STUDIES ON FERTIGATION IN BITTER GOURD (*Momordica charantia* L.)

by

ANJALI A HARI

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THESIS

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DECLARATION

I, hereby declare that this thesis entitled **"STUDIES ON FERTIGATION IN BITTER GOURD (*Momordica charantia* L.)"** 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.

Vellayani

Date: 30.07.2016

ANJALI A HARI

(2014-11-139)

CERTIFICATE

Certified that this thesis entitled **"STUDIES ON FERTIGATION IN BITTER GOURD (*Momordica charantia* L.)"** is a record of research work done independently by Ms. Anjali A Hari (2014-11-139) under my guidance and supervision and that it has not previously formed the basis for the award of any degree, diploma, fellowship or associateship to her.

30\7\2016

Vellayani
Date: 30|07|2016

Dr. L. Girija devi
(Major advisor, Advisory committee)
Professor (Agronomy)
College of Agriculture
Vellayani

CERTIFICATE

We, the undersigned members of the advisory committee of Ms. Anjali A Hari, a candidate for the degree of **Master of Science in Agriculture** with major in Agronomy, agree that the thesis entitled **"Studies on fertigation in bitter gourd (*Momordica charantia* L.)"** may be submitted by Ms. Anjali A Hari, in partial fulfilment of the requirement for the degree.

27/7/2016

Dr. L. Girija devi
(Major advisor, Advisory committee)
Professor (Agronomy)
Department of Agronomy
College of Agriculture, Vellayani

27/7/16

Dr. Ameeena, M.
(Member, Advisory committee)
Assistant Professor (Agronomy)
Department of Agronomy
College of Agriculture, Vellayani

27/7/16

Dr. Sheela, K. R
(Member, Advisory committee)
Professor and Head (Agronomy)
Department of Agronomy
College of Agriculture, Vellayani

27/7/16.

Dr. R. Gladis
(Member, Advisory committee)
Assistant Professor
Department of Soil Science & Ag. Chemistry
College of Agriculture, Vellayani

27/7/16

EXTERNAL EXAMINER
Dr. T. Ragavan
Professor (Agronomy)
Department of Agronomy
Agriculture College and Research Institute, Madurai

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Anjali A Hari

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LIST OF ABBREVIATIONS

@	At the rate of
^{0}C	Degree Celcius
^{0}Brix	Degree Brix
%	Per cent
₹ ha^{-1}	Rupees per hectare
B:C	Benefit : Cost
CD	Critical difference
cm	Centimeter
CPE	Cumulative pan evaporation
d S m^{-1}	Deci siemen per meter
DAS	Days after sowing
^{0}E	East
EC	Emulsifiable concentrate
et al.	Co-workers / co-authors
Fig.	Figure
FYM	Farmyard manure
g	Gram
g L^{-1}	Gram per litre
ha	Hectare
hr^{-1}	Per hour
i.e	That is
IW	Irrigation water
K	Potassium
K_2O	Potassium oxide
KAU	Kerala Agricultural University
kg	Kilogram
kg $plant^{-1}$	Kilogram per plant
kg ha^{-1}	Kilogram per hectare
kg $hamm^{-1}$	Kilogram per hectare millimeter

kPa	Kilopascal
m	Meter
mm	Millimetre
$mL\ L^{-1}$	Millilitre per litre
$mg\ 100\ g^{-1}$	Milligram per 100 gram
$mg\ g^{-1}$	Milligram per gram
N	Nitrogen
^{0}N	North
O	Oxygen
P	Phosphorus
P_2O_5	Phosphorus pentoxide
Pit^{-1}	Per pit
$Plant^{-1}$	Per plant
POP	Package of practices
SE_m	Standard Error of mean
t	Tonnes
$t\ ha^{-1}$	Tonnes per hectare
TSS	Total soluble solids
viz.	Namely
vs.	Versus
WP	Wettable powder
WUE	Water use efficiency

INTRODUCTION

1. INTRODUCTION

Bitter gourd (*Momordica charantia* L.) occupies a prominent position among the vegetables cultivated during the summer season in Kerala and the importance of this vegetable has long been accepted. Bitter gourd is called by different names since it grows in tropical regions such as India, Malaya, China, tropical Africa, Middle East, America (Kirtikar and Basu, 1993) and Thailand. The other names of this crop are balsam pear, bitter melon, bitter cucumber and African cucumber (Heiser, 1979).

Bitter gourd is mainly cultivated for its green edible fruits containing high nutritional and medicinal value. The green fruits can also be sliced and dried for use during off seasons. The fruits are rich source of vitamin C, phosphorus and iron (Wills *et al.*, 1984). The vegetable is a good source of ascorbic acid and fair source of protein, minerals, while poor source of sugar (Kalra *et al.*, 1988). The calorific value of bitter gourd is the highest among all other cucurbitaceous vegetables.

The main constituents of bitter gourd which are responsible for the antidiabetic effects are triterpene, protein, steroid, alkaloid, lipid, and phenolic compounds. The bitter principle in bitter gourd is cucurbitacin (tetracycline triterpenes), a bitter glucoside which prevents the spoilage of cooked vegetable and keeps it fit for consumption even for two to three days (Aykrod *et al.*, 1951). The bitter gourd roots, vines, leaves, flowers and seeds are also used in medicinal preparations (Morton, 1967). The juice of bitter gourd is consumed by diabetic patients due to its potent oxygen free radical scavenging activity (Sreejayan and Rao, 1991). The fruits, flowers and young shoots can be used for flavouring (Marr *et al.*, 2004).

Water and fertilizer are the two costly inputs in vegetable production. Water is, however the most limiting among them during summer season. The supply of water throughout the growth period is important especially during the critical periods like flowering and fruit development. It influences the availability and uptake of plant nutrients as well as growth and yield.

In vegetable cultivation, to economise the water and fertilizer application the best methods to be adopted are micro-irrigation and fertigation (Clothier *et al.*, 1985) and these help in lowering leaching losses of nutrients (Ristimaki, 1999). In India drip irrigation is more effective in utilisation of water (Pandey and Mahajan, 1999). Drip irrigation system when compared with other methods of irrigation have lower water consumption, a reduction in the incidence of diseases, higher yields and better quality of the produce (Hochmuth, 1994) and it also enhances the movement of nutrients like P and K in soil (Hebbar *et al.*, 2004).

Fertigation is used as one of the most effective and convenient method of supplying nutrient and water according to the specific requirements of the crop to maintain optimum soil fertility and better quality produce (Shirgure *et al.*, 2000). Drip fertigation plays a major role in summer season for irrigation and nutrient application as there is a shortage of irrigation water and high competition for available water resources. Through drip irrigation, water soluble fertilizers in small amounts are supplied frequently by exerting the soil buffer characteristic and by reducing the time interval between successive irrigations (Gao *et al.*, 2006; Zhao and Li, 2001).

Mulching and drip irrigation have been developed to enhance crop growth and improve water use efficiency (Elmstrom *et al.*, 1981). Polyethylene mulch has been used in vegetable production for enhancement of earliness in yield, weed control, reduction of nutrient loss by leaching, and providing favorable soil temperature and moisture regime (Bhella and Kwolek, 1984; Sweeney *et al.*, 1987; Bhella, 1988).

The full potential of any cultivar of a crop can be exploited only with judicious water and fertilizer management practices. Research works have already been undertaken to find out the quantity of nutrients and water required for efficient growth and production of bitter gourd. Since the cost of inputs mainly nutrients is increasing and water is becoming limited, new technologies like drip fertigation, site specific nutrient application and soil test based nutrient application etc. have to be developed for the efficient use of these resources for a précised farming situation. Hence to assess the profitability of precision farming for increasing the yield and improving the quality of bitter gourd an experiment was conducted with the following objectives:

- To standardize the fertigation schedule for precision farming in bitter gourd.
- To assess the impact of precision farming practices on growth and yield of the crop.
- To work out the economics.

REVIEW OF LITERATURE

2. REVIEW OF LITERATURE

Bitter gourd (*Momordica charantia* L.), member of cucurbitaceae family is one of the most nutritive and commercially important vegetable grown in South India. Improved performance of the crop in open field condition can provide high yield and profit to the bitter gourd growers. Drip fertigation is considered as an effective method for timely application of fertilizers to the root zone in order to increase yield and quality of crop. In Kerala research work on fertigation in bitter gourd is lacking and hence published works on this is limited. The available review on this crop is cited and wherever references are not sufficient, review on other crops are also included.

2.1 NUTRIENT MANAGEMENT

Nutrient management is the important component of scientific crop production. The availability of nutrients and interaction between the nutrients in soil play a vital role in crop growth and production. Hence soil nutrient management is gaining more attention in today's world.

The conventional broadcasting method of fertilizer application is widely practiced in vegetable cultivation. But conventional broadcasting method causes the fixation of nutrients and low fertilizer use efficiency. Also in conventional method of application the requirement of labour is more. But need based application of fertilizers helps to reduce the loss of nutrients and increases the nutrient use efficiency in the conventional methods of application (Greeff, 1975).

Fertigation is a recent innovative useful for vegetable production. In simple words, it is the application of fertilizers through irrigation water. Fertigation through drip irrigation helps in saving water soluble fertilizers due to its precise application and also increases the yield when compared to the conventional methods of fertilizer and water application. Moreover, it is spoon feeding of nutrients required by the plants. Fertigation supplies water soluble fertilizers through irrigation water at appropriate concentrations to the root zone of crops (Bar-Yosef and Sheikholslami, 1976; Papadopoulos, 1986). The benefit of fertigation is that it gives greater flexibility for time of fertilizer application according to the crop demand (Bresler, 1977) and reduces the fertlization losses, especially nitrogen by leaching and increases the fertilizer recovery (Miller *et al.*, 1981; Fiskell and Locascio, 1983).

Fertigation is an attractive technology in modern irrigated agriculture as it increases yield and quality together with improvement of water and fertilizer efficiency (Papadopoulos, 1992). Fertigation is mainly practiced for N than for P and P is applied to soil by conventional methods in drip irrigated fields (Bar-Yosef and Imas, 1995), as commonly used P fertilizers are slightly soluble in water causing precipitation with calcium and clogging of the irrigation system.

Hartz and Hochmuth (1996) reported that to increase the yield, minimize the fertilizer consumption and to reduce the unfavourable effects of environmental factors, the dosage and time of application of fertilizer has to be adjusted and this is possible through fertigation. Papadopoulos (1997) reported that through fertigation the soluble fertilizers are applied through irrigation water to meet the need of crops and this will help in optimizing the use of water and nutrients to the area where there is good root activity.

In conventional surface application, the utilization of P by the plants was poor (Blane *et al.*, 2000). But in fertigation the continuous application of P through irrigation water increases the uptake later in the season and can also improve mobility and availability of P by creating a favourable moisture condition in the soil. Use of acidic P fertilizers has been found to overcome this clogging in drip fertigation (Ristimäki and Papadopoulos, 2000) and thus P fertigation was reported to be better than conventional method by maintaining continuous high concentration of P in the soil solution (Papadopoulos, 2000).

Effective and uniform application of water soluble fertilizers and other chemicals can be done along with the irrigation water (Patel and Rajput, 2000; Narda and Chawla, 2002). According to many researchers, the fertilizer application through fertigation can save fertilizers up to 20 to 50 per cent and also improves the yield and quality than that of the common methods of fertilizer application (Vaezi *et al.*, 2003 and Asadi *et al.*, 2005).

The advantages of fertigation include improvement in fertilizer use efficiency, saving fertilizers, time and labour and it also includes the precise and uniform application of fertilizers directly to the root zone which will give higher yield and quality (Singandhupe *et al.*, 2003).

Mohammad (2004) reported that application of N through fertigation is more effective in increasing the squash yield than conventional soil application. A lower rate of N is adequate in fertigation to produce yield as high as that achieved through high rate of N applied through conventional soil application, thus fertigation lowers fertilization cost and minimizes the environmental impact. Hence fertigation as a sophisticated and efficient method of applying fertilizers in which the irrigation system is deployed as the carrier and distributer of plant nutrients which ensures accurate and uniform application of nutrients in the vicinity of active root zone (Singh *et al.*, 2005).

The nutrient use efficiency of drip fertigation is about 90 per cent compared to that of conventional methods where there is only 40-60 per cent nutrient use efficiency (Solaimalai *et al.*, 2005). For optimizing water and nutrient uptake, a properly laid drip fertigation is required that supplies water and nutrients at optimum rate, duration and frequency, minimizing the nutrient leaching from the root zone (Gardenas *et al.*, 2005). Drip fertigation is highly profitable as it saves input, labour and energy to about 54 per cent than that of conventional methods (Bhat and Sujatha, 2006).

2.1.1 Effect of Nutrient Management on Crop Growth with Special Reference to Cucurbits

The availability of nutrients and water, the interactions between nutrients and also between nutrients and water play a vital role in crop growth and production. Water and fertilizer are the two costly inputs in vegetable production. Water is, however the most limiting among them during summer season. It influences the availability and uptake of nutrients.

Thomas (1984) reported that bitter gourd responds to frequent irrigation and high levels of fertilizers. Siyag and Arora (1988) reported that application of 75 kg N ha^{-1} increased the length of main vine and 50 kg N ha^{-1} increased the branches at final harvest in sponge gourd. Application of nitrogen increases the vine length, number of leaves per plant and dry matter production in bitter gourd (Suresh and Pappiah, 1991). Samdyan *et al.* (1992) reported that the application of different nitrogen levels influenced the length of main vine and number of branches per plant in bitter gourd and maximum early fruit yield was recorded with the application of 50 kg N ha^{-1}.

Islam (1995) observed that application of N alone @ 240 kg ha^{-1} improved the vegetative growth of bitter gourd due to the increase in the number and length of vines, diameter of stem, length and diameter of leaves and the application of NPK significantly increased the number of fruits per plant, size and weight of fruits and the fruit yield compared to N application alone.

The significant effect of N and K fertilizer applications on the yield of cucumber variety Poung was reported by Phu (1997). The application of nitrogen and potassium at 100–100 kg ha^{-1} gave promising number of fruits, main stem length, branches and yield.

Satisha (1997) reported that through fertigation the nitrogen fertilizer required for vegetative growth, high amount of phosphorus fertilizer required in the early growth stage to encourage rooting and high potassium fertilizers for flowering and fruiting can be applied. Raman *et al.* (2000) reported that in gherkins the yield and quality can be improved by application of water soluble fertilizers through fertigation and 25 per cent of the fertilizer can be saved without affecting the yield.

The number of flowers per plant, number of female flowers per plant, days to first female flower appearance and node at which first female flower appeared were higher for bitter gourd crop at 100 per cent water soluble fertilizers in combination with micronutrients whereas the sex ratio was found to be least at 100 per cent water soluble fertilizers in combination with micronutrients (Meenakshi, 2002).

In bottle gourd *cv.* Arka Bahar, the nitrogen application gave significant increase in the vine length and number of branches per vine. The application of phosphorus also showed a good influence on vine length but for potassium at different levels there was no significant influence on vine length and number of branches per vine (Umamaheswarappa, 2003).

In an experiment conducted by Meenakshi and Vadivel (2003), to study the effect of different levels of fertigation at 100, 75 and 50 per cent with macro and micronutrients on growth and dry matter production of hybrid bitter gourd (cv. CoBgoH-1), it was found that 100 per cent macro and micronutrients in water soluble form showed progressive growth and also the highest leaf area, number of primary branches per plant, specific leaf weight and total dry matter production. Also the chlorophyll content showed significant difference with increased level of water soluble fertilizers. The chlorophyll content was the highest at 100 per cent macro and micronutrients in water soluble form and it was 2.309 and 2.427 mg g^{-1}. It increased upto 60 DAS and then decreased.

Reddy and Rao (2004) reported that in bitter gourd (*Momordica charantia*), application of higher levels of nitrogen and vermicompost application delayed flowering and the best treatment for increasing the yield was application of 13.8 t vermicompost and 34.18 kg N ha^{-1} (through urea).

The effect of nitrogen and potassium concentration in fertigation on growth and yield of cucumber was studied by Watcharasak and Thammasak (2005) and found that the highest leaf number, leaf area, fresh and dry weight of shoot and roots in cucumber was obtained with the application of 150 mg N L^{-1}.

Agba and Enya (2006) studied the response of cucumber (*Cucumis sativa* L.) to nitrogen and reported that application of nitrogen increased the growth and yield of cucumber. The vegetative growth attributes, *viz.,* vine length, leaves and number of braches plant^{-1} increased with successive increase in nitrogen rates (0, 80, 100, 120, 140, 160, 180 and 200 kg ha^{-1}).

The chlorophyll content of the leaf in green house grown fertigated cucumber was affected by nitrogen concentration (Guler *et al.*, 2006). In an experiment Ahmed *et al.* (2007) studied the effect of different levels of nitrogen on the growth and production of cucumber and found that maximum fruit length, fruit weight, vine length and yield of cucumber were achieved with increase in application of nitrogen.

The total dry matter accumulation and chlorophyll a, b and total chlorophyll in the leaves of bitter gourd was influenced by different levels of fertigation at different growth stages. The chlorophyll a, b and total chlorophyll content were the highest for 100 per cent macronutrient applied in combination with micronutrients and it increased up to 60 days and then decreased. It was also noticed that the chlorophyll content increases with increase in fertigation levels (Meenakshi *et al.*, 2008a).

2.1.2 Effect of Nutrient Management on Yield and Yield Attributes with Special Reference to Cucurbits

Parikh and Chandra (1970) observed that nitrogen application had effect on appearance of female flowers. The application of higher dose of nitrogen @ 120 kg ha^{-1} delayed the appearance of first female flower in cucumber. In water melon, the application of 1680 kg ha^{-1} NPK mixed fertilizer caused more female flower production (Brinen *et al.*, 1979).

Bhella and Wilcox (1985) reported that nitrogen application must be changed from 150 kg ha^{-1} N during the vegetative growth to 50 kg ha^{-1} N during the reproductive stage, without preplant N application in musk melon for attaining maximum yield. In musk melon the total fruit per plant was increased by 12 per cent in trickle injection of nitrogen compared to that of the broadcasting method of application with 45, 90, 135, or 180 kg N ha^{-1} applied either preplant broadcast incorporated or injected through the trickle system (De Buchananne and Taber, 1985).

In rockmelons under trickle irrigation with N and K at rates of 40, 80, 120 or 240 kg ha^{-1} and N:K ratios of 2:1 and 1:1 using urea and K_2SO_4 as sources, the yield obtained was higher for 1:1 (25.4 t ha^{-1} with N:K at 240:240 kg ha^{-1}) than with the 2:1 N:K ratio (Pryor and Kelly, 1987).

Das *et al.* (1987) reported that the increased level of P_2O_5 application increases the plant growth in pointed gourd. Lingaiah *et al.* (1988) reported that in coastal regions, the highest yield of bitter gourd was obtained at N: P_2O_5: K_2O at 80:30:20 kg ha^{-1}. In an experiment conducted by Satish *et al.* (1988) with N at 0, 25, 50 and 75 kg ha^{-1} and P at 0, 20, and 40 kg ha^{-1} to sponge gourd (*Lagenaria aegytiaca*) cv. Pusa Chikni, in which half of the N dose and all P were applied before sowing and the remaining N was used for top dressing in 2 equal doses at 25 and 50 days after sowing, the maximum number of fruits and the greatest weight per plant and total yields were achieved at 50 kg N+20 kg P ha^{-1}. The application of 25 kg N + 40 kg P ha^{-1} in the summer crop and 40 kg P ha^{-1} in the rainy season gave maximum fruit dry matter content.

In a study conducted by Ravikrishnan (1989), it was observed that application of 90 kg N ha^{-1}, 25 kg P_2O_5 ha^{-1} and 50 kg K_2O ha^{-1} (NK ratio 2:1) recorded the maximum yield and net returns from bitter gourd cv. VK-1(Priya). He also observed that an increase in potash level to 75 kg ha^{-1} increased the weight, girth and potassium content of fruits. He also reported that, the days to first male and female flower opening in bitter gourd increased with increase in the level of nitrogen application.

Arora and Satish (1989) studied the effect of N and P on growth and sex expressions in sponge gourd and reported that application of nitrogen and phosphorus increased the number of female flower production.

Manuca (1989) reported that the application of K_2O improves the vine growth, production of female flower and increases the fruit yield up to 10 to 40 per cent in cucumber. The application of nitrogen and potassium at 150: 100 kg ha^{-1} gave maximum number of staminate and pistillate flower.

In a field experiment with cucumbers, on a silty loam soil, in Lower Bavaria, Germany, the largest yield, 74 t ha^{-1}, was obtained with drip laterals under mulch and fertigation with NPK and the lowest, 65 t ha^{-1}, with overhead sprinkler irrigation and urea as a foliar fertilizer (Mosler *et al.,* 1998).

In a study conducted by Rekha (1999), it was revealed that the treatment which received 20 t ha^{-1} of FYM, 2.5 t ha^{-1} of poultry manure, 2.5 t ha^{-1} of fresh cowdung slurry drenching with NPK @ 70:25:50 kg ha^{-1} gave the highest productivity in bitter gourd with maximum fruit size. The treatment which received 20 t ha^{-1} of FYM as basal and 2.5 t ha^{-1} of poultry manure at vining stage and 2.5 t ha^{-1} cowdung slurry gave double the yield than that of the treatment which received 25 t ha^{-1} of FYM only.

The melon cv. Makdimon F_1 cultivated during winter-spring season under two different soil water tensions (35 kPa and 55 kPa) and four different nitrogen concentrations gave maximum yield at 98 mg N L^{-1} concentration under 35 kPa soil water tension and at 55 kPa, the maximum yield was recorded at 68 mg N L^{-1} (Dasgan *et al.*, 1999).

A basal application of ammonium sulphate was compared to potassium nitrate applied via fertigation at three N rates for cucumbers grown on an alluvial soil (pH 7.9). The largest amount of N given by fertigation gave the largest yield. Nitrate leaching losses were least from the nitrate fertigated treatment because N use efficiency was greater (75-97 per cent) than with ammonium sulphate (10 per cent efficiency) (Brito *et al.,* 1999).

In an experiment conducted by Pan *et al.* (1999) to compare the conventional irrigation and fertilization with drip fertigation in tomato, it was found that the fertigated tomatoes produced a red fruit yield of 72 t ha^{-1} while those under conventional irrigation and fertilization yielded only 44 t ha^{-1}. The number of fruits was also doubled by fertigation. Improved nutrient availability provided by fertigation was considered to be one of the important factors causing the increase in yield. In another experiment, fertigation increased tomato yield from 39 to 50 t ha^{-1} and improved fruit quality considerably compared to traditionally fertilized and sprinkler irrigated crops (Siviero and Sandei, 1999). In tomato, through broadcast application, the yield increased linearly up to 50 kg P ha^{-1}. But in fertigation it was 25 kg P ha^{-1} and 50 per cent of P was saved through fertigation due to increased fertilizer use efficiency (Carrijo and Hochmuth, 2000).

Increase in yield was noticed in liquid-fertilised cucumber plants than that from plants fertilized by broadcasting (Raman *et al.*, 2000; Choudhari and More, 2002; Güler and Ibrikci, 2002; Kaniszewski and Elkner, 2002). Raman *et al.* (2000) studied the effect of fertigation on yield and growth of gherkins at four fertigation treatments with different soluble fertilizer combinations at two levels (100 and 75 per cent NPK) and compared with the band application of recommended dose of solid fertilizers and found that the highest yield was in 75 per cent recommended dose of NPK through fertigation, saving 25 per cent of total recommended dose of fertilizer.

Rekha and Gopalakrishnan (2001) in their study revealed that bitter gourd (*Momordica charantia* L.) cv. Preethi yielded the best with respect to total yield, marketable yield and size of fruits for the treatment which received a basal application of 20 tonnes of dry cowdung, 2.5 tonnes of poultry manure, fortnightly drenching of 2.5 tonnes of cowdung and a fertilizer dose of 70:25:25 kg NPK ha^{-1}.

Guler *et al.* (2006) found that in fertigation continuous nitrogen is not required. The most suited fertigation was application of 200 mg N L^{-1} nitrogen concentration twice per week and it yielded 86.6 t ha^{-1}. The highest yield in drip fertigated green house grown cucumber was obtained at 200 mg N L^{-1}.

In an experiment conducted in pointed gourd (*Trichosanthes dioica*), it was found that fertigation with 100 per cent recommended dose at monthly interval produced a higher yield of 4.27 t ha^{-1} which was statistically on par with 75 per cent of recommended dose. It was also reported that there was 25 per cent savings of fertilizer when applied through drip system. Improved fertilizer use efficiency of nitrogen, phosphorus and potassium was noticed with the application of 50 per cent recommended dose of fertilizer and when the fertilizer dose was increased to 100 per cent recommended dose of fertilizer there was a reverse in the trend (Singandhupe *et al.*, 2007).

The application of N at levels 210 and 180 kg ha^{-1} in cucumber produced longer vines and average fruit length and weight as well as the yield $plot^{-1}$ was comparatively higher in these two N levels but not significantly different from those receiving 120 and 150 kg N ha^{-1} (Ahmed *et al.,* 2007).

In an experiment to assess the effect of nitrogen and potassium fertilization on fruit yield and quality of *Momordica charantia*, nitrogen as ammonium nitrate in three doses of 100, 200 and 300 kg $acre^{-1}$ and potassium as sulphate in graded doses of 50 and 100 kg $acre^{-1}$ were applied by side dressing. The fruit production increased by nitrogen alone in graded doses up to 200 kg of ammonium nitrate $acre^{-1}$, also all doses of potassium increased fruit production proportionally to doses. Use of the combined medium nitrogen dose and high potassium doses produced the highest number of fruits (El-Gengaihi *et al.*, 2007).

Meenakshi *et al.* (2008b) observed that the highest yield in bitter gourd was obtained when 100 per cent macro and micronutrients in water soluble fertilizer form was applied through fertigation than conventional method of fertilizer application. Jilani *et al.* (2009) reported that different levels of NPK had significant effect on fruits plant^{-1}, fruit length, fruit weight and fruit yield of cucumber. The application of NPK @ 100-50-50 kg ha^{-1} recorded the highest fruit number (35.5), fruit length (18.36 cm), fruit weight (150.69 g) and yield (60.02 t ha^{-1}).

In an experiment conducted by Spiżewski and Knaflewski (2009) for studying the effect of irrigation methods on the yield of pickling cucumber, using drip irrigation combined with fertigation, and sprinkler irrigation combined with broadcast fertilization for three years, it was reported that there was no difference in the yields obtained from drip and sprinkler irrigated plants on average except in one of the year the highest total and marketable yields were obtained from drip-irrigated and fertigated plants and significantly lower yields from sprinkler and broadcast fertilized plants.

In an experiment conducted in bitter gourd (hybrid RHRBG-3) for three years with four levels of N and two levels of P and K each, it was found that the fruit yield, number of branches and diameter of fruits were higher at 250:50:100 kg ha^{-1} NPK (Sanap *et al.*, 2010).

Imamsaheb *et al.* (2011) reported that drip fertigation helps in obtaining higher crop yield and ensures good soil and environmental health by optimizing water and nutrient application. Heidari and Mohammad (2012) revealed that there was significant effect on fruit yield in bitter gourd by both rate and time of nitrogen application. The nitrogen @ 225 kg ha^{-1} and time of nitrogen application as 1/3 at 3 and 4 leaves, 1/3 before flowering and 1/3 after fruit to start recorded the highest fruit yield.

The marketable yield of water melon was recorded higher for fertigation than the conventional soil application of fertilizers (Prabhakar *et al.*, 2013).

Among the fertigation treatments 70 per cent recommended dose of NPK (70:70:70 kg N: P_2O_5: K_2O ha^{-1}) using conventional fertilizers supplied through fertigation gave the highest marketable fruit yield and net income.

Drip fertigation with 100 per cent Ep (pan evaporation) combined with 200 per cent recommended dose of fertilizer gave high vegetative growth, maximum fruit weight, number, volume and yield in oriental pickling melon (Ningaraju, 2013). Different nitrogen fertigation frequencies on watermelon (*Citrullus lanatus*) culture was studied by Fernandes *et al.* (2014) and found that the highest yield of 80.69 t ha^{-1} was achieved with the treatment of 64 fertigations in a cycle. The fruit yield of cucumber was reported to be the highest for starter doses 7-14-7 and 7-28-7 kg N-P_2O_5-K_2O ha^{-1} combined with 125 per cent of recommended dose (Fleafel *et al.*, 2014).

Ughade and Mahadkar (2015) reported that fertigation levels had significant influence on yield and yield attributes of brinjal and 100 per cent recommended dose of fertilizer (RDF) through drip (water soluble fertilizer) recorded the highest number of fruits $plant^{-1}$, (27.02), mean fruit length (15.68 cm), mean fruit diameter (14.39 cm), mean fruit weight (82.34 g) and fruit weight $plant^{-1}$ (2238.8 g) over 80 per cent RDF through drip (water soluble fertilizer). Soil application of 100 per cent RDF in combination of surface irrigation with IW/CPE ratio of 1.0 recorded the lowest number of fruits per plant (21.5), average fruit length (13.7 cm), mean fruit diameter (12.7 cm), mean fruit weight (69.8 g) and fruit weight $plant^{-1}$ (1500.7 g).

An experiment to test the response of 'sugar baby' watermelon [*Citrullus lanatus* [Thumb]. Mansf.] to four levels of nitrogen, found the positive effect of nitrogen on days to flowering, sex expression ratio, number of fruits $plant^{-1}$, fruit weight, firmness and rind thickness. The number of fruits, fruit weight and fruit yield were recorded the highest in N applied @ 120 kg ha^{-1} followed by 80 kg ha^{-1}, while the lowest in absolute control (Maluki *et al.*, 2016).

2.1.3 Effect of Nutrient Management on Fruit Quality with Special Reference to Cucurbits

Maurya (1987) reported that vitamin C and protein content of fruits increased with increasing levels of nitrogen up to 80 kg ha^{-1} in cucumber (*Cucumis sativus* Linn.). Application of 90 kg N ha^{-1} recorded maximum protein content in snake gourd (Haris, 1989). In ridge gourd the highest ascorbic acid content was recorded in fruits with the application of 60 kg N ha^{-1} and the lowest was recorded with higher dose of nitrogen @ 90 kg ha^{-1} (Arora *et al.*, 1995).

The experiment conducted by Meenakshi *et al.* (2007) on hybrid bitter gourd revealed that the length, flesh thickness and girth of fruit increased from fruit set to maturity in all the levels of macro and micronutrient fertigation and maximum in the same was noticed at 100 per cent macro and micro nutrient fertigation except for fruit diameter, which showed maximum with 100 per cent macronutrient fertigation alone. The TSS, iron and vitamin C content were the highest at 100 per cent macronutrient in combination with micronutrient fertigation.

In a study to elucidate the effect of fertigation on quality of cucumber, it was revealed that the fertigation treatments with 100 per cent water soluble fertilizers applied in combination with calcium chloride spray improved most of the fruit quality traits, *viz.*, firmness, TSS, ascorbic acid, titrable acidity, shelf life and moisture content (Sumathi *et al.*, 2011).

In an experiment conducted in bitter gourd, it was noticed that when nitrogen levels were increased from 75 to 225 kg N ha^{-1}, the content of nitrogen, phosphorus and potassium in fruit increased. Nitrogen levels had a significant effect on calcium and manganese content at 225 kg N ha^{-1} (Heidari and Mohammad, 2012).

An experiment to study response of two watermelon cultivars to supplemental potassium application and fruit thinning revealed that by increasing the level of application of potassium, all watermelon fruit characters except mean fruit weight increased gradually and the highest potassium application level showed the highest values of fruit diameter, fruit length, TSS, N, P and K per cent (El-Bassiony *et al.*, 2012).

Maluki *et al.* (2016) studied the effect of nitrogen levels on quality of water melon and found that application of N @ 120 kg ha^{-1} resulted in the highest TSS content, thin fruit rinds and more firm fruits followed by 80 and 40 kg ha^{-1} respectively.

2.1.4 Effect of Nutrient Management on Nutrient Uptake with Special Reference to Cucurbits

Rilley and Barber (1971) reported that nitrogen can stimulate vegetative growth and can enhance uptake of nutrients such as P and K. Qawasmi *et al.* (1999) evaluated the response of bell pepper (*Capsicum annuum*) to nitrogen fertigation @ 0, 150, 250, and 350 N kg ha^{-1}. The study revealed that the maximum growth rate and rate of accumulation of dry matter in the fruits was occurred during the period of 90 to 150 days after planting. The application of higher levels of N increased the uptake of nitrogen by the plants and at the same time enhanced the uptake of potassium and phosphorus.

Mohammad (2000) reported that as the roots are concentrated on the top soil, nutrient uptake is enhanced by fertigation. Chaudhari and More (2002) reported that application of 150:90:90 kg NPK ha^{-1} through drip recorded the maximum uptake of nitrogen and potash in tropical gynoecious cucumber hybrid - Phule Prachi and also this dose showed the better uptake of N, P and K (136.59, 24.83 and 92.24 kg ha^{-1} respectively).

Nitrogen rates and fertigation frequency had direct effect on uptake of N by leaves and fruits in tomato. The uptake in tomato was increased by both N rates and shorter fertigation frequency (daily, 3 days and weekly). Dialy fertigation recorded significantly higher N uptake in the fruits than with biweekly fertigation. With increasing N rate and with more frequent fertigation, the total N uptake was increased and application of 215 kg N ha^{-1} recorded the highest total above ground N uptake (Badr and El-Yazied, 2007).

Meenakshi *et al.* (2008b) conducted a study in bitter gourd and revealed that macro and micronutrients in water soluble fertilizer form when applied at 100 per cent rate increased the nutrient content and uptake of N, P, K, and Fe than other fertigation levels.

Rajees (2013) conducted an experiment in oriental pickling melon variety 'Saubhagya' and observed that application of recommended dose of NPK upto 125 per cent recorded an increase in shoot N content. The uptake of N by the crop was found the highest in 125 per cent recommended dose of NPK. Application of 150 per cent recommended dose of NPK recorded the highest P content in the shoot, while fruit uptake was the highest at application of 125 percent recommended dose of NPK. Potassium uptake by shoot at harvest was recorded the highest in 125 per cent recommended dose of NPK.

The experiment conducted in oriental pickling melon by Ningaraju (2013) in Kerala Agricultural University revealed that the uptake of nutrients was depended on total dry matter production and their content in fruit and shoot dry matter and the uptake increased up to the application of 200 per cent recommended dose of fertilizer.

2.1.5 Effect of Nutrient Management on Water Use Efficiency

Under water-limited conditions, the primary determinant of yield is crop water use efficiency. The water use efficiency (WUE) of capsicum was recorded the highest at 100 per cent recommended dose of water soluble fertilizer through drip irrigation (Muralidhar, 1999). In an experiment conducted in eggplant (*Solanum melongena* L.), to elucidate the effects of different quantities of N and water applied through drip and furrow irrigation on water use efficiency, it was revealed that WUE as estimated from fruit yield per unit millimetre use of water increased with increasing N application. The WUE increased up to 120 kg N ha^{-1} in drip irrigation at levels of water 100 and 75 per cent and increased up to 150 kg N ha^{-1} in drip irrigation at levels of water 50 per cent. The highest values of WUE recorded for different quantities of water applied through drip and furrow irrigation methods were reversely proportional to the quantity of water applied through both the methods of irrigation (Aujla *et al.*, 2007).

The results of an experiment on irrigation water use efficiency (IWUE) in melon crop (*Cucumis melo* L. cv. Sancho) revealed that the different levels of N had a significant effect on IWUE and application of 85 and 112 kg N ha^{-1} recorded the best values. The N fertilization conditioned irrigation water use efficiency, but as the irrigation level increased its effect decreased. The highest IWUE was recorded in application of both the irrigation at 60 per cent ETc (crop evapotranspiration) and N applied at 93 kg N ha^{-1} (12.88 kg m^{-3}) and the lowest IWUE was recorded in the three N treatments (93, 243 and 393 kg N ha^{-1}) with the irrigation level of 140 per cent ETc (Cabello *et al.*, 2009).

In a study aimed to work out water use efficiency of cucumber as influenced by drip and surface irrigation method, it was reported that maximum water use efficiency of 10.9 t ha^{-1}mm was recorded in 80 per cent of recommended dose of water soluble fertilizer with a water saving of 65.9 per cent in drip irrigation system than conventional method of irrigation (Patwardahan, 2014).

2.1.6 Nutrient Management and Economics

The economic analysis of an experiment conducted by Meenakshi (2002) in bitter gourd revealed that fertigation with 100 per cent water soluble fertilizer along with micronutrients produced the highest benefit-cost ratio in kharif and rabi season of 2001 - 2002 (4.16 and 6.57) than the other levels of fertigation. At the same time, fertigation with 75 per cent water soluble fertilizer in combination with micronutrients recorded benefit-cost ratio of 4.03 and 6.33 with lower cost of production than other two higher levels of fertigation. Application of 100 per cent recommended NPK through drip fertigation system registered the highest benefit cost ratio in chilli (2.17) (Tumbare and Bhoite, 2002).

Irrigation at 80 per cent ET through drip with 80 per cent recommended NPK through fertigation recorded the highest B:C ratio and net income in hybrid cucumber (Gupta *et al.,* 2014). A combination of irrigation level at 0.3 pan evaporation and fertigation level at 80 per cent recommended dose through water soluble fertilizer gave the highest net income (₹ 44,580 ha^{-1}) and B:C ratio (1.94) in cucumber (Patwardhan, 2014).

MATERIALS AND METHODS

3. MATERIALS AND METHODS

The research project entitled "Studies on fertigation in bitter gourd (*Momordica charantia* L.)" was carried out in summer season of 2015. The details of experiment with special reference to the materials used and methods adopted during the course of investigation are presented below.

3.1 MATERIALS

3.1.1 Experimental Site

The experiment was carried out in farmer's field at Pirappancode, Thiruvananthapuram district situated at 8°39′0″ N latitude and 76°55′0″ E longitude at an altitude of 18 m above mean sea level.

3.1.2 Soil

The soil type of the experimental field is sandy clay loam. Soil is acidic in reaction with medium in available nitrogen, high in available phosphorus and low in available potassium. The data on the mechanical composition and chemical properties of the soil of the experimental site are presented in Table 1a and 1b.

3.1.3 Cropping History

The experimental field was under a bulk crop of Nendran during the previous cropping season.

3.1.4 Season

The field experiment was conducted during the summer season of 2015 from March to June.

3.1.5 Weather Conditions

Data on weather parameters like maximum and minimum temperature, relative humidity, sunshine hours, rainfall and evaporation during the crop period

Table 1a. Mechanical composition of soil

Particulars	Value	Method used
Mechanical composition (%)		
Sand	45.44	Bouyoucos hydrometer method (Bouyoucos, 1962)
Silt	26.66	
Clay	27.90	

Table 1b. Chemical properties of soil of experimental field before the experiment

Particulars	Value	Rating	Method used
Soil reaction (pH)	5.40	Strongly acidic	pH meter with glass electrode (Jackson, 1973)
Electrical conductivity (d S m^{-1})	0.17	Normal	Conductivity meter (Jackson, 1958)
Organic C (%)	1.77	High	Chromic acid wet digestion method (Walkley and Black 1934)
Available N (kg ha^{-1})	351.23	Medium	Alkaline Permanganate method (Subbiah and Asija, 1956)
Available P (kg ha^{-1})	97.78	High	Bray's colorimetric method (Jackson, 1973)
Available K (kg ha^{-1})	106.62	Low	Ammonium acetate method (Jackson, 1973)

are shown in Fig. 1 and Appendix I.

The mean maximum and minimum temperature ranged between 30.4^{0}C to 33.2^{0}C and 23.3^{0}C to 26.1^{0}C respectively. The mean relative humidity ranged from 77.5 to 91.6 per cent. The mean sunshine hours ranged from 6.5 to 9.9 hours. A total rainfall of 197.3 mm was recorded during cropping period. The maximum evaporation recorded was 4.9 mm.

3.1.6 Variety

The bitter gourd variety 'Preethi' (MC 84) released from College of Horticulture, Vellanikkara, Kerala Agricultural University (KAU) was used for the experiment. The variety bears white fruits which are spiny, medium long with average fruit length of 30 cm, average weight of 310 g and average yield of 20 t ha^{-1}. The duration of the variety is 4-5 months (Appendix II).

3.1.7 Source of Seed Material

The seed material of variety 'Preethi' was obtained from Department of Olericulture, College of Agriculture, Vellayani.

3.1.8 Manures and Fertilizers

FYM (0.70 per cent N, 0.31 per cent P_2O_5, and 0.5 per cent K_2O) was used as organic source. Urea (46 per cent N), Rajphos (20 per cent P_2O_5) and Muriate of potash (60 per cent K_2O) were the inorganic sources. In control 1, water soluble fertilizers, *viz.*, Urea, 19:19:19, 13:0:45 and 12:61:0 were used to supply the major nutrients required for the crop through fertigation.

3.2 METHODS

3.2.1 Design and Layout

The field experiment was laid out in split plot design. The layout of the experiment is shown in Fig. 2. The details of field experiment are given below.

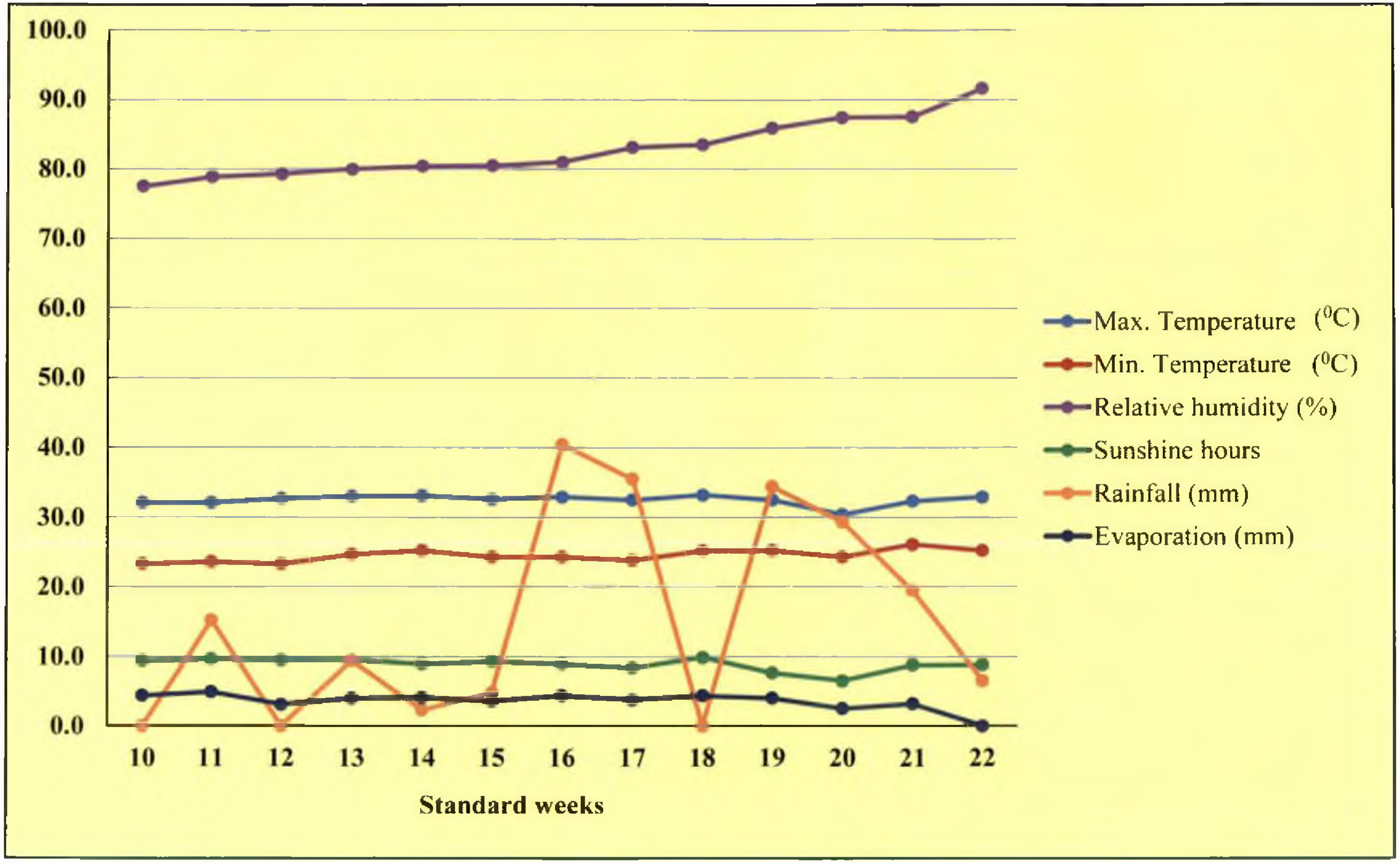

Fig. 1. Weather parameters during the cropping period (March 2015 – June 2015)

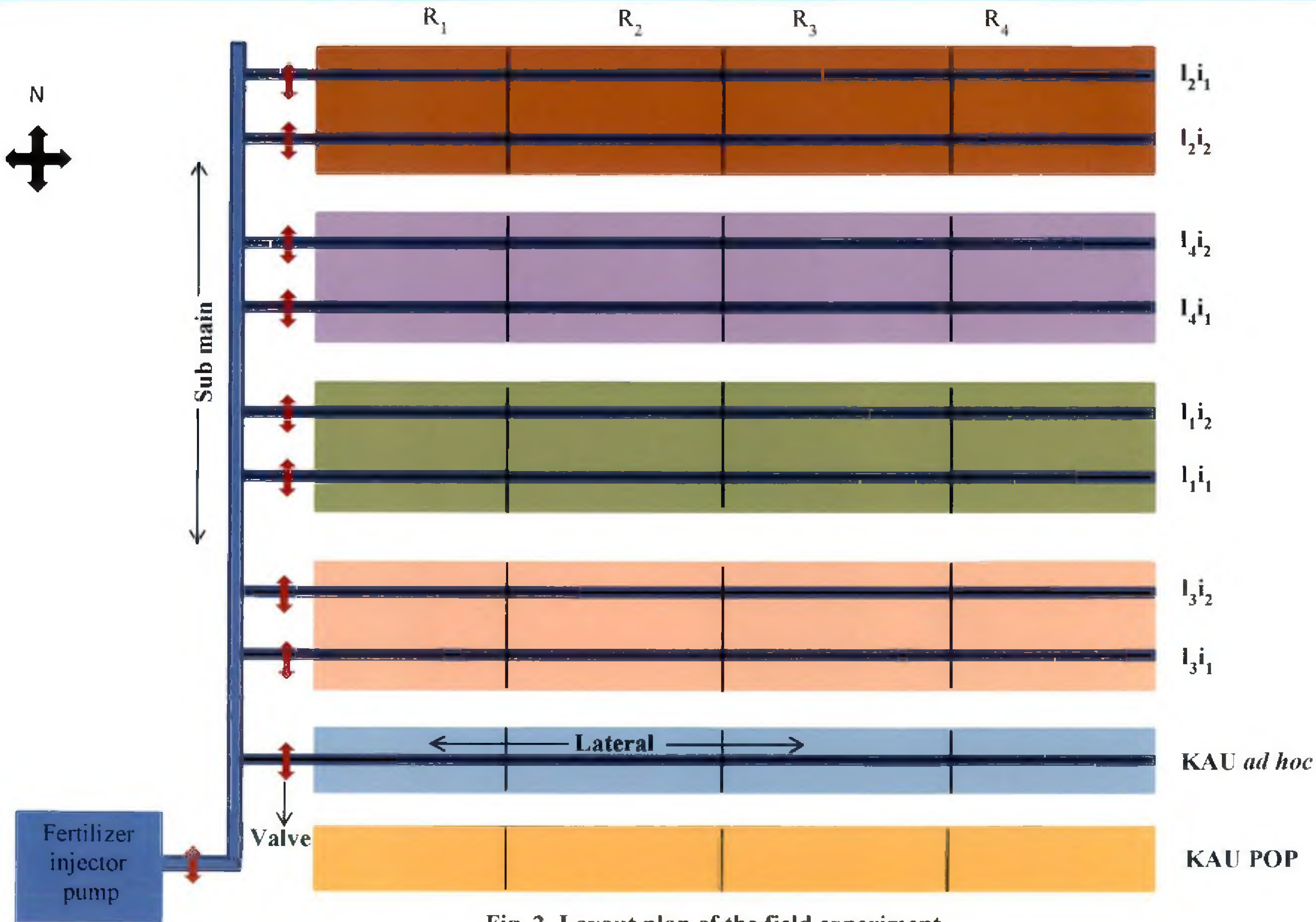

Fig. 2. Layout plan of the field experiment

Design : Split plot

Replication : 4

Treatment : 4 main plot treatments, 2 sub plot treatments and 2 controls

Sub plot size : 4 m × 2 m

Spacing : 2 m × 2 m

3.2.2 Treatments

3.2.1.1 Main Plot Treatments

Levels of nutrients or Fertigation levels (l)

l_1 – 75 per cent recommended dose of N and K
l_2 – 100 per cent recommended dose of N and K
l_3 – 150 per cent recommended dose of N and K
l_4 – 200 per cent recommended dose of N and K

(The KAU POP recommended dose for bitter gourd is 70:25:25 kg N, P_2O_5 and K_2O ha^{-1}. Based on initial soil nutrient status, suitable modifications were made and the modified recommendation used was 70:20:32 kg N, P_2O_5 and K_2O ha^{-1}).

3.2.1.2 Sub Plot Treatments

Fertigation intervals (i)

i_1 – Fertigation at 4 days interval
i_2 – Fertigation at 8 days interval

3.2.1.3 Control (2)

Control 1: KAU *ad hoc* recommendation for precision farming.

Control 2: KAU POP recommendation (Normal planting in shallow raised bed with basin irrigation and soil application of fertilizers without mulching).

Treatment combinations- 8+2= 10

l_1i_1 l_2i_1 l_3i_1 l_4i_1

l_1i_2 l_2i_2 l_3i_2 l_4i_2

control 1 control 2

The fertilizer schedule of treatments and controls are given in Table 2a and 2b.

3.3 CULTURAL OPERATIONS

3.3.1 Land Preparation

The experimental field was ploughed using cultivator attached to tractor. Plots were laid out as per the layout plan and pits were taken. Deep ploughing at a depth of 50 cm, preparation of raised beds, polythene mulching and laying of drip irrigation system were followed uniformly for all treatments except control 2. A buffer strip of 50 cm width was given around each main plot to account seepage loss of water.

3.3.2 Application of Manures and Fertilizers

Organic manure @ 25 t ha^{-1} and lime @ 350 kg ha^{-1} were applied uniformly and thoroughly incorporated. Based on the initial soil status, P_2O_5 @ 20 kg ha^{-1} was applied uniformly as basal dose to all treatments except control 1. For control 1, P_2O_5 @ 37 kg ha^{-1} was given as basal dose. Urea and Muriate of Potash were the sources for fertigation treatments except for control 1. Fertigation was done using injector pump. In control 2, half nitrogen and entire dose of phosphorus and potassium were applied as basal dose. The remaining 50 per cent nitrogen was applied in 3 splits at fortnightly intervals.

3.3.3 Sowing

Overnight soaking of seeds in water was done and three seeds per pit was sown uniformly at a spacing of 2 x 2 m.

Table 2a. Fertilizer schedule of drip fertigation treatments

Fertigation levels	Quantity of fertilizers				Quantity of fertilizers in kg ha^{-1} $application^{-1}$			
					Fertigation at 4 days interval		Fertigation at 8 days interval	
	Urea (g pit^{-1})	MOP (g pit^{-1})	Urea (kg ha^{-1})	MOP (kg ha^{-1})	Urea	MOP	Urea	MOP
l_1	45.65	16.00	114.13	40.00	4.08	1.43	8.15	2.86
l_2	60.87	21.33	152.17	53.30	5.43	1.90	10.87	3.81
l_3	91.30	32.00	190.21	80.00	6.79	2.86	13.59	5.71
l_4	121.74	42.67	228.26	106.60	8.15	3.81	16.30	7.61

*Quantity of fertilizers must be reduced for initial 4-5 applications

Table 2b. Fertilizer schedule of KAU *ad hoc* recommendation for precision farming

Fertilizers	1-6th application (g pit^{-1})	7-18th application (g pit^{-1})	19-40th application (g pit^{-1})	Total quantity of fertilizers (g pit^{-1})
19:19:19	1.96	0.96	0.96	44.40
13:0:45	0.332	4.60	4.60	158.39
Urea	3.36	1.88	3.80	126.32
12:61:0	0.00	0.304	0.304	10.34
NPK ratio – 220.94 : 73.85 : 199.28 kg ha^{-1} Rajphos -74 g pit^{-1}				

Plate 1. Drip layout

Plate 2. Mulching

Plate 3. Early crop growth stage

Plate 4. Field view at crop growth stage

3.3.4 After Cultivation Practices

The seedlings were thinned to two per pit and gap filling was done. Three weedings and soil rakings were given at 15, 35 and 50 days after sowing (DAS) for control 2. Trellis was established with bamboo, casuarina poles and plastic nets and plants were trailed on this.

3.3.5 Irrigation

All the treatments except control 2 were irrigated by drip irrigation. Daily irrigation was practised and the quantity of water applied was calculated based on growth stage of crop. Online drippers (1 dripper pit^{-1}) with a discharge rate of 4 L hr^{-1} were used. The fertilizers were applied along with irrigation water at specified intervals for all the fertigation treatments and control 1, and in control 2 daily hose watering was practiced.

3.3.6 Plant Protection

The pest and disease occurrence were under control by appropriate spraying of plant protection chemicals. Red pumpkin beetles were seen at the initial stage of crop growth and quinalphos (ekalux 25 EC) @ 1.5 mL L^{-1} was sprayed to control them. Carbendazim + mancozeb 75 WP (Saaf) @ 2 g L^{-1} was used as a protective measure against wilt during the early stage of crop. Cue lure pheromone traps and banana traps were hung at the time of flowering to manage fruit fly attack. Mosaic was also observed during early stages but it was not severe and was brought under control by uprooting the infected ones and application of dimethoate @1.5 mL L^{-1} to control white flies.

3.3.7 Harvesting

Fruits were harvested as and when they mature for vegetable purpose and the maturity was judged visually. Harvesting started at 52 DAS.

3.4 OBSERVATIONS

The observations were taken from randomly selected six plants (3 pits) per plot and the average worked out for understanding the effects of treatments on growth and yield.

3.4.1 Growth and Growth Attributes

3.4.1.1 Length of Vine

The length of vine at 20 and 35 DAS was measured from the sample plants from the base to the tip of the youngest leaf using a meter scale, average was worked out and expressed in m.

3.4.1.2 Number of Leaves Plant^{-1}

The number of leaves plant^{-1} at 20 and 35 DAS were observed and counted from the base to the tip of the main vine and average was worked out.

3.4.1.3 Leaf Area Index

Leaf area index at 55 DAS was calculated. The area of six leaves representing three parts of the plant such as base, middle and top was measured using graph paper method and leaf area index was calculated by dividing the total leaf area by the land area occupied by the plant (Watson, 1947).

3.4.1.4 Days to First Male Flower Appearance

The number of days taken by 50 per cent plants for first male flower opening was noted from the date of sowing.

3.4.1.5 Days to First Female Flower Appearance

The number of days taken by 50 per cent plants for first female flower opening was noted from the date of sowing.

3.4.2 Yield and Yield Attributes

3.4.2.1 Fruit Length and Girth at all Harvest

The length and girth of fruits of observational plants were recorded by

Plate 5. Crop at trailing stage

Plate 6. Crop at flowering and fruiting

selecting fruits at random at each harvest. The length was measured from pedicel attachment of fruit to the apex and girth of fruit was measured at centre. The measurement was done using twine and scale and average was worked out and expressed in cm.

3.4.2.2 Fruit Weight at all Harvest

The weight of fruits used for recording fruit length and girth at each harvest was taken at all harvests and mean weight noted in g.

3.4.2.3 Number of Fruits Plant^{-1} at all Harvest

The number of fruits harvested from observational plants at all harvest was recorded and total noted.

3.4.2.4 Yield of Fruits

The total weight of fruits harvested from observational plants at all harvest was recorded and the yield was expressed in kg plant^{-1}and t ha^{-1}.

3.4.2.5 Dry Matter Yield

Dry matter yield was recorded during two growth stages, *viz.,* 55 DAS and at final harvest. One plant from each plot was randomly selected for the purpose at each stage. The plants for measuring dry matter yield were uprooted, dried under shade and then oven dried at 80 ± 5^0 C to constant weight. The dry weight of fruits already harvested from vines prior to the stage of observation was added to the above dry weight to get total dry matter yield and was expressed in g plant^{-1}.

3.4.2.6 Days to First Harvest

The days from sowing to first fruit harvest was noted from each observational plants.

3.4.2.7 Days to Consequent Harvest

The number of days between consecutive fruit harvest was noted from each observational plants.

3.4.2.8 Days to Final Harvest

The number of days from sowing to final fruit harvest was noted from each observational plants.

3.4.2.9 Number of Harvests

The total number of harvest from each observational plants was noted.

3.4.3 Quality Attributes

3.4.3.1 TSS (Total Soluble Solids)

The total soluble solids (TSS) of fruit was determined using a pocket refractometer and concentration was expressed in ^{0} Brix (Ranganna, 1977).

3.4.3.2 Protein

The total nitrogen content of fruit was estimated by modified microkjeldahl method as given by Jackson (1973) and percentage of protein in the fruit was calculated by multiplying nitrogen content with the factor 6.25 (Simpson *et al.*, 1965).

3.4.3.3 Ascorbic Acid

The ascorbic acid content of green fruit was estimated by 2,6-dichlorophenol indophenol dye method (Sadasivam and Manickam, 1996) and was expressed in mg 100 g^{-1} of fresh green fruit.

3.4.3.4 Phosphorus

The fruit phosphorus content was determined by vanado-molybdo phosphoric yellow colour method using spectrophotometer (Jackson, 1973) and

Plate 7. Crop at harvest

Plate 8. General view of field

expressed in per cent.

3.4.3.5 Potassium

The potassium content of fruit was determined by using a flame photometer (Jackson, 1973) and expressed in per cent.

3.4.3.6 Iron Content

The iron content in fruit was estimated by atomic absorption spectrophotometer after digestion of samples using di-acid mixture given by Perkin – Elmer Corporation (1982) and expressed in per cent.

3.4.4. Moisture Studies

3.4.4.1 Water Use Efficiency

Water use efficiency was calculated using the following formula and expressed in kg ha mm^{-1}.

$$\text{Water use efficiency (WUE)} = \frac{\text{Economic yield (kg ha}^{-1}\text{)}}{\text{Total water requirement (mm)}}$$

The total water requirement is estimated directly by adding the quantity of water required for irrigation with effective rainfall and soil moisture contribution. As soil moisture contribution was insignificant, it was not considered. Effective rainfall was taken as 70 per cent of total seasonal rainfall (Dastane, 1974). Thus total water requirement was calculated by adding irrigation requirement and effective rainfall.

3.4.4.2 Water Productivity

Water productivity was estimated by the formula suggested by Kijne *et al.* (2003) and expressed in kg ha mm^{-1}.

$$\text{Water productivity (WP)} = \frac{\text{Total biomass (kg ha}^{-1}\text{)}}{\text{Total water requirement (mm)}}$$

3.4.5 Pest and Disease Incidence

Observations on major pest and disease incidence was noted and suitable control measures were adopted.

3.4.6 Chemical Analysis

3.4.6.1 Chlorophyll Content at Flowering

The total chlorophyll content was estimated from fresh fully opened 3rd leaf and middle leaf at the time of flowering by Dimethyl sulphoxide (DMSO) method (Yoshida *et al.*, 1976) and chlorophyll content in the leaf extract was read in spectrophotometer. The mean value of reading from 3rd leaf and middle leaf was taken and expressed in mg g^{-1} of fresh leaf weight.

3.4.6.2 NPK Uptake by Crop at Harvest

The sample plants and fruits collected from each plot at harvest stage were sun dried, oven dried to constant weight at a temperature of 80 ± 5^0 C, ground and passed through a 0.5 mm sieve. The required quantity of sample was weighed out accurately in an electronic balance and was subjected to acid extraction before carrying out the chemical analysis. The nitrogen content in plants and fruits were estimated by modified micro kjeldhal method (Jackson, 1973). The plant phosphorus content was determined by Vanado-molybdo phosphoric yellow colour method using spectrophotometer (Jackson, 1973). The potassium content was determined by flame photometry method (Jackson, 1973).

The total uptake of nitrogen, phosphorus and potassium by crop was calculated by adding the product of content of these nutrients in plant samples and respective plant dry weight, to product of the nutrient content of fruit sample and total fruit dry weights and expressed in kg ha^{-1}.

3.4.6.3 Soil Nutrient Status before and after the Experiment

The composite soil sample taken from the field before the experiment and soil samples taken after the experiment were air dried. The air dried samples were passed through a 2 mm sieve and were used for the analysis of physio-chemical properties. The available nitrogen, phosphorus and potassium content of soil was estimated before and after the experiment. The available nitrogen content was estimated using alkaline permanganate method (Subbiah and Asija, 1956) and expressed in kg ha^{-1}. The available phosphorus content was determined by Dickman and Bray's molybdenum blue method with Bray No.1 reagent as extractant (Jackson, 1973) and expressed in kg ha^{-1}. The available potassium content of soil was determined by neutral normal ammonium acetate extract using Flame photometer (Jackson, 1973) and expressed in kg ha^{-1}.

3.4.6.4 Organic Carbon

The soil organic carbon content was estimated before and after the experiment using Walkley and Black's rapid titration method (Jackson, 1973) and expressed in per cent.

3.4.6.5 Soil pH

The soil pH was estimated before and after the experiment using pH meter (Jackson, 1958).

3.4.7 Economic Analysis

The economics of production was worked out based on cost of cultivation (input costs and labour charges) and the prevailing market price of the fruits of bitter gourd at the time of harvest.

3.4.7.1 Net Income

Net income was computed using the formula

Net income (₹ ha^{-1}) = Gross income - Total expenditure or cost

3.4.7.2 Benefit Cost Ratio (B:C ratio)

$$\text{BCR} = \frac{\text{Gross income (₹ ha}^{-1}\text{)}}{\text{Total expenditure or cost (₹ ha}^{-1}\text{)}}$$

3.4.8 Statistical Analysis

The data obtained from field experiment relating to different characters were subjected to statistical analysis by applying the technique of analysis of variance (ANOVA) for split plot design and the significance was tested by F test (Snedecor and Cohran, 1975). In cases where F values were found significant, critical differences (CD) were calculated. The results and discussions were based on level of significance.

RESULTS

4. RESULTS

A field experiment was conducted in farmer's field at Pirappancode, Thiruvananthapuram district during March 2015 to June 2015 to standardize the fertigation schedule for precision farming in bitter gourd (*Momordica charantia* L.), to assess the impact of precision farming practices on growth and yield and also to work out the economics. The results of the experiment are presented below with main as well as interaction effect along with the effect of two controls.

4.1 GROWTH AND GROWTH ATTRIBUTES

4.1.1 Length of Vine

The data on effect of four fertigation levels (l) (l_1- 75 per cent recommended dose (RD) of N and K, l_2- 100 per cent RD of N and K, l_3- 150 per cent RD of N and K and l_4- 200 per cent RD of N and K), two fertigation intervals (i) (i_1- 4 days and i_2- 8 days) and interactions (l x i) on length of vine at 20 and 35 DAS along with the effect of two controls (control 1- KAU *ad hoc* recommendation for precision farming and control 2- KAU POP recommendation) are presented in Table 3.

The fertigation levels (l) did not influence the vine length at 20 and 35 DAS.

The fertigation intervals (i) had significant influence on vine length, with fertigation at 4 days interval (i_1) producing the longest vines at 20 and 35 DAS (69.74 and 187.76 cm respectively) when compared to fertigation at 8 days interval (i_2) (60.33 and 174.09 cm respectively).

None of the interactions (l x i) were significant.

The comparison between the two controls revealed that there was significant difference between the two controls, with control 1 producing the longest vines at both the stages (60.17 and 187.30 cm respectively) and between the controls and fertigation treatments, though control 1 did not differ significantly from fertigation treatments, control 2 differed significantly at both the stages.

4.1.2 Number of Leaves Plant^{-1}

The data on effect of four fertigation levels (l), two fertigation intervals (i) and interactions (l x i) on number of leaves plant^{-1} at 20 and 35 DAS along with the effect of two controls are presented in Table 4.

The fertigation levels (l) had no significant influence on number of leaves plant^{-1} at 20 DAS but had significant influence at 35 DAS, with l_2 producing more leaves (32.53) which was on par with l_3 (32.18) and l_4 (32.20), and l_1, the less (29.97).

The fertigation intervals (i) had significant influence at 20 DAS, with i_1 producing more leaves (17.93) than i_2 (16.09).

The interactions (l x i) were significant, with l_3i_1 producing more leaves at 20 DAS (18.06), which was on par with l_1i_1, l_2i_1, l_4i_1 and l_4i_2, while l_2i_2, the less (14.41). At 35 DAS, l_2i_1 produced more leaves (33.85) and was on par with all others except l_1i_1, which recorded the lowest (27.54).

The comparison between the two controls revealed that there was significant difference between the controls at 35 DAS, with control 1 producing more leaves (33.36), and between the controls and fertigation treatments, both the controls were significantly inferior to fertigation treatments at 20 DAS (13.92, 14.22 and 17.01 respectively), while at 35 DAS, only control 2 was significantly inferior (28.26 and 31.72 respectively).

4.1.3 Leaf Area Index (LAI)

The data on effect of four fertigation levels (l), two fertigation intervals (i) and interactions (l x i) on leaf area index (LAI) at 55 DAS along with the effect of two controls are presented in Table 5.

Table 3. Effect of fertigation levels, fertigation intervals and interactions on length of vine, cm

Treatments	Length of vine	
	20 DAS	35 DAS
Fertigation levels (l)		
l_1	63.44	170.91
l_2	64.14	182.67
l_3	65.50	183.42
l_4	67.07	186.70
SEm (±)	2.431	4.159
CD (0.05)	NS	NS
Fertigation intervals (i)		
i_1	69.74	187.76
i_2	60.33	174.09
SEm (±)	1.120	3.864
CD (0.05)	3.452	11.907
Interaction (l x i)		
l_1i_1	67.43	185.17
l_1i_2	59.45	156.64
l_2i_1	68.52	187.84
l_2i_2	59.76	177.50
l_3i_1	70.83	188.81
l_3i_2	60.16	178.03
l_4i_1	72.17	189.23
l_4i_2	61.96	184.17
SEm (±)	2.241	7.728
CD (0.05)	NS	NS
Treatment mean	65.04	180.92
Control 1 mean	60.17	187.30
Control 2 mean	40.14	121.83
Control 1 vs. Control 2	S	S
Control 1 vs. Treatment	NS	NS
Control 2 vs. Treatment	S	S

S: Significant at 5% level NS: Not significant at 5% level

Table 4. Effect of fertigation levels, fertigation intervals and interactions on number of leaves

Treatments	Number of leaves	
	20 DAS	35 DAS
Fertigation levels (l)		
l_1	17.02	29.97
l_2	16.15	32.53
l_3	17.12	32.18
l_4	17.75	32.20
SEm (±)	0.364	0.565
CD (0.05)	NS	1.807
Fertigation intervals (i)		
i_1	17.93	31.50
i_2	16.09	31.93
SEm (±)	0.239	0.586
CD (0.05)	0.738	NS
Interaction (l x i)		
l_1i_1	17.87	27.54
l_1i_2	16.17	32.39
l_2i_1	17.89	33.85
l_2i_2	14.41	31.21
l_3i_1	18.06	32.23
l_3i_2	16.18	32.12
l_4i_1	17.90	32.38
l_4i_2	17.59	32.01
SEm (±)	0.479	1.172
CD (0.05)	1.477	3.614
Treatment mean	17.01	31.72
Control 1 mean	13.92	33.36
Control 2 mean	14.22	28.26
Control 1 vs. Control 2	NS	S
Control 1 vs. Treatment	S	NS
Control 2 vs. Treatment	S	S

S: Significant at 5% level NS: Not significant at 5% level

Table 5. Effect of fertigation levels, fertigation intervals and interactions on LAI

Treatments	LAI (55 DAS)
Fertigation levels (l)	
l_1	0.56
l_2	1.12
l_3	1.55
l_4	1.00
SEm (±)	0.067
CD (0.05)	0.213
Fertigation interval (i)	
i_1	1.06
i_2	1.05
SEm (±)	0.053
CD (0.05)	NS
Interaction (l x i)	
l_1i_1	0.54
l_1i_2	0.57
l_2i_1	1.19
l_2i_2	1.04
l_3i_1	1.56
l_3i_2	1.53
l_4i_1	0.95
l_4i_2	1.04
SEm (±)	0.106
CD (0.05)	NS
Treatment mean	1.05
Control 1 mean	1.20
Control 2 mean	0.42
Control 1 vs. Control 2	S
Control 1 vs. Treatment	NS
Control 2 vs. Treatment	S

S: Significant at 5% level NS: Not significant at 5% level

The fertigation levels (l) significantly influenced LAI, with l_3 recording the highest LAI (1.55), followed by l_2 (1.12), and l_2 was on par with l_4 (1.00), and l_1, the lowest (0.56).

The fertigation intervals (i) and the interactions (l x i) were not significant.

The comparison between the two controls revealed that there was significant difference between the controls, with control 1 producing the highest LAI (1.20), and between the controls and fertigation treatments, though control 1 did not differ significantly from fertigation treatments, control 2 differed significantly (0.42 and 1.05 respectively).

4.1.4 Days to First Male and Female Flower Appearance

The data on effect of four fertigation levels (l), two fertigation intervals (i) and interactions (l x i) on days to first male and female flower appearance along with the effect of two controls are presented in Table 6.

The fertigation levels (l) significantly influenced the date of female flower appearance, with l_1, the earliest (43.13 days) which was on par with l_2 (44.71days), and l_4, the late (48.70 days) which was on par with l_3 (47.95 days).

The fertigation intervals (i) and the interactions (l x i) were not significant.

The comparison between the two controls revealed that the female flower appearance was early in control 2 (42.27 days) and late in control 1 (46.71 days), and between the controls and fertigation treatments, though control 1 did not differ significantly from fertigation treatments, control 2 differed significantly (42.27 and 46.12 days respectively).

4.2 YIELD AND YIELD ATTRIBUTES

4.2.1 Fruit Length and Girth at all Harvest

The data on effect of four fertigation levels (l), two fertigation intervals (i) and interactions (l x i) on length and girth of fruits along with the effect of two controls are presented in Table 7.

The length and girth of fruits were not influenced by fertigation levels (l) and fertigation intervals (i). Similarly the interactions (l x i) were also not significant.

The comparison between the two controls revealed the superiority of control 2 over control 1 in producing the longest fruits (26.03 and 24.84 cm respectively), and between the controls and fertigation treatments, though control 1 did not differ significantly from fertigation treatments, control 2 differed significantly (26.03 and 24.75 cm respectively).

4.2.2 Fruit Weight and Number of Fruits Plant^{-1}

The data on effect of four fertigation levels (l), two fertigation intervals (i) and interactions (l x i) on fruit weight and number of fruits plant^{-1} along with the effect of two controls are presented in Table 8.

The fertigation levels (l) did not influence the fruit weight, but it influenced the number of fruits plant^{-1}, with l_2 producing more fruits (31.76), and l_4, the less (25.65), which was on par with l_1 (28.15) and l_3 (26.78).

The fertigation intervals (i) and the interactions (l x i) were not significant.

There was no significant difference between the two controls and also between the controls and fertigation treatments.

4.2.3 Yield

The data on effect of four fertigation levels (l), two fertigation intervals (i) and interactions (l x i) on yield of fruits plant^{-1} and hectare^{-1} along with the effect of two controls are presented in Table 9.

The fertigation levels (l) significantly influenced fruit yield, with l_2 recording the highest fruit yield (4.26 kg plant^{-1} and 21.30 t ha^{-1} respectively), and l_4, the lowest (3.37 kg plant^{-1} and 16.84 t ha^{-1} respectively) and was on par with l_1

Table 6. Effect of fertigation levels, fertigation intervals and interactions on first male and female flower appearance, days

Treatments	First male flower appearance	First female flower appearance
Fertigation levels (l)		
l_1	37.65	43.13
l_2	38.70	44.71
l_3	39.60	47.95
l_4	40.29	48.70
SEm (±)	1.016	0.920
CD (0.05)	NS	2.943
Fertigation intervals (i)		
i_1	38.99	45.89
i_2	39.12	46.36
SEm (±)	0.522	0.656
CD (0.05)	NS	NS
Interaction (l x i)		
l_1i_1	37.57	43.00
l_1i_2	37.73	43.25
l_2i_1	38.55	44.00
l_2i_2	38.84	45.42
l_3i_1	39.59	47.73
l_3i_2	39.61	48.17
l_4i_1	40.26	48.82
l_4i_2	40.31	48.58
SEm (±)	1.044	1.316
CD (0.05)	NS	NS
Treatment mean	39.06	46.12
Control 1 mean	38.67	46.71
Control 2 mean	37.67	42.27
Control 1 vs. Control 2	NS	S
Control 1 vs. Treatment	NS	NS
Control 2 vs. Treatment	NS	S

S: Significant at 5% level NS: Not significant at 5% level

Table 7. Effect of fertigation levels, fertigation intervals and interactions on length and girth of fruits, cm

Treatments	Fruit length	Fruit girth
Fertigation levels (l)		
l_1	24.92	21.67
l_2	24.71	21.94
l_3	24.73	21.84
l_4	24.65	22.07
SEm (±)	0.236	0.288
CD (0.05)	NS	NS
Fertigation intervals (i)		
i_1	24.82	21.86
i_2	24.68	21.89
SEm (±)	0.17	0.228
CD (0.05)	NS	NS
Interaction (l x i)		
l_1i_1	24.55	21.45
l_1i_2	25.29	21.89
l_2i_1	24.53	21.58
l_2i_2	24.89	22.29
l_3i_1	25.29	22.26
l_3i_2	24.16	21.41
l_4i_1	24.91	22.16
l_4i_2	24.39	21.98
SEm (±)	0.34	0.459
CD (0.05)	NS	NS
Treatment mean	24.75	21.88
Control 1 mean	24.84	21.9
Control 2 mean	26.03	22.36
Control 1 vs. Control 2	S	NS
Control 1 vs. Treatment	NS	NS
Control 2 vs. Treatment	S	NS

S: Significant at 5% level NS: Not significant at 5% level

Table 8. Effect of fertigation levels, fertigation intervals and interactions on fruit weight and number of fruits plant^{-1}

Treatments	Fruit weight (g)	Number of fruits plant^{-1}
Fertigation levels (l)		
l_1	229.30	28.15
l_2	226.71	31.76
l_3	225.37	26.78
l_4	231.41	25.65
SEm (±)	1.880	1.005
CD (0.05)	NS	3.215
Fertigation intervals (i)		
i_1	222.30	28.21
i_2	234.10	27.95
SEm (±)	3.889	0.860
CD (0.05)	NS	NS
Interaction (l x i)		
l_1i_1	223.36	28.17
l_1i_2	235.23	28.13
l_2i_1	217.18	32.42
l_2i_2	236.24	31.09
l_3i_1	217.26	26.96
l_3i_2	233.48	26.59
l_4i_1	231.38	25.29
l_4i_2	231.44	26.00
SEm (±)	7.775	1.723
CD (0.05)	NS	NS
Treatment mean	228.20	28.08
Control 1 mean	231.19	28.38
Control 2 mean	227.61	25.59
Control 1 vs. Control 2	NS	NS
Control 1 vs. Treatment	NS	NS
Control 2 vs. Treatment	NS	NS

S: Significant at 5% level NS: Not significant at 5% level

Table 9. Effect of fertigation levels, fertigation intervals and interactions on fruit yield

Treatments	Yield of fruits	
	kg plant^{-1}	t ha^{-1}
Fertigation levels (l)		
l_1	3.54	17.71
l_2	4.26	21.30
l_3	3.69	18.43
l_4	3.37	16.84
SEm (±)	0.13	0.644
CD (0.05)	0.416	2.061
Fertigation intervals (i)		
i_1	3.70	18.47
i_2	3.74	18.67
SEm (±)	0.129	0.645
CD (0.05)	NS	NS
Interaction (l x i)		
l_1i_1	3.47	17.36
l_1i_2	3.61	18.05
l_2i_1	4.32	21.59
l_2i_2	4.20	21.01
l_3i_1	3.70	18.48
l_3i_2	3.68	18.38
l_4i_1	3.29	16.44
l_4i_2	3.45	17.23
SEm (±)	0.259	1.287
CD (0.05)	NS	NS
Treatment mean	3.72	18.57
Control 1 mean	3.74	18.68
Control 2 mean	3.41	17.05
Control 1 vs. Control 2	NS	NS
Control 1 vs. Treatment	NS	NS
Control 2 vs. Treatment	NS	NS

S: Significant at 5% level NS: Not significant at 5% level

(3.54 kg plant^{-1} and 17.71 t ha^{-1} respectively) and l_3 (3.69 kg plant^{-1} and 18.43 t ha^{-1} respectively).

The fertigation intervals (i) and the interactions (l x i) were not significant.

There was no significant difference between the two controls and also between the controls and fertigation treatments.

4.2.4 Dry Matter Yield

The data on effect of four fertigation levels (l), two fertigation intervals (i) and interactions (l x i) on dry matter yield at 55 DAS and total dry matter yield at harvest along with the effect of two controls are presented in Table 10.

The fertigation levels (l) had significant influence on dry matter yield at 55 DAS and also total dry matter yield at harvest, with l_3 recording the highest at 55 DAS (97.50 g plant^{-1}) and l_2, the highest at harvest (636.92 g plant^{-1}), and l_3 was on par with l_4 at 55 DAS (92.50 g plant^{-1}), while it was the lowest in l_1 at 55 DAS (63.25 g plant^{-1}), and l_4 at harvest (541.19 g plant^{-1}) which was on par with l_1 and l_3 (557.28 and 561.21 g plant^{-1} respectively).

The fertigation intervals (i) and the interactions (l x i) were not significant.

The comparison between the two controls revealed that there was significant difference between the controls, with control 1 producing the highest dry matter at 55 DAS (87.50 g plant^{-1}), and between the controls and fertigation treatments, though control 1 did not differ significantly from fertigation treatments, control 2 differed significantly at 55 DAS (56.25 and 84.16 g plant^{-1} respectively).

4.2.5 Days to First Harvest

The data on effect of four fertigation levels (l), two fertigation intervals (i) and interactions (l x i) on days to first harvest along with the effect of two controls are presented in Table 11.

Table 10. Effect of fertigation levels, fertigation intervals and interactions on dry matter yield, g plant^{-1}

Treatments	Dry matter yield	
	55 DAS	Final harvest
Fertigation levels (l)		
l_1	63.25	557.28
l_2	83.38	636.92
l_3	97.50	561.21
l_4	92.50	541.19
SEm (±)	2.454	15.498
CD (0.05)	7.851	49.577
Fertigation intervals (i)		
i_1	86.69	560.74
i_2	81.63	587.55
SEm (±)	3.112	12.264
CD (0.05)	NS	NS
Interaction (l x i)		
l_1i_1	62.50	536.49
l_1i_2	64.00	578.06
l_2i_1	86.75	661.62
l_2i_2	80.00	612.22
l_3i_1	102.50	541.30
l_3i_2	92.50	581.11
l_4i_1	95.00	503.56
l_4i_2	90.00	578.82
SEm (±)	6.228	24.532
CD (0.05)	NS	NS
Treatment mean	84.16	574.15
Control 1 mean	87.50	588.67
Control 2 mean	56.25	563.93
Control 1 vs. Control 2	S	NS
Control 1 vs. Treatment	NS	NS
Control 2 vs. Treatment	S	NS

S: Significant at 5% level NS: Not significant at 5% level

The fertigation levels (l) had significant influence on number of days taken for first harvest, with an early harvest in l_3 (62.25 days) which was on par with l_2 (62.77 days) and late in l_1 and l_4 (64.80 and 64.42 days respectively).

The fertigation intervals (i) and the interactions (l x i) were not significant.

There was no significant difference between the two controls, and also between the controls and fertigation treatments.

4.2.6 Days to Consequent Harvest

The data on effect of four fertigation levels (l), two fertigation intervals (i) and interactions (l x i) on days to consequent harvest along with the effect of two controls are presented in Table 11.

None of the treatments were significant.

4.2.7 Days to Final Harvest

Days to final harvest was uniform for all treatments and irrespective of treatments, and the harvesting completed by 90 days.

4.2.8 Number of Harvests

The data on effect of four fertigation levels (l), two fertigation intervals (i) and interactions (l x i) on number of harvests along with the effect of two controls are presented in Table 11.

The fertigation levels (l) significantly influenced number of harvests, with l_2 recording more frequent harvests (5.74), and l_3, the less (4.82), which was on par with l_1 (5.03) and l_4 (4.87).

The fertigation intervals (i) and the interactions (l x i) were not significant.

The comparison between the two controls revealed that there was no significant difference between the controls, and between the controls and fertigation treatments, there was no significant difference between control 2 and

Table 11. Effect of fertigation levels, fertigation intervals and interactions on first harvest, consequent harvest and number of harvests

Treatments	First harvest (days)	Consequent harvest (days)	Number of harvests
Fertigation levels (l)			
l_1	64.80	5.60	5.03
l_2	62.77	5.44	5.74
l_3	62.25	5.42	4.82
l_4	64.42	5.27	4.87
SEm (±)	0.491	0.118	0.127
CD (0.05)	1.569	NS	0.405
Fertigation intervals (i)			
i_1	62.77	5.41	5.10
i_2	62.25	5.45	5.13
SEm (±)	0.634	0.104	0.174
CD (0.05)	NS	NS	NS
Interaction (l x i)			
l_1i_1	62.92	5.59	5.25
l_1i_2	66.67	5.60	4.80
l_2i_1	63.00	5.34	5.63
l_2i_2	62.54	5.54	5.85
l_3i_1	62.00	5.41	4.75
l_3i_2	62.50	5.42	4.88
l_4i_1	65.00	5.30	4.75
l_4i_2	63.83	5.23	4.98
SEm (±)	1.271	0.213	0.345
CD (0.05)	NS	NS	NS
Treatment mean	63.56	5.43	5.11
Control 1 mean	65.00	5.34	4.25
Control 2 mean	64.00	5.38	4.38
Control 1 vs. Control 2	NS	NS	NS
Control 1 vs. Treatment	NS	NS	S
Control 2 vs. Treatment	NS	NS	NS

S: Significant at 5% level NS: Not significant at 5% level

fertigation treatments, while control 1 differed significantly from fertigation treatments (4.25 and 5.11 respectively).

4.3 QUALITY ATTRIBUTES

4.3.1 TSS (Total Soluble Solids)

The data on effect of four fertigation levels (l), two fertigation intervals (i) and interactions (l x i) on fruits content of along with the effect of two controls are presented in Table 12.

TSS content of fruits was not influenced by fertigation levels (l) and fertigation intervals (i). Similarly the interactions (l x i) were also not significant.

The comparison between the two controls revealed that there was no significant difference between the controls, and between the controls and fertigation treatments, though control 1 did not differ significantly, control 2 differed significantly from fertigation treatments (3.25^0 and 2.50^0 Brix respectively).

4.3.2 Protein Content

The data on effect of four fertigation levels (l), two fertigation intervals (i) and interactions (l x i) on protein content along with the effect of two controls are presented in Table 12.

The protein content of fruits was not influenced by fertigation levels (l) and fertigation intervals (i).

The interactions (l x i) were significant, with l_4i_1 recording the highest protein content (24.72 per cent) which was on par with l_3i_1 (23.84 per cent), while l_3i_1 was on par with l_2i_2 and l_4i_2, and l_1i_1, the lowest (18.81 per cent) which was on par with l_1i_2, l_2i_1 and l_3i_2.

The comparison between the two controls revealed that there was significant difference between the controls, with control 2 recording the highest protein content (23.18 per cent), and between the controls and fertigation treatments, though control 2 did not differ significantly from fertigation treatments control 1 differed significantly (19.47 and 21.79 per cent respectively).

4.3.3 Ascorbic Acid Content

The data on effect of four fertigation levels (l), two fertigation intervals (i) and interactions (l x i) on ascorbic acid content along with the effect of two controls are presented in Table 12.

The fertigation levels (l) had significant influence on ascorbic acid content of fruits, with l_2 recording the highest (54.05 mg 100 g^{-1}) and l_1, the lowest (46.62 mg 100 g^{-1}).

The fertigation intervals (i) and the interactions (l x i) were not significant.

The comparison between the two controls revealed that there was no significant difference between the controls, and between the controls and fertigation treatments, there was no significant difference between control 2 and fertigation treatments, while control 1 differed significantly from fertigation treatments (46.75 and 50.47 mg 100 g^{-1} respectively).

4.3.4 Iron Content

The data on effect of four fertigation levels (l), two fertigation intervals (i) and interactions (l x i) on iron content along with the effect of two controls are presented in Table 12.

None of the treatments were significant.

4.3.5 P and K Content

The data on effect of four fertigation levels (l), two fertigation intervals (i) and interactions (l x i) on P and K content along with the effect of two controls are presented in Table 13.

The fertigation levels (l) influenced K content of fruit, with l_3 recording the highest (3.85 per cent) which was on par with l_2 and l_4 (3.68 and 3.56 per cent

Table 12. Effect of fertigation levels, fertigation intervals and interactions on fruit quality

Treatments	TSS (^{0}Brix)	Protein (%)	Ascorbic acid (mg 100 g^{-1})	Iron (%)
Fertigation levels (l)				
l_1	2.63	20.01	46.62	0.032
l_2	2.50	21.22	54.05	0.030
l_3	2.38	22.42	51.83	0.029
l_4	2.50	23.52	49.39	0.028
SEm (±)	0.184	1.536	0.682	0.0017
CD (0.05)	NS	NS	2.183	NS
Fertigation intervals (i)				
i_1	2.69	21.98	50.51	0.031
i_2	2.31	21.60	50.44	0.028
SEm (±)	0.147	0.390	0.652	0.0012
CD (0.05)	NS	NS	NS	NS
Interaction (l x i)				
l_1i_1	2.75	18.81	47.84	0.033
l_1i_2	2.50	21.21	45.40	0.030
l_2i_1	2.50	20.56	51.62	0.031
l_2i_2	2.50	21.87	56.48	0.028
l_3i_1	2.75	23.84	52.43	0.031
l_3i_2	2.00	21.00	51.22	0.027
l_4i_1	2.75	24.72	50.13	0.028
l_4i_2	2.25	22.31	48.65	0.028
SEm (±)	0.298	0.780	1.308	0.0025
CD (0.05)	NS	2.403	NS	NS
Treatment mean	2.50	21.79	50.47	0.030
Control 1 mean	2.75	19.47	46.75	0.027
Control 2 mean	3.25	23.18	48.10	0.028
Control 1 vs. Control 2	NS	S	NS	NS
Control 1 vs. Treatment	NS	S	S	NS
Control 2 vs. Treatment	S	NS	NS	NS

S: Significant at 5% level NS: Not significant at 5% level

Table 13. Effect of fertigation levels, fertigation intervals and interactions on phosphorus and potassium content of fruit, per cent

Treatments	P	K
Fertigation levels (l)		
l_1	0.36	3.26
l_2	0.34	3.68
l_3	0.34	3.85
l_4	0.32	3.56
SEm (±)	0.016	0.094
CD (0.05)	NS	0.301
Fertigation intervals (i)		
i_1	0.33	3.66
i_2	0.35	3.52
SEm (±)	0.009	0.047
CD (0.05)	NS	NS
Interaction (l x i)		
l_1i_1	0.35	3.28
l_1i_2	0.36	3.24
l_2i_1	0.32	3.63
l_2i_2	0.36	3.73
l_3i_1	0.33	4.12
l_3i_2	0.34	3.57
l_4i_1	0.31	3.60
l_4i_2	0.33	3.52
SEm (±)	0.015	0.091
CD (0.05)	NS	0.281
Treatment mean	0.34	3.59
Control 1 mean	0.29	4.18
Control 2 mean	0.33	4.19
Control 1 vs. Control 2	NS	NS
Control 1 vs. Treatment	NS	S
Control 2 vs. Treatment	NS	S

S: Significant at 5% level NS: Not significant at 5% level

respectively), and l_1, the lowest (3.26 per cent).

The fertigation intervals (i) had no significant influence.

The interactions (l x i) were significant only for K content, with l_3i_1 recording the highest (4.12 per cent) followed by l_2i_2 (3.73 per cent) and l_2i_2 was on par with l_2i_1, l_3i_2, l_4i_1 and l_4i_2 respectively, while l_1i_2 the lowest (3.24 per cent) and was on par with l_1i_1 and l_4i_2.

The comparison between the two controls and also between the controls and fertigation treatments revealed that there was significant difference between the controls and fertigation treatments only, and both the controls recorded higher K content than fertigation treatments (4.18, 4.19 and 3.59 per cent respectively).

4.4 MOISTURE STUDIES

4.4.1 Water Use Efficiency (WUE) and Water Productivity

The data on effect of four fertigation levels (l), two fertigation intervals (i) and interactions (l x i) on water use efficiency (WUE) and water productivity along with the effect of two controls are presented in Table 14.

The WUE and water productivity of the crop was found influenced by fertigation levels (l), with l_2 recording the highest (24.41 and 3.65 kg ha mm^{-1} respectively), followed by l_3 (21.12 kg ha mm^{-1} and 3.22 kg ha mm^{-1} respectively), and l_4, the lowest (19.29 and 3.11 kg ha mm^{-1}) and l_4 was on par with l_1 and l_3.

The fertigation intervals (i) and the interactions (l x i) were not significant.

The comparison between the two controls revealed that there was significant difference between the controls, with control 1 recording the highest WUE (21.40 kg ha mm^{-1}) and water productivity (3.37 kg ha mm^{-1}), and between the controls and fertigation treatments, though control 1did not differ significantly from fertigation treatments, control 2 differed significantly, with the fertigation treatments recording the highest WUE (21.28 kg ha mm^{-1}) and water productivity (3.29 kg ha mm^{-1}).

Table 14. Effect of fertigation levels, fertigation intervals and interactions on water use efficiency and water productivity, kg ha mm^{-1}

Treatments	Water use efficiency	Water productivity
Fertigation levels (l)		
l_1	20.29	3.20
l_2	24.41	3.65
l_3	21.12	3.22
l_4	19.29	3.11
SEm (±)	0.740	0.089
CD (0.05)	2.366	0.285
Fertigation intervals (i)		
i_1	21.16	3.22
i_2	21.39	3.37
SEm (±)	0.739	0.069
CD (0.05)	NS	NS
Interaction (l x i)		
l_1i_1	19.90	3.08
l_1i_2	20.68	3.31
l_2i_1	24.74	3.79
l_2i_2	24.08	3.51
l_3i_1	21.17	3.10
l_3i_2	21.06	3.33
l_4i_1	18.84	2.89
l_4i_2	19.74	3.32
SEm (±)	1.475	0.142
CD (0.05)	NS	NS
Treatment mean	21.28	3.29
Control 1 mean	21.40	3.37
Control 2 mean	16.64	2.75
Control 1 vs. Control 2	S	S
Control 1 vs. Treatment	NS	NS
Control 2 vs. Treatment	S	S

S: Significant at 5% level NS: Not significant at 5% level

4.5 PEST AND DISEASE INCIDENCE

There was no serious pest and disease occurrence due to the timely application of control measures like spraying of quinalphos (ekalux 25 EC) @ 1.5 mL L^{-1} at the initial stage of crop growth to control red pumpkin beetles and spraying of dimethoate @ 1.5 mL L^{-1} to control white flies. Mosaic was also observed during early stages, but it was not severe and was brought under control by uprooting the infected plants.

4.6 CHEMICAL ANALYSIS

4.6.1 Chlorophyll Content at Flowering

The data on effect of four fertigation levels (l), two fertigation intervals (i) and interactions (l x i) on chlorophyll content at flowering along with the effect of two controls are presented in Table 15.

None of the treatments were significant.

4.6.2 N Uptake

The data on effect of four fertigation levels (l), two fertigation intervals (i) and interactions (l x i) on N uptake by crop along with the effect of two controls are presented in Table 16.

The fertigation levels (l) had no significant influence on N uptake.

The fertigation intervals (i) had significant influence on N uptake, with i_2 recording the highest N uptake compared to i_1 (103.62 and 92.14 kg ha^{-1} respectively).

The interactions (l x i) were not significant.

There was no significant difference between the two controls and also between the controls and fertigation treatments.

Table 15. Effect of fertigation levels, fertigation intervals and interactions on chlorophyll content at flowering, mg g^{-1}

Treatments	Total chlorophyll
Fertigation levels (l)	
l_1	1.18
l_2	1.19
l_3	1.30
l_4	1.23
SEm (±)	0.082
CD (0.05)	NS
Fertigation intervals (i)	
i_1	1.22
i_2	1.23
SEm (±)	0.04
CD (0.05)	NS
Interaction (l x i)	
l_1i_1	1.23
l_1i_2	1.12
l_2i_1	1.15
l_2i_2	1.23
l_3i_1	1.28
l_3i_2	1.31
l_4i_1	1.20
l_4i_2	1.25
SEm (±)	0.08
CD (0.05)	NS
Treatment mean	1.22
Control 1 mean	1.30
Control 2 mean	1.40
Control 1 vs. Control 2	NS
Control 1 vs. Treatment	NS
Control 2 vs. Treatment	NS

S: Significant at 5% level NS: Not significant at 5% level

4.6.3 P Uptake

The data on effect of four fertigation levels (l), two fertigation intervals (i) and interactions (l x i) on P uptake by crop along with the effect of two controls are presented in Table 16.

The fertigation levels (l) influenced P uptake, with l_2 recording the highest (10.61 kg ha^{-1}), which was on par with l_1 (9.57 kg ha^{-1}), and l_4, the lowest (8.70 kg ha^{-1}), which was on par with l_3 (8.90 kg ha^{-1}) and l_1 (9.57 kg ha^{-1}).

The fertigation intervals (i) and the interactions (l x i) were not significant.

There was no significant difference between the two controls and also between the controls and fertigation treatments.

4.6.4 K Uptake

The data on effect of four fertigation levels (l), two fertigation intervals (i) and interactions (l x i) on K uptake by crop along with the effect of two controls are presented in Table 16.

The fertigation levels (l) influenced K uptake, with l_2 recording the highest (111.51 kg ha^{-1}), which was on par with l_3 (107.36 kg ha^{-1}), and l_4, the lowest (91.86 kg ha^{-1}), which was on par with l_1 (93.76 kg ha^{-1}).

The fertigation intervals (i) and the interactions (l x i) were not significant.

The comparison between the two controls revealed that there was no significant difference between the controls, and between the controls and fertigation treatments, both the controls were significantly superior to fertigation treatments (119.38, 114.53 and 101.12 kg ha^{-1} respectively).

4.6.5 Soil Nutrient Status after the Experiment

The data on effect of four fertigation levels (l), two fertigation intervals (i) and interactions (l x i) on soil nutrient status along with the effect of two controls are presented in Table 17.

Table 16. Effect of fertigation levels, fertigation intervals and interactions on uptake of nutrients, kg ha^{-1}

Treatments	Uptake of nutrients		
	N	P	K
Fertigation levels (l)			
l_1	87.13	9.57	93.76
l_2	103.90	10.61	111.51
l_3	100.48	8.90	107.36
l_4	100.01	8.70	91.86
SEm (±)	5.551	0.428	3.164
CD (0.05)	NS	1.37	10.121
Fertigation intervals (i)			
i_1	92.14	9.27	98.33
i_2	103.62	9.61	103.91
SEm (±)	2.434	0.325	2.782
CD (0.05)	7.501	NS	NS
Interaction (l x i)			
l_1i_1	76.50	9.58	84.66
l_1i_2	97.76	9.55	102.85
l_2i_1	97.75	10.75	108.20
l_2i_2	110.05	10.46	114.81
l_3i_1	99.87	8.76	114.72
l_3i_2	101.09	9.03	99.99
l_4i_1	94.44	7.99	85.75
l_4i_2	105.58	9.40	97.97
SEm (±)	4.868	0.653	5.564
CD (0.05)	NS	NS	NS
Treatment mean	97.88	9.44	101.12
Control 1 mean	102.37	8.47	119.38
Control 2 mean	102.97	8.42	114.53
Control 1 vs. Control 2	NS	NS	NS
Control 1 vs. Treatment	NS	NS	S
Control 2 vs. Treatment	NS	NS	S

S: Significant at 5% level NS: Not significant at 5% level

Table 17. Effect of fertigation levels, fertigation intervals and interactions on nutrients in soil after the experiment, kg ha^{-1}

Treatments	Available nutrient status		
	N	P	K
Fertigation levels (l)			
l_1	341.82	82.79	116.80
l_2	399.85	97.71	138.26
l_3	363.78	93.92	135.37
l_4	401.42	76.98	130.08
SEm (±)	6.188	4.321	3.302
CD (0.05)	19.795	13.822	10.564
Fertigation intervals (i)			
i_1	390.44	92.05	130.70
i_2	362.99	83.65	129.56
SEm (±)	5.611	3.300	2.054
CD (0.05)	17.293	NS	NS
Interaction (l x i)			
l_1i_1	335.55	87.61	114.86
l_1i_2	348.08	77.97	118.74
l_2i_1	442.19	99.11	127.45
l_2i_2	357.50	96.30	149.07
l_3i_1	370.05	95.35	142.86
l_3i_2	357.50	92.49	127.88
l_4i_1	413.95	86.13	137.63
l_4i_2	388.88	67.83	122.53
SEm (±)	11.227	6.596	4.109
CD (0.05)	34.596	NS	12.662
Treatment mean	376.71	87.85	130.13
Control 1 mean	395.13	100.41	127.83
Control 2 mean	432.75	68.41	97.61
Control 1 vs. Control 2	S	S	S
Control 1 vs. Treatment	NS	NS	NS
Control 2 vs. Treatment	S	S	S

S: Significant at 5% level NS: Not significant at 5% level

The available nitrogen (N), phosphorus (P) and potassium (K) status of soil were significantly influenced by fertigation levels (l), with l_4 recording the highest N (401.42 kg ha^{-1}) which was on par with l_2 (399.85 kg ha^{-1}), and l_1, the lowest (341.82 kg ha^{-1}). The P and K content of the soil were the highest in l_2 (97.71 and 138.26 kg ha^{-1} respectively) and for K, this was on par with l_3 and l_4 (135.37 and 130.08 kg ha^{-1}), while for P, this was on par with l_3 only (93.92 kg ha^{-1}). The P status was the lowest in l_4 (76.98 kg ha^{-1}) and was on par with l_1 (82.79 kg ha^{-1}) and K status was the lowest in l_1 (116.80 kg ha^{-1}).

The fertigation intervals (i) significantly influenced N status only, with i_1 recording the highest (390.44 kg ha^{-1}).

The interactions (l x i) were significant on N and K status of soil, with l_2i_1 recording the highest N (442.19 kg ha^{-1}) which was on par with l_4i_1 (413.95 kg ha^{-1}), while, l_1i_1 the lowest (335.55 kg ha^{-1}) and was on par with l_1i_2, l_2i_2, l_3i_1 and l_3i_2. The status of K was the highest in l_2i_2 (149.07 kg ha^{-1}), which was on par with l_3i_1 and l_4i_1 (142.86 and 137.63 kg ha^{-1} respectively), while the lowest in l_1i_1 (114.86 kg ha^{-1}) and was on par with l_1i_2, l_2i_1 and l_4i_2.

The comparison between the two controls revealed that there was significant difference between the controls, with control 1 recording the lowest N (395.13 kg ha^{-1}) and the highest P and K (100.41 and 127.83 kg ha^{-1} respectively) than control 2 (432.75, 68.41 and 97.61 kg ha^{-1} respectively), and between the controls and fertigation treatments, though control 1 did not differ significantly from fertigation treatments, control 2 differed significantly from the fertigation treatments in NPK content (432.75 and 376.71 kg N ha^{-1}, 68.41 and 87.85 kg P ha^{-1}, and 97.61 and 130.13 kg K ha^{-1}).

4.6.6 Organic Carbon

The data on effect of four fertigation levels (l), two fertigation intervals (i) and interactions (l x i) on organic carbon content of soil after the experiment along with the effect of two controls are presented in Table 18.

None of the treatments were significant.

4.6.7 Soil pH

The data on effect of four fertigation levels (l), two fertigation intervals (i) and interactions (l x i) on soil pH after the experiment along with the effect of two controls are presented in Table 18.

The fertigation levels (l) had significant influence on soil pH, with l_3 recording the highest (5.42) which was on par with l_2 (5.32), while l_4, the lowest (5.10) and was on par with l_1 (5.23).

The fertigation intervals (i) had no significant influence on soil pH.

The interactions (l x i) were significant, with l_3i_1 recording the highest soil pH (5.46) which was on par with l_1i_2, l_2i_1, l_2i_2 and l_3i_2, while l_4i_2, the lowest (5.04) and was on par with l_1i_1 and l_4i_1 (5.09 and 5.16 respectively).

The comparison between the two controls revealed that there was significant difference between the controls, with control 1 recording the highest soil pH (5.16) than control 2 (4.82), and between the controls and fertigation treatments, though control 1 did not differ significantly from fertigtion treatments, control 2 differed significantly (4.82 and 5.26 respectively).

4.7 ECONOMIC ANALYSIS

4.7.1 B:C Ratio and Net Income

The data on effect of four fertigation levels (l), two fertigation intervals (i) and interactions (l x i) on B:C ratio and net income along with the effect of two controls are presented in Table 19 and 20.

The fertigation levels (l) had significant influence on B:C ratio, with l_2 recording the highest (4.94), followed by l_3 (4.25), and l_4, the lowest (3.86).

The fertigation intervals (i) and the interactions (l x i) were not significant.

Table 18. Effect of fertigation levels, fertigation intervals and interactions on organic carbon and soil pH

Treatments	Organic carbon (%)	Soil pH
Fertigation levels (l)		
l_1	1.97	5.23
l_2	2.00	5.32
l_3	2.09	5.42
l_4	2.08	5.10
SEm (±)	0.112	0.046
CD (0.05)	NS	0.146
Fertigation intervals (i)		
i_1	2.04	5.28
i_2	2.03	5.25
SEm (±)	0.086	0.037
CD (0.05)	NS	NS
Interaction (lxi)		
l_1i_1	1.81	5.09
l_1i_2	2.13	5.36
l_2i_1	2.18	5.39
l_2i_2	1.81	5.24
l_3i_1	2.00	5.46
l_3i_2	2.18	5.37
l_4i_1	2.16	5.16
l_4i_2	1.99	5.04
SEm (±)	0.171	0.074
CD (0.05)	NS	0.228
Treatment mean	2.03	5.26
Control 1 mean	2.12	5.16
Control 2 mean	1.80	4.82
Control 1 vs. Control 2	NS	S
Control 1 vs. Treatment	NS	NS
Control 2 vs. Treatment	NS	S

S: Significant at 5% level NS: Not significant at 5% level

Table 19. Effect of fertigation levels, fertigation intervals and interactions on B:C ratio

Treatments	B:C ratio
Fertigation levels (l)	
l_1	4.12
l_2	4.94
l_3	4.25
l_4	3.86
SEm (±)	0.147
CD (0.05)	0.471
Fertigation intervals (i)	
i_1	4.26
i_2	4.32
SEm (±)	0.148
CD (0.05)	NS
Interaction (l x i)	
l_1i_1	4.03
l_1i_2	4.20
l_2i_1	4.99
l_2i_2	4.88
l_3i_1	4.25
l_3i_2	4.24
l_4i_1	3.76
l_4i_2	3.95
SEm (±)	0.296
CD (0.05)	NS
Treatment mean	4.29
Control 1 mean	2.74
Control 2 mean	3.21
Control 1 vs. Control 2	NS
Control 1 vs. Treatment	S
Control 2 vs. Treatment	S

S: Significant at 5% level NS: Not significant at 5% level

Table 20. Economics

Treatments	Total cost excluding treatment cost (₹ ha^{-1})	Treatment cost (₹ ha^{-1})	Total cost (₹ ha^{-1})	Gross income (₹ ha^{-1})	Net income (₹ ha^{-1})	B:C ratio
l_1i_1	106864	65617	172481	694500	522019	4.03
l_1i_2	106864	65029	171893	722000	550107	4.20
l_2i_1	106864	66148	173012	863500	690488	4.99
l_2i_2	106864	65560	172424	840500	668076	4.88
l_3i_1	106864	67210	174074	739000	564926	4.25
l_3i_2	106864	66622	173486	735000	561514	4.24
l_4i_1	106864	68272	175136	657500	482364	3.76
l_4i_2	106864	67684	174548	689000	514452	3.95
Control 1	106864	166087	272951	747000	474049	2.74
Control 2	106864	105724	212588	682000	469412	3.21

The comparison between the two controls revealed that there was no significant difference between the controls, and between the controls and fertigation treatments, the fertigtion treatment was significantly superior to both the controls (4.29, 2.74 and 3.21 respectively).

The highest net income was recorded in l_2i_1 (₹ 6,90,488 ha^{-1}), where fertigation with 100 per cent recommended dose of N and K at 4 days interval and this was followed by l_2i_2 (₹ 6,68,076 ha^{-1}), which was fertigated with 100 per cent recommended dose of N and K at 8 days interval, while the lowest in l_4i_1, where 200 per cent recommended dose of N and K applied through fertigation at 4 days interval (₹ 4,82,364 ha^{-1}).

The net income was the lowest in both the controls (₹ 4,74,049 ha^{-1} and ₹ 4,69,412 ha^{-1} respectively).

DISCUSSION

5. DISCUSSION

The results obtained from the experiment entitled "Studies on fertigation in bitter gourd (*Momordica charantia* L.)" are briefly discussed in this chapter.

Interpretation of results of this investigation demand a better understanding of weather prevailed during the crop growth period. The experiment was conducted during summer season of 2015 (March to June). The total rainfall received was 656.7 mm (33 rainy days out of 90 days), while the mean rainfall of past 5 years (2010-2014) was 315.6 mm (24.6 rainy days out of 90 days). The high rainfall during harvest affected the soil nutrient status and soil pH after the experiment. The results of those were discussed with this contingency in mind.

5.1 EFFECT OF FERTIGATION LEVELS (l), FERTIGATION INTERVALS (i) AND INTERACTIONS (l x i) ON GROWTH AND GROWTH ATTRIBUTES

The results of the study revealed that the growth attributes like number of leaves (35 DAS), leaf area index (LAI) (55 DAS) and days to first female flower appearance were influenced by fertigation levels. The number of leaves (35 DAS) was the highest in fertigation level l_2, where fertigation at 100 per cent recommended dose of N and K and this was on par with l_3 and l_4, where fertigation at 150 and 200 per cent recommended dose of N and K. The fertigation level l_3, where 150 per cent recommended dose of N and K through fertigation produced the highest LAI. Significant response to the applied nutrients on growth and growth attributes was reported in cucumber by Eromorkhin and Naumenko (1975), Tserling *et al.* (1979) and Lakshmi (1997). The role of nitrogen is important as an essential constituent of chlorophyll, which has got a direct bearing on the rate of photosynthesis and as a constituent of protein for the promotion of growth of meristematic tissues. The effect of nitrogen in promoting vegetative growth and also the role of potassium as an essential element for promotion of growth of meristematic tissue has been well established (Tisdale *et* *al.*, 1985). A lower value of LAI in l_4, where fertigation at 200 per cent recommended dose of N and K, was observed than in l_3, where fertigation at 150 per cent recommended dose of N and K. Under drip irrigation, the higher levels of nitrogen applied over the crop requirement in the soil might have been lost due to more lateral movement of nitrogen which reduced the available nitrogen in the root zone. Similar results were reported by Singh *et al.* (1984), Haynes (1990), Christov *et al.* (1991), Antil *et al.* (1992), Szaloki (1992) and Lakshmi (1997). Szaloki (1992) reported that due to increased seepage in soil, the potassium from the root zone gets washed out easily. In the soil, potassium concentration will be at high distances and depths more than 0.5 m from the dripper when applied at high levels through drip irrigation (Christensen *et al.*, 1991).

Among the flower character, the female flower appearance was late in l_4 and l_3 where the highest levels were given. As evident from tables of LAI (Table 5) and dry matter yield at 55 DAS (Table 10), it could be seen that the vegetative growth was promoted as nitrogen levels were increased, which naturally delayed flower production in bitter gourd resulting in late appearance of female flowers in l_4 and l_3. The same trend was observed by Parikh and Chandra (1970) in cucumber, Ogunremi (1978) in water melon and Ravikrishnan (1989) in bitter gourd.

On perusal of data on effect of fertigation intervals, it can be seen that the fertigation intervals influenced vine length (20 and 35 DAS) and also number of leaves (20 DAS). Fertigation at 4 days interval (i_1) produced the longest vines (20 and 35 DAS) and the highest number of leaves (20 DAS). This might be due to frequent supply of fertilizers through drip irrigation in the vicinity of root zone so that the nutritional requirement of crop is met leading to maximum absorption and translocation of nutrients resulting in increased cell size, cell elongation, cell multiplication and enhanced net assimilation rate, hence more vine length and number of leaves. These results were in accordance with Lee *et al.* (2005), Eifediyi and Remison (2009), Sharma *et al.* (2009), Jilani *et al.* (2009), Ughad *et al.* (2015), Yasser *et al.* (2009) and Feleafel and Mirdad (2013). The frequent application of recommended dose of N and K at 4 days interval with P as basal dose increases the availability of these nutrients leading to increased uptake of N, P and K during growth period which increases protein and protoplasm synthesis for higher rate of mitosis resulting in increased growth attributes. These results are in agreement with those reported by Al-Jaloud *et al.* (1999) and Shinde *et al.* (2010).

Interactions were significant on leaf production (20 and 35 DAS). The leaf production was the highest in l_3i_1 at 20 DAS, where fertigation with 150 per cent recommended dose of N and K at 4 days interval and at 35 DAS, it was the highest in fertigation with 100 per cent recommended dose of N and K at 4 days interval, *i.e.*, in l_2i_1. In drip irrigation due to frequent supply of water and fertilizer, nutrients might be effectively utilized, as there was direct contact with the root system with negligible loss of nutrient through leaching, as applied irrigation water did not move beyond 30 cm soil depth (Sampathkumar and Pandian, 2010). This might have increased the vegetative growth at 4 days interval fertigation and hence the number of leaves produced.

The biometric characters such as vine length, number of leaves and LAI were found to be improved in fertigation treatments and control 1 where nutrients were supplied through fertigation, but control 2 where nutrients were supplied through conventional method, was found inferior to both of them. Adequate amount of nutrients supplied through fertigation might have led to better crop growth, which in turn resulted in increased vine length, more number of leaves and better LAI in fertigation treatments and control 1 (KAU *ad hoc* recommendation). Similar results were reported in tomato (Hebbar *et al.*, 2004), chilli (Shashidhara, 2006) and maize (Sampathkumar and Pandian, 2010). Also nitrogen is considered as the kingpin in crop nutrition and one of the main functions of nitrogen is to promote vegetative growth in crops (Tisdale *et al.*, 1985) and hence frequent and increased application might have resulted in increased vine length, number of leaves and LAI. Female flower appearance was late in fertigation treatments and control 1, compared to control 2. This might be due to the high vegetative growth in fertigation treatments and control 1 as evident from the tables of vine length at 20 and 35 DAS (Table 3), number of leaves at 35 DAS (Table 4), LAI at 55 DAS (Table 5) and dry matter yield at 55 DAS (Table 10). Increased nitrogen application in fertigation treatments and control 1, might have delayed flowering in bitter gourd. This is in agreement with findings of Parikh and Chandra (1970) and Haris (1989).

5.2 EFFECT OF FERTIGATION LEVELS (l), FERTIGATION INTERVALS (i) AND INTERACTIONS (l x i) ON YIELD AND YIELD ATTRIBUTES

The yield attributes such as fruit number and fruit yield were found influenced by fertigation levels, with l_2 recording the highest fruit number and fruit yield (Fig. 3 and 4). Abduljabbar and Ghurbat (2010) reported that mineral nutrients influence sex expression and in soils that are deficient in K, the inclusion of K in the compound fertilizer increased the female flowers and subsequently enhanced fruit yield in squash. Modification of sex expression in favour of pistillate flower has been reported to have potential to increase number of fruits per plant in fluted pumpkin (Odejimi and Akpan, 2006). As evident from the tables it can be seen that the fertigation level l_2, recorded the highest number of leaves at 35 DAS (Tables 4), fruits (Table 8), number of harvests (Table 11), early female flower appearance (Table 6), early harvest and the highest P and K uptake (Table 16) and these might be the reasons for increased fruit yield. Also potassium might have functioned as a mobilizer of photosynthates as well as other nutrients in plants, could have helped in the promotion of early growth and vigour, thereby increased the fruit yield (Ananthi, 2002).

The dry matter yield at 55 DAS was the highest in l_3, where fertigation at 150 per cent recommended dose of N and K and at final harvest, the highest in l_2, where fertigation at 100 per cent recommended dose of N and K. The dry matter yield depends on the effectiveness of photosynthesis of the crop and further more on the plants whose vital activities are functioning effectively (Arnon, 1975). The highest LAI (55 DAS) in l_3 (Table 5) might be the reason for the highest dry

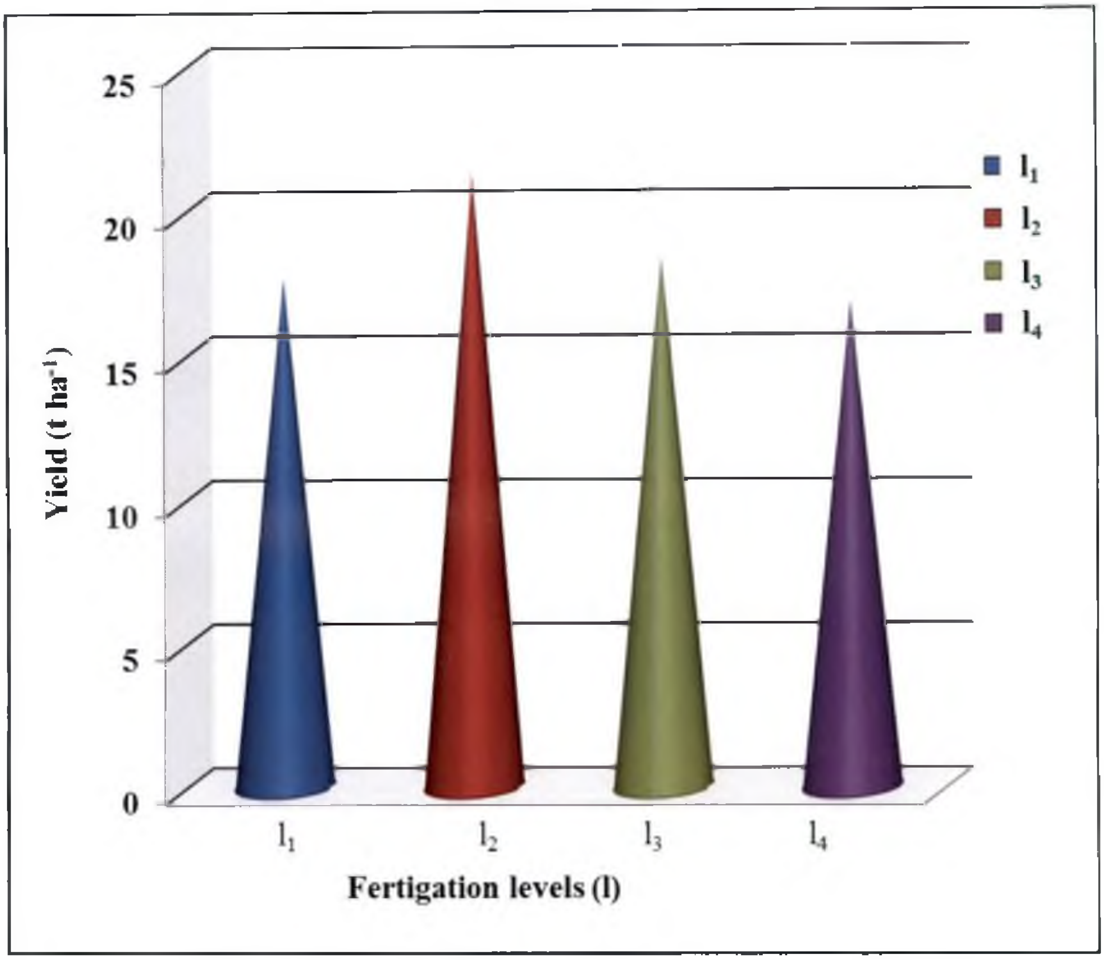

Fig. 3. Fruit yield as influenced by fertigation levels

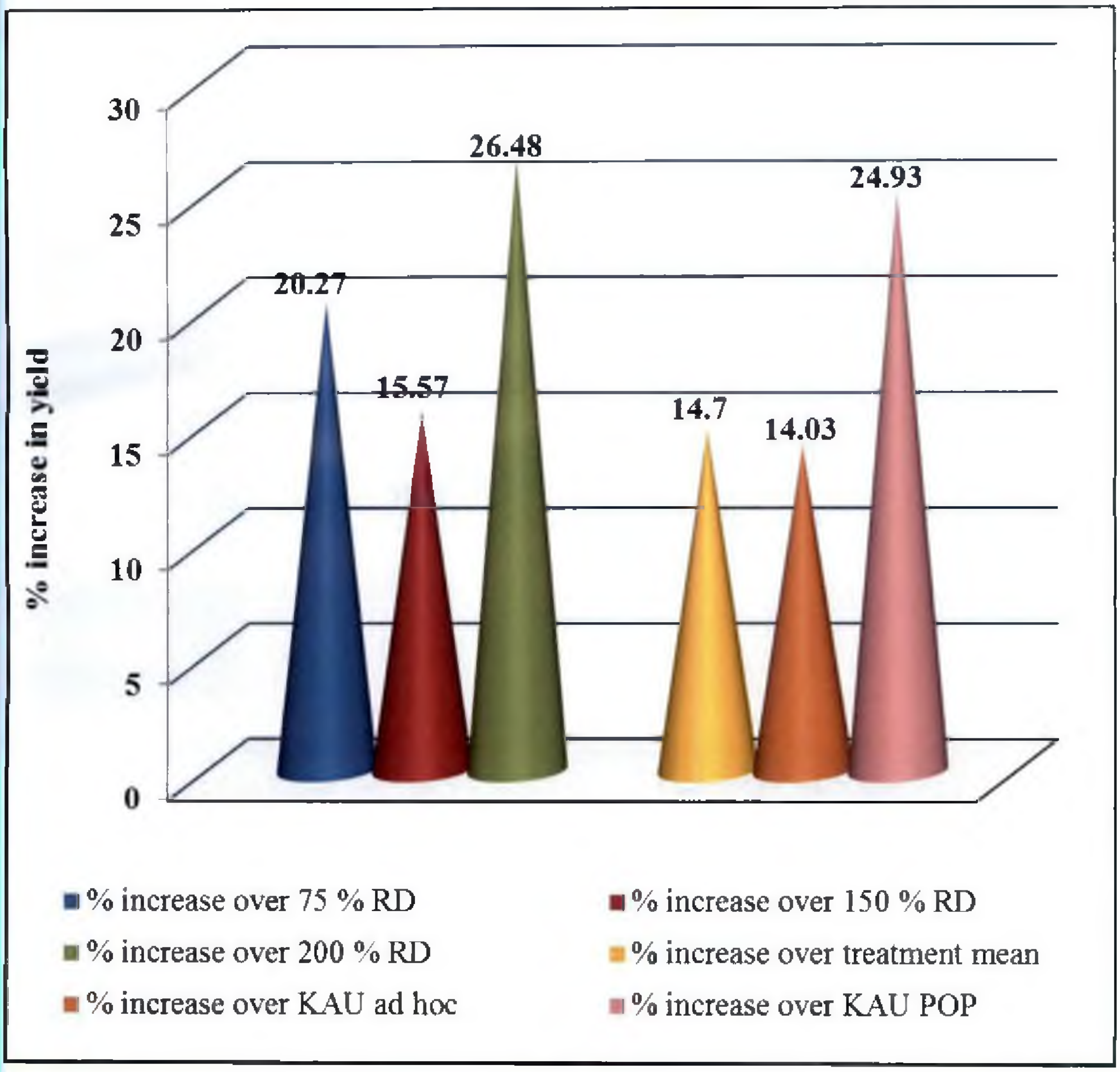

Fig. 4. Per cent yield increase in I_2 (100 per cent RD of N and K)

matter yield at 55 DAS. The main organs of photosynthesis are the leaves of the plants and LAI is the best measure of capacity of a crop for producing dry matter. The lower photosynthetic efficiency was evident from low LAI and hence low dry matter yield. Similar results were reported by Cummins and Kretchman (1975), Ortega and Kretchman (1982), Thomas (1984) and Lakshmi (1997) in cucurbits. As fruit yield was the highest in l_2, the dry matter yield at final harvest stage was also the highest in l_2, since dry matter yield at harvest stage is the sum total of the dry weights of both fuits and vegetative portion.

Though flowering delayed in l_3, harvesting was early in l_3, where fertigation at 150 per cent recommended dose of N and K and this was on a par with l_2, where 100 per cent recommended dose of N and K through fertigation. Even though the higher nutrient level l_3, delayed the female flower initiation considerably, the incremental fertilizer doses might have increased the production of male and female flowers but not to the same extend and the male and female flower ratio might have remained unaffected. Delayed harvesting was observed in l_1 and l_4 where fertigation at 75 and 200 per cent recommended dose of N and K. In l_1 and l_4 where the lowest and the highest levels of nutrients were given, the male and female flower ratio might have affected. Similar results have been reported by Rekhi *et al.* (1968), Parikh and Chandra (1970) in cucumber and Jassal *et al.* (1972) in musk melon, Pandey and Singh (1973) in bottle gourd, Raychaudhuri *et al.* (1982) in long melon, Haris (1989) in snake gourd and Ravikrishnan (1989) in bitter gourd. The harvesting completed uniformly at 90 days irrespective of treatments in all plants, with more frequent harvests in l_2, and this might be due to the highest number of fruits produced in l_2 (Table 8).

On perusal and comparison of data on both the controls and fertigation treatments, it can be seen that the fruit length was the highest in control 2 where the entire dose of N and K were applied as basal. Increased fruit size in ashgourd due to the influence of potassium was reported by Menon (1990). Potassium plays a major role in providing necessary pressure for cell wall expansion and division (Hsiao, 1973). Application of potassium as basal dose may be attributed to the cell expansion and division. Also translocation of large quantity of photosynthates to fruits might have resulted in higher mean length of fruits (Lakshmi, 1997).

The dry matter yield at 55 DAS was found to be the lowest in control 2 compared to control 1 and fertigation treatments and this might be due to the lowest LAI recorded in control 2 compared to control 1 and fertigation treatments (Table 5).

5.3 EFFECT OF FERTIGATION LEVELS (l), FERTIGATION INTERVALS (i) AND INTERACTIONS (l x i) ON QUALITY ATTRIBUTES OF FRUITS

The quality attributes such as ascorbic acid and potassium content were found to be influenced by fertigation levels, while interaction between fertigation levels and intervals affected protein and potassium content of fruits. The other quality parameters such as total soluble solids (TSS), iron and phosphorus content were not affected by any of the treatments. The effect of nutrients on fruit quality of bitter gourd was revealed earlier by More and Shinde (1991). Application of major nutrients in proper ratio and required optimum quantity can help growers to get the maximum benefit out of these inputs (Kavitha *et al.*, 2007).

The ascorbic acid content increased up to level l_2, and then decreased in higher levels of fertigtion and it was the lowest in l_1. In a study conducted by Sumathi *et al.* (2011), it was found that the ascorbic acid content was the highest under 100 per cent water soluble fertilizer plus calcium chloride spray combination. The decrease in ascorbic acid content in higher fertigation levels might be due to the effect of high N rates that induces higher rate of respiration and influences the ascorbic acid content in the cell by increasing the rate of consumption or by depressing ascorbic acid synthesis by stimulating other competitive synthesis (Mapson, 1955). This result is also in agreement with findings of Maurya (1987) and Rajasree (1999).

Fertigation with 200 per cent recommended dose of N and K at 4 days interval recorded the highest protein content and fertigation with 150 per cent recommended dose of N and K at 4 days interval, the highest K content. This might be due to the higher levels of N and K in higher doses than in the lower doses.

The TSS and K content were the highest in control 2, where the entire quantity of K was applied as basal dose. Potassium has a major role in improving the fruit quality and is one of the essential mineral nutrients in plant food and one of major nutrient taken up by roots from the soil solution in its ionic form. It is involved in numerous physiological processes that control plant growth, yield and quality parameters such as sugars, titratable acidity (TA), soluble solids (SS), total soluble solids (TSS), taste, colour, firmness and meliness (Wuzhong, 2002 and Lester *et al.*, 2005). Okur and Yagmur (2004) reported that potassium has important effect on some quality parameters of watermelon and the application of an adequate K fertilizer with irrigation increased fruit quality. Also according to several authors, it plays a key role in the improvement of several quality traits in almost all vegetables (Cakmak, 2005; Chapagain and Wiesman, 2004; Dorais *et al.*, 2001). High K content can thus increase TSS. This is in agreement with results of Nzanza *et al.* (2005) and might be the reason for increased TSS in control 2.

On perusal and comparison of data between fertigation treatments and control 2, a decrease in TSS content in fertigation treatments was noticed and that might be due to lower amount of sunshine intercepted by plants under shade due to high vegetative growth as evident from tables (Table 3, 4 and 10), which emphasis the necessity of solar radiation for conversion of starch into sugar. A similar result was obtained for Sharma and Tiwari (1993) in cucumber, where the quality parameters were found reduced when light was reduced indicating that high temperature was favourable for synthesis of sugars and acids in cucumber plants. Similar result on TSS content was reported by Sumathi *et al.* (2011). Ascorbic acid content was recorded the lowest in control 1 and this might be due to inverse relation of ascorbic acid content to shading of plants. Fritz and Habben

(1972) and Rajasree (1999) reported similar results on ascorbic acid content. Inspite of the high quantity of fertilizers applied in control 1, the protein content was low. This might be due to the partitioning of nitrogen taken up by the plant more for vegetative growth as evidenced by tables for LAI (Table 5) and dry matter yield at 55 DAS (Table 10), decreasing the N content in fruits and hence the protein content.

5.4 EFFECT OF FERTIGATION LEVELS (l), FERTIGATION INTERVALS (i) AND INTERACTIONS (l x i) ON WATER USE EFFICIENCY AND WATER PRODUCTIVITY

Water use efficiency (WUE) and water productivity which dependent on yield and total dry matter production of crops were found affected by fertigation levels, with l_2 recording the highest (Fig. 5). Bangar and Chaudari (2004) reported that the water and nutrients when applied throughout the crop period by fertigation at regular interval to meet the demand of crop, improves the crop yield and WUE due to effective utilization of water and nutrients. The increased WUE and water productivity in the fertigation level l_2 was mainly due to the better performance of crop as evident from increased yield (Table 9). As same quantity of water was used for irrigating the treatments, WUE varied according to the yield produced (Table 9) and water productivity according to the dry matter yield (Table 10).

On perusal and comparison of data between fertigation treatments and the two controls, it was observed that the WUE and water productivity were the lowest in control 2, where conventional method of irrigation practiced (Fig. 6). Drip irrigation system when compared with other methods of irrigation have lower water consumption (Hochmuth, 1994). The total water requirement and irrigation requirement were high in control 2 compared to fertigation treatments and control 1, where drip system of irrigation was practiced (Fig. 7). Hence reduced water consumption might have resulted in high WUE. Water productivity is an indication of total dry matter production per unit quantity of

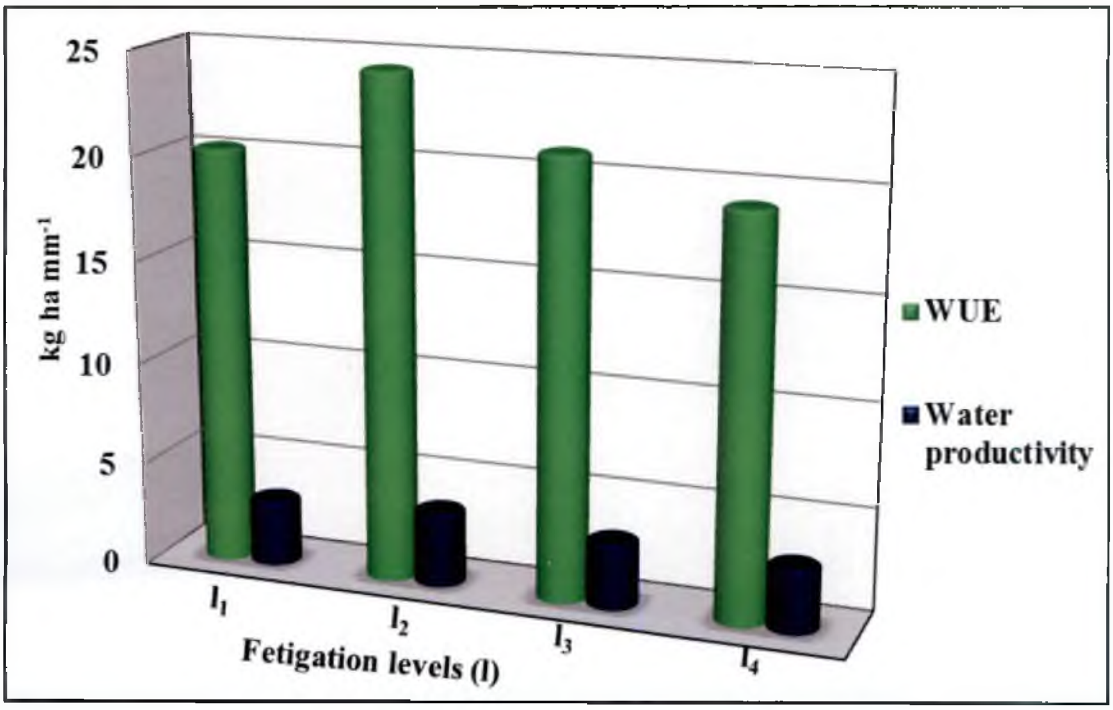

Fig. 5. Water use efficiency and water productivity as influenced by fertigation levels

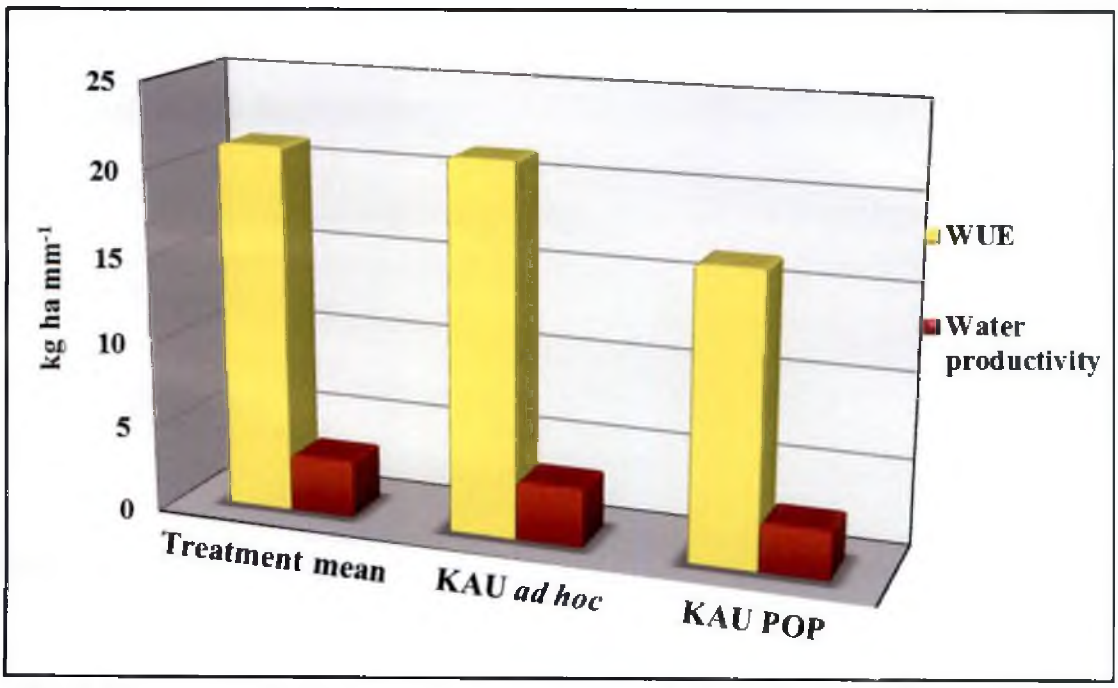

Fig. 6. Water use efficiency and water productivity as influenced by treatments and controls

water, hence increased biomass production as evident from the dry matter yield at final harvest (Table 10) and low water requirement (Fig. 8) might have increased the water productivity in drip fertigation treatments and control 1. The results are in accordance with the findings of Bucks *et al.* (1974), Grimes *et al.* (1976), Chartzaulakis and Michelakis (1988), Michelakis and Chartzaulakis (1988), Smith *et al.* (1991) Bordovsky (2001), Veeranna *et al.* (2001), Janat and Somi (2002), Kamilov *et al.* (2003), Sharma *et al.* (2012) and Kumari *et al.* (2014).

5.5 EFFECT OF FERTIGATION LEVELS (l), FERTIGATION INTERVALS (i) AND INTERACTIONS (l x i) ON NUTRIENT UPTAKE

The P and K uptake were influenced by fertigation levels and was recorded the highest in l_2, while N uptake by fertigation intervals, with i_2 recording the highest. The higher uptake of P and K was the result of significantly higher dry matter yield in l_2 (Table 10). According to Largskii (1971), the soil reserve of mobile nutrients in soil is enhanced by fertilizer application. The frequent application of nutrients to the root zone through fertigation coupled with better root activity increases the uptake per plant due to the better availability of nutrients. Also in drip fertigation the leaching loss of nutrients is lower compared to soil application of fertilizer. Similar observations of increased uptake as a result of fertigation have been reported by Vasane *et al.* (1996), Hebbar *et al.* (2004) and Lakshmi (1997).

On perusal and comparison of data between fertigation treatments and both the controls, it was found that K uptake was high in the two controls compared to fertigation treatments. In control 1, high dose of water soluble fertilizers were applied through fertigation at frequent intervals and in control 2, conventional method of soil application of fertilizer was practiced and entire quantity of K was given as basal dose. These might have resulted in increased uptake in control 1 and control 2. Thomas (1984) observed that the uptake of potassium was high in bitter gourd (50 to 80 kg ha^{-1}) under conventional method of cultivation where entire dose of K was applied as basal. In control 1, where

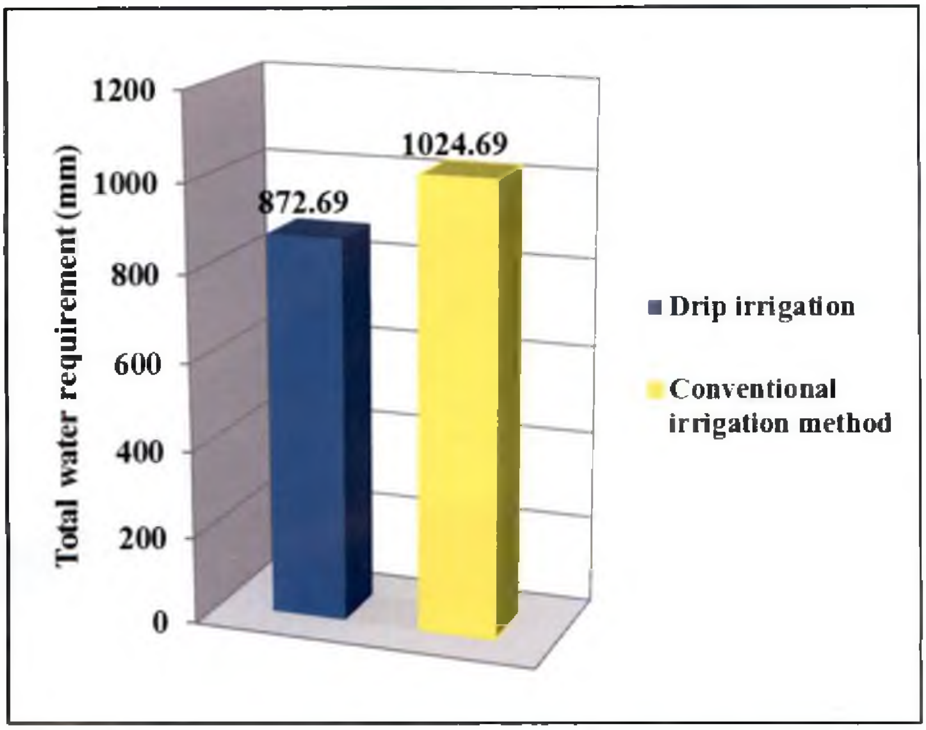

Fig. 7. Irrigation requirement in drip and conventional systems

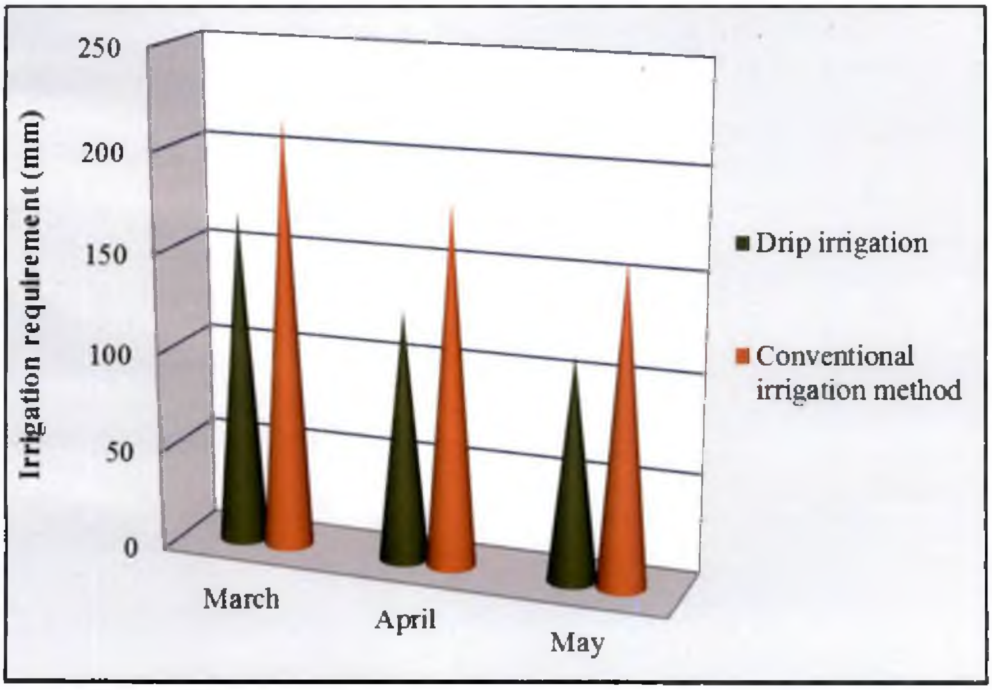

Fig. 8. Water requirement in drip and conventional systems

water soluble fertilizers were given in high quantity through drip fertigation (Table 2b), luxury consumption of K might have occurred. The frequent fertigation replenishes the nutrients in the vicinity of root and also enhance the transportation of dissolved nutrients through mass flow, resulting in increased uptake (Silber *et al.*, 2003). This might have resulted in increased uptake of K in control 1 compared to fertigation treatments. The increased availability of nutrients leads to increase in the uptake of N, P and K during growth period which increases protein and protoplasm synthesis for higher rate of mitosis resulting in increased growth attributes. These results are in agreement with those reported by Al-Jaloud *et al.* (1999) and Shinde *et al.* (2010).

5.6 EFFECT OF FERTIGATION LEVELS (l), FERTIGATION INTERVALS (i) AND INTERACTIONS (l x i) ON SOIL NUTRIENT STATUS AND SOIL pH AFTER THE EXPERIMENT

The fertigation levels significantly influenced NPK status of soil and fertigation interval, the N status only, with l_4 recording the highest N and l_2, the highest P and K content in soil after the experiment. Fertigation with 100 per cent recommended dose of N and K at 4 days interval recorded the highest N status and the same dose at 8 days interval the highest K status in soil.

On perusal and comparison of data between the two controls and fertigtion treatments, it was found that the N status of the soil was the highest in control 2, while P and K status, the lowest. The fertilizers applied in the soil if not utilized by the crop increases nutrient status in soil. Moreover, the availability of NPK is influenced by release of nutrients from farmyard manure (Ravikrishnan, 1989; Lavanya and Manickam,1991; Yadav *et al.*, 1991 and Prasad and Goswami, 1992). The results were in conformity with the findings of Mani and Ramanathan (1980), Thomas (1984), Ravikrishnan (1989) and Lakshmi (1997).

The fertigation levels had significant influence on pH of soil, with l_3 recording the highest which was on par with l_2, and l_4, the lowest. Interactions were significant and 150 per cent recommended dose of N and K through fertigation at 4 days interval (l_3i_1) recorded the highest soil pH, while 200 per cent recommended dose of N and K through fertigation at 8 days interval (l_4i_2) recorded the lowest. The soil acidification by nitrification occurs in fertigation with high rate of N addition and so pH decreases in soil (Haynes and Swift, 1987). Iles and Dosmann (1999) found in a study that bare soils are more acidic than soil covered by inorganic mulch. This might be the reason for the high pH in both fertigation treatments and control 1 where mulching was practiced.

5.7 EFFECT OF FERTIGATION LEVELS (l), FERTIGATION INTERVALS (i) AND INTERACTIONS (l x i) ON ECONOMICS

Fertigation with 100 per cent recommended dose of N and K at 4 days interval (l_2i_1) recorded the highest net income (Fig. 9). This could be attributed to the highest fruit yield recorded in l_2 (Table 9). The net income was the lowest in control 2, where conventional method of crop production was practiced. Though control 2 gave a comparable fruit yield as that of fertigation treatments, gross income in control 2 was less than in l_2i_1 (Table 20). Moreover the production cost was also high in control 2 because of the manual labour involved in after cultivation operations like weeding and irrigation compared to fertigation treatments (Table 20). All these might be the reasons for low net income in control 2.

As fruit yield was the highest in l_2, and net income, the highest in l_2i_1, the B:C ratio was also the highest in l_2 (Fig. 10).

On perusal and comparison of data between fertigation treatments and the two controls, it was found that the B:C ratio was the highest in fertigation treatments than both the controls. Among the two controls, control 1 recorded the lowest B:C ratio because of the high cost of production owing to the high cost of inputs involved (Appendix IV).

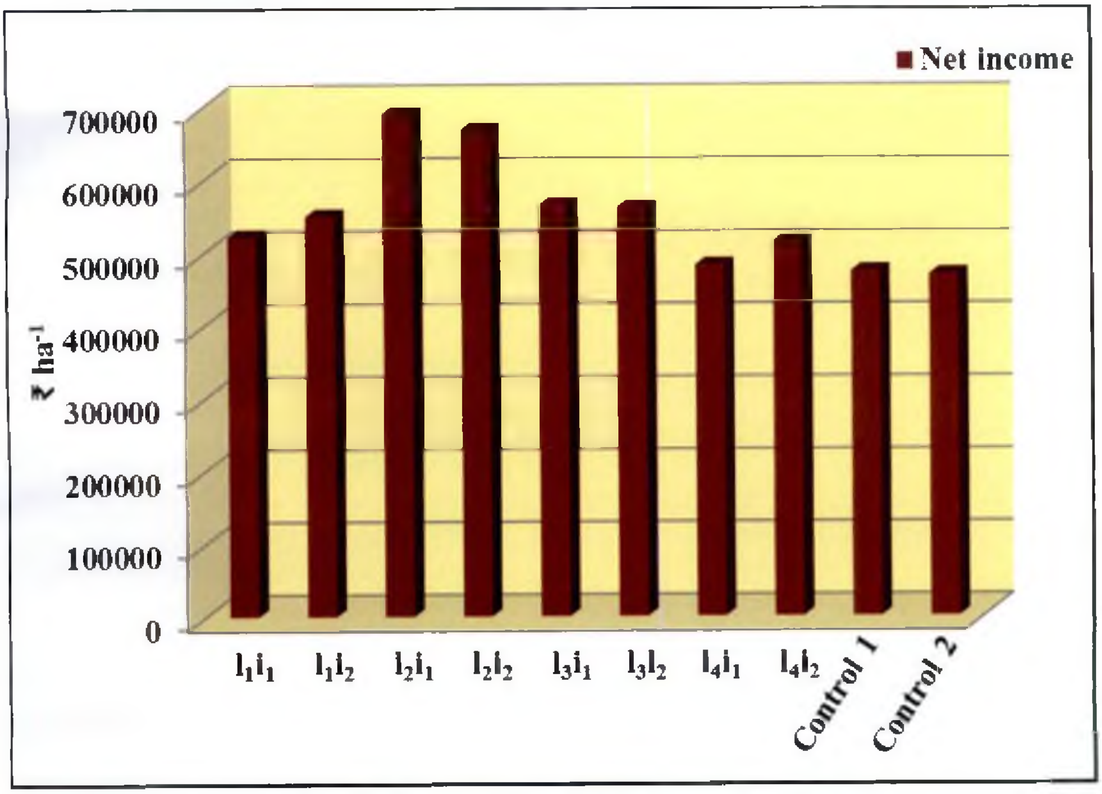

Fig. 9. Economics of bitter gourd cultivation

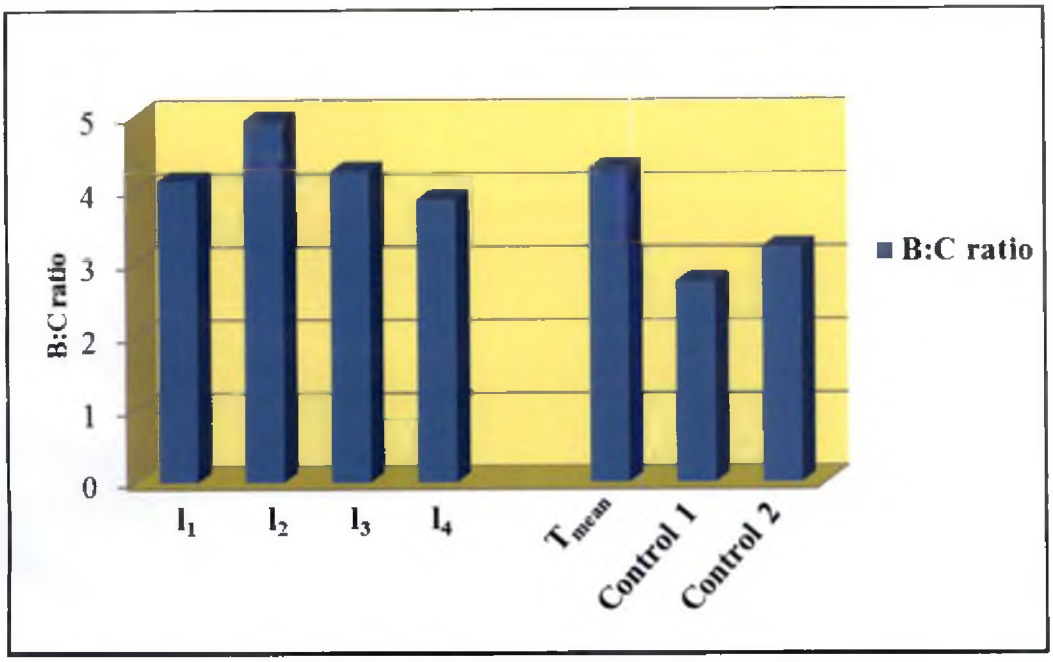

Fig. 10. B:C ratio as influenced by treatments

SUMMARY

6. SUMMARY

An experiment entitled "Studies on fertigation in bitter gourd (*Momordica charantia* L.)" was conducted in farmer's field at Pirappancode, Thiruvananthapuram district to standardize the fertigation schedule for precision farming in bitter gourd (*Momordica charantia* L.) using variety 'Preethi'. The study also aimed to assess the impact of precision farming practices on growth and yield and also to work out the economics.

The experiment was laid out in split plot design with four replications. The main plot treatments included four fertigation levels (l), *viz.*, l_1- 75 per cent recommended dose (RD) of N and K, l_2- 100 per cent RD of N and K, l_3- 150 per cent RD of N and K and l_4- 200 per cent RD of N and K. Fertigation intervals (i) (i_1- fertigation at 4 days interval and i_2- fertigation at 8 days interval) formed the sub plot treatments. Two controls were included in the study, *viz.*, control 1- Kerala Agricultural University (KAU) *ad hoc* recommendation for precision farming and control 2- KAU Package of Practices (POP) recommendation. Uniform application of FYM @ 25 t ha^{-1} in all treatments and P @ 25 kg ha^{-1} in all treatments except control 1.

The observations on growth parameters were recorded at 20 and 35 days after sowing (DAS) except LAI which was recorded at 55 DAS. The dry matter yield was recorded at 55 DAS and at harvest of the crop. Yield observations were recorded as and when the fruits were harvested and the mean recorded.

The growth attributes like number of leaves, leaf area index (LAI) and days to first female flower appearance were influenced by fertigation levels (l) and vine length (20 and 35 DAS) and number of leaves (20 DAS) by fertigation intervals (i). The interactions (l x i) were significant for number of leaves (20 and 35 DAS). The number of leaves (35 DAS) was the highest in l_2 (32.53), and l_3 produced the highest LAI (1.55). The female flower appeared early in l_1 (43.13 days) and was found on par with l_2 (44.71 days) and late in l_4 (48.70 days) which was on a par with the next higher dose l_3 (47.95 days).

Fertigation at 4 days interval (i_1) produced the longest vines at 20 and 35 DAS (69.74 and 187.76 cm respectively) and the highest number of leaves at 20 DAS (17.93).

The interaction was significant for leaf production and it was the highest in l_3i_1 at 20 DAS (18.06) and the highest in l_2i_1 at 35 DAS (33.85).

The comparison of data between fertigation treatments and the controls revealed the superiority of fertigation treatments over the controls in vine length, number of leaves and LAI, and out of the two controls, control 2 was found inferior to fertigation treatments and control 1, while control 2 did not differ significantly from control 1 in number of leaves at 20 DAS. The female flower appeared early in control 2 (42.27 days) when compared to fertigation treatments (46.12 days) and control 1 (46.71 days).

The yield and yield attributes such as length, girth and weight of fruits were not influenced by any of the fertigation treatments, while fruit number and fruit yield were found influenced by fertigation levels, with l_2 recording the highest fruit number (31.76) and fruit yield (4.26 kg $plant^{-1}$ and 21.30 t ha^{-1} respectively).

The comparison of data between fertigation treatments and the controls revealed the superiority of control 2 in fruit length over control 1 and fertigation treatments (26.03, 24.84 and 24.75 cm respectively).

The dry matter yield of the plant was found influenced by fertigation levels and fertigation intervals. The dry matter yield was the highest in l_3 at 55 DAS (97.50 g $plant^{-1}$) and in l_2 at harvest (636.92 g $plant^{-1}$).

The comparison of data between fertigation treatments and the controls revealed that the dry matter yield was the lowest in control 2 at 55 DAS (56.25 g $plant^{-1}$) than in control 1 (87.50 g $plant^{-1}$) and fertigation treatments (84.16 g $plant^{-1}$).

Though an early harvesting was observed in l_3 and l_2 (62.25 and 62.77 days) and late in l_1 and l_4 (64.80 and 64.42 days respectively), the harvesting completed uniformly by 90 days in all the treatments irrespective of treatments with a more frequent harvest in l_2 (5.74).

The comparison of data between fertigation treatments and the controls revealed more harvests in fertigation treatments (5.11) than in control 1 (4.25).

The quality attributes such as ascorbic acid and K content were found to be influenced by fertigation levels, with l_2 recording the highest ascorbic acid content (54.05 mg 100 g^{-1}) and l_3, the highest K content (3.85 per cent). The interactions were significant in protein and potassium content of fruits with l_4i_1 recording the highest protein content (24.72 per cent) and l_3i_1 the highest potassium content (4.12 per cent). The other quality parameters such as total soluble solids (TSS), iron and phosphorus content were not affected by any of the treatments.

The comparison of data between fertigation treatments and the controls revealed the superiority of control 2 over fertigation treatments in TSS and K content (3.25^0 and 2.50^0 Brix and 4.19 and 3.59 per cent respectively) and over control 1 in protein content (23.18 and 19.47 per cent respectively), while the superiority of fertigation treatments over control 1 in ascorbic acid content (50.47 and 46.75 mg $100g^{-1}$).

The water use efficiency (WUE) and water productivity were found influenced by fertigation levels, with l_2 recording the highest (24.41 and 3.65 kg ha mm^{-1} respectively), whereas comparison between fertigation treatments and both the controls revealed the superiority of control 1 (21.40 and 3.37 kg $hamm^{-1}$ respectively) over control 2 (16.64 and 2.75 kg ha mm^{-1} respectively), and fertigation treatments (21.28 and 3.29 kg ha mm^{-1} respectively) over control 2.

The P and K uptake were influenced by fertigation levels, with l_2 recording the highest (10.61 and 111.51 kg ha^{-1} respectively), while N uptake was influenced by fertigation intervals, with i_2 recording the highest (103.62 kg ha^{-1}). The comparison of data between fertigation treatments and the two controls revealed the superiority of both the controls over fertigation treatments in K uptake (119.38, 114.53 and 101.12 kg ha^{-1} respectively).

The fertigation levels significantly influenced NPK status of soil, with l_4 the highest N (401.42 kg ha^{-1}), and l_2, the highest P and K (97.71 and 138.26 kg ha^{-1} respectively). Fertigation at 4 days interval recorded the highest N (390.44 kg ha^{-1}). The interactions had significant influence on N and K status of soil with l_2i_1 recording the highest N (442.19 kg ha^{-1}), and l_2i_2, the highest K (149.07 kg ha^{-1}). The comparison between fertigation treatments and both the controls revealed the superiority of control 2 in N status (432.75 kg ha^{-1}) compared to control 1 (395.13 ha^{-1}) and fertigation treatments (376.71 kg ha^{-1}), while the P and K status were the lowest in control 2 (68.41 and 97.61 kg ha^{-1} respectively).

The pH of the soil after the experiment was the highest in l_3 (5.42) and in the combination l_3i_1 (5.46). The comparison of data between fertigation treatments and both the controls revealed the superiority of fertigation treatments and control 1 over control 2 (5.26, 5.16 and 4.82 respectively).

The B:C ratio was significantly influenced by ferigation levels, with l_2 recording the highest (4.94) followed by l_3 (4.25), and, l_4, the lowest (3.86). The comparison of data between fertigation treatments and both the controls revealed the superiority of fertigation treatments over both the controls (4.29, 2.74 and 3.21 respectively).

The net income was the highest in l_2i_1 (₹ 6,90,488 ha^{-1}) and the lowest in control 2 (₹ 4,69,412 ha^{-1}).

An analysis of the results of the study revealed the superiority of the fertigation level l_2 (100 per cent N and K through fertigation) in producing the highest fruit yield in bitter gourd (4.26 kg $plant^{-1}$ and 21.30 t ha^{-1}) with the highest B:C ratio (4.94) over other fertigation levels and the two controls. The fertigation level, l_2, recorded 26 per cent yield increase over l_4, where the highest level of fertigation was practiced. The B:C ratio was 28 per cent more over l_4, 80 per cent more over KAU *ad hoc* recommendation (control 1) and 54 per cent more over KAU POP recommendation (control 2).

Also the combination of l_2 with i_1 (l_2i_1) recorded the highest net income of ₹6,90,488 ha^{-1} which was 21 per cent more than the mean net income of fertigation treatments and 46 and 47 per cent respectively over control 1 and control 2.

Hence a nutrient recommendation of 152 kg ha^{-1} urea and 53 kg ha^{-1} MOP through fertigation at 4 days interval along with a basal dose of 100 kg ha^{-1} rajphos (equivalent to 70:20:32 kg N, P_2O_5 and K_2O ha^{-1} modified from KAU recommendation of 70:25:25 kg N, P_2O_5 and K_2O ha^{-1} as per soil test) and 25 t ha^{-1} FYM can be suggested for precision farming in bitter gourd for high yield and net income.

Future line of work

- A fertigation level between 100 and 150 per cent, *viz.,* 125 per cent recommended dose of N and K should be tried, since 100 per cent recommended dose of N and K gave the highest yield in this study. Similarly a dose between 75 and 100 per cent can also be studied.
- Other varieties and hybrids as well as fertigation intervals should be evaluated.
- Ecofriendly mulches can be evaluated.

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APPENDICES

APPENDIX – I

Standard week wise weather parameters during cropping period

(March 2015 – June 2015)

Standard weeks	Temperature (^{0}C)		Relative humidity (%)	Sunshine hours	Rainfall (mm)	Evaporation (mm)
	Max. temp.	Min. temp.				
10	32.1	23.3	77. 5	9.4	0.0	4.4
11	32.1	23.6	80.4	9.6	15.2	4.9
12	32.7	23.3	79.3	9.5	0.0	3.1
13	33.0	24.7	78.9	9.5	9.4	4.0
14	33.1	25.2	81.0	8.9	2.3	4.1
15	32.6	24.3	80.0	9.3	4.8	3.6
16	32.9	24.3	83.1	8.9	40.4	4.4
17	32.5	23.8	83.5	8.4	35.5	3.8
18	33.2	25.2	80.5	9.9	0.0	4.4
19	32.5	25.2	87.5	7.6	34.4	4.0
20	30.4	24.3	91.6	6.5	29.3	2.5
21	32.3	26.1	87.4	8.8	19.5	3.2
22	32.9	25.2	85.9	8.8	6.5	0.0

APPENDIX – II

Characters of bitter gourd variety Preethi

Characters	Description
Source or parent or pedigree	Local collection
Method of breeding	Selection
Fruit color	White
Average fruit weight	310 g
Average fruit length	30 cm
Productivity	20-25 t ha^{-1}
Duration	4-5 months

APPENDIX – III

Quantity of fertilizers in control 2 (KAU Package of Practices)

Fertilizers	Quantity	
	(g pit^{-1})	(kg ha^{-1})
Urea	60.80	152.17
Rajphos	21.30	100.00
MOP	40.00	53.30

APPENDIX – IV

Price of fertilizers

Fertilizers	Price (₹ kg^{-1})
Urea	8.00
Muriate Of Potash	17.00
Rajphos	7.00
13.0.45	200.00
19.19.19	140.00
12.61.0	140.00

STUDIES ON FERTIGATION IN BITTER GOURD (*Momordica charantia* L.)

by

ANJALI A HARI

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VELLAYANI, THIRUVANANTHAPURAM – 695522

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ABSTRACT

The research project titled "Studies on fertigation in bitter gourd (*Momordica charantia* L.)" was undertaken in the farmer's field at Pirappancode, Thiruvananthapuram district, during March 2015 to June 2015, to standardize the fertigation schedule for precision farming in bitter gourd, to assess the impact of precision farming practices on growth and yield of the crop and to work out the economics.

The experiment was laid out in split plot design with four replications. The main plot treatments included four fertigation levels (l), *viz.*, l_1- 75 per cent recommended dose (RD) of N and K, l_2- 100 per cent RD of N and K, l_3- 150 per cent RD of N and K and l_4- 200 per cent RD of N and K. Fertigation intervals (i) (i_1- fertigation at 4 days interval and i_2- fertigation at 8 days interval) formed the sub plot treatments. Two controls were included in the study, *viz.*, control 1- Kerala Agricultural University (KAU) *ad hoc* recommendation for precision farming and control 2- KAU Package of Practices (POP) recommendation. Uniform application of P @ 25 kg ha^{-1} in all treatments except control 1.

The results revealed that the growth attributes like number of leaves at 35 days after sowing (DAS), leaf area index (LAI) and days to first female flower appearance were influenced by fertigation levels and vine length (20 and 35 DAS) and leaf production (20 DAS) were influenced by fertigation intervals. The number of leaves (35 DAS) was the highest in l_2, while l_3 produced the highest LAI (55 DAS). The female flower appearance was early in l_1 and late in l_4.

Fertigation with l_2 recorded the highest fruit yield (4.26 kg $plant^{-1}$ and 21.30 t ha^{-1}) fruit number (31.76), number of harvests (5.74), total dry matter yield (636.92 g $plant^{-1}$) and ascorbic acid content (54.05 mg 100 g^{-1}), while the same level of nutrient through conventional method of application (control 2) gave a comparable fruit yield (3.41 kg $plant^{-1}$ and 17.05 t ha^{-1}) and protein content (23.18 per cent) as that of fertigation treatment and also registered the highest content of TSS (3.25^0 Brix) and K (4.19 per cent).

Water use efficiency (WUE) and water productivity were found to be influenced by fertigation levels with l_2 recording the highest (24.41 and 3.65 kg ha mm^{-1} respectively)..

The uptake of nutrients particularly P and K were the highest in l_2. Also K uptake was the highest in both the controls than in fertigation treatments. Fertigation at 8 days interval recorded the highest N uptake.

Fertigation treatments and control 1 improved the N and K status of soil, while N status improved and K decreased in control 2.

Economic analysis revealed the superiority of fertigation treatments over both the controls and within fertigation levels, the level l_2 as reflected in the respective B:C ratios. The mean B:C ratio in fertigation was 4.29 and in l_2, it was 4.94. The B:C ratio recorded in the two controls were 2.74 and 3.21 respectively. Similarly the net income was the highest in l_2i_1 (₹6,90,488 ha^{-1}), the lowest in control 2 (₹4,69,412 ha^{-1}), and though control 1 gave a comparable fruit yield, its economics in respect of B: C ratio and net income were the lowest.

The results of the study revealed that the current nutrient recommendation of KAU (70:25:25 kg N, P_2O_5 and K_2O ha^{-1}) is sufficient for bitter gourd, but giving it through fertigation, the yield can be further increased.

Based on the results, a fertigation schedule of 152 kg ha^{-1} urea and 53 kg ha^{-1} MOP at 4 days interval along with a basal dose of 100 kg ha^{-1} rajphos (equivalent to 70:20:32 kg N, P_2O_5 and K_2O ha^{-1} modified from KAU recommendation of 70:25:25 kg N, P_2O_5 and K_2O ha^{-1} as per soil test) can be given as a recommendation for precision farming in bitter gourd for high yield, quality produce and the highest net income and B:C ratio.

സംഗ്രഹം

കൃത്യതാ കൃഷിയുടെ ഭാഗമായി വിളവർദ്ധനവിനും കൃഷി ആദായകരമാക്കുന്നതിനും, 'പാവലിൽ ഫെർട്ടിഗേഷൻ വഴി സസ്യപോഷണം' എന്ന വിഷയത്തിൽ വെള്ളായണി കാർഷിക കോളേജിൽ 2015 അദ്ധ്യയനവർഷം ഒരു പഠനം നടത്തി. പഠനത്തിന്റെ പ്രധാന ഉദ്ദേശ്യം പാവലിൽ ഫെർട്ടിഗേഷൻ വഴിയുള്ള വളപ്രയോഗത്തിൽ, വളത്തിന്റെ അളവും, അവ നൽകേണ്ട സമയവും ക്രമീകരിക്കുക എന്നുള്ളതായിരുന്നു. വളത്തിന്റെ നാലുതരം അളവുകളും (ശുപാർശചെയ്യപ്പെട്ട നൈട്രജന്റേയും, പൊട്ടാസ്യത്തിന്റേയും 75, 100, 150, 200 ശതമാനം വീതം എന്ന ക്രമത്തിൽ), രണ്ടു സമയക്രമങ്ങളും (നാലും, എട്ടും ദിവസം ഇടവിട്ടുള്ള ഫെർട്ടിഗേഷൻ) ഉപയോഗിച്ച് 'സ്പ്ലിറ്റ് പ്ലോട്ട് ഡിസൈൻ' എന്ന സാംഖ്യകീയ രീതിയിൽ ആണ് പഠനം നടത്തിയത്. പാവലിൽ കേരള കാർഷിക സർവ്വകലാശാലയുടെ വളപ്രയോഗത്തിന്റെ നിലവിലുള്ള രണ്ടു ശുപാർശകൾ, അതായത് സാധാരണ പാവൽ കൃഷിചെയ്യുന്നതിനുള്ള ശുപാർശയും ഫെർട്ടിഗേഷൻ വഴി ചെയ്യുന്നതിനുള്ള അഡ്ഹോക്ക് ശുപാർശയും - മേൽപറഞ്ഞവയോട് താരതമ്യം ചെയ്യുന്നതിനായി ഈ രണ്ട് ശുപാർശകളും ഉൾക്കൊള്ളിച്ചു കൊണ്ട് രണ്ട് നിയന്ത്രണ പ്ലോട്ടുകളും പഠനത്തിൽ ഉൾപ്പെടുത്തി.

പാവൽ കൃഷിക്ക് കേരള കാർഷിക സർവ്വകലാശാലയുടെ ഇപ്പോൾ ശുപാർശ ചെയ്യപ്പെട്ടിട്ടുള്ള വളപ്രയോഗമായ, ഹെക്ടറിന് 70:25:25 കി. ഗ്രാം N: P_2O_5: K_2O തന്നെ മതിയാകുമെന്നും എന്നു കാണാൻ കഴിഞ്ഞു. എന്നാൽ ഈ വള പ്രയോഗത്തിൽ ഫോസ്ഫറസ് വളം മൊത്തമായും, അടിവളമായി നൈട്രജനും പൊട്ടാഷും ഫെർട്ടിഗേഷൻ വഴി നൽകുന്നത് വളം നേരിട്ടു മണ്ണിൽ ചേർത്തു കൊടുക്കുന്നതിനേക്കാൾ വിള വർദ്ധനവിനും ആദായം കൂട്ടാനും സഹായകരമാണെന്ന് കണ്ടു. പാവലിന്റെ പോഷകഗുണ നിലവാരം നിശ്ചയിക്കുന്ന ഘടകങ്ങളിലൊന്നായ 'അസ്കോർബിക് ആസിഡി'ന്റെ അളവ് ഫെർട്ടിഗേഷൻ വഴി പോഷണം നൽകുന്നതിൽ കൂടുതലാണെന്ന് കണ്ടു. കൂടാതെ ജലവിനിയോഗ ക്ഷമതയും (വാട്ടർ യൂസ് എഫിഷൻസി), ജല ഉൽപ്പാദന ക്ഷമതയും (വാട്ടർ പ്രൊഡക്റ്റിവിററി) ഈ രീതിയിൽ വർദ്ധിക്കുന്നു എന്നും കണ്ടു.

കേരള കാർഷിക സർവ്വകലാശാല പ്രസിദ്ധീകരണമായ 'പാക്കേജ് ഓഫ് പ്രാക്റ്റീസസ് – 2011' എന്ന പുസ്തകത്തിൽ ശുപാർശ ചെയ്ത പോഷക മൂലകങ്ങളുടെ തോത് (ഹെക്ടറിന് 70:25:25 കി. ഗ്രാം N: P_2O_5: K_2O) മണ്ണ് പരിശോധനയുടെ അടിസ്ഥാനത്തിൽ ഹെക്ടറിന് 70:20:32 കി. ഗ്രാം N: P_2O_5: K_2O ആയി ക്രമീകരിക്കുകയും ചെയ്തു. ഈ പോഷകങ്ങൾ ലഭ്യമാക്കുന്നതിനായി 152 കി. ഗ്രാം യൂറിയയും 53 കി. ഗ്രം മ്യൂറിയേറ്റ് ഓഫ് പൊട്ടാഷും പാവൽ നട്ട് പത്താമത്തെ ദിവസം തുടങ്ങി നാലു ദിവസം ഇടവിട്ട് അവസാനത്തെ വിളവെടുപ്പിനു മുൻപുവരെ (ഏകദേശം 20-28 പ്രാവശ്യം) ഫെർട്ടിഗേഷൻ വഴി നൽകിയാൽ പാവലിൽ നിന്നുള്ള വിളവ് വർദ്ധിപ്പിക്കാമെന്നും ആദായം കൂട്ടാമെന്നും ഈ പഠനത്തിൽനിന്ന് തെളിഞ്ഞു. ഇതിനോടൊപ്പം അടിവളമായി 100 കി. ഗ്രാം രാജ്ഫോസും 25 ടൺ കാലിവളവും നൽകണം.