, phosphorus and potassium contents in leaf. In water melon, daily irrigation with 100 per cent Ep resulted in highest N, P, K, Ca and Mg concentration and uptake, vide studies conducted by Srinivasa *et al.*, (1986).

Under high density planting leaf nitrogen, phosphorus and potassium content increased significantly with increase in fertilizer level both at 30 and 60 DAS from 100 to 200 per cent. It indicates that with increase in the levels of application of nutrients, there is a trend to absorb and accumulate more nutrients in the leaves. Excess nutrients are believed to be stored in the vacuoles of leaf cells. This result is in conformity with the results of Al-Sahaf and Al-Khafagi, (1990) and Tunacy *et al.* (1999).

Interaction between irrigation and fertilizer levels was significant on chemical composition of leaves except nitrogen content at 60 DAS. I_3F_3 recorded significantly the highest nutrient contents in leaves both at 30 and 60 DAS. So there was positive interaction up to 100 per cent Ep through drip irrigation and

200 per cent of fertilizer level. Higher level of irrigation through farmers practice and lower level of irrigation through drip did not interact favourably with fertilizer levels in promoting higher nutrient contents in leaves of oriental pickling melon both at 30 and 60 DAS.

The favourable interaction between nutrients and water is a well known fact. The study revealed that a favourable interaction takes place only under an ideal moisture level supplemented by drip irrigation with 75 or 100 percent Ep. Less than an optimum moisture supplementation by drip method with 50 per cent Ep or high level of moisture supply by a flooding method like pot irrigation do not contribute to favourable interaction between irrigation and nutrients on nutrient uptake by the crop.

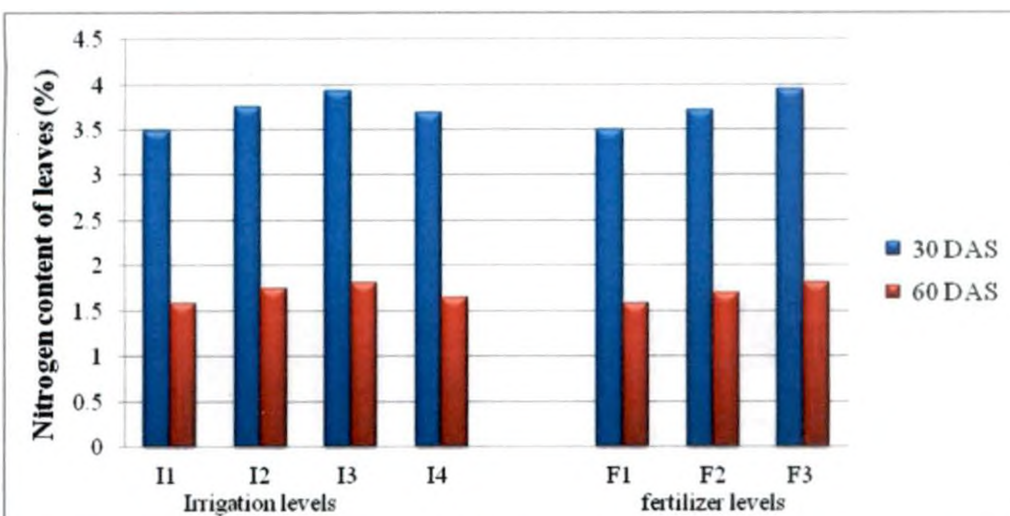

Fig.12. Leaf nitrogen content (%) as influenced by irrigation and fertilizer levels at 30 and 60 DAS

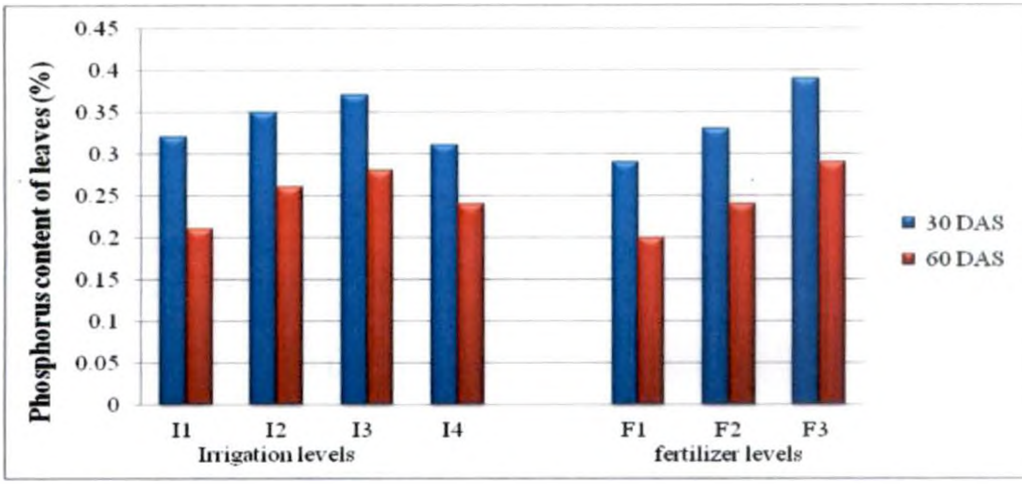

Fig.13. Leaf phosphorus content (%) as influenced by irrigation and fertilizer levels at 30 and 60 DAS

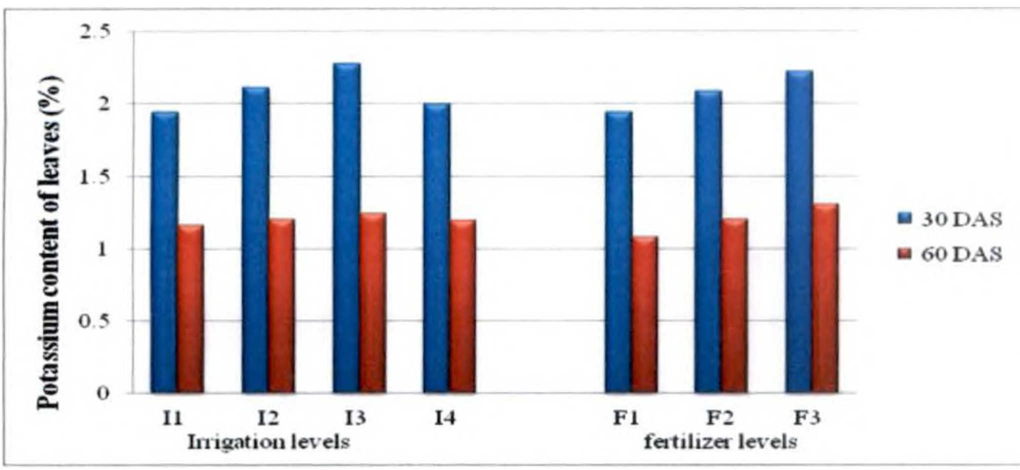

Fig.14. Leaf potassium content (%) as influenced by irrigation and fertilizer levels at 30 and 60 DAS

5.6 Nitrogen content of fruit, shoot at harvest and uptake.

Nitrogen content of fruit and total uptake increased significantly with increase in drip irrigation level up to 50 per cent Ep to 100 per cent Ep. A high irrigation level by pot irrigation totalling 706.1mm was inferior to both 75 per cent Ep and 100 per cent Ep through drip irrigation. Nitrogen content of shoot increased up to 100 per cent Ep and was at par with pot irrigation (Table 10. Fig.15and16).

Under high density planting, N content of shoot, fruit and total N uptake increased linearly with increase in fertilizer level from 100 to 200 per cent. It indicates that under high density planting which has 33,333 plants per hectare needs a fertilizer dose more than 200 per cent of recommended dose for the normal population of 10,000 plants per hectare. Nitrogen uptake by fruits depended solely on the fruit dry weight, which was maximum at 200 per cent of fertilizer level. Total N uptake by the crop also was the maximum at 200 per cent fertilizer level, which was higher by 15.77 kg per hectare over 150 per cent and 26.15 kg per hectare over 100 per cent fertilizer levels.

Interaction between irrigation and fertilizer was significant on total uptake of nitrogen by the crop. I_3F_3 recorded significantly the highest N uptake by the crop. So there was positive interaction up to 100 per cent Ep through drip irrigation and 200 per cent fertilizer level, which also recorded the highest fruit yield in the experiment. Interaction between irrigation and fertilizer was not impressive at the lowest level of drip irrigation with 50 per cent Ep and at the highest level of irrigation by pot watering. Because of this growth and yield were lower in these treatments and uptake of nitrogen also was affected. This result is in conformity with results of Pew and Gardner (1972), Singh *et al.* (1982) and Anoop (2009).

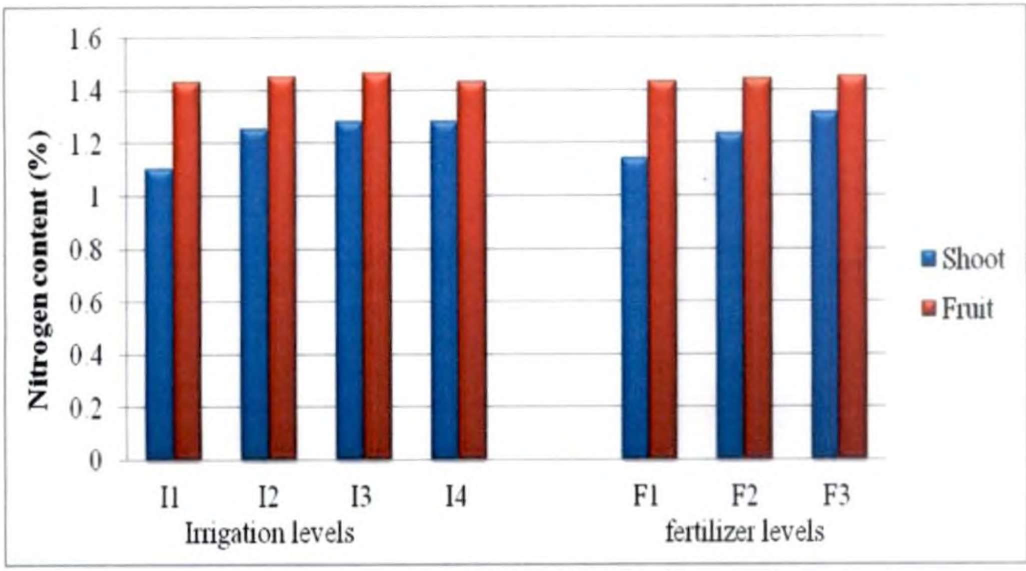

Fig.15. Nitrogen content (%) of shoot and fruit at harvest as influenced by irrigation and fertilizer levels

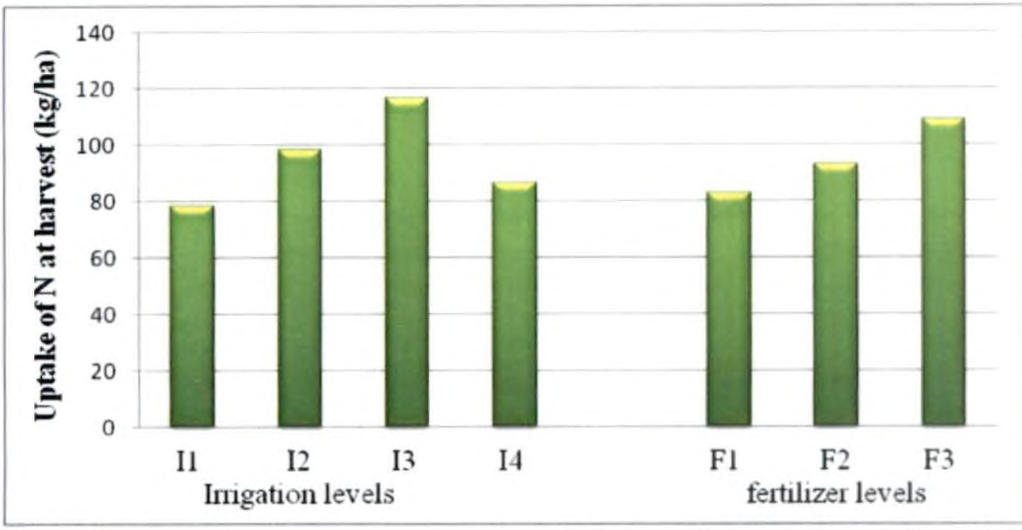

Fig.16. Total uptake of nitrogen at harvest as influenced by irrigation and fertilizer levels

5.7 Phosphorus content of shoot, fruit at harvest and uptake

Phosphorus content of shoot, fruit and total uptake increased significantly with increase in drip irrigation from 50 to100 per cent Ep. A high irrigation level of pot irrigation totalling 706.1mm was inferior to both 75per cent Ep and 100per cent Ep through drip irrigation (Table 11. Fig. 17and 18). P uptake is a multiple of P content and dry matter production. Dry matter production of fruit at harvest exerted more influence on P uptake rather than P content of shoot.

Total P uptake by the crop increased significantly up to I_3 irrigation level and then decreased, because fruit yield also increased up to I_3 irrigation level and then decreased. The per cent increases in total P uptake by the crop under I_2 and I_3 irrigation levels over I_1 are in the order of 24.3 and 47.3 respectively.

Under high density planting, P content of shoot, fruit and uptake increased linearly with increase in fertilizer level from 100 to 200 per cent Ep. Higher P content and dry matter production with increase in fertilizer level up to F_3 contributed to higher P uptake by shoot and fruit at harvest. Total P uptake by the crop at harvest was maximum in F_3, it was higher by 5.03 kg per hectare over F_1 and 3.06 kg per hectare over F_2.

The interaction between irrigation levels and fertilizer levels was non significant in the case of P content in shoot, fruit and total uptake. This is in conformity with the results of Jyothi (1995) and Anoop (2009) in vegetable crops.

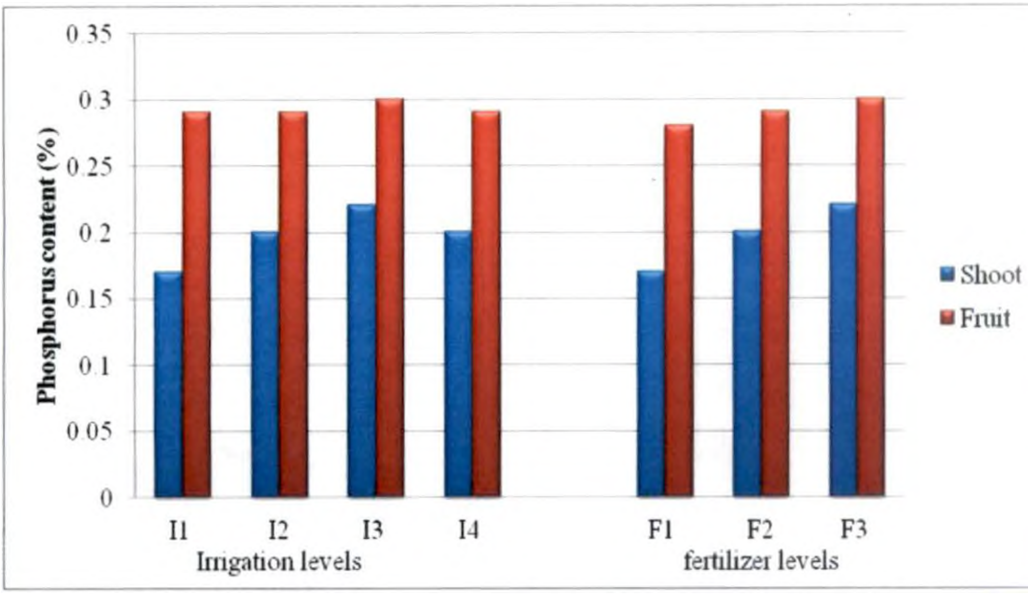

Fig.17. Phosphorus content (%) of shoot and fruit at harvest as influenced by irrigation and fertilizer levels

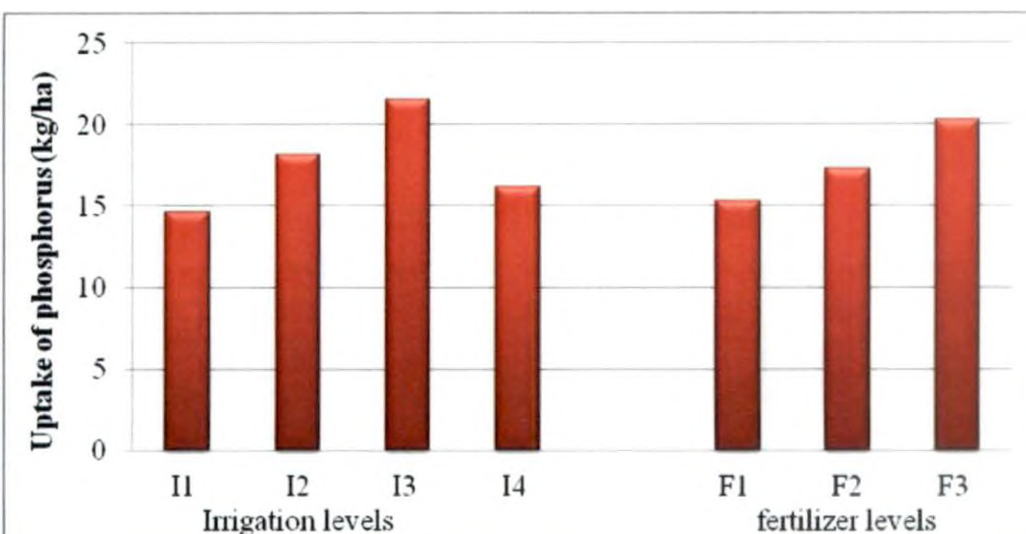

Fig.18. Total uptake of phosphorus (kg/ha) at harvest as influenced by irrigation and fertilizer levels

5.8 Potassium content of shoot, fruit at harvest and uptake.

Irrigation and fertilizer levels significantly influenced potassium content of shoot, fruit and total uptake (Table 12. Fig. 19 and 20). As in the case of nitrogen and phosphorus, potassium content in shoot at harvest also increased significantly with increase in irrigation level up to I_3 and then decreased.

Potassium content in fruits was not at all influenced by the irrigation levels. But K uptake by the crop increased significantly up to 100 per cent of Ep and then decreased because of reduced fruit yield under pot irrigation. The total uptake of K at harvest was higher by 22.4 and 43.0 percent respectively under I_2 and I_3 level of irrigation over I_1. Dry matter production by shoot and fruit was maximum in I_3.

Potassium uptake by shoot increased significantly up to 200 per cent fertilizer level. Uptake was significantly highest at 200 per cent fertilizer level due to more dry matter production in F_3. Total K uptake was maximum at 200 per cent fertilizer level and it was higher by 18.0 kg over 100 per cent and 11.1 kg over 150 per cent of fertilizer levels.

Interaction between irrigation and fertilizer level was non significant on potassium content of shoot, fruit and total uptake.

Uptake of nitrogen, phosphorus and potassium by the crop depended on the total dry matter production and their contents in fruit and shoot dry matter. In general their uptakes increased significantly up to I_3 (100% Ep through drip irrigation) and up to F_3 (200% nutrient level). Since the increase in uptake of nutrients showed linear relationship, higher levels of drip irrigation above 100 per cent Ep and nutrient level above 200 per cent are to be tried under high density planting. A high level of irrigation through pot watering (706.1 mm) resulted in reduced uptake of nutrients because of lesser crop growth and yield. Interaction between water and nutrients was the best at I_3F_3 on nutrient uptake by oriental pickling melon.

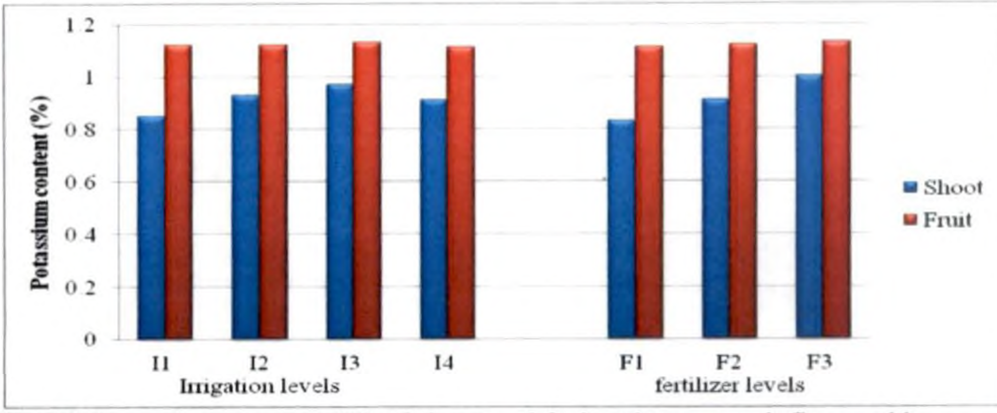

Fig.19. Potassium content (%) of shoot and fruit at harvest as influenced by irrigation and fertilizer levels

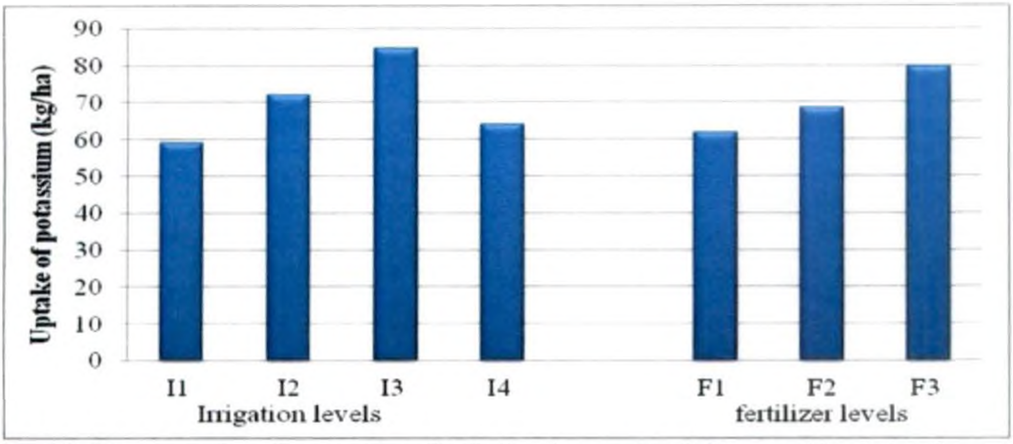

Fig.20. Total uptake of potassium (kg/ha) at harvest as influenced by irrigation and fertilizer levels

5.9 Field water use efficiency

Field water use efficiency decreased with increase in irrigation level from 50 per cent Ep to 100 per cent Ep and also in pot irrigation. Highest FWUE was recorded by the lower irrigation level of 50 per cent Ep and lesser FWUE by pot irrigation. The increase in field water use efficiency in I_1, I_2 and I_3 by drip method over normal pot irrigation of I_4 level was 255.0, 203.0 and 171.0 per cent respectively (Table 13. Fig. 21).

FWUE increased significantly with increase in fertilizer level from 100 to 200 per cent. The highest field water use efficiency was noticed from the 200 per cent of fertilizer level. Interaction between irrigation and fertilizer levels was significant on field water use efficiency. I_1F_3 recorded significantly the highest FWUE. Higher level of irrigation through farmers practice did not interact favourably with high dose of fertilizer to increase FWUE. The result is in confirmity with the study of Anoop, (2009) and with the results of Rekha *et al.* (2005). The results indicate the maximum use of applied water by the crop with decrease in the quantity of irrigation water. But such as increase in FWUE at very low irrigation level has not benefitted the crop.

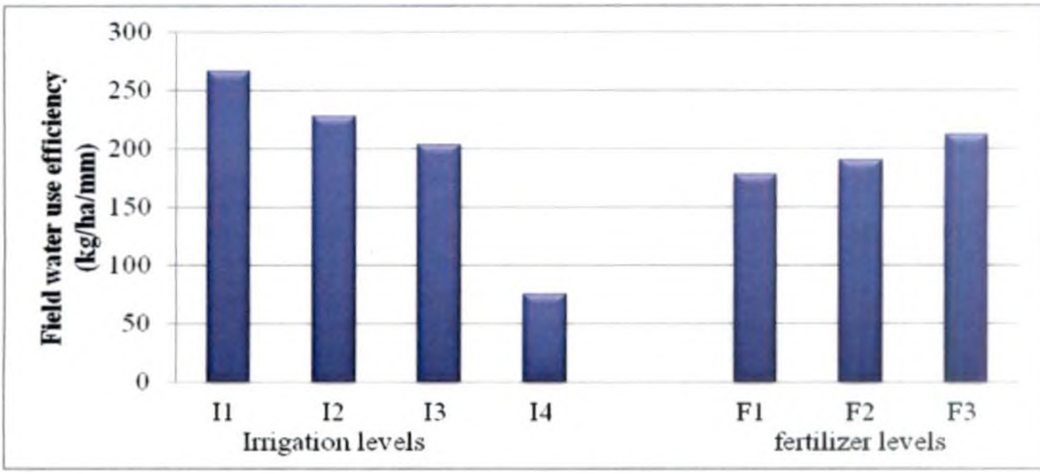

Fig. 21. Effect of irrigation and fertilizer levels on field water use efficiency

5.10 Available nitrogen of soil during different crop growth stages and after harvest

Available nitrogen in soil at different growth stages and after harvest decreased significantly with increase in irrigation level from 50 per cent Ep to 100 per cent Ep through drip irrigation and also with pot irrigation. The lowest nitrogen content in soil was observed in pot irrigation level at all the growth stages probably due to greater leaching down of nitrogen through excess water (Table 14. Fig. 22). The decrease in available nitrogen in soil with increase in irrigation level from 50 per cent Ep to 100 per cent Ep is due to progressive increase in the uptake of nitrogen by the crop.

Available nitrogen in soil increased linearly with increase in fertilizer level from 100 to 200 per cent at all the growth stages. The result indicates the favourable influence of increasing doses of applied nitrogen on available nitrogen in soil at different growth stages of the crop.

Interaction between irrigation and fertilizer levels was significant as regards available nitrogen content of soil at 15 DAS, 45 DAS and at harvest, but non significant at 30 DAS. At all the irrigation levels, available nitrogen increased with increasing fertilizer levels at all the growth stages. Among the treatment combinations I_1F_3 recorded highest available nitrogen at 15 DAS, 45 DAS and after harvest because of less uptake by the crop and more availability from the highest dose of F_3. The lowest available nitrogen was observed in I_3F_2 at 15 DAS, I_3F_1 and I_3F_2 at 45 DAS and after harvest in drip irrigated treatments due to more uptake by the crop.

There was an increase in the quantity of available nitrogen in soil from 15 DAS to 30 DAS due to application of nitrogen in six splits at weekly interval from 10 DAS to 40 DAS, from 30 DAS to harvest available nitrogen in soil decreased progressively in all treatments due to uptake by the crop as well as losses through different ways.

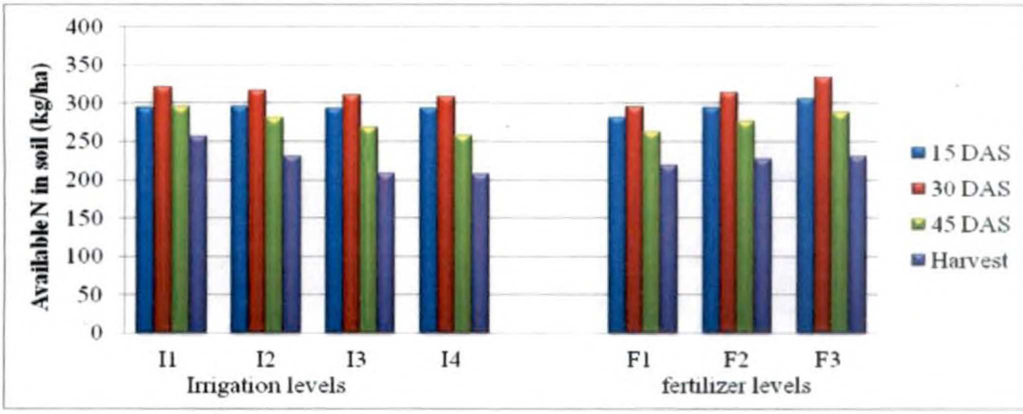

Fig.22. Available nitrogen in soil (kg/ha) at different growth stages as influenced by irrigation and fertilizer levels

5.11 Available phosphorus in soil during different crop growth stages and at harvest

Available phosphorus in soil during different crop growth stages is shown in (Table 15. Fig. 23). There was not much variation in available phosphorus in soil between irrigation levels at 15 and 30 DAS. This is because phosphorus mobility with water moving in the soil is negligible and that crop uptake does not vary very much at the younger stage between irrigation levels. At 45 DAS and after harvest available P decreased significantly with increase in irrigation level from I_1 to I_3 and again increased under I_4. At both there stages, decrease in available phosphorus in soil was in direct proportion to the increase in dry matter production.

Available P in soil increased linearly with increase in fertilizer level from 100 to 200 per cent at all the growth stages. This indicates the influence of higher levels of phosphorus application as the available phosphorus in soil.

Interaction between irrigation and fertilizer levels was not significant on available phosphorus in soil, except after harvest. It was the lowest in the combinations of I_3 with F_1, F_2 and F_3 because; total dry matter production was the highest in these combinations.

There was no depletion of phosphorus content of soil by the crop compared to pre trial of 31.3 kg per hectare. The phosphorus made available in the soil through 25 tonnes per hectare of FYM and chemical fertilizer was sufficient to meet the P requirement of the crop. In fact this could enhance the available P status of the soil after the harvest of the crop.

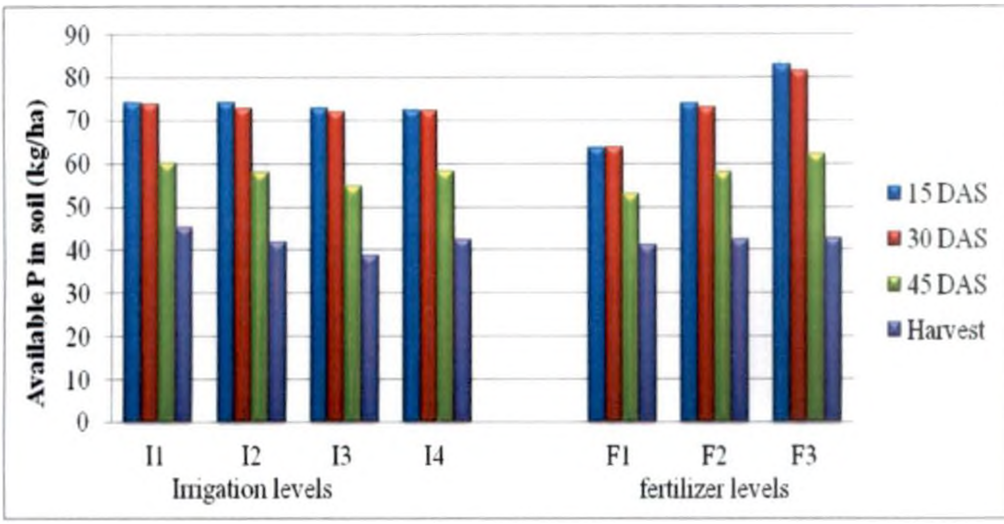

Fig.23. Available phosphorus in soil (kg/ha) at different growth stages as influenced by irrigation and fertilizer levels

5.12 Available potassium in soil during different crop growth stages and at harvest

Available K in soil decreased with increasing irrigation level from 50 to 100 per cent Ep in drip irrigation. Available K contents at I_3 and I_4 were similar except after harvest. At harvest available K was the lowest in I_3. Higher K content was observed in I_1 level of irrigation at all the growth stages because of less moisture content of soil, growth and yield were lowest in I_1 and hence K uptake was also lowest in I_1. Lowest available K observed in I_3 was due to its highest uptake because of more production of dry matter (Table 16. Fig. 24).

Available K in soil increased linearly with increase in fertilizer level from 100 to 200 per cent at all the growth stages. A progressive decline in available K in soil was observed from 15 DAS to harvest in all the treatments.

Interaction between irrigation and fertilizer levels was significant on available K in soil at all the growth stages. In general available K in soil increased with increase in fertilizer level at all stages. From among the treatment combinations I_3 with F_1, F_2 and F_3 had the lowest available K in soil after the harvest of the crop because of higher uptake of K by these treatments.

There was a steady decline in available K in the soil from 15 DAS to harvest in all the treatments in direct proportion to the increase in dry matter production with successive stages.

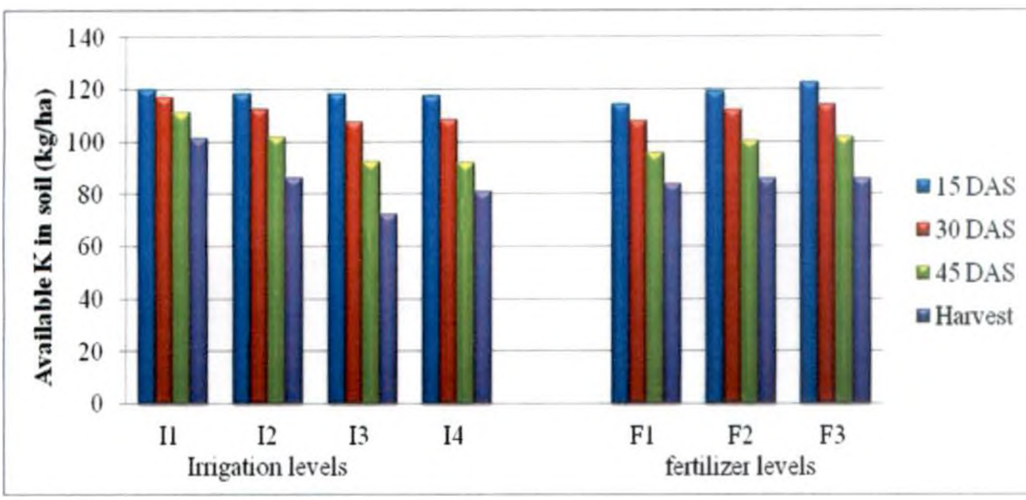

Fig.24. Available potassium in soil (kg/ha) at different growth stages as influenced by irrigation and fertilizer levels

5.13 Soil moisture studies

Moisture content of soil at different crop growth stages increased with increase in irrigation level from 50 per cent Ep of drip irrigation to pot irrigation in all the depths *viz.* 0-15, 15-30 and 30-60 cm. Fertilizer level had no appreciable impact on soil moisture content at different levels of irrigation. When the quantity of irrigation water used was less (I_1 and I_2), soil moisture content in the lower layer of 30-60 cm remained unchanged with I_1 level, soil moisture content changed only in the surface layer (0-15 cm), that too by 45 DAS. With I_2, soil moisture increased in the surface layer and middle layer by 30 DAS and further increased by 45 DAS. When drip irrigation level was increased to 100 per cent Ep, by15 DAS, moisture content increased in the surface layer only. But by 30 DAS and 45 DAS, moisture per cent increased in all the three layers. The trend observed under I_4 was similar to that of I_3, but in each layer, it maintained higher percentage of moisture at all the three stages of observation.

When the amount of water applied is less (50 % Ep) moisture content increases gradually in the surface layer alone. At higher level of irrigation (75 % Ep), moisture content gradually increases in the surface (0-15 cm) and middle layer (15-30 cm). When the crop is irrigated with 100 per cent Ep, moisture increases in all the three layers by 30 DAS. When the crop is irrigated liberally as done by the farmers practice (I_4) moisture content in all the three layers increases by 30 DAS and maintains more moisture in all the layers than I_3 (Table 17).This result is conformity to Gebremedhin, (2001) and Anoop, (2009).

5.14 Chemical properties of soil

There was no appreciable change in soil pH and EC by irrigation or fertilizer levels. Chemical properties of soil are not likely to be influenced by short term management of irrigation and fertilizer application. Oriental pickling melon var. Saubhagya is a short duration variety maturing in 65 days. Probably due to this no significant effect of irrigation and fertilizer levels could not be observed on chemical properties (Table 18 and 19) of soil.

5.15 Economics of production

Drip irrigation with 100 per cent Ep and fertilizer levels gave the highest net profit per hectare and net income per rupee invested. Among them, I_3F_3 recorded the highest net profit and net income per rupee invested; second best treatment combination was I_3F_2. I_3F_3 gave an additional profit of Rs 61,947 per hectare over I_3F_2. There was not much variation in the total cost of production of oriental pickling melon among the drip irrigation treatments. But because of favorable interaction between I_3 level of drip irrigation and F_3 and F_2 levels of fertilizer, yield was highest in I_3F_3 followed by I_3F_2 and this contributed to the highest net profit and net return per rupee invested in I_3F_3 followed by I_3F_2 (Table 20. Fig. 25).

The final recommendation is that for the most profitable production of irrigated oriental pickling melon under high density planting during summer months, daily drip irrigation at the rate of 100 percent Ep should be combined with 200 per cent of recommended fertilizer dose. As there was a linear increase in production of oriental pickling melon fruits with increase in water applied through drip irrigation and increase of fertilizer level, the optimum level of irrigation water to be applied through drip irrigation and fertilizer level could not be assessed in this trial, for which further studies are needed.

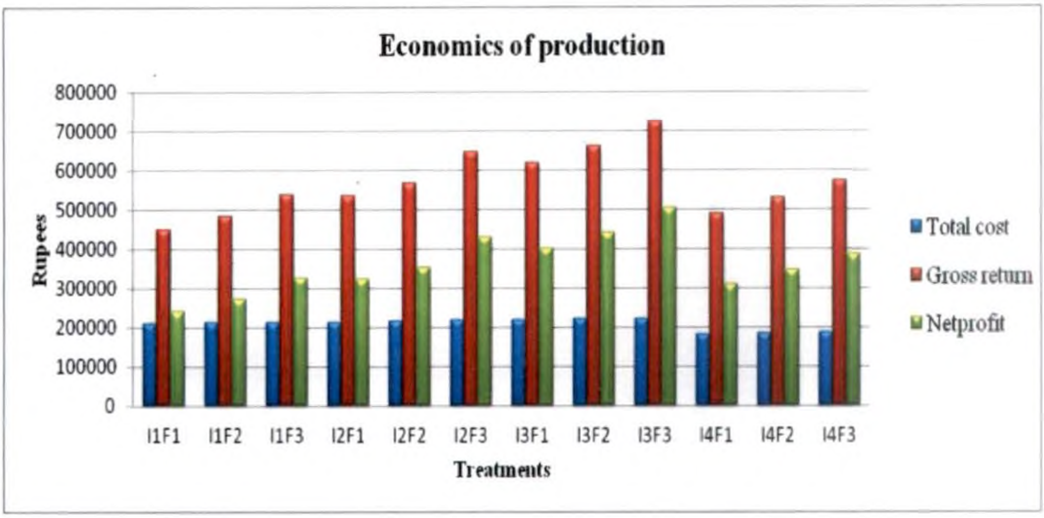

Fig. 25. Cost of production and profit as influenced by combination of irrigation and fertilizer levels.

5.16 Conclusion

From the above discussion we can infer that there was a linear increase in vegetative parameters and fruit yield of oriental pickling melon up to 100 per cent Ep through drip irrigation and up to 200 per cent of fertilizer through fertigation under high density planting. It is necessary to study the effect of higher levels of drip irrigation with water above 100 per cent Pan Evaporation and fertilizer above 200 percent RDF under high density planting.

5.17 Future line of work

Only one season data could be taken in the present experiment. For confirmation of the findings the experiment may be repeated for 2-3 seasons. Effect of mulching, lower dose of fertilizer than actual recommendation are to be studied for knowing crop performance to fertigation. Also needs to evaluate the keeping quality of fruits after harvest in fertigated crop under high density planting.

Summary

6. SUMMERY

A field experiment was conducted at the Agricultural Research Station, Mannuthy, Thrissur during the summer season (December 2012 to February 2013) to study the effect of "Fertigation in oriental pickling melon (*Cucumis melo* var. *conomon* (L.) Makino) under high density planting" grown in summer rice fallows.

The soil of the experimental field was sandy clay loam with bulk density of 1.34 g cm^{-3}. It was acidic in reaction, medium in organic carbon (0.62), available nitrogen (225.79 kg ha^{-1}) and potassium (90 kg ha^{-1}) and low in available phosphorus (31.3 kg ha^{-1}). The weather during the period was hot and humid with an average daily pan evaporation (5.15 mm), relative humidity (morning 72.1 and evening 37.62 percent), and wind speed (5.36 km hr^{-1}). There was no rainfall during the cropping period.

The experiment was laid out in Randomised Block Design (RBD) with three replications. The treatments consisted of combinations of four irrigation levels (50, 75 and 100 per cent Ep through drip irrigation and farmers practice of pot irrigation @ 10 litres per plant) and three fertilizer levels (100, 150 and 200 per cent RDF). Hence totally it consisted of 12 treatment combinations.

The study was carried out with the short duration and less spreading oriental pickling melon variety Saubhagya. The salient findings and conclusions drawn out from the investigation are summarised below.

1) Levels of irrigation significantly influenced the average length of vines at harvest. Maximum length of vines at harvest (135.6 cm) was recorded at 100 per cent Ep through drip irrigation and was significantly superior to all other irrigation levels. Fertilizer levels also significantly influenced average length of vines; the highest length of vine (133.6 cm) was recorded with 200 per cent RDF.

2) Number of leaves per vine was significantly influenced by the levels of irrigation. Maximum number of leaves per vine (18.3) was recorded at 100 per cent Ep given through drip irrigation and was significantly superior to all other irrigation levels. Fertilizer levels also significantly influenced number of leaves per vine. The highest number of leaves per vine (18.4) was recorded with 200 per cent RDF.

3) Levels of irrigation significantly influenced the number of branches per vine. Maximum number of branches per vine (3.6) was recorded at100 per cent Ep given through drip irrigation and was significantly superior to all other irrigation levels. Fertilizer levels also significantly influenced number of branches per vine. The highest number of branches per vine (3.2) was recorded with 200 per cent RDF.

4) Levels of irrigation significantly influenced the LAI. Maximum LAI (2.08) was recorded at 100 per cent Ep given through drip irrigation and was significantly superior to all other irrigation levels. Fertilizer levels also significantly influenced LAI. The highest LAI (2.00) was recorded with 200 per cent RDF.

5) Both days to flowering and harvesting did not show significant change under irrigation or fertilizer levels. The interaction between them was also non significant. In general, days taken to flowering were 23 days in case of drip irrigation and 24 days in pot irrigation. Days to harvest were early in drip irrigated plots than pot irrigated plots.

6) Interaction effect of irrigation and fertilizer was significant on vegetative characters like average length of vine, number of leaves, number of branches per vine and LAI. The highest values of these parameters were recorded by the treatment of 100 per cent Ep given through drip irrigation with 200 per cent RDF.

7) Number of fruits per plant was significantly influenced by the irrigation levels. Maximum number of fruits per plant (2.8) was recorded at at100 per cent Ep given through drip irrigation and was significantly superior to all other irrigation levels. Fertilizer levels also significantly influenced number

of fruits per plant. The highest number of fruits per plant (2.7) was recorded with 200 per cent RDF.

8) The fruit characteristics like weight of fruit and volume of fruit were significantly influenced by the levels of irrigation. Maximum average weight and volume of fruit (710.2 g and 724.4 cm^3 respectively) were observed at 100per cent Ep given through drip irrigation and was significantly superior to all other irrigation levels. Fertilizer levels also significantly influenced weight and volume of fruit. The highest average weight of fruit and volume (666.7g and 680.0 cm^3 respectively) were observed with 200 per cent RDF.

9) Levels of irrigation significantly influenced the fruit yield. Maximum fruit yield (66.8 t/ha) was recorded at the irrigation level of I_3 and was significantly superior to all other irrigation levels. Fertilizer levels also significantly influenced fruit yield. Significantly the highest fruit yield (62.0 t/ha) was observed with F_3. Among the treatment combinations maximum fruit yield (72.4 t/ha) was recorded at100 per cent Ep given through drip irrigation with 200 per cent RDF (I_3F_3) and it was significantly superior to all other irrigation and fertilizer levels.

10) Dry matter production of both shoot and fruit at harvest was maximum in100 per cent Ep given through drip irrigation. Among fertilizer levels 200 per cent RDF produced the highest shoot and fruit dry matter. Both these levels are superior to other levels. Interaction effect of irrigation and fertilizer was non significant with regard to fruit dry matter production, but was significant in shoot dry matter production. The highest shoot dry matter production (2043 kg ha^{-1}) was recorded at100 per cent Ep given through drip irrigation with 200 per cent RDF (I_3F_3) and it was significantly superior to all other irrigation and fertilizer levels.

11) Levels of irrigation significantly influenced the total nitrogen content (per cent) of leaf at 30 and 60 DAS. Maximum total nitrogen content of leaf at 30 and 60 DAS (3.93 and 1.81%) respectively was recorded at 100 per cent Ep given through drip irrigation. Fertilizer levels also significantly

influenced total nitrogen content of leaf at 30 and 60 DAS. The highest nitrogen content of leaf at 30 and 60 DAS (3.94 and 1.81%) respectively was recorded with 200 per cent RDF. The interaction was significant at 30 DAS and highest nitrogen content (4.10%) was recorded with I_3F_3.

12) Levels of irrigation and fertilizer significantly influenced the phosphorus content (%) of leaf at 30 and 60 DAS. Interaction also was significant in both the stages. Among the treatment combinations the highest phosphorus content of leaf at 30 and 60 DAS (0.44 and 0.33%) respectively were recorded at 100 per cent Ep given through drip irrigation with 200 per cent RDF (I_3F_3).

13) Levels of irrigation and fertilizer significantly influenced the potassium content (%) of leaf at 30 and 60 DAS. Interaction also was significant at both the stages. Among the treatment combinations, highest potassium contents of leaf at 30 and 60 DAS (2.38 and1.38%) were rerecorded at100 per cent Ep drip irrigation with 200 per cent RDF (I_3F_3).

14) Levels of irrigation significantly influenced the nitrogen content of shoot and fruit. Maximum nitrogen content of shoot and fruit (1.28 and 1.46% respectively) was recorded at 100 per cent Ep given through drip irrigation and was significantly superior to all other irrigation levels. Fertilizer levels also significantly influenced nitrogen content of shoot and fruit. The highest nitrogen content of shoot and fruit (1.31 and 1.45% respectively) was recorded with 200 per cent RDF. Interaction was significant on nitrogen content of fruit but non significant with shoot nitrogen content.

15) Levels of irrigation significantly influenced the total uptake of nitrogen by the crop. Maximum nitrogen uptake (116.50 kg ha^{-1}) was observed at the irrigation level of I_3 and was significantly superior to all other irrigation levels. Fertilizer levels also significantly influenced total uptake of nitrogen. Significantly highest uptake of nitrogen (108.8 kg ha^{-1}) was observed with F_3. Among the treatment combinations the highest nitrogen uptake 136.4 kg ha^{-1} was recorded at100 per cent Ep given

through drip irrigation with 200 per cent RDF (I_3F_3) and the lowest nitrogen uptake recorded by I_1F_1.

16) Levels of irrigation significantly influenced the phosphorus content of shoot and fruit. Maximum phosphorus content of shoot and fruit (0.22 and 0.3% respectively) was recorded at 100 per cent Ep given through drip irrigation and was significantly superior to all other irrigation levels. Fertilizer levels also significantly influenced phosphorus content of shoot and fruit. Higher phosphorus content of shoot and fruit (0.22 and 0.30% respectively) were recorded with 200 per cent RDF. Interaction was not significant in both the cases.

17) Levels of irrigation significantly influenced the potassium content of shoot and fruit. Maximum potassium contents of shoot and fruit (0.97 and 1.13% respectively) were recorded at100 per cent Ep drip irrigation and was significantly superior to all other irrigation levels. Fertilizer levels also significantly influenced potassium content of shoot and fruit. The highest potassium content of shoot and fruit (1.0 and 1.13% respectively) was recorded with 200 per cent RDF (F_3). In the case of shoot, F_3 was significantly superior to F_1 and F_2 and in the case of fruit; F_3 was at par with F_2.

18) Total uptake of phosphorus and potassium of the crop was significantly influenced by the levels of irrigation. Maximum phosphorus and potassium uptake (21.52 kg ha^{-1} and 84.56 kg ha^{-1} respectively) was observed at100 per cent Ep given through drip irrigation and was significantly superior to all other irrigation levels. Fertilizer levels also significantly influenced total uptake of phosphorus and potassium. Highest uptake of phosphorus and potassium by the crop (20.31kg per hectare and 79.59 kg ha^{-1} respectively) was recorded with 200 per cent RDF. Interaction was non significant in both the cases.

19) Field water use efficiency decreased significantly with increase in irrigation levels and increased with increase in fertilizer levels. From among the treatment combinations, 50 per cent Ep drip irrigation with 200

per cent RDF (I_1F_3) recorded significantly the highest field water use efficiency (292.1 kg ha-mm^{-1}) and the lowest by pot irrigation.

20) Levels of irrigation and fertilizer significantly influenced the available nitrogen in soil at different growth stages of the crop and after harvest. With increasing irrigation level, there was decreasing of available nitrogen content of soil at all the stages. Highest available nitrogen at all the cropping period and at harvest was recorded with 200 per cent RDF.

21) Levels of irrigation significantly influenced the available phosphorus in soil at cropping period and after harvest. With increasing irrigation level, there was decreasing of available phosphorus of soil. The decrease in available phosphorus in soil was significant up to I_3 at 45 DAS and after harvest. I_4 recorded more available phosphorus in soil than I_3 at 30 and 45 DAS and after harvest. Fertilizer levels also significantly influenced available phosphorus in soil. Available phosphorus in soil decreased gradually from 15 DAS to harvest both under irrigation levels and fertilizer levels.

22) Levels of irrigation and fertilizer levels significantly influenced the available potassium in soil at all the cropping period and after harvest. With increasing irrigation level there was decreasing of available potassium in soil at all the stages of observation. The decrease was significant up to 100 per cent Ep given through drip irrigation at 30 and 45 DAS and after harvest. After harvest, pot irrigated plots recorded more available potassium in soil than 100 per cent Ep given through drip irrigation. Higher available potassium in soil was observed at 15, 30 and 45 DAS with 200 per cent RDF.

23) Soil moisture content increased with increase in irrigation level from I_1 to I_4 in all the layers *viz.* 0-15, 15-30 and 30-60 cm at 15, 30 and 45 DAS. In I_1, increase in soil moisture was observed only at 45 DAS that too in the surface layer of 0-15 cm. Middle and bottom layers did not express any significant change in soil moisture during 15, 30 and 45 DAS. In I_2, there was increase in soil moisture in the surface layer of 0-15 cm during

30 DAS and further increase at 45 DAS. But in the lower layer of 30-60 cm, soil moisture remained unchanged during 15, 30 and 45 DAS. In I_3, soil moisture content increased in all the three layers during 30 and 45 DAS compared to 15 DAS. In I_4 also soil moisture content increased in all the three layers during 30 and 45 DAS compared to 15 DAS.

24) There was no appreciable change in soil chemical properties like pH and EC due to levels of irrigation or fertilizer doses. A slight increase in soil EC was observed with increase in fertilizer levels at all the stages of observation *viz.* 15, 30 and 45 DAS and at harvest.

25) Results of irrigation and fertilizer levels indicated that, in all the irrigation treatments fertilizer levels tremendously increased net profit over actual recommend dose of fertilizer. F_3 fertilizer level (200% RDF) was better than F_2 and F_1 fertilizer levels, in all the treatments at high density planting. Among the treatment combinations I_3F_3 recorded the highest net profit of Rs. 5,02,523 per hectare and was followed by I_3F_2 (Rs. 4,40,581 per hectare). Third best combination was I_2F_3 (Rs. 4, 29,880). Maximum benefit cost ratio (2.26) was also recorded by I_3F_3. This treatment can be followed where family labour is utilized for cultivation of oriental pickling melon variety Saubhagya, where there is a water scarcity and farmers can invest more for vegetable cultivation.

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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	1.91
Irrigation	3	840.57**
Fertilizer	2	643.84**
Interaction (IXF)	6	40.39
error	16	3.89

** Significant at 1 percent level
*Significant at 5 percent level

b) Anova table for number of leaves per vine

Source	Degrees of freedom	Mean square
Replication	2	0.65
Irrigation	3	16.20**
Fertilizer	2	24.63**
Interaction (IXF)	6	0.34
error	16	0.11

** Significant at 1 percent level
*Significant at 5 percent level

c) Anova table for number of branches per vine

Source	Degrees of freedom	Mean square
Replication	2	0.02
Irrigation	3	3.34**
Fertilizer	2	2.47**
Interaction (IXF)	6	0.23
error	16	0.01

** Significant at 1 percent level
*Significant at 5 percent level

d) Anova table for leaf area index

Source	Degrees of freedom	Mean square
Replication	2	0.00
Irrigation	3	0.55**
Fertilizer	2	0.54**
Interaction (IXF)	6	0.02
error	16	0.00

** Significant at 1 percent level
*Significant at 5 percent level

e) Anova table for days to flowering and days to harvest

Source	Degrees of freedom	Mean square	
		flowering	harvest
Replication	2	0.00	0.0
Irrigation	3	2.25	9.0
Fertilizer	2	0.00	0.0
Interaction (IXF)	6	0.00	0.0
error	16	0.00	0.0

** Significant at 1 percent level
*Significant at 5 percent level

f) Anova table for number of fruits per plant and mean fruit yield

Source	Degrees of freedom	Mean square	
		No. of fruits per plant	Mean fruit yield
Replication	2	0.002	1.97
Irrigation	3	0.530**	529.26**
Fertilizer	2	0.441**	289.45**
Interaction (IXF)	6	0.009	2.38
error	16	0.005	0.69

** Significant at 1 percent level
*Significant at 5 percent level

g) Anova table for average weight and volume of fruit

Source	Degrees of freedom	Mean square	
		Average weight of fruit	Volume of fruit
Replication	2	2.84	5.18
Irrigation	3	14744.02*	15264.90*
Fertilizer	2	2564.67*	2554.35*
Interaction (IXF)	6	511.45	500.14
error	16	260.50	283.39

** Significant at 1 percent level
*Significant at 5 percent level

h) Anova table for dry matter production

Source	Degrees of freedom	Mean square	
		Shoot dry matter	Fruit dry matter
Replication	2	226.78	37733.4
Irrigation	3	607017.80**	4309158.9**
Fertilizer	2	519130.86**	2360014.2**
Interaction (IXF)	6	52804.60	17976.1
error	16	938.50	11496.4

** Significant at 1 percent level
*Significant at 5 percent level

i) Anova table for nitrogen content leaf and shoot

Source	Degrees of freedom	Mean square		
		30 DAS	60 DAS	Harvest
Replication	2	0.016	0.000	0.001
Irrigation	3	0.308*	0.097*	0.067**
Fertilizer	2	0.601**	0.167**	0.080**
Interaction (IXF)	6	0.016	0.002	0.001
error	16	0.002	0.001	0.000

** Significant at 1 percent level
*Significant at 5 percent level

j) Anova table for phosphorus content of leaf and shoot

Source	Degrees of freedom	Mean square		
		30 DAS	60 DAS	Harvest
Replication	2	0.000	0.000	0.000
Irrigation	3	0.006*	0.008*	0.004*
Fertilizer	2	0.032**	0.027**	0.008**
Interaction (IXF)	6	0.001	0.000	0.000
error	16	0.000	0.000	0.000

** Significant at 1 percent level
*Significant at 5 percent level

k) Anova table for potassium content of leaf and shoot

Source	Degrees of freedom	Mean square		
		30 DAS	60 DAS	Harvest
Replication	2	0.004	0.002	0.005
Irrigation	3	0.191*	0.009*	0.024*
Fertilizer	2	0.234**	0.146**	0.083**
Interaction (IXF)	6	0.002	0.003	0.000
error	16	0.001	0.000	0.000

** Significant at 1 percent level
*Significant at 5 percent level

l) Anova table for nutrient content of fruit

Source	Degrees of freedom	Mean square		
		Nitrogen	Phosphorus	Potassium
Replication	2	0.000	0.000	0.000
Irrigation	3	0.001*	0.000	0.001*
Fertilizer	2	0.001**	0.001**	0.001**
Interaction (IXF)	6	0.000	0.000	0.000
error	16	0.000	0.000	0.000

** Significant at 1 percent level
*Significant at 5 percent level

m) Anova table for total nutrient uptake

Source	Degrees of freedom	Mean square		
		Nitrogen	Phosphorus	Potassium
Replication	2	1.31	2.95	45.91
Irrigation	3	2478.05**	80.00**	1130.60*
Fertilizer	2	2079.05**	77.22**	991.44**
Interaction (IXF)	6	45.00	1.13	15.40
error	16	0.25	0.59	8.75

** Significant at 1 percent level
*Significant at 5 percent level

n) Anova table for water use efficiency

Source	Degrees of freedom	Mean square
Replication	2	27.21
Irrigation	3	61593.01**
Fertilizer	2	3548.34**
Interaction (IXF)	6	216.38
error	16	7.86

** Significant at 1 percent level
*Significant at 5 percent level

o) Anova table for available nitrogen in soil

Source	Degrees of freedom	Mean square			
		15 DAS	30 DAS	45 DAS	Harvest
Replication	2	19.14	21.66	12.32	2.56
Irrigation	3	18.03*	290.31*	2379.22**	4847.82**
Fertilizer	2	1808.75**	4570.70**	2060.84**	444.04**
Interaction (IXF)	6	7.76	14.19	111.29	99.93
error	16	2.25	13.06	3.60	4.49

** Significant at 1 percent level
*Significant at 5 percent level

p) Anova table for available phosphorus in soil

Source	Degrees of freedom	Mean square			
		15 DAS	30 DAS	45 DAS	Harvest
Replication	2	1.10	3.26	0.73	0.40
Irrigation	3	7.29*	5.68	45.01*	68.24**
Fertilizer	2	1098.25**	942.96**	254.56**	9.28*
Interaction (IXF)	6	1.13	1.49	1.22	1.68
error	16	0.47	0.70	0.51	0.53

** Significant at 1 percent level *Significant at 5 percent level

q) Anova table for available potassium in soil

Source	Degrees of freedom	Mean square			
		15 DAS	30 DAS	45 DAS	Harvest
Replication	2	2.23	3.63	0.26	2.48
Irrigation	3	8.36*	167.13*	736.91**	1374.96**
Fertilizer	2	214.92**	121.88**	125.97**	20.65*
Interaction (IXF)	6	1.91	7.70	7.75	17.00
error	16	0.51	2.07	0.82	2.09

** Significant at 1 percent level *Significant at 5 percent level

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)	7	3,000	21,000
2	2" PVC pipe	100 m	36	3,600
3	12 mm lateral	3350 m	3.96	13,266
4	4 mm extension tube	33333 m	1.65	54,999
5	Drippers (2 l hr^{-1})	33333 No.	4.5	1,49,998
6	Belt wash	180 No.	13	2,340
7	Pin connector	33333 No.	1.1	36,666
8	2" PVC end cap	2 No.	10	20
9	2" MTA	7 No.	9.75	68.25
10	2" FTA	7 No.	14.5	101.5
11	2" bend	7 No.	12	84
12	2" coupling	7 No.	9.5	66.5
13	2" valve	7 No.	350	2,450
14	Screen filters	7 No.	1,800	12,600
15	Installation cost		3,500	3,500
	Total	**3,00,759**		

b) Cost of cultivation

Sl no.	Particulars	Quantity	Unit cost (Rs)	Total cost (Rs)
1	Ploughing by tractor	3hr	400	1,200
2	Digging of corners and trimming of bunds	5 men	300	1,500
3	Pit/channel preparation	115 men	300	34,500
4	Transport + application of FYM	26 women	210	5,460
5	Incorporation of FYM and filling	44 men	300	13,200
6	Sowing of seeds	20 women	210	4,200
7	Pot watering up to10 DAS (5 times)	55 women	210	11,550
8	Basal fertilizer application + weeding	26 women	210	5,460
9	Thinning and gap filling	9 women	210	1,890
10	weeding	48 women	210	10,080
11	Top dressing of fertilizer	26 women	210	5,460
12	Raking and earthing up	45 women	210	9,450
13	Collection and spreading of coconut leaves	22 men	300	6,600
14	Imidacloprid spray (2 spray)	4 men	300	1,200
15	Harvesting and transportation	8 men	300	2,400
		27 women	210	5,670
	Total	**1,19,820**		

c) Labour cost for irrigation and cost of electricity

Sl no.	Treatments	Quantity	Unit cost (Rs)	Total cost (Rs)
1	I_1 (Drip irrigation @ 50% Ep)			
	- Labour cost	27 men	300	8,100
	- Electricity cost	108 units	2.90	313.2
			Total	**8,413**
2	I_2 (Drip irrigation @ 75% Ep)			
	- Labour cost	40 men	300	12,000
	- Electricity cost	162 units	2.90	469.8
			Total	**12,469**
3	I_3 (Drip irrigation @ 100% Ep)			
	- Labour cost	54 men	300	16,200
	- Electricity cost	216 units	2.90	626.4
		Total		**16,826**
4	I_4 Pot watering			
	- Labour cost	81 men	300	24,300
	- Electricity cost	156 units	2.90	452.4
		Total		**24752**

d) Cost of inputs per hectare

Sl no.	Input	Quantity	Unit cost (Rs)	Total cost (Rs)
1	Seed	1.67 kg	700	2505
2	FYM (t)	25	750	18500
3	Urea			
	- F_1	152 kg	6	912
	- F_2	228 kg	6	1,368
	- F_3	304 kg	6	1,824
4	MOP			
	- F_1	41.75 kg	17	710
	- F_2	62.63 kg	17	1,064
	- F_3	82.5 kg	17	1,420
5	SSP			
	- F_1	156	16	2,496
	- F_2	234	16	3,744
	- F_3	312	16	4,992
6	Imidacloprid	300 ml	Rs. 300 per 100ml	900
	Total		**-F1**	**26,027**
			-F2	**28,082**
			F3	**30,140**

Abstract

FERTIGATION IN ORIENTAL PICKLING MELON

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

UNDER HIGH DENSITY PLANTING

By

NINGARAJU, G. K.

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ABSTRACT OF THESIS

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ABSTRACT

A field experiment was conducted at the Agricultural Research Station, Mannuthy, Thrissur during December 2012 to February 2013 to study the effect of "Fertigation in oriental pickling melon (*Cucumis melo* var. *conomon* (L.) Makino) under high density planting" grown in summer rice fallows. Balanced growth, development and yield of oriental pickling melon demand adequate supply of water and nutrients. This research was aimed at increasing the yield and quality of oriental pickling melon by high density planting and fertigation. The crop was planted at a population of 33,333 plants per hectare.

The experiment was laid out in Randomised Block Design (RBD) with three replications. The treatments consisted of combinations of four irrigation levels (50, 75 and 100 % Ep through drip irrigation and farmers practice of pot irrigation) and three fertilizer levels (100, 150 and 200 % RDF). Hence totally it consisted combinations of 12 treatments.

Levels of irrigation significantly influenced the length of vines at harvest, number of leaves per vine, number of branches per vine and LAI. Drip irrigation with 100 per cent Ep recorded the highest values of these parameters. Fertilizer levels also significantly influenced these parameters and the highest values were recorded with 200 per cent RDF.

Interaction between irrigation and fertilizer level was significant on length of vine, number of leaves per vine, number of branches per vine, LAI and shoot dry matter production. In all the growth parameters, I_3F_3 (100 % Ep with 200 % RDF) recorded significantly the highest length of vine, number of leaves per vine, number of branches per vine, LAI and shoot dry matter production. So there was positive interaction up to 100 per cent Ep through drip irrigation and 200 per cent of fertilizer level. A very high level of irrigation through farmers practice did not respond favourably to increasing doses of fertilizers as under I_2 (75 % Ep) and I_3 (100 % Ep) in promoting the growth parameters of oriental pickling melon.

Number of fruits per plant was significantly influenced by the irrigation levels. Maximum number of fruits per plant was recorded at 100 per cent Ep given through drip irrigation and was significantly superior to all other irrigation levels. Fertilizer levels also significantly influenced number of fruits per plant. The highest number of fruits per plant was recorded with 200 per cent RDF.

The fruit characteristics like weight of fruit and volume of fruit were significantly influenced by the levels of irrigation. Maximum weight and volume of fruits were observed at 100 per cent Ep given through drip irrigation and was significantly superior to all other irrigation levels. Fertilizer levels also significantly influenced weight and volume of fruit. The highest average weight of fruit and volume were observed with 200 per cent RDF.

Levels of irrigation significantly influenced the fruit yield. Maximum fruit yield was recorded at the irrigation level of I_3 and was significantly superior to all other irrigation levels. Fertilizer levels also significantly influenced fruit yield.. Significantly the highest fruit yield was observed with F_3.

Interaction between irrigation and fertilizer level was significant on fruit yield. I_3F_3 recorded significantly the highest fruit yield. So there was positive interaction up to 100 per cent Ep through drip irrigation and 200 per cent of fertilizer level.

Uptake of nitrogen, phosphorus and potassium by the crop depended on the total dry matter production and their contents in fruit and shoot dry matter. In general, their uptake increased significantly up to I_3 (100 % Ep) and up to F_3 (200 % nutrient level). Since the increase in uptake of nutrients showed linear relationship, higher levels of drip irrigation with more than 100 per cent Ep and nutrient level above 200 per cent are to be tried under high density planting. A high level of irrigation through pot watering resulted in reduced uptake of nutrients.

The favourable interaction between nutrients and water is a well known fact. The study revealed that the favourable interaction between them took place only under an ideal moisture level supplemented by drip irrigation with 75 or 100 per cent Ep. Less than an optimum moisture supplementation by drip method with 50 per cent Ep or very high level of moisture supply by a flooding method like pot irrigation did not contribute to favourable interaction between irrigation and nutrients on nutrient uptake.

Field water use efficiency decreased significantly with increase in irrigation levels. From among the treatment combinations, 50 per cent Ep drip irrigation with 200 per cent RDF recorded significantly the highest field water use efficiency and the lowest by pot irrigation.

Levels of irrigation and fertilizer significantly influenced the available nitrogen, phosphorus and potassium in soil at different growth stages of the crop and after harvest. With increasing irrigation level, the nutrient content of soil was decreased at all the stages. Highest available nutrients at all the cropping period and at harvest were recorded with 200 per cent RDF.

Soil moisture content increased with increase in irrigation level from I_1 to I_4 in all the layers *viz.* 0-15, 15-30 and 30-60 cm at 15, 30 and 45 DAS. There was no appreciable change in soil chemical properties like pH and EC due to levels of irrigation or fertilizer doses. A slight increase in soil EC was observed with increase in fertilizer level at all the stages of observation.

Among the treatment combinations I_3F_3 recorded the highest net profit per hectare and was followed by I_3F_2. Maximum benefit cost ratio was also recorded by I_3F_3. Most profitable production of irrigated oriental pickling melon under high density planting during summer months was obtained by fertigation with daily drip irrigation at the rate of 100 percent Ep combined with 200 per cent of recommended fertilizer dose. Since the crop response to drip irrigation levels and fertilizer level was linear, it is necessary to further study the effect of fertigation level above 100 per cent Ep and fertilizer level above 200 per cent of recommended dose in oriental pickling melon.