PRODUCTION TECHNOLOGY OF CHILLI (*Capsicum annuum* L.) UNDER PROTECTED CULTIVATION

by

PINTU ROY VATTAKUNNEL

(2012 - 11 - 139)

THESIS

Submitted in partial fulfilment of the

requirements for the degree of

MASTER OF SCIENCE IN AGRICULTURE

Faculty of Agriculture

Kerala Agricultural University

DEPARTMENT OF AGRONOMY

COLLEGE OF AGRICULTURE

VELLAYANI, THIRUVANANTHAPURAM – 695 522

KERALA, INDIA

2014

DECLARATION

I, hereby declare that this thesis entitled **"PRODUCTION TECHNOLOGY OF CHILLI (*Capsicum annuum* L.) UNDER PROTECTED CULTIVATION"** is a bonafide record of research 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: 21 - 07 - 2014

PINTU ROY VATTAKUNNEL
(2012 -11-139)

CERTIFICATE

Certified that this thesis entitled **"PRODUCTION TECHNOLOGY OF CHILLI (*Capsicum annuum* L.) UNDER PROTECTED CULTIVATION"** is a record of research work done independently by Ms. Pintu Roy Vattakunnel (2012-11-139) 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.

Vellayani,
21-07-2014

Dr. T. Sajitha Rani
(Major Advisor, Advisory committee)
Associate Professor (Agronomy)
College of Agriculture
Vellayani

CERTIFICATE

We, the undersigned members of the advisory committee of Ms. Pintu Roy Vattakunnel (2012-11-139), a candidate for the degree of **Master of Science in Agriculture** with major in Agronomy, agree that the thesis entitled **"PRODUCTION TECHNOLOGY OF CHILLI (*Capsicum annuum* L.) UNDER PROTECTED CULTIVATION"** may be submitted by Ms. Pintu Roy Vattakunnel, in partial fulfilment of the requirement for the degree.

Dr. T. Sajitha Rani
(Chairperson, Advisory Committee)
Associate Professor (Agronomy)
Department of Agronomy
College of Agriculture, Vellayani

Dr. Geethakumari, V.L
(Member, Advisory Committee)
Professor and Head,
Department of Agronomy
College of Agriculture, Vellayani

Dr. Arthur Jacob, J
(Member, Advisory Committee)
Professor and Head, Instructional Farm
College of Agriculture, Vellayani

Dr. Hajilal, M. S
(Member, Advisory Committee)
Professor (Agrl. Engineering)
Instructional Farm,
College of Agriculture, Vellayani

Dr. S. Chandini
(Member, Advisory Committee)
Professor (Academic)
College of Agriculture, Vellayani,

cleared on 10.8.2014
Dr. V. Shankaranarayana,
Prof. and Head (Agronomy)
College of Sericulture,
Chintamani - 563125
Karnataka -
[EXTERNAL EXAMINER]

Dedicated

To

The God Almighty

ACKNOWLEDGEMENT

First of all, I bow my head before Lord Almighty for his kindness, countless blessings and unspeakable help rendered through various hands throughout, which made this venture a success.

I would like to put on record of my heartfelt sincere gratitude to Dr. T. Sajitha Rani, Associate Professor (Agronomy), Instructional Farm, College of Agriculture Vellayani, esteemed chairman of the advisory committee, for her expert and inspiring guidance, timely advice, constant encouragement, motherly affection and understanding throughout the course of this investigation and preparation, critical evaluation of this thesis, without which this work would not have seen the light of the day. I feel proud of myself in confessing that it has been an unique privilege for me to have been one of her students.

I express my gratitude to the members of the advisory committee, Dr. Geethakumari, V.L., Professor and Head, Department of Agronomy, Dr. Arthur Jacob, J., Professor and Head, Instructional Farm, Dr. Hajilal, M. S., Professor (Agrl. Engineering) Instructional Farm, Dr. S. Chandini, Professor (Academic) for their valuable suggestions, moral support, timely correction of thesis and encouragement.

I gratefully acknowledge Sri. C. E. Ajithkumar, Programmer, Department of Agricultural Statistics for his co-operation during the statistical analysis of the data.

I wish to place on record my thanks to each and every teaching and non teaching staff of Agronomy Department and Instructional farm for their sincere and wholehearted co-operation throughout the research work.

I am thankful to Kerala Agricultural University for providing the Kerala Agricultural University Junior Fellowship.

I avail this opportunity to express my sincere regards to my batchmates, especially Anju V. S., Pavan, Arya, V. C., Nayana, Sonia, Jayalekshmi, Anushma,

Hemanth, Reshma, Athira and Sasna for their unreserved help during the course of my study and my senior friends, Maria chechi, Asha chechi and Poornima chechi for their inspiration.

At this moment, I recall with love and gratitude, the constant encouragement and inspiration given to me by my family members, especially my mother. I am deeply obliged to them in making this endeavour a success.

PR

PINTU ROY VATTAKUNNEL

CONTENTS

LIST OF TABLES

LIST OF TABLES CONTINUED

LIST OF TABLES CONTINUED

LIST OF FIGURES

LIST OF FIGURES CONTINUED

LIST OF PLATES

LIST OF APPENDICES

LIST OF ABBREVIATIONS

@	at the rate of
^{o}C	Degree Celsius
%	Per cent
m^{-2}	Per square metre
CD	Critical difference
cm	Centimetre
DAT	Days after transplanting
et al.	And others
FUE	Fertilizer use efficiency
Fig.	Figure
FYM	Farmyard manure
ha^{-1}	Per hectare
g	Gram
i.e.	That is
K	Potassium
K_2O	Potash
kg ha^{-1}	Kilogram per hectare
K. lux	Kilolux
LAI	Leaf area index

LIST OF ABBREVIATIONS CONTINUED

l day^{-1}	Litre per day
Max.	Maximum
mg	Milligram
ml l^{-1}	Millilitre per litre
Min.	Minimum
mm	Millimetre
MOP	Muriate of potash
N	Nitrogen
NUE	Nitrogen use efficiency
No.	Number
NS	Non significant
P	Phosphorus
P_2O_5	Phosphate
$Plant^{-1}$	Per plant
POP	Package of practices
q ha^{-1}	Quintal per hectare
RH	Relative humidity
Rs	Rupees
sp.	Species

LIST OF ABBREVIATIONS CONTINUED

SE	Standard error
Sl.	Serial
t ha^{-1}	Tonnes per hectare
UV	Ultra violet
viz.	Namely
WAP	Week after planting

INTRODUCTION

1. INTRODUCTION

Chilli (*Capsicum annuum* L.), an important spice cum vegetable crop cultivated extensively in India is used in salads, chatney, sauces, pickles and is a main ingredient of Indian diet in every home. Chilli contains an alkaloid, 'capsaicin' which is a substituted benzyl amine derivative, has significant physiological action and is used in many pharmaceutical preparations like balms, lineaments and ointments for cold, sore throat and chest congestion. It is reported to be a rich source of vitamin A and C with plenty of minerals and have carminative, tonic and stimulative properties. It is also used in the preparations of natural colouring agents, cosmetics like lipsticks, perfumes and for colouring food stuffs due to its attractive colour which ranges from orange to blood red. The principal colouring matter is the carotenoid pigment, capsanthin constituting about 35 per cent of the total pigments. Chilli is a spice crop with tremendous export potential, so together with yield, quality also has to be considered.

Despite of its economic importance, growers are not in a position to produce good quality chilli with high productivity due to various biotic (pest and diseases), abiotic (rainfall, temperature, relative humidity and light intensity) and physiological factors (flower and fruit drop). Due to erratic behaviour of weather, the crops grown in open field are often exposed to fluctuating levels of temperature, humidity, wind flow *etc.* which ultimately affect the crop productivity adversely (Ochigbu and Harris, 1989). Besides this, limited availability of land for cultivation hampers the vegetable production. Protected cultivation is an option to ensure production of good quality produce during all seasons.

Protected cultivation is a cropping technique through which the microclimate surrounding the plant is controlled partially or fully, as per the requirement of the plant species grown, during their growth period (Mishra *et al.*, 2010). Under protected cultivation, chilli is grown under protected structures such as green houses or poly houses. Green house, the latest word in Indian agriculture is one such means where the plant are grown under controlled

or partially controlled environment resulting in higher yields than that is possible under open conditions (Navale *et al.*, 2003).

Green house helps to provide a conducive microclimate that facilitate the growth of healthy crops producing high yield, premium quality and higher price. It is also possible to make the produce available in the market, when it is in great demand, provided the grower follows protected cultivation.

Water and fertilizers are the most important factors of crop production but become costly over years. Efficient use of these inputs is the basis for survival of agriculture due to shrinking land area, increasing fertilizer prices, hunting energy crisis, wide spread pollution and fast degradation of natural resources. The only one solution to the above problem is by providing fertilizers and water as per the requirement of the plant and by applying these factors in such a way that plant can absorb them easily and efficiently. The application of fertilizers through the irrigation system (fertigation) became a common practice in modern agriculture. By this method of fertilizer application, nutrient loss through seepage and evaporation can be reduced. Fertigation allows nutrient placement directly into root zone around plants through a pipe network with the help of emitters near plant roots during critical periods of nutrient requirement (Imas *et al.*, 1997a and 1997b). Increased yield, improvement in quality of the produce, water and nutrient expense efficiency and protection of the environment are some of the main characteristics of this method. Fertigation system is necessary for crop production under green house to supply precise amount of water and fertilizer solution, increase water and fertilizer use efficiency, increase crop productivity and quality.

Different varieties perform in different manner under varied environment conditions. Selection of suitable varieties is an important step for the successful and economic cultivation under green house. Vellayani Athulya, Jwalamukhi and Anugraha, being the most promising KAU varieties of chilli in open field, their suitability for growing in poly house has to be evaluated. There is not much information available on green house cultivation of chilli and its response to fertigation.

Hence the present study was conducted with following objectives:

1. To find out the effect of fertigation on chilli in poly house and open field conditions.
2. To study the relative performance of chilli varieties under poly house and open conditions.
3. To study the influence of different growing conditions on productivity and quality of chilli.
4. To assess the economics of growing chilli under poly house and open condition.

REVIEW OF LITERATURE

2. REVIEW OF LITERATURE

Now a days, growers are not in a position to produce good quality chilli with high productivity due to shrinking land areas, biotic factors (pest and diseases), abiotic factors (rainfall, temperature, relative humidity and light intensity), leaching loss of nutrients etc. To overcome this problem, growing crops under protected cultivation and with fertigation is most appropriate. Chilli (*Capsicum annuum* L.) is an important spice cum vegetable crop cultivated extensively in India. The literacture pertaining to use of poly house, fertigation and varieties have been reviewed and presented in this chapter.

2.1 EFFECT OF GROWING CONDITION ON GROWTH CHARACTERS OF CROPS

2.1.1 Effect of Growing Condition on Growth Characters of *Capsicum* sp.

Bhatt and Rao (1993) studied the response of bell pepper to photosynthesis, growth, flower and fruit setting to night temperature and he observed that the higher temperatures have more adverse influence on net photosynthesis than lower temperature leading to decreased production of photosynthates above a certain temperature.

From a trial conducted on low plastic tunnels with *Capsicum annuum,* Marsin and Osvald (1997) observed that taller plants compared to unprotected condition. Megharaja (2000) observed significantly higher plant height and number of branches in capsicum under polyhouse condition compared to open field condition. Burt (2005) reported that optimum temperatures for fruit setting are between 16°C and 21°C. Night temperatures of 15–17°C and day temperatures of 24–30°C are best for good fruit development.

Naik (2005) studied the Influence of N-substitution levels through organic and inorganic sources on growth of capsicum under protected condition and reported a higher growth of roots under protected condition. Yellavva (2008) found that under naturally ventilated polyhouse, capsicum performed better in

terms of growth characters like plant height, number of leaves and number of branches compared to shade house.

In a study conducted by Zende (2008) to investigate the production techniques in capsicum under protected cultivation, it was revealed that plant height, number of leaves plant^{-1} and leaf area plant^{-1} were higher under naturally ventilated polyhouse compared to shade house.

Ganiger (2010) studied the response of bell pepper to organic nutrition under different environments and observed that the crop under shade house condition put forth better growth than open field condition in terms of plant height (90.34 cm and 67.98 cm, respectively) and plant spread (50.33 cm and 44.37 cm, respectively).

Kumar and Arumugam (2010) found that poly house grown chillies exhibited better performance on growth characters like plant height (165.84 cm), number of branches (47.21) and inter nodal length (12.12 cm) compared to open conditions (80.33 cm, 35.50 cm and 7.86 cm, respectively).

Singh *et al.* (2013) studied the effect of low poly-tunnel on the growth, yield and harvesting span of sweet pepper and observed that plant height was significantly more in low plastic non perforated tunnel compared to unprotected and February transplanted crops.

2.1.2 Effect of Growing Condition on Growth Characters of Other Vegetable Crops

In a trial in tomato, Nagoata *et al.* (1979) observed higher plant height under 20 and 40 per cent shade compared to those grown under normal light conditions.

Higher growth rate of tomato under green house have been reported by Papadopoulos and Ormorod (1991). The plant growth and development at earlier stages was faster in tomato plants under shade than open place (Chowdhury and Bhuyan, 1992).

Sharma and Tiwari (1993) reported that tomato plants grown under 50 per cent shade exhibited better growth in terms of plant height and dry matter production compared to those grown in open field.

Siddeque *et al.* (1993) have found out the possibilities of raising tomato crop successfully under plastic rain shelter from March to June and July to October, when it was not possible to raise crop without protection due to high rainfall.

Gimenes *et al.* (1994) observed an increase in all growth parameters of lettuce which are grown under tunnels and it was also found that plants grown under condition of 30 per cent reduction in solar radiation have shown the highest plant growth rate.

In a study conducted in tomato, Ganesan (2002a) reported that the height of the plant, number of nodes, internodal length and total dry matter production increased under greenhouse conditions compared to open field condition.

In a field trial conducted in tomato, Hazarika and Phookan (2005) found that plants under plastic rain shelter had higher growth rate compared to open condition.

Srichandran *et al.* (2006) observed higher growth parameters of cauliflower under shade net condition than under the open condition.

Dixit (2007) studied the performance of leafy vegetables like spinach, amaranthus, fenugreek and coriander under field and green house conditions and reported that plant height, number of leaves plant^{-1}, number of branches, length of leaves and width of leaves were higher for plants grown under green house condition compared to those in the open field. Tomato plants grown under shade exhibited better growth in terms of plant height and dry matter production compared to those in open field (Thangam and Thamburaj, 2008).

In a trial in tomato, Kavitha *et al.* (2009) reported that the growth characters like plant height and number of primary branches were higher under shade net as compared to open field condition.

Kittas *et al.* (2009) studied the influence of shade on growth of tomato and observed an increase of about 40 per cent in LAI compared to open field condition.

In a study conducted on tomato, Parvej *et al.* (2010) found that plant height, number of branches plant^{-1}, leaf area expansion rate and LAI were higher

under poly house when compared to natural condition. Prabhu *et al.* (2009) have observed that plant height and leaf production were maximum under shade net cover.

2.2 EFFECT OF GROWING CONDITION ON YIELD AND YIELD ATTRIBUTES OF CROPS

2.2.1 Effect of Growing Condition on Yield and Yield Attriibuting Characters of *Capsicum* sp.

Rylski and Spigelman (1986) reported that under field condition during the summer, a reduction in radiation of approximately 26 per cent had a significant impact and increased production in *Capsicum annuum* compared with exposure to full sunlight.

Bhatnagar *et al.* (1990) reported that the yield of capsicum was high under green house compared to open field.

Mean marketable yield of sweet pepper (4.62 kg m^{-2}) was high under plastic cover as compared to open (3.4 kg m^{-2}) and harvesting was early under plastic cover as compared to open field (Buczkowska, 1990).

Rumpel and Grudzien (1990) observed an early and higher total marketable yield in sweet peppers by growing under non woven row cover and low plastic tunnel.

Nimje and Shyam (1991) reported that three vegetable crop sequence of okra- capsicum-capsicum gave capsicum yield of 105 t $ha^{-1}annum^{-1}$ inside the green house when compared to 38 t $ha^{-1}annum^{-1}$ under open field.

Lange and Combark (1997) studied the effect of using plant covers and soil mulches on yield of seedless watermelon and it was reported that, with the use of plastic covers in August and September a higher yield of 76 t ha^{-1} was obtained in watermelon compared to uncovered plants (49 t ha^{-1}).

Marsin and Osvald (1997) reported more fruits $plant^{-1}$ from *Capsicum annuum* when gown under plastic tunnel.

Hazara and some (1999) found that the percentage of unmarketable fruit yield or poor quality fruits obtained was almost nil under polyhouse condition compared to open condition.

A field experiment conducted by Jeevansab (2000) revealed that the fruit yield of capsicum differed significantly with the growing environments and it was found that fresh fruit yield (30.5 t ha^{-1}) was highest under polyhouse than that of open field condition (12 t ha^{-1}).

Megharaja (2000) observed higher fruit length, fruit breadth, fruit volume, fruit weight and total fruits number in capsicum under polyhouse condition compared to open field.

In capsicum, Akhilesh *et al.* (2001) reported that the fruit yield $plant^{-1}$ was positively and significantly correlated with number of fruits $plant^{-1}$ and number of pickings.

Bowen and Frey (2002) carried out an experiment to study the performance of plasticultured tomato, it was observed that plants grown using polyethylene mulch and mini-tunnels had shown larger and more productive fruit with thicker pericarps and higher water content.

Singh *et al.* (2003) reported that productivity of capsicum (76.4 t ha^{-1}) was higher in greenhouse compared to open field condition. In a study conducted by Kamaruddin *et al.* (2006) on the response of capsicum under naturally ventilated tropical green house, it was observed that yield of capsicum was 24 t ha^{-1} compared to 6 t ha^{-1} in open field.

Venthamoni and Natarajan (2008) conducted a study on cultivation of sweet pepper cultivars (*Capsicum annuum* var. grossum L.) under shade net in tropical plains of Tamil nadu and found that capsium performed well under 35 per cent shade with high yield.

In a trial carried out in capsicum, Yellavva (2008) reported that the yield attributing characters like percentage of fruit set, number of fruits $plant^{-1}$, fruit weight, yield $plant^{-1}$, fruit yield ha^{-1} and total marketable yield were high in naturally ventilated polyhouse.

Zende (2008) in a study to investigate the production techniques of capsicum under protected cultivation observed significantly higher values of number of flowers $plant^{-1}$, number of fruits $plant^{-1}$, percentage fruit set, fruit

weight, fruit length, yield plant^{-1}, fruit m^{-2} and total fruit yield under naturally ventilated polyhouse compared to open field condition.

In high rainfall area of Jorhat, capsicum raised as off season crop yielded 55 t ha^{-1} during winter under sub tropical climate of Pant Nagar (Prabhu *et al.*, 2009).

Ganiger (2010) reported that the yield of capsicum was higher (18.19 t ha^{-1}) under shade house than open field (14.92 t ha^{-1}).

Kumar and Arumugam (2010) observed that fruit length (14.52 cm), average fruit weight (11.68 g) and number of fruits plant^{-1} (73.47) was maximum under naturally ventilated polyhouse compared to open conditions (10.16 cm, 9.66 g and 57.56, respectively) and the percentage of yield increase in polyhouse grown chilli was about 175.85 per cent over open field.

Singh *et al.* (2011) studied performance of sweet pepper (*Capsicum annuum*) varieties under protected and open field conditions in Uttarakhand and it was observed that average crop duration (200 days), fruit diameter (5.14 cm), number of fruits plant^{-1} (42.0), individual fruit weight (49.85g), fruits yield kg plant^{-1} (2.12 kg) and yield kg m^{-2} (12.75 kg) was higher under polyhouse compared to open field condition.

Singh *et al.* (2012) reported a loss of 51.30 per cent of fruit yield in capsicum in open field condition compared to poly house condition, whereas in terms of economic loss there was 74.19 per cent saving in yield. Percentage of unmarketable yield or poor quality fruits obtained was almost nil under polyhouse condition whereas, in open field condition, it was 35.50 per cent for capsicum.

Singh *et al.* (2013) studied the effect of low poly-tunnel on the yield and harvesting span of sweet pepper and reported that fruit number plant^{-1} (18.9), total yield (278.2 q ha^{-1}) and harvesting span (93 days) were significantly more in low plastic non perforated tunnel compared to unprotected and February transplanted crops.

2.2.2 Effect of Growing Condition on Yield and Yield Attriibuting Characters of Other Vegetable Crops

In a study conducted on cucumber, Sari *et al.* (1994) reported an yield increase of 51 per cent under low tunnel

Mashego (2001) conducted a study to evaluate the effect of different types of shade netting as well as in full sunlight on tomato production and it was found that the highest number of fruit plant^{-1} (47) was produced under shaded condition compared to open field condition.

Protected cultivation of cucumber provides the best way to enhance the productivity and quality along with the possibility of its year-round cultivation (Singh, 2003).

In a study conducted at IARI, New Delhi an average of 100 t ha^{-1} yield has been recorded for tomato under green house. In high rainfall area of Jorhat, tomato yields were observed to be 60-70 per cent higher under polyrain shelter. Like tomato, many other vegetable *viz.* cucumber, bottle gourd, bitter gourd and sponge gourd have been raised as off season crop during winter under subtropical climate of Pant Nagar and average yields of 129,136, 65 and 52 t ha^{-1}, respectively were obtained (Prabhu *et al.*, 2009).

Kumar and Arumugam (2010) conducted a study on the performance of vegetables under naturally ventilated polyhouse and found that yield and yield attributes of vegetables like tomato, brinjal, bhindi and cluster bean were maximum under poly house compared to open field and the percentage of yield increase in vegetables was found to be the highest under polyhouse viz. cluster bean (121.05 per cent), tomato (109.97 per cent), bhendi (76.95 per cent) and brinjal (69.33 per cent) over open field.

Parvej *et al.* (2010) have conducted an experiment to study phenological development and production potentials of tomato under polyhouse climate and the harvesting period was found to be extended by about 9 days and the individual tomato plants obtained from polyhouse were observed to be about 10 per cent bigger than fruits obtained from plants grown in open field with a fruit yield of

81 t ha^{-1} under polyhouse against 57 t ha^{-1} from the open field, it was about 29 per cent higher than open field.

In a study conducted by Singh *et al.* (2012) on tomato, it was revealed that percentage of unmarketable yield or poor quality fruits obtained was almost nil under polyhouse condition whereas in open field condition, it was 42.50 for tomato and reported a loss of 58.66 per cent of fruit yield in tomato in open field condition compared to poly house condition, whereas in terms of economic loss there was 69.84 per cent saving in yield.

2.3 EFFECT OF GROWING CONDITION QUALITY ATTRIBUTES OF CROPS

2.3.1 Effect of Growing Condition on Quality Attributes of *Capsicum* sp.

Capsicum fruits obtained from polyhouse had higher ascorbic acid compared to fruits of open field (Jeevansab, 2000). Yellavva (2008) conducted a study on capsicum plants, it was revealed that plants under naturally ventilated polyhouse had higher shelf life compared to other conditions.

In a study conducted on capsicum, Zende (2008) observed that fruits grown under naturally ventilated polyhouse recorded significantly higher shelf life compared to shade house.

The capsicum fruits from shade house cultivated crops stored well under ambient condition by recording less physiological loss in weight and found to be high in ascorbic acid content compared to fruits obtained from open field conditions (Ganiger, 2010).

Rahman and Inden (2012) conducted an experiment to study the effect of temperature stress on capsaicin content in sweet pepper cultivars. The six cultivars of sweet pepper were grown under two growing conditions of high temperature stress and low temperature and it was observed that capsaicin content of cultivars increased with high temperature treatment over low temperature treatment.

2.3.2 Effect of Growing Condition on Quality Attributes of Other Vegetable Crops

As per the study conducted by Ahluwalia *et al.* (1996), quality of tomato obtained from greenhouse condition was better compared to open field condition. High nutrition value of leafy vegetables produced in trenches under cold desert condition of Leh was reported by Yadav *et al.* (1999).

Singh *et al.* (2005) conducted a study on cucumber, summer squash and okra and found that percentage of poor quality fruits was minimum under protected cultivation as compared to unprotected cultivation.

Mahajan and Singh (2006) conducted a study on tomato under low cost naturally ventilated greenhouse and greenhouse tomato fruits were found to be superior than fruits of open field crop in view of fruit size, TSS content, ascorbic acid content and pH.

Thangam and Thamburaj (2008) reported a decrease in ascorbic acid content under shade in tomato.

2.4 EFFECT OF GROWING CONDITION ON NUTRIENT UPTAKE AND AVAILABILITY

Leonardi *et al.* (2009) studied about the nutrient uptake of tomato grown under protected cultivation and the nutrient uptake was found to be about 197 - 398 kg ha^{-1} for nitrogen, 89 - 196 kg ha^{-1} for P_2O_5 and 346 - 731 kg ha^{-1} for K_2O.

After the cropping season Ganiger (2010) observed that, physico-chemical properties of soils were not found to be varied much in open field and shade house condition with respect to EC, PH, water holding capacity, bulk density, organic carbon and available nitrogen and potassium.

2.5 EFFECT OF GROWING CONDITION ON PEST AND DISEASE INCIDENCE OF CROPS

2.5.1 Effect of Growing Condition on Pests and Disease Incidence in *Capsicum* sp.

The incidence of pests and diseases in capsicum was lower under naturally ventilated polyhouse compared to shadow hall structure and the higher incidence

of pests and diseases were noticed under shade house with misting (Yellavva, 2008).

Under naturally ventilated condition, Zende (2008) observed that the incidence of pest and disease in capsicum were lower (5 per cent and 10 per cent, respectively) compared to shade house condition (15 and 25 per cent, respectively).

Singh *et al.* (2012) studied about the insect pest incidence in capsicum and found that pest incidence was lower in polyhouse when compared to open field.

2.5.2 Effect of Growing Condition on Pests and Disease Incidence in Other Vegetable Crops

Satparthy *et al.* (1998) and Singh (1998) reported that under open field, vegetables were highly susceptible to insects (white fly, mites, aphid, house fly, fruit fly, borers, cutworm, hoppers and beetle) attack, which caused about 30-40 per cent loss in vegetable yield.

Ganesan and Subhasini (2001) observed that by growing crops under polyhouse, it was easy to protect the crops against pests and diseases under extreme climatic conditions.

Protected structures act as physical barrier and play a key role in integrated pest management by preventing spreading of insects, pests and viruses causing severe damage to the crop (Chandra and Gupta, 2003).

Singh *et al.* (2003) and Singh *et al.* (2005) reported that the pest affected plants and disease incidence through insect vectors in cucumber, summer squash and okra were low under protected condition compared to open condition and there by savings of insecticide and money was higher under protected cultivation..

Singh *et al.* (2009) reported a minimal incidence of fruit borer and vector white fly in tomato plants grown under polyhouse structure

Kittas *et al.* (2009) studied the influence of shade on disease incidence on tomato, and observed a reduction of about 50 per cent incidence of disease than that under open field condition.

Sing *et al.* (2011) reported that tomato plants grown in polyhouse experienced minimum incidence of bacterial wilt (3.08 per cent) and blossom end-

rot in fruits (4.32 per cent) whereas it was maximum in open field condition, 75 per cent and 16 per cent, respectively.

Singh *et al.* (2012) studied insect pest incidence in tomato and he found that pest incidence was lower in polyhouse when compared to open field. Similar findings were obtained by Singh (1998) and Satpathy *et al.* (1998).

2.6 EFFECT OF GROWING CONDITION ON ECONOMICS OF CULTIVATION

2.6.1 Effect of Growing Condition on Economics of Cultivation of *Capsicum* sp.

Megharaja (2000) conducted a study on capsicum under green house, it was found that capsicum grown under greenhouse resulted in highest net profit (Rs. 7,698 100 $m^{-2}crop^{-1}$) compared to open condition (282 100 m^{-2} $crop^{-1}$) with a cost benefit ratio of 1:1.46 as compared to open condition 1:0.24.

Singh *et al.* (2003) conducted a study to evaluate the performance of capsicum under medium cost green house and obtained a net income of Rs.8 m^{-2} per season for production of capsicum inside greenhouse.

Growing capsicum under polyhouse was not only productive (7614.60 kg 500 m^{-2} $year^{-1}$) compared to shadow hall structure (3108.00 kg 500 $m^{-2}year^{-1}$) but also profitable in obtaining fruits of excellent quality fetching relatively higher price (Yellavva, 2008).

Murthy *et al.* (2009) conducted a study on economic feasibility of production of capsicum under poly house and reported that production of capsicum under naturally ventilated polyhouse was found to be higher and total net returns (undiscounted) for six years period was found to be Rs.115.4 lakhs ha^{-1} with an annual average net return of Rs.19.2 lakhs ha^{-1} with a benefit cost ratio of 1.8: 1.

In capsicum, Singh *et al.* (2011) had found that gross return (Rs 211.81 m^{-2}), net returns (Rs 158.16 m^{-2}) and B: C ratio (1.0: 3.81) was higher under protected conditions compared to open condition.

2.6.2 Effect of Growing Condition on Economics of Cultivation of Other Vegetable Crops

Singh *et al.* (2003) conducted a study to evaluate the performance of tomato under medium cost green house and obtained a net income of Rs. 7 m^{-2} per season for production of tomato inside greenhouse.

A study carried out on musk melon and summer squash by Singh *et al.* (2005) revealed that the plastic low tunnel technology for off season cultivation of musk melon and summer squash was highly profitable and suitable with a BC ratio of 3.98: 1 for muskmelon and 3.96: 1 for summer squash in their off season cultivation. It was also observed that growing of parthenocarpic cucumber under naturally ventilated green house was feasible with B: C ratio of 1:2.29 in peri urban areas of northern India and yield of about 80 quintals of high quality fruits of cucumber were harvested from 3 crop together with higher yield of okra.

Singh and kumar (2006) studied techno economic feasibility of indigenously designed naturally ventilated greenhouses for year round cucumber cultivation and the cost-benefit ratio of cucumber cultivation for the naturally ventilated greenhouses was found to be 1:2.06 under Delhi conditions of India. It was concluded that the low cost natural ventilated greenhouses are suitable and economical for year round cucumber cultivation in the northern plains of India.

Singh *et al.* (2009) carried out a study on tomato inside naturally ventilated green house and the B: C ratio and net return m^{-2} were worked out as 1.92 and Rs.72/- respectively, which clearly shows that the greenhouse vegetable cultivation projects were worth making the investment.

2.7 EFFECT OF GROWING CONDITION ON MICROCLIMATE

Smith *et al.* (1984) reported that under shading nets the air temperature was lower than that of the ambient air depending on the shading intensity.

Gent (1990) conducted an experiment with tomato under floating row cover and it was observed that plant temperature under row cover was about 3-10°C higher than those grown in the open.

obtained similar results but RH at 8 am was found to be lower inside the greenhouse except from May to August and the light intensity inside the greenhouse was also found to be lower than in the open condition.

The shading was effective in reducing light penetration and temperature inside the shade house thereby creating better microclimate for production of higher yield and quality of fruits (Tiwari *et al.*, 2002).

In capsicum and bhindi, Basavaraja *et al.* (2003) reported that higher yields obtained from polyhouse due to favourable air temperature, optimum RH and light intensity present in structure.

In a study conducted in polyhouse, Cheema *et al.* (2004) reported that the early and higher yield of different vegetable crops inside the polyhouse was mainly because of higher temperature (more than 4-9°C) compared to the nearby open field during winter months.

Lower amount of available PAR under polyhouse could not affect the growth and yield of tomato (Aberkain *et al.*, 2006).

Kamaruddin *et al.* (2006) conducted a study under naturally ventilated tropical green house and the measured air temperature, wind speed, RH, light intensity and carbon dioxide were found to be in the range of 30-40°C, 0.5-3.0 m s^{-1}, 53-83 per cent, 170-1400 x 10^3 lux and 300-400 ppm, respectively.

Parvej *et al.* (2010) reported that the RH inside the polyhouse was always 5-10 per cent lower and temperature was about 8°C higher than that of the nearby open field together with that maximum available PAR inside the polyhouse was found to be about 40 per cent lower than that of the open field.

Mawalagedera *et al.* (2012) conducted an experiment in a naturally ventilated glasshouse under hot and humid conditions, and observed that the mean daytime temperature was found to be about 29±3.7° C and the daytime RH was relatively found to be high at early stages of crop growth (65–71 per cent) but rather lower at late stages (60–62.5 per cent).

2.8 EFFECT OF FERTIGATION ON GROWTH CHARACTERS OF CROPS

2.8.1 Effect of Fertigation on Growth Characters of *Capsicum* sp.

Ashoka (2005) studied the response of red chilli with fertigation, it was revealed that application of N and K through split application significantly improved morphological characters like plant height, number of branches, leaf area, LAI as well as dry matter production.

Shashidhara (2006) studied the response of chilli to fertigation on a vertisol of Malaprabha command area. Growth characters like plant height and LAI was observed to be higher in plants grown with fertigation.

Gupta *et al.* (2009) studied the effect of drip fertigation on growth of capsicum under Kashmir conditions and concluded that application of 80 per cent recommended NPK through fertigation produced maximum plant height (44.6 cm) and number of branches plant^{-1} (4.84) compared to that obtained under conventional method of fertilizer application.

Kanwar *et al.* (2013) evaluated the effect of fertigation on growth attributing characters of sweet pepper, it was found that plant height and number of branches were superior under 120 per cent recommended dose of fertilizer application through fertigation than recommended dose of fertilizer on soil application.

2.8.2 Effect of Fertigation on Growth Characters of Other Vegetable Crops

Alcantar *et al.* (1999) studied the effect of drip fertigation on growth of tomato and reported higher dry matter accumulation from plants with drip fertigated conditions compared to conventionally fertilized practices.

Narda and Lubana (1999) conducted trickle fertigation studies in tomato with three levels of nitrogen viz., 33.3, 50 and 100 kg N ha^{-1} in 3, 5 and 7 splits, respectively and furrow irrigation with band placement of 100 kg N ha^{-1} in 2 splits. The results revealed that the crops with trickle fertigation performed better in terms of growth dynamics viz., plant height, leaf area index, crop growth rate, relative growth rate, leaf area duration, biomass duration, net assimilation rate and dry matter production over furrow irrigated crop.

Tumbare (1999) studied the effect of drip fertigation on growth of okra, and reported that drip fertigation with 75 per cent nitrogen resulted in maximum plant height, leaf area, number of branches and dry matter production in okra over band placement of 100 per cent nitrogen through furrow irrigation.

Hebbar *et al.* (2004) reported that dry matter production and leaf area index of tomato was higher in fertigation over furrow irrigation.

Brahma *et al.* (2010) conducted a field experiment to study the effect of drip-fertigation on performance of tomato under Assam conditions and growth parameters like plant height and branch number were found to be maximum with cent per cent fertigation of recommended dose of N and K compared to conventional soil application of N and K.

Savitha *et al.* (2010) studied the effect of drip fertigation on growth of onion and drip fertigation at 75 per cent recommended dose of fertilizer recorded the highest plant height, number of leaves plant^{-1} and root length compared to soil application of recommended dose of fertilizer

2.9 EFFECT OF FERTIGATION ON YIELD AND YIELD ATTRIBUTES OF CROPS

2.9.1 Effect of Fertigation on Yield and Yield Attributes of *Capsicum* sp.

Pareya (1992) studied the effect of fertigation on various aspects and it was reported that chilli fruit production was minimized @ 240 kg N ha^{-1} applied weekly through drip irrigation on sandy soils of Central America.

Olsen *et al.* (1993) studied the effect of fertigation on fruit yield of sweet pepper and it was observed that fruit yield of sweet pepper was maximum with nitrogen fertiagtion @ 210 to 280 kg ha^{-1} on 10 equal doses through irrigation water.

Singh and Saxena (2001) studied the effect of fertigation on yield of chilli and it was reported that chilli attained maximum yield with application of 180 kg N ha^{-1} applied through drip system on alternate day from 15 days after planting to 150 days period.

Benefits of drip irrigation, in combination with mulching and fertilizer application (fertigation), have been reported by Antony and Singandhupe (2004) in sweet pepper and Shinde *et al.* (2002) in chilli.

Tumbare and Bhoite (2002) studied the effect of solid soluble fertilizer applied through fertigation on growth and yield of chilli (*Capsicum annuum*) and it was observed that the fruit yield of chilli increased significantly when nitrogen was applied through fertigation over surface application method.

Ashoka (2005) conducted an experiment to study the effect of split application of nitrogen and potassium on growth, yield and quality of red chilli under drip irrigation system, it was found that fruit yield get increased by 41per cent and 26 per cent with nitrogen and potassium as split (2971 kg ha^{-1}) and nitrogen alone (2649 kg ha^{-1}) respectively as compared to drip as control (2097 kg ha^{-1}). It was observed that as the number of split application of nitrogen and potassium increased, there was more number of fruits $hill^{-1}$and fruit length.

Shashidhara (2006) studied the response of chilli to fertigation on a vertisol of malaprabha command area. Yield attributing characters like average fruit weight and fruit number was found to be higher in plants grown with fertigation.

Mahajan *et al.* (2007) studied the response of red hot pepper (*Capsicum annuum* L.) to water and nitrogen under drip and check basin method of irrigation, it was observed that 75 per cent recommended nitrogen through drip irrigation performed better in terms of yield compared to application through check basin method of irrigation.

Gupta *et al.* (2010) studied the effect of fertigation on yield of capsicum and it was observed that 80 per cent of recommended NPK through fertigation performed well in terms of yield and yield attributes compared to manual fertilizer application.

Ramachandrappa *et al.* (2010) studied the effect of fertigation on yield of green chilli and observed higher fruit yield with fertigation compared to soil application fertilizers.

Singh *et al.* (2010) studied effect of fertigation on yield of capsicum, it was observed that capsicum attained maximum yield (12.15 kg m^{-2}) with fertigation and it was about 25.14 per cent higher yield compared to top dressing.

2.9.2 Effect of Fertigation on Yield and Yield Attributes of Other Vegetable Crops

Amjad *et al.* (2001) studied effect of conventional nitrogen fertilization on fertilizer use efficiency in light soils and it was observed a greater loss of nitrogen through leaching and volatilization

Balasubrahmanyam *et al.* (2001) reported a maximum onion bulb yield of 39.4 t ha^{-1} with application of 150:125:200 kg NPK ha^{-1} as liquid fertilizer through drip water as compared to lower and higher level of liquid fertilizer selected for the study.

Hebbar *et al.* (2004) carried out a field experiment to study the effect of fertigation on yield tomato and it was reported that significant increase in fruit yield with cent per cent fertigation of recommended dose (water soluble fertilizers) over drip irrigation control.

Singandhupe *et al.* (2005) studied the effect of fertigation on field grown tomato (*Lycopersicon esculentum*). He reported that application of 31 per cent and 69 per cent N during initial crop growth stages and flowering to reproductive stages, respectively resulted in 41 t ha^{-1} total fruit yield compared to recommended dose of 80 kg N ha^{-1}, applied in 10 equal splits at 7 day intervals with 50 per cent during vegetative and rest 50 per cent during flowering to reproductive stage. In other treatments where 23.5 to 27.3 per cent N was applied during vegetative stages and the rest 72.7 to 76.3 per cent during flowering to reproductive stages resulted in 38.6 - 40.5 t ha^{-1} fruit yield. In general application of more quantity of N during reproductive stage enhanced the vegetative growth and produced less fruit yield.

In cucumber, Wabel *et al.* (2006) observed a significant increase in yield by supplying nitrogen through fertigation system than by using other methods of soil application.

Brahma *et al.* (2010) conducted a field experiment to study the effect of drip-fertigation on performance of tomato under Assam conditions, it was observed that yield and yield parameters like fruit number per plant^{-1} and individual fruit weight were found to be maximum with 100 per cent fertigation of recommended dose of N and K compared to conventional application.

Savitha *et al.* (2010) studied the effect of drip fertigation on growth of onion and drip fertigation at 75 per cent recommended dose of fertilizer recorded the highest yield and yield attributes compared to soil application of recommended dose of fertilizer.

Singh *et al.* (2010) studied effect of fertigation on yield of tomato, it was observed that tomato attained maximum yield (10.85 kg m^{-2}) and it was about 25.14 per cent higher yield with compared to top dressing.

2.10 EFFECT OF FERTIGATION ON QUALITY ATTRIBUTES OF CROPS

Alcantar *et al.* (1999) studied the effect of drip fertigation on quality of tomato and it was observed that quality parameters like size, firmness and soluble sugars of tomato fruit produced was found to be higher under drip fertigated conditions compared to conventionally fertilized practices.

Rana *et al.* (2005) studied the effect of fertigation in quality aspects of tomato hybrids and an improvement in ascorbic acid of tomato hybrids through fertigation was observed.

Shashidhara (2006) studied the response of chilli to fertigation on a vertisol of Malaprabha command area. Yield attributing characters like average fruit weight and fruit number was found to be higher in plants grown with fertigation.

Brahma *et al.* (2010) conducted a field experiment to study the effect of drip-fertigation on performance of tomato under Assam conditions and quality parameters like total soluble solid and ascorbic acid were found to be maximum with cent per cent fertigation of recommended dose of N and K compared to conventional application.

Gupta *et al.* (2010) studied the effect of fertigation on quality of capsicum and better quality of chilli in terms of vitamin C content, TSS etc were obtained under fertigation compared to manual fertilizer application.

Ramachandrappa *et al.* (2010) studied the effect of fertigation on quality aspects of green chilli, it was found that parameter like ascorbic acid content was higher in fertigation treatments as compared to soil application of fertilizers. Similar results observed by Rana *et al.* (2005) in tomato.

2.11 EFFECT OF FERTIGATION ON NUTRIENT UPTAKE OF CROPS

2.11.1 Effect of Fertigation on Nutrient Uptake of *Capsicum* sp.

Veeranna *et al.* (2001) conducted field experiments to investigate effects of broad cast application and fertigation of normal and water soluble fertilizers at 3 rates through drip and furrow irrigation and fertilizer use efficiency of 5.28 was obtained in drip fertiagtion with 80 per cent water soluble fertilizers which was effective in producing about 31 per cent and 24.7 per cent higher chilli fruit yield along with 20 per cent saving of fertilizers over soil application of normal fertilizers at 100 per cent recommended level in furrow and drip irrigation methods, respectively.

Ashoka (2005) reported an increase in fertilizer use efficiency in chilli by 46 per cent and 26 per cent with N and K (10.79) and N alone (9.62) in combination with drip over drip as control (7.62), it was observed that split application of either 12/9 splits of N and K and 12 splits of N alone recorded significantly higher uptake of plant nutrient over drip as control and FUE was found to be significantly higher in drip method (7.62) compared to surface method of irrigation (5.65).

Shashidhara (2006) studied the response of chilli to fertigation on a vertisol of Malaprabha command area. N uptake was found to be higher in plants grown with fertigation.

Gupta *et al.* (2010) studied the effect of fertigation on fertilizer use efficiency of capsicum and better fertilizer use efficiency was observed with fertigation compared to manual fertilizer application.

Ramachandrappa *et al.* (2010) studied the effect of fertigation on nutrient uptake of green chilli and observed a better anutrient uptake under drip fertigation compared to fertilizer application through furrow irrigation.

2.11.2 Effect of Fertigation on Nutrient Uptake of Other Vegetable Crops

Silber et al. (2003) studied the effect of fertigation frequency on uptake of nutrients and it was reported that frequent fertigation improved the uptake of nutrients.

Singandhupe *et al.* (2003) conducted an experiment on fertigation studies in tomato crop (*Lycopersicon esculentum* L.), it was reported that application of nitrogen through the drip irrigation in ten equal splits at 8-days interval saved 20 to 40 per cent nitrogen as compared to the furrow irrigation where nitrogen was applied in two equal splits and it was also found that total nitrogen uptake in drip irrigation was 8-11 per cent higher than that of furrow irrigation.

Singandhupe *et al.* (2005) studied the effect of fertigation on field grown tomato (*Lycopersicon esculentum*), it was reported that application of 31 per cent and 69 per cent nitrogen during initial crop-growth stages and flowering to reproductive stages respectively, saved 27.5 per cent nitrogen compared to recommended dose of 80 kg nitrogen ha^{-1}. The nitrogen recovery, agronomic efficiency and physiological efficiency was 38 per cent, 286 kg fruit yield kg^{-1} nitrogen applied and 930 kg fruit yield kg^{-1} nitrogen uptake respectively in 58 kg nitrogen ha^{-1}.

Wabel *et al.* (2006) observed an increase in nitrogen and potassium content in leaf, nitrogen in shoot and reduction in phosphorus content by the application of nitrogen through fertigation system in cucumber and it was also found that NUE was higher under fertigation system than under soil application.

2.12 EFFECT OF FERTIGATION ON NUTRIENT AVAILABILITY

Application of fertilizers along with irrigation water supply and maintain an optimum level of nutrients within the root zone (Fen and Mackenzie, 1993).

Battilani (2003) conducted fertigation studies in tomato and leachable nitrogen was found to be reduced by about 25-30 per cent in tomato under fertigation.

Monaghan et al. (2010) studied about nutrient use efficiency of lettuce under fertigation, it was observed that nitrogen availability with drip-fertigation (155 and 165 kg N ha^{-1}) was greater than conventional method.

Savitha *et al.* (2010) reported a reduction in loss of nutrients when N and K were applied through the drip fertigation system compared to soil application.

2.13 EFFECT OF FERTIGATION IN PEST AND DISEASES

Singh *et al.* (2010) studied the incidence of disease in vegetables under fertigated condition and it was observed that disease incidence was greatly reduced under fertigated condition.

2.14 EFFECT OF FERTIGATION ON ECONOMICS OF CULTIVATION OF CROPS

2.14.1 Effect of Fertigation on Economics of Cultivation of *Capsicum* sp.

As per the study conducted by Muralidhar (1998) in capsicum, among the methods of water and fertilizer application, fertigation method resulted in higher gross and net returns with achievement of maximum B: C ratio of 1:4.8 in capsicum.

Ramachandrappa *et al.* (2010) studied the effect of fertigation on yield of green chilli and achieved a higher net return and B: C ratio with Urea, SSP and MOP at 125 per cent recommended NPK fertigation compared to soil application fertilizers.

Kanwar *et al.* (2013) studied the effect of fertigation on economics of sweet pepper, it was observed that maximum net income, highest benefit:cost ratio, maximum profit for rupee $investment^{-1}$ were achieved in sweet pepper by applying 80 per cent recommended dose of fertilizer application through fertigation compared to recommended dose of fertilizer application on soil.

2.14.2 Effect of Fertigation on Economics of Cultivation of Other Vegetable Crops

Amarananjundeshwara *et al.* (1999) found that highest profit was obtained when 100 per cent water soluble fertilizers were drip fertigated, but in terms of BC ratio, application of 100 per cent normal fertilizers under drip fertigation was found better with a ratio of 1:2.24 in potato crop.

2.15 INTERACTION EFFECT BETWEEN FERTIGATION AND GROWING CONDITION ON GROWTH AND YIELD OF CAPSICUM SPECIES

Canadas *et al.* (1985) conducted a study to assess the performance of sweet pepper under green house with fertigation, it was found that leaf area and fresh weight of sweet pepper were greater with fertigation than with flood irrigation in green house.

Kamaruddin *et al.* (2006) conducted an experiment to study response of fertigation on capsicum growth under naturally ventilated tropical green house and increased stem diameter, plant height and leaf width were observed.

Madile *et al.* (2012) carried out an experiment to study the effect of tensiometer based drip irrigarion and fertigation on growth yield of capsicum (*Capsicum annuum* L.) under polyhouse and observed an increase in growth parameters, yield and yield attributes compared to conventional method.

2.16 INTERACTION EFFECT BETWEEN FERTIGATION AND GROWING CONDITION ON YIELD OF OTHER VEGETABLE CROPS

Mahajan and Singh (2006) conducted a field experiment during 2002–2004 at Department of Soil and Water Engineering, Punjab Agricultural University, Ludhiana to investigate the effect of fertigation on greenhouse tomato and it was observed that fertigation with 100 per cent recommended nitrogen resulted an increase in fruit yield by 59.5 per cent over control (recommended practices) inside the greenhouse and by 116.2 per cent over control (recommended practices) outside the greenhouse, respectively.

Kavitha *et al.* (2008) conducted an experiment to elucidate the effect of shade and fertigation on growth, yield and quality of tomato hybrid, Ruchi. The experiment was concluded with the results that the shade and fertigation levels singly and in combination significantly influenced the yield and it was observed that the highest yield was obtained at 100 per cent water soluble fertilizer and shade followed by 100 per cent straight fertilizers under shade in all the three seasons.

Kavitha *et al.* (2009) studied effect of fertigation in tomatoes under shade condition and it was observed that yield attributing characters like fruit weight and

number of fruits plant^{-1} and yield ha^{-1} was higher with application of 100 per cent water soluble fertilizers in shade grown tomatoes.

2.17 INTERACTION EFFECT BETWEEN FERTIGATION AND GROWING CONDITION ON QUALITY ASPECTS OF CROPS

Suh (1999) studied about the combined effect of rain shelter and fertigation on quality aspects of chinese cabbage, it was observed that heads grown under open condition without fertigation, were of less quality with poor compactness and content of soluble solids and were free of soil parcticles compared to those grown under rain shelters with fertigation.

Mahajan and Singh (2006) conducted an experiment to study the effect of fertigation on green house tomato and it was observed that ascorbic acid content was higher with fertigation under green house over control inside green house and control outside green house.

2.18 INTERACTION EFFECT BETWEEN FERTIGATION AND GROWING CONDITION ON NUTRIENT UPTAKE AND AVAILABILITY

Mahajan and Singh (2006) studied about the response of greenhouse tomato to fertigation and were observed that nutrient uptake was higher with fertigation under green house over control inside green house and control outside green house.

Mawalagedera *et al.* (2012) conducted an experiment at Dodangolla Experimental Station of the University of Peradeniya to study the effect of fertigation and naturally ventilated glasshouse on tomato under hot and humid conditions of tropical environment, it was observed that leaf nitrogen and phosphorus compositions in all the fertigation treatments gradually reduced with plant growth but increased again at the late fruit development stage, 20 weeks after planting and in case of potassium, reserves in leaves appeared to be depleting during 8–12 WAP to meet the demand from reproductive boom of the plant.

2.19 INTERACTION EFFECT BETWEEN FERTIGATION AND GROWING CONDITION ON PEST AND DISEASE INCIDENCE

Suh (1999) studied about the combined effect of rain shelter and fertigation on pest and disease incidence in chinese cabbage and the number of pest and disease affected head was found to be minimum under rain shelters with fertigation compared to those grown under open condition without fertigation.

2.20 INTERACTION EFFECT BETWEEN FERTIGATION AND GROWING CONDITION ON ECONOMICS

Madile *et al.* (2012) carried out an experiment with capsicum to study about the economic feasibility of tensiometer based drip irrigarion and fertigation under polyhouse and it was found to be economically profitable and B: C ratio varied from 2.88 - 9.32.

2.21 EFFECT OF VARIETIES ON GROWTH CHARACTERS OF CROPS

2.21.1 Effect of Varieties on Growth Characters of *Capsicum* sp.

Shivkumar (2005) carried out biometrical studies among various chilli genotypes and variation in growth characters like plant height and number of branches was observed among genotypes.

Ganiger (2010) studied among different bell pepper varieties and it was found that local bell pepper variety of capsicum put forth better growth in terms of plant height (74.88 cm), plant spread (46.76 cm), number of primary branches (2.52) and number of secondary branches (7.72) than California Wonder.

2.21.2 Effect of Varieties on Growth Characters of Other Vegetable Crops

Parvej *et al.* (2010) reported that among the two varieties of tomato, Ratan and BARI Tomato-3, 'Ratan' exhibited better performances in terms of plant height, number of branches plant^{-1}, leaf area expansion rate and LAI as compared to BARI Tomato-3.

Kengar (2011) studied the performance of different tomato hybrids in terms of growth characters. Among hybrids, higher plant height, number of branches and number of leaves were observed in STH-801.

Among the tomato lines tested, the maximum plant height was recorded in EC-524087 (175.22 cm) and among cross combinations (F_1's) maximum plant

height was recorded by EC- 521041 x FT-5 (198.25 cm) (Kumari and Sharma, 2011).

2.22 EFFECT OF VARIETIES ON YIELD OF CROPS

2.22.1 Effect of Varieties on Yield of *Capsicum* sp.

Rahman and Elsheik (1994) studied the performance of different capsicum varieties like California wonder, Yolo wonder and HW yellow and observed that California wonder yielded high under green house among 3 capsicum varieties tested and among the 3 capsicum cultivars (Colombo, Galaxy and Gedeon), Cultivar 'colombo' was found to be performed well.

Munij and Almedia (1998) reported that, among six capsicum cultivars evaluated for commercial yields, number of fruits plant^{-1}, fruit weight and size, the most productive cultivars were Ruby King, Early Calwonder and Ikeda (15.8-19.5, 15.5-19.5 and 16.6-18.4 t ha^{-1}, respectively) and the lowest yield (12.0-12.7 t ha^{-1}) was shown by the cultivar Nara.

Shivkumar (2005) carried out biometrical studies among various chilli genotypes and variation in yield attributing characters like number of fruits plant^{-1} and length of fruits were observed among genotypes.

In capsicum, Yellavva (2008) reported that number of flowers, extent of fruit set, number of fruits plant^{-1}, yield plant^{-1} and fruit yield ha^{-1} were higher in Indra compared to other hybrids evaluated but higher fruit weight was observed from Bomby.

Ganiger (2010) studied the response of two varieties of bell pepper, California Wonder and local variety under different environmental conditions, it was found that irrespective of environment conditions grown, California Wonder performed well with respect to yield parameters like fruit weight (570.20 g plant^{-1}), fruit breadth (6.35 cm) and fruit length (6.76 cm) and the yield of California Wonder was significantly higher (20.21 t ha^{-1}) than Local variety (16.18 t ha^{-1}).

Singh *et al.* (2011) carried out a study among 5 sweet pepper varieties, California Wonder (an open variety), Bharat, Indum 5, US 181 and Tanvi. Among these varieties, the hybrid 'Tanvi' produced maximum fruit diameter,

number of fruits plant^{-1}, individual fruits weight, weight of fruits, yield, gross income, net income and BC ratio in both open and protected condition similar observations were reported by US-181 and Indum 5 under both conditions.

2.22.2 Effect of Varieties on Yield of Other Vegetable Crops

Parvej *et al.* (2010) conducted a study on two tomato varieties 'BARI Tomato-3' and 'Ratan'and it was found that the tomato variety 'BARI Tomato-3' performed well in terms of number of flower clusters plant^{-1}, flowers cluster^{-1}, flowers plant^{-1} and number of fruits compared to Ratan.

Kengar (2011) studied the performance of different tomato hybrids in terms of yield characters. Among hybrids, higher fruit yield plant^{-1} was observed in STH-801.

2.23 EFFECT OF VARIETIES ON QUALITY ASPECTS OF CROPS

2.23.1 Effect of Varieties on Quality Aspects of *Capsicum* sp.

Hundal and Khanna (2002) studied the capsaicin content of different hybrids of chilli. Among different chilli hydrids evaluated, Ch-3 performed well in terms of capsaicin content.

Yellavva (2008) conducted a study on performance of capsicum hybrids like Indra and Orobelle, it was found that the hybrid Indra showed higher shelf life compared to Orobelle.

Ganiger (2010) reported that the fruits of California Wonder had better quality aspects like ascorbic acid content and shelf life compared to local variety of capsicum.

Nwokem *et al.* (2010) conducted an experiment for the determination of the capsaicin content in five commonly consumed pepper in Nigeria and the Yellow pepper (*Capsicum chinense*), Nsukka was found to be having highest concentration of capsaicin content and the lowest concentration was reported in Zaria tatashe.

Ozguven and Yaldiz (2011) conducted a field experiment to identify capsaicin content in thirty three varieties of capsicum. Capsaicin contents of the investigated red peppers were found to be varied from 0.04 mg g^{-1} to 4.05 mg g^{-1} and the highest value was reported by local population Acı Cicek 52 and the

lowest value of capsaicin content was obtained from the varieties *C. frutescens* 24 and *C.* sp.7.

2.23.2 Effect of Varieties on Quality Aspects of Other Vegetable Crops

Hazarika and Phookan (2005) reported that among the different varieties of tomato evaluated, maximum amount of ascorbic acid was recorded by DRD-8014.

Kengar (2011) studied the shelf life of different tomato hybrids and it was observed that the hybrids differed significantly with respect to the shelf life of fruits. Among different hybrids of tomato, STH-39 had the highest shelf life which was on par with STH-801.

Among the different tomato lines and hybrids evaluated by Kumari and Sharma (2011) maximum ascorbic acid content was reported in EC-60531 (36.15 mg 100 g^{-1}) among lines. Among F_1's, maximum ascorbic acid content was found in EC- 13736 x Solan Vajr (39.36 mg 100 g^{-1}).

2.24 EFFECT OF VARIETIES ON ECONOMICS OF CROPS

2.24.1 Effect of Varieties on Economics of *Capsicum* sp.

Singh et al. (2011) conducted an experiment to study the performance of sweet pepper (*Capsicum annuum*) varieties in terms of economics under protected and open field conditions in Uttarakhand. Among different varieties, hybrid Tanvi recorded maximum gross income, net income and benefit-cost ratio.

2.25 INTERACTION EFFECT BETWEEN VARIETIES AND ENVIRONMENT ON GROWTH CHARACTERS OF CAPSICUM SPECIES

Rahman and Sheikh (1994) observed that among three capsicum cultivars (Colombo, Galaxy and Gedcon) evaluated under plastic house, Colombo produced highest dry matter content (4.59 per cent)

Megharaja (2000) recorded significantly higher plant height (94.36 cm) and number of branches (31.94) in capsicum cv. Indra under polyhouse condition compared to plants grown under open condition (45.33 cm, 14.25 and 5.43, respectively).

Nagalakshmi *et al.* (2001) reported that the capsicum variety 'Green Gold' grown under naturally ventilated polyhouse have shown improved growth

components like increased plant height (92.3 cm) and number of branches plant^{-1} (8.3) compared to open condition.

Sharma *et al.* (2004) conducted a study with capsicum cv. California Wonder under green house and reported that California Wonder registered maximum plant height (56 cm), number of branches (5.86) and number of leaves (80.76) compared to open field condition.

2.26 INTERACTION EFFECT BETWEEN VARIETIES AND ENVIRONMENT ON YIELD OF CAPSICUM SPECIES

Megharaja (2000) recorded higher values with regard to fruit length, fruit breadth and fruit weight (8.54 cm, 6.76 cm and 120.06 g respectively) with capsicum cv Indra fruit grown under greenhouse condition compared to those procured from open field (5.67 cm, 4.40 cm, 56.17 g and 114.42 g, respectively).

Nagalakshmi *et al.* (2001) reported that the capsicum variety Green Gold grown under naturally ventilated polyhouse produced four fold increase in yield over open conditions (80 and 20.2 t ha^{-1}, respectively).

Sharma *et al.* (2004) studied the performance of different capsicum varieties under green house and open field condition, It was observed that California Wonder exhibited more number of fruits (15.03), fruit weight (723.28 g) and more yield (5.35 kg m^{-2}) under green house condition compared to open field condition.

Singh and Kumar (2006) evaluated thirteen varieties of sweet pepper, Mazurka, Fiesta, NVH 6-8 (all European varieties), HA-1038, HA- 1195, HA-1931, HA-1972 (all Israeli), Flamingo (USA) Orobelle, Nun-3020, Nun-3019, Tanvi and California Supreme in semi climate controlled green house, it was reported that variety Nun-3020 (yellow fruited) produced highest fruit yield (420.10 q/ha) maximum fruit weight (230.0 gram fruit^{-1}) followed by variety Mazurka (416.20 q ha^{-1}).

Two years results of study done by Appireddy *et al.* (2008) revealed that among the five varieties of bell pepper, performance of US Agril 181 was significantly higher in fruit yield (25.42 t ha^{-1} and 28.82 t ha^{-1}) in 2005 and 2006,

respectively as compared with other varieties and also gave highest net returns followed by Aishwarya and California Wonder under green house condition.

Combination of capsicum variety, Indra under polyhouse recorded maximum number of flowers plant^{-1}, maximum per cent of fruit set higher number of fruits, high yield plant^{-1} and fruit yield ha^{-1}, but higher fruit weight was recorded by Bomby under polyhouse (Yellavva, 2008).

Aruna and Sudagar (2009) evaluated three capsicum varieties, Arka Bharat, Arka Mohini and Arka Gaurav under polyhouse condition, it was observed that Arka Mohini recorded increased fruit weight (199.6 gm) and length of the fruit (10.54 cm). It was found that the variety Arka Mohini registered an increased yield of 1.204 kg plant^{-1} followed by Arka Gaurav (0.678 kg plant^{-1}) and Arka Bharat (0.403 kg plant^{-1}).

Ganiger (2010) studied the response of two varieties of bell pepper, California Wonder and Gangavati local bell pepper variety under shade house and open condition. Results revealed that variety California Wonder performed better with respect to growth, yield and fruit quality under both the environments and it yielded about (20.21 and 16.92 t ha^{-1}) higher than local variety (16.18 and 12.91 t ha^{-1}) under shade house and open field condition, respectively.

2.27 INTERACTION EFFECT BETWEEN VARIETIES AND ENVIRONMENT ON QUALITY OF CAPSICUM SPECIES

Ganiger (2010) studied the response of two varieties of bell pepper, California Wonder and Gangavati local bell pepper variety under shade house and open condition and results revealed that variety California Wonder performed better in terms of quality aspects especially regard to longer shelf life compared to local variety.

2.28 INTERACTION EFFECT BETWEEN VARIETIES AND ENVIRONMENT ON NUTRIENT UPTAKE

Leonardi *et al.* (2009) studied about the nutrient uptake of tomato cultivars grown under protected cultivation, it was observed that the cultivar, Lucinda performed well with higher uptake of nutrients like nitrogen, phosphorus and potassium (56 per cent, 36 per cent and 39 per cent, respectively).

2.29 INTERACTION EFFECT BETWEEN VARIETIES AND ENVIRONMENT ON ECONOMICS

Singh *et al.* (2005) studied the techno-economic feasibility of Tomato R-144 cultivation under indigenously- designed naturally-ventilated green house of 500 m^2 and it was found that cultivation of tomato in green house is remunerative with maximum net profit and Cost-Benefit ratio of 1: 2.

Wahundeniya *et al.* (2006) conducted a study to compare growth and yield performances of 15 tomato (*Lycopersicon esculentum* mill.) varieties under controlled environment conditions and it was reported that N-162 had the highest number of inflorescence. Makis and Ninja gave the highest and lowest number of fruits where highest fruit yield was given by variety, Big beef and lowest fruit yield was reported by Lapsigede. Variety Head Master and Ninja gave lowest number of fruits $plant^{-1}$ while Lapsigede gave highest number of fruits $plant^{-1}$. Big beef had highest fruit weight which is on par with Ninja and the lowest was shown by Lapsigede.

Yellavva (2008) conducted a study on performance of capsicum hybrids like Indra and Orobelle under polyhouse and among these two varieties, Combination of variety, Indra under polyhouse recorded higher net return and higher gross return.

MATERIALS AND METHODS

3. MATERIALS AND METHODS

The investigation entitled "Production technology of chilli (*Capsicum annuum* L.) under protected cultivation" was taken up at the Instructional Farm, College of Agriculture, Vellayani, Thiruvananthapuram, Kerala, during March 2013 to September 2013. The objective of the field experiment was to study the performance of chilli varieties and the effect of fertigation on productivity of chilli (*Capsicum annuum* L.) under protected cultivation.

3.1 EXPERIMENTAL SITE

The experiment was conducted in the garden land of the Instructional Farm attached to the College of Agriculture, Vellayani, Kerala. The farm is situated at 8.5^0 North latitude and 76.9^0 East longitude, at an altitude of 29 m above mean sea level.

3.1.1 Soil

Prior to the investigation, composite soil samples were drawn from 0 - 30 cm layer of the soil, both from inside poly house and open condition and analyzed for its mechanical composition and chemical properties. The data on the mechanical composition and chemical nature of the soil of the experimental site are presented in Tables 1a and 1b, respectively.

The soil of the experimental site was sandy clay loam, belonging to the taxonomical order Oxisol. Soil of poly house was acidic in reaction, medium in organic carbon content, medium in available nitrogen, medium in available phosphorus and medium in available potassium status and soil of open condition was also acidic in reaction and analyzed same status of organic carbon, nitrogen and potassium while, phosphorus status was low.

3.1.2 Cropping History of the Field

The area was under a bulk crop of cowpea before the experiment.

Table 1a. Mechanical composition of the soil of the experimental site

Sl. No.	Fractions	Content in soil (%)		Method used
		Open condition	Poly house	
1	Coarse sand	49.15	47.01	Bouyoucos hydrometer method (Bouyoucos ,1962)
2	Fine sand	14.50	16.64	
2	Silt	6.25	4.34	
3	Clay	27.50	29.41	

Table 1b. Chemical properties of the soil of the experimental site

Sl. No.	Parameter	Content in soil		Method used
		Open condition	Poly house	
1	Available N (kg ha^{-1})	401.40 kg ha^{-1} (med)	426.50 kg ha^{-1} (med)	Alkaline permanganate method (Subbiah and Asija, 1956)
2	Available P (kg ha^{-1})	6.69 kg ha^{-1} (low)	16.51kg ha^{-1} (med)	Bray colorimetric method (Jackson,1973)
3	Available K (kg ha^{-1})	137.50 kg ha^{-1} (med)	147.60 kg ha^{-1} (med)	Ammonium acetate method (Jackson,1973)
4	Organic carbon (%)	0.73% (med)	0.67% (med)	Walkley and black rapid titration method (Jackson,1973)
5	Soil reaction (pH)	5.4	5.1	1:2.5 Soil solution ratio using pH meter with glass electrode (Jackson,1973)

3.1.3 Season

The experiment was conducted during the summer season from March 2013 to September 2013.

3.1.4 Weather

The weekly averages of *viz.* maximum and minimum temperature, relative humidity, light intensity and rainfall in open field condition are given in Appendix II and illustrated in fig 1b. and maximum temperature, minimum temperature, relative humidity and light intensity inside the poly house are given in Appendix I and illustrated in Fig. 1a.

3.2 MATERIALS

3.2.1 Cultivar Used

Three chilli varieties viz. Vellayani Athulya, Anugraha and Jwalamukhi were used for the experiment.

The chilli variety, Vellayani Athulya (Plate: 1) was released from College of Agriculture, Vellayani and the variety is a selection from Aryanadu local. Plants are short statured with good spread, tolerant to shade and is of highly branching type. Fruit had an attractive light green colour with medium pungency. Matured fruits are 8-10 cm long.

The chilli variety, Anugraha (Plate: 1) was released from College of Horticulture, Vellanikkara and was developed through back cross breeding of Ujwala and Pusa Jwala. Plants are short statured with good spread and is resistant to bacterial wilt. It had an attractive light green coloured long fruits.

The chilli variety, Jwalamukhi (Plate: 1) was developed through recombination breeding of Vellanotchi and Pusa Jwala in College of Agriculture, Vellayani. Plants are tolerant to little leaf and leaf spot diseases and are tolerant to partial shade and are of moderate branching type. Fruits are protracted, succulent and low pungency fruits and are of medium size.

3.2.2 Source of Seed Material

The seeds for the study were obtained from the Department of Olericulture, College of Agriculture, Vellayani, Thiruvananthapuram, Kerala and

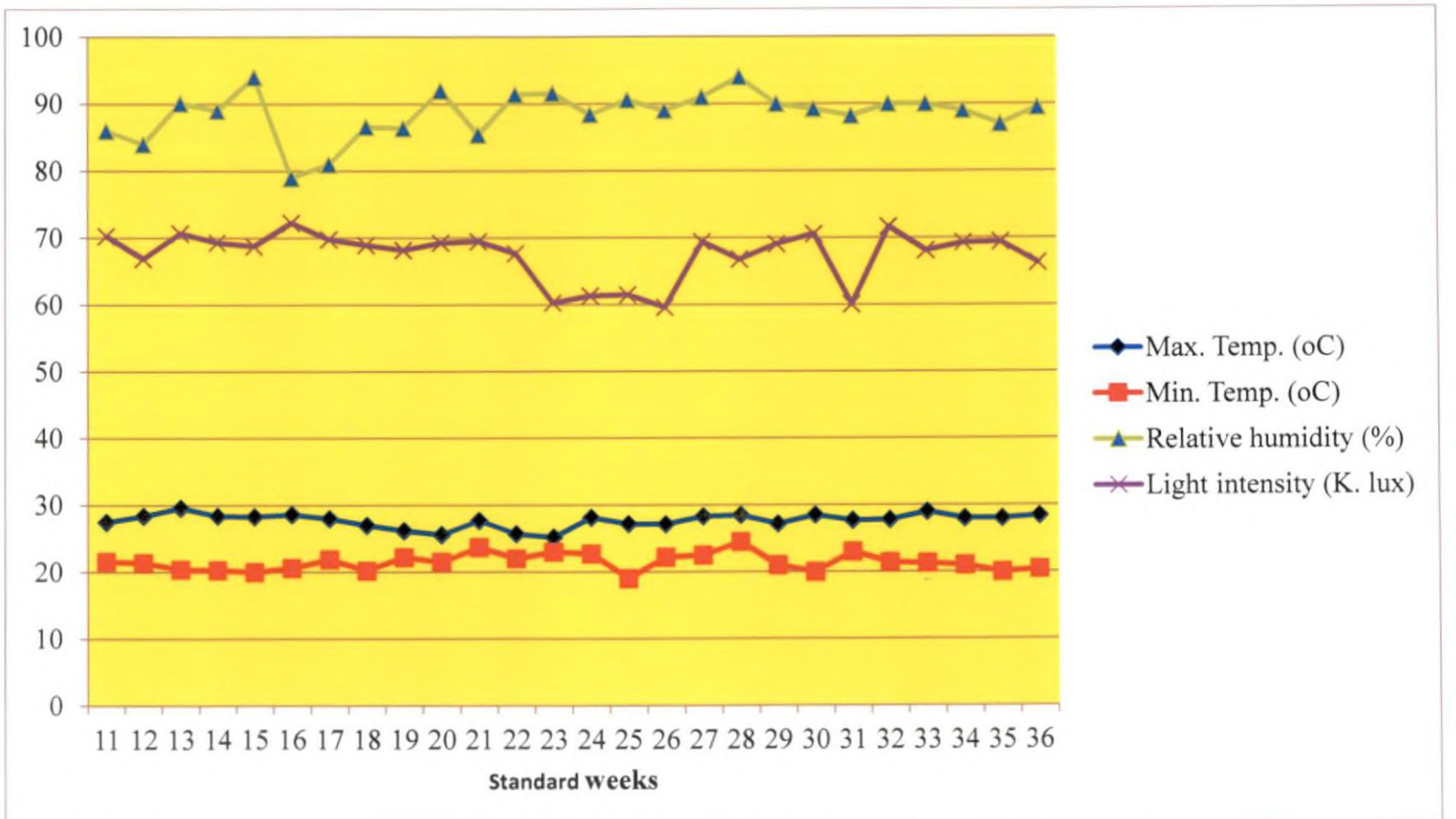

Fig. 1a. Weather parameters in poly house during the cropping period (13th March – 13th September, 2013)

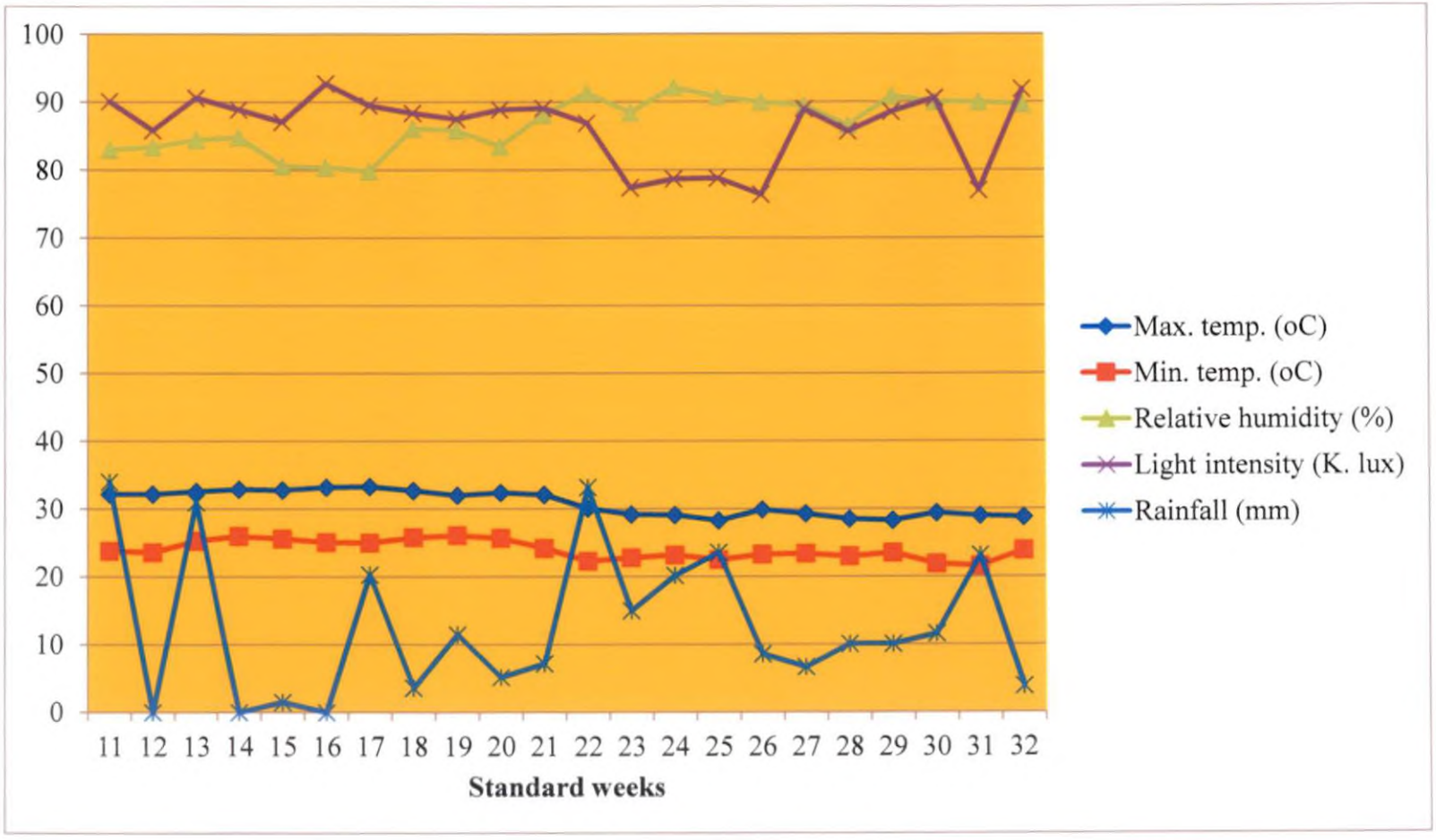

Fig. 1b. Weather parameters in open field during the cropping period (13th March – 13th August, 2013)

(A)

(B)

(C)

Plate1.Varieties selected for the experiment: (A) Vellayani Athulya (B) Anugraha and (C) Jwalamukhi

Department of Olericulture, College of Horticulture, Vellanikkara, Thrissur, Kerala.

3.2.3 Manures and Fertilizers

Farm yard manure (0.50 % N, 0.2 % P_2O_5, 0.50 % K_2O) was used as the organic source. Urea (46 % N), Rajphos (20 % P_2O_5) and MOP (60 % K_2O) were used as the inorganic sources for the experiment.

3.3 METHODS

3.3.1 Design and Layout

The investigation was laid out in split plot design (Fig. 2) with main plot treatment as a combination of growing condition (two levels) and fertigation (two levels) and the sub plot treatment was three varieties.

The details of the layout are given below.

3.3.2 Treatments

Two growing conditions, two levels of fertigations and three varieties

Season: Summer

Treatment combinations : 12

Replication : 4

Plot size : 2.7 × 1.8 m

Spacing : 45 × 45 cm

Main plot Treatments- Combination of growing conditions and fertigation- 4

i) Growing conditions (G) - 2

G_1 – Poly house

G_2 – Open condition

ii) Fertigation (F) - 2 levels

F_1 – With fertigation

F_2 – Without fertigation

Sub plot treatments – 3

iii) Varieties (V) – 3 Varieties

V_1 – Vellayani Athulya

V_2 – Anugraha

V_3 – Jwalamukhi

$G_1F_2V_3$	$G_1F_2V_1$	$G_1F_2V_2$	$G_1F_1V_1$	$G_1F_1V_3$	$G_1F_1V_2$	R_1
$G_1F_2V_2$	$G_1F_2V_3$	$G_1F_2V_1$	$G_1F_1V_3$	$G_1F_1V_2$	$G_1F_1V_1$	R_2
$G_1F_2V_1$	$G_1F_2V_2$	$G_1F_2V_3$	$G_1F_1V_2$	$G_1F_1V_1$	$G_1F_1V_3$	R_3
$G_1F_2V_3$	$G_1F_2V_1$	$G_1F_2V_2$	$G_1F_1V_3$	$G_1F_1V_2$	$G_1F_1V_1$	R_4
$G_2F_1V_3$	$G_2F_1V_2$	$G_2F_1V_1$	$G_2F_1V_2$	$G_2F_1V_3$	$G_2F_1V_1$	R_1
$G_2F_1V_2$	$G_2F_1V_1$	$G_2F_1V_3$	$G_2F_1V_1$	$G_2F_1V_2$	$G_2F_1V_3$	R_2
$G_2F_2V_1$	$G_2F_2V_3$	$G_2F_2V_2$	$G_2F_2V_3$	$G_2F_2V_1$	$G_2F_2V_2$	R_3
$G_2F_2V_2$	$G_2F_2V_1$	$G_2F_2V_3$	$G_2F_2V_2$	$G_2F_2V_3$	$G_2F_2V_1$	R_4

G_1- Poly house

G_2- Open condition

F_1- With fertigation

F_2- Without fertigaton

V_1-Vellayani Athulya

V_2- Anugraha

V_3- Jwalamukhi

Fig. 2. Layout plan of the experiment

(A)

(B)

Plate :3 General view of the field experiment (A) Poly house (B) Open field

Treatment combinations

$g_1f_1v_1$	$g_2f_1v_1$
$g_1f_1v_2$	$g_2f_1v_2$
$g_1f_1v_3$	$g_2f_1v_3$
$g_1f_2v_1$	$g_2f_2v_1$
$g_1f_2v_2$	$g_2f_2v_2$
$g_1f_2v_3$	$g_2f_2v_3$

3.4 CULTURAL OPERATIONS

The details of cultural operations carried out during the course of investigation are as follows.

3.4.1 Nursery

The soil was brought to fine tilth and raised seed beds of size 6' x 3' x 10" height were prepared and well rotten powdered farmyard manure was applied and incorporated into the soil. Chilli seeds were sown in rows of 10 cm apart and covered with a thin layer of soil. The nursery beds were watered twice daily. The seedlings were sprayed with nimbicidin (2 ml l^{-1}), two weeks after sowing and spray was repeated after two weeks.

3.4.2 Land Preparation

The land was ploughed twice to bring the soil to fine tilth. Plots were laid out as per the layout plan and the plot size was 2.7 m × 1.8 m. One healthy seedling of 30 days old was transplanted at 45 cm x 45 cm spacing in main field.

3.4.3 Manure and Fertilizer Application

As per POP recommendation of KAU, 25 t ha^{-1} of FYM was applied as basal at the time of land preparation along with 75:40:25 kg N: P_2O_5: K_20 ha^{-1} as fertilizer. Fertilizers used were urea as nitrogen source, rajphos as phosphorus source and MOP as potassium source.

For plants grown without fertigation, half of nitrogen and potash and full dose of phosphorous applied as basal dose before transplanting. One fourth of nitrogen and half of potash applied at 30 days after planting. The remaining quantity of nitrogen was applied at two months after planting.

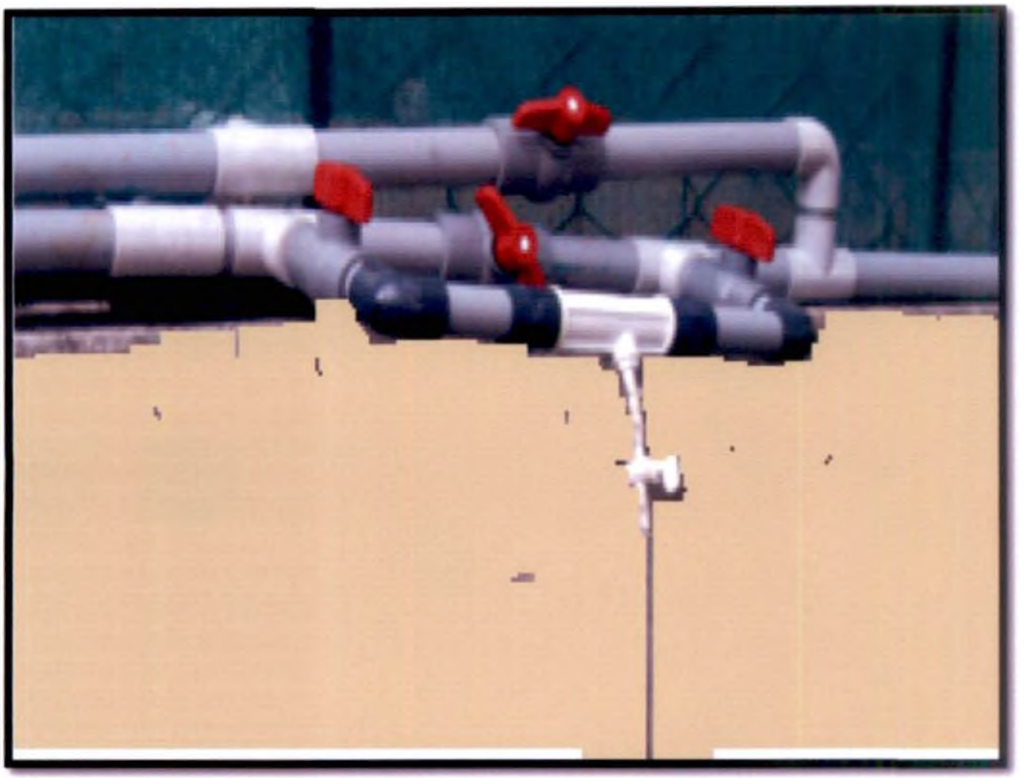

Plate2. Venturi system used for fertigation

For plants grown with fertigation, fertilizer was applied through drip irrigation using venturi system (Plate: 2). Phosphorus was applied as basal by direct soil application and N and K was applied in 9 and 11 splits respectively, at 1 week interval through drip irrigation.

3.4.4 Drip Irrigation

Both in open field situation and poly house situation, water was applied through drip irrigation. Requirement of water for chilli was calculated as 1.41 l day^{-1}.

3.4.5 Gap Filling

Gap filling was done 8 days after transplanting to ensure optimum plant population.

3.4.6 Other Management Practices

Two hand weedings were done at 25 and 45 days after transplanting (DAT).

3.4.7 Harvest

The crop was ready for first harvest 45 DAT in both poly house and open condition and subsequent harvests were made at 10 days interval (13 pickings in poly house condition and10 pickings in open condition). The fruits were picked when a slight yellowish green colour appeared.

3.5 OBSERVATIONS

For analyzing the growth pattern of the crop, five plants were selected randomly from the net plot area in each treatment and various observations were recorded. The parameters and procedures followed are given below.

3.5.1 Biometric Observations

3.5.1.1 *Plant Height*

Height of the five observational plants was recorded. Height was taken from the base to the growing tip at 5 stages *viz.* 30, 60, 90, 120 DAT and at harvest from open field and at 6 stages *viz.* 30, 60, 90, 120, 150 DAT and at harvest from poly house were taken. The mean plant heights were worked out and expressed in cm.

3.5.1.2 *Number of Primary Branches*

Numbers of primary branches at 5 stages *viz.* 30, 60, 90, 120 DAT and at harvest from open field and at 6 stages *viz.* 30, 60, 90, 120, 150 DAT and at harvest from poly house were taken and the mean worked out.

3.5.1.3 *Leaf Area Index (LAI)*

The LAI was calculated by the following formula developed by Watson (1947).

$$LAI = \frac{\text{Leaf area plant}^{-1}\ (cm^2)}{\text{Land area occupied by the plant}\ (cm^2)}$$

3.5.1.4 *Length of Tap Root*

Length of tap root was recorded at final harvest and expressed in cm.

3.5.1.5 *Lateral Root Spread*

The length of the largest lateral root on both sides of the taproot was measured, the mean worked out and expressed in cm.

3.5.1.6 *Root Shoot Ratio*

The plants were pulled out at harvest and the dry weights of shoots and roots were recorded. From this, root-shoot ratio was calculated.

3.5.2 Yield and Yield Attributes

3.5.2.1 *Number of Fruits Plant*$^{-1}$

Numbers of fruits of five observational plants were recorded and the mean worked out.

3.5.2.2 *Length of Fruit*

Length of randomly selected fruits from the five observational plants was measured and mean worked out and expressed in cm.

3.5.2.3 *Weight of Fruits Plant*$^{-1}$

The weight of green fruits obtained from observational plants was recorded at each harvest. The total weight of fruits plant^{-1} from the vegetable harvests was worked out and the mean weight was calculated and expressed in g.

3.5.2.4 *Mature Fruit Yield*

The total weight of mature fruits obtained from the net plot area was recorded and yield in kg ha^{-1} was computed.

3.5.3 Quality Parameters of Fruit

3.5.3.1 *Capsaicin*

Capsaicin content was determined by Folin-Dennis method. The pungent principle reacts with Folin-Dennis reagent to give a bluish complex, which was estimated colorimetrically (Mathew *et al.*, 1971). The capsaicin values were represented in per cent.

3.5.3.2 *Ascorbic Acid*

Ascorbic acid content of green fruits was estimated by 2, 6-dichlorophenol indophenols dye method (Sadasivam and Manickam, 1992). Ascorbic acid content of the sample was calculated using the formula.

$$\text{Ascorbic acid content (mg } 100g^{-1} \text{ fresh fruit)} = \frac{\text{Titre} \times \text{dye factor} \times \text{volume made upto} \times 100}{\text{Aliquot of extract taken} \times \text{weight of sample taken}}$$

3.5.3.3 *Shelf Life*

Sample fruits were taken treatment wise separately and the number of days taken from the harvest of fruits to the stage at which fruits become shrunken and lost firmness was recorded. The shelf life was represented in days.

3.5.4 Plant Analysis

The plant samples were subjected to chemical analysis for determining the total N, P, and K content. For this purpose, plant samples from each plot were dried in an electric hot air oven to constant weights at a temperature of 70^0C, 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.

3.5.4.1 *Uptake of Nitrogen*

The nitrogen content in plants samples was estimated by the modified micro kjeldhal method (Jackson, 1973) and the uptake of nitrogen was calculated

by multiplying the nitrogen content of plant sample with the total dry weight of plants. The uptake values were expressed in kg ha^{-1}.

3.5.4.2 *Uptake of Phosphorus*

The plant sample was undergone nitric-perchloric (9:4) digestion and phosphorus content in plants samples was determined colorimetrically using Vanadomolybdo phosphoric yellow colour method (Jackson, 1973). The uptake of phosphorus was calculated by multiplying the phosphorus content of plant sample with the total dry weight of plants. The uptake values were expressed in kg ha^{-1}.

3.5.4.3 *Uptake of Potassium*

The plant sample was undergone nitric-perchloric (9:4) digestion and potassium content in plants samples was determined by flame photometry method (Jackson, 1973). The uptake of potassium was calculated by multiplying the potassium content of plant sample with the total dry weight of plants. The uptake values were expressed in kg ha^{1}.

3.5.5 Soil Analysis

Soil samples were taken from the experimental area before and after the experiment. The air dried samples passed through 2 mm sieve were used for the analysis of physico-chemical properties.

3.5.5.1 *Organic Carbon Content*

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

3.5.5.2 *Available Nitrogen Content*

The available N content of soil after the experiment was estimated using alkaline permanganate method (Subbiah and Asija, 1956) and expressed in kg ha^{-1}.

3.5.5.3 *Available Phosphorus Content*

The available P content in soil after the experiment was estimated using Dickman and Bray's molybdenum blue method using Bray No.1 reagent for

extraction and estimated using spectrophotometer (Jackson, 1973) and expressed in kg ha^{-1}.

3.5.5.4 ***Available Potassium Content***

The available K content in soil after the experiment was determined using neutral ammonium acetate extract and was read in Flame photometer (Jackson, 1973) and expressed in kg ha^{-1}.

3.5.6 Scoring of Pest and Diseases

No incidence of disease was found to infect the crop beyond the economic threshhold level demanding control measures and hence no scoring was done. Leaf curl complex caused by thrips and mite were scored. The following scale (0-4) was adopted for cataloguing the damage.

Score	Per cent infestation
0	0
1	1-25
2	26-50
3	51-75
4	>76

3.5.7 Meteorological Parameters

Meteorogical parameters like temperature, relative humidity and light intensity were recorded inside poly house between 1 pm and 1:15 pm.

3.5.7.1 ***Temperature***

The observations on maximum and minimum air temperature inside the polyhouse were recorded daily by using a mercury thermometer (0-50°C) at canopy height in °C and averages were computed.

3.5.7.2 ***Relative Humidity***

The relative humidity in polyhouse was recorded by using wet bulb and dry bulb thermometer (0-100%) in per cent.

3.5.7.3 ***Light Intensity***

Light intensity inside the polyhouse was recorded with luxmeter at crop canopy level and recorded in K. lux.

3.5.8 Economic Analysis

Economics of cultivation was worked out for the field experiment after taking into account the cost of cultivation and prevailing market price of chilli. The net income and B: C ratio were calculated as follows.

Net income (Rs ha^{-1}) = Gross income- total expenditure

$$\text{Benefit: Cost ratio} = \frac{\text{Gross income}}{\text{Total expenditure}}$$

3.5.8 Statistical Analysis

Data generated from the experiment were subjected to statistical analysis applying ANOVA technique and significance tested by 'F' test (Snedecor and Cochran, 1975). In the cases where the effects were found to be significant, CD was calculated using standard techniques.

RESULTS

4. RESULTS

Field experiment to study the performance of chilli varieties and the effect of fertigation on productivity of chilli (*Capsicum annuum* L.) under protected cultivation was conducted at Instructional Farm attached to COA, Vellayani during the period from March to September 2013. The experimental data collected were statistically analyzed and the results obtained are presented in this chapter.

4.1 GROWTH CHARACTERS

4.1.1 Height of the Plant (cm)

Average height of the plant recorded at 30, 60, 90, 120, 150 days after transplanting (DAT) and at harvest is presented in table 2, 3, 4, 5, 6 and 7.

The perusal of the data revealed that different growing conditions significantly influenced the plant height at all growth stages. Maximum plant height was recorded by the plants grown under polyhouse (G_1) at all growth stages.

Different fertigation levels didn't cause significant variation in plant height at all stages of growth except at 60 DAT, at which plants treated with fertigation (F_1) showed maximum plant height (88.89 cm).

Varieties had significant influence on plant height at all growth stages except at 90 DAT. At 30 DAT, Vellayani Athulya (V_1) showed maximum plant height (32.04 cm) and it was on par with Anugraha (V_2) (27.88 cm). The lowest plant height was recorded by Jwalamukhi (V_3) (26.31 cm) and it was on par with Anugraha (V_2) (27.88 cm). At 60 DAT, V_1 showed maximum plant height (92.15 cm) and the lowest plant height was shown by V_2 (77.94 cm) and it was on par with V_3 (81.58 cm). At 120 DAT, maximum plant height was shown by V_1 (110.05 cm) and was on par with V_3 (104.79 cm) which was on par with V_2 (97.94 cm). At 150 DAT, V_1 showed maximum plant height (114.58 cm) and V_2 showed lowest plant height (103.36 cm) and it was on par with V_3 (108.45 cm).

The G x V interaction didn't show significant variation in plant height at any stages of growth except at 60 DAT, with maximum value of 125.43 cm by

g_1v_1 (Vellayani Athulya grown under poly house) and the lowest value was shown by Jwalamukhi grown in open field condition (g_2v_3) (53.27 cm) and it was on par with Anugraha grown in open field condition (g_2v_2) (55.96 cm) and Vellayani Athulya grown in open field condition (g_2v_1) (58.87 cm).

The interaction of growing conditions, fertigation level and varieties (G x F x V) caused significant variation in plant height at 150 DAT. Maximum value for plant height was observed from Vellayani Athulya grown under poly house with fertigation ($g_1f_1v_1$) (152.49 cm) and it was on par with Vellayani Athulya grown under poly house without fertigation ($g_1f_2v_1$) (149.17 cm), Anugraha grown under poly house with fertigation ($g_1f_1v_2$) (148.87 cm), Jwalamukhi grown under poly house with fertigation ($g_1f_1v_3$) (142.33 cm) and Jwalamukhi grown under poly house without fertigation ($g_1f_2v_3$) (142.31 cm). The lowest value was reported by Anugraha grown in open field condition with fertigation ($g_2f_1v_2$) (66.44 cm) and it was on par with Anugraha grown in open field condition without fertigation ($g_2f_2v_2$) (69.99 cm), Vellayani Athulya grown under poly house with fertigation ($g_2f_1v_1$) (72.38 cm), Jwalamukhi grown in open field condition without fertigation ($g_2f_2v_3$) (72.73 cm) and Jwalamukhi grown in open field condition with fertigation ($g_2f_1v_3$) (76.45 cm).

Interaction between fertigation levels and varieties (F x V) and interaction between levels of growing condition and fertigation (G x F) didn't caused significant variation in plant height at any stages of growth.

4.1.2. Number of Branches Plant^{-1}

Average number of branches recorded at 30, 60, 90, 120, 150 days after transplanting (DAT) and at harvest is presented in table 8, 9, 10, 11, 12 and13.

Different growing conditions caused significant variation in number of branches at all growth stages except at 60, 90 and 120 DAT. At all growth stages, maximum number of branches was shown by plants grown under polyhouse.

Number of branches was significantly influenced by the levels of fertigation at 120 DAT, at which plants grown with fertigation (F_1) showed maximum number of branches (10.69).

Table 2. Effect of growing conditions, fertigation and varieties on height of the plant at 30 and 60 DAT, cm

Treatments	30 DAT				60 DAT			
	Vellayani Athulya (V_1)	Anugraha (V_2)	Jwala-mukhi (V_3)	Mean	Vellayani Athulya (V_1)	Anugraha (V_2)	Jwala-mukhi (V_3)	Mean
G_1 (Poly house)	38.44	32.93	33.17	34.85	125.43	99.92	109.88	111.74
G_2 (Open condition)	25.64	22.82	19.46	22.64	58.87	55.96	53.27	56.04
F_1(With fertigation)	33.40	29.58	27.15	30.04	95.85	85.59	85.22	88.89
F_2 (Without fertigation)	30.68	26.18	25.48	27.45	88.45	70.29	77.94	78.89
Mean	32.04	27.88	26.31		92.15	77.94	81.58	

	G	F	V	G x V	F x V	G	F	V	G x V	F x V
SE m ±	1.122	1.122	1.042	2.085	2.085	2.871	2.871	1.533	3.067	3.067
CD(0.05)	3.593	NS	4.310	NS	NS	9.191	9.191	6.339	8.965	NS

NS- Not significant

Table 3. Interaction effect of growing conditions, fertigation and varieties on height of the plant at 30 and 60 DAT, cm

Treatments	30 DAT				60 DAT			
	Vellayani Athulya (V_1)	Anugraha (V_2)	Jwala-mukhi (V_3)	Mean	Vellayani Athulya (V_1)	Anugraha (V_2)	Jwala- mukhi (V_3)	Mean
g_1f_1	38.80	35.95	34.57	36.44	132.35	115.84	114.90	121.03
g_1f_2	38.07	29.92	31.78	33.26	118.52	84.00	104.87	102.46
g_2f_1	28.00	23.21	19.72	23.64	59.36	55.35	55.55	56.75
g_2f_2	23.29	22.44	19.19	21.64	58.39	56.58	51.00	55.32

	G x F	G x F x V	G x F	G x F x V
SE m ±	1.587	2.953	4.060	4.344
CD(0.05)	NS	NS	NS	NS

NS- Not significant

g_1f_1 - Poly house + fertigation
g_1f_2 - Poly house + without fertigation
g_2f_1 - Open condition + fertigation
g_2f_2 - Open condition + without fertigation

Table 4. Effect of growing conditions, fertigation and varieties on height of the plant at 90 and 120 DAT, cm

Treatments	90 DAT				120 DAT			
	Vellayani Athulya (V_1)	Anugraha (V_2)	Jwala-mukhi (V_3)	Mean	Vellayani Athulya (V_1)	Anugraha (V_2)	Jwala-mukhi (V_3)	Mean
G_1 (Poly house)	139.97	127.49	134.91	134.12	146.67	132.22	139.03	139.31
G_2 (Open condition)	67.92	60.05	65.90	64.63	73.43	63.67	70.56	69.22
F_1 (With fertigation)	102.67	99.43	101.12	101.07	107.88	103.64	105.51	105.68
F_2 (Without fertigation)	105.22	88.11	99.69	97.67	112.22	92.25	104.07	102.85
Mean	103.95	93.77	100.41		110.05	97.94	104.79	

	G	F	V	G x V	F x V	G	F	V	G x V	F x V
SE m ±	3.034	3.034	2.080	4.161	4.161	2.503	2.503	2.071	4.143	4.143
CD(0.05)	9.713	NS	NS	NS	NS	8.016	NS	8.564	NS	NS

NS- Not significant

Table 5. Interaction effect of growing conditions, fertigation and varieties on height of the plant at 90 and 120 DAT, cm

Treatments	90 DAT				120 DAT			
	Vellayani Athulya (V_1)	Anugraha (V_2)	Jwala-mukhi (V_3)	Mean	Vellayani Athulya (V_1)	Anugraha (V_2)	Jwala-mukhi (V_3)	Mean
g_1f_1	144.70	139.16	133.12	138.99	149.03	144.68	137.90	143.87
g_1f_2	135.24	115.82	136.70	129.25	144.32	119.75	140.16	134.74
g_2f_1	60.64	59.70	69.13	63.15	66.74	62.60	73.13	67.49
g_2f_2	75.21	60.41	62.68	66.10	80.12	64.75	67.99	70.95

	G x F	G x F x V	G x F	G x F x V
SE m ±	4.290	5.895	3.540	5.869
CD(0.05)	NS	NS	NS	NS

NS- Not significant

g_1f_1 - Poly house + Fertigation
g_1f_2 - Poly house + Without fertigation
g_2f_1 - Open condition + Fertigation
g_2f_2 - Open condition + Without fertigation

Table 6. Effect of growing conditions, fertigation and varieties on height of the plant at 150 DAT and 180 DAT, cm

Treatments	150 DAT				180 DAT #			
	Vellayani Athulya (V_1)	Anugraha (V_2)	Jwala-mukhi (V_3)	Mean	Vellayani Athulya (V_1)	Anugraha (V_2)	Jwala-mukhi (V_3)	Mean
G_1 (Poly house)	150.83	138.52	142.32	143.89	160.26	147.49	153.32	153.69
G_2 (Open condition)	78.34	68.21	74.59	73.71	0.00	0.00	0.00	0.00
F_1 (With fertigation)	112.43	107.65	109.39	109.82	81.00	77.28	81.45	79.91
F_2 (Without fertigation)	116.73	99.08	107.52	107.78	79.26	70.21	71.87	73.78
Mean	114.58	103.36	108.45		80.13	73.75	76.66	

	G	F	V	G x V	F x V
SE m ±	2.401	2.401	1.286	2.573	2.573
CD(0.05)	7.686	NS	5.319	NS	NS

Data statistically not analyzed

NS- Not significant

Table 7. Interaction effect of growing conditions, fertigation and varieties on height of the plant at 150 DAT, cm

Treatments	150 DAT			
	Vellayani Athulya (V_1)	Anugraha (V_2)	Jwalamukhi (V_3)	Mean
g_1f_1	152.49	148.87	142.33	147.89
g_1f_2	149.17	128.17	142.31	139.88
g_2f_1	72.38	66.44	76.45	71.75
g_2f_2	84.30	69.99	72.73	51.43

	G x F	G x F x V
SE m ±	3.395	3.645
CD(0.05)	NS	10.638

NS- Not significant

g_1f_1 - Poly house + Fertigation
g_1f_2 - Poly house + Without fertigation
g_2f_1 - Open condition + Fertigation
g_2f_2 - Open condition + Without fertigation

G x F interaction showed significant variation in number of branches at 60, 120 and 150 DAT. At 60 DAT, maximum number of branches (5.55) was shown by g_1f_1 (plants grown under poly house with fertigation) followed by g_2f_2 (plants grown in open field without fertigation) (4.63), which was on par with g_1f_2 (plants grown under poly house without fertigation) (4.58) and g_2f_1 (plants grown in open condition with fertigation) (4.22). At 120 DAT, g_2f_1 showed maximum number of branches (10.95) and was on par with g_1f_1 (10.43) and the lowest number of branches was reported from g_2f_2 (8.00), which was on par with g_1f_2 (10.00). At 150 DAT, maximum number of branches was reported from g_1f_1 (13.22). The lowest number of branches was reported by g_1f_2 (12.03), which was on par with g_2f_1 (12.08) and g_1f_2 (12.50).

The number of branches plant^{-1} was observed to vary significantly among varieties at all growth stages. At 30 DAT, Anugraha (V_2) showed maximum number of branches (3.96) followed by Vellayani Athulya (V_1) (2.54). The lowest number of branches was recorded by Jwalamukhi (V_3) (1.81) and it was on par with V_1. At 60 DAT, Vellayani Athulya (V_1) showed maximum number of branches (5.49) and it was on par with Anugraha (V_2) (5.45). The lowest number of branches was recorded in Jwalamukhi (V_3) (3.30). At 90 DAT, Anugraha (V_2) showed maximum number of branches (8.18) and was on par with Vellayani Athulya (V_1) (8.01). The lowest number of branches was recorded from Jwalamukhi (V_3) (6.20). At 120 DAT, V_2 (Anugraha) showed maximum number of branches (10.34) and it was on par with Vellayani Athulya (V_1) (10.24). The lowest number of branches was found in Jwalamukhi (V_3) (8.96). At 150 DAT, V_2 recorded maximum number of branches (13.41) followed by V_1 (12.35) and it was on par with V_3 (11.61).

The F x V interaction didn't show significant variation in number of branches at any stages of growth except at 120 DAT, with maximum value of 11.50 by f_1v_2 (Anugraha grown with fertigation) and it was on par with Vellayani Athulya with fertigation (f_1v_1) (11.48). The lowest value was recorded by Jwalamukhi without fertigation (f_2v_3) (8.83) and it was on par with Vellayani

Athulya without fertigation (f_2v_1) (9.00), Jwalamukhi grown with fertigation (f_1v_3) (9.10) and Anugraha without fertigation (f_2v_2) (9.18).

The interaction effect of G x V and G x F x V didn't show significant variation in number of branches at any stages of growth.

4.1.3. Leaf Area Index (LAI)

LAI recorded at 30, 60, 90, 120, 150 days after transplanting (DAT) and at harvest is presented in table 14, 15, 16, 17, 18 and19.

The perusal of the data revealed that different levels of growing conditions caused significant variation in LAI at all growth stages. Higher LAI was shown by the plants grown under polyhouse (G_1).

Different fertigation levels didn't cause significant variation in LAI at all growth stages except at 60 and 120 DAT. At 60 DAT, plants treated with fertigation (F_1) showed maximum LAI (1.22). At 120 DAT, plants grown with fertigation (F_1) recorded higher LAI (4.49).

LAI was found to be significantly influenced by the interaction of growing condition and fertigation (G x F) at 120 DAT. Combination of poly house and fertigation (g_1f_1) recorded higher LAI (5.02) followed by g_2f_1 (open field condition and fertigation) (3.96). The lowest LAI (1.78) was observed with g_2f_2 (open field and without fertigation).

Varieties significantly influenced the LAI at 30, 60 and 120 DAT. At 30 DAT, Vellayani Athulya (V_1) and Anugraha (V_2) recorded maximum LAI (0.23). At 60 DAT, Vellayani Athulya recorded maximum LAI (1.32) followed by Anugraha (1.01). At 120 DAT, Vellayani Athulya recorded maximum LAI (3.57) and it was on par with Anugraha (3.42).

Interaction between growing conditions and varieties (G x V) showed significant influence on leaf area at 90 DAT. Jwalamukhi grown under poly house recorded maximum LAI (g_1v_3) (3.98) and it was on par with Vellayani Athulya grown under poly house (g_1v_1) (3.32). The lowest LAI was observed with Jwalamukhi grown under open field condition (g_2v_3) (1.53) and it was on par with Anugraha grown under open field condition (g_2v_2) (1.74).

Table 8. Effect of growing conditions, fertigation and varieties on number of branches at 30 and 60 DAT

Treatments	30 DAT				60 DAT			
	Vellayani Athulya (V_1)	Anugraha (V_2)	Jwala-mukhi (V_3)	Mean	Vellayani Athulya (V_1)	Anugraha (V_2)	Jwala-mukhi (V_3)	Mean
G_1 (Poly house)	2.63	4.48	1.78	2.96	6.10	5.53	3.58	5.07
G_2 (Open condition)	2.45	3.45	1.85	2.58	4.88	5.38	3.03	4.43
F_1 (With Fertigation	2.43	4.10	1.80	2.78	5.30	5.50	3.85	4.88
F_2 (Without fertigation)	2.65	3.83	1.83	2.77	5.68	5.40	2.75	4.61
Mean	2.54	3.96	1.81		5.49	5.45	3.30	

	G	F	V	G x V	F x V	G	F	V	G x V	F x V
SE m ±	0.189	0.189	0.213	0.426	0.426	6.850	1.260	31.35	1.48	2.83
CD(0.05)	NS	NS	0.880	NS	NS	0.555	NS	0.653	NS	NS

NS- Not significant

Table 9. Interaction effect growing conditions, fertigation and varieties on number of branches at 30 and 60 DAT

Treatments	30 DAT				60 DAT			
	Vellayani Athulya (V_1)	Anugraha (V_2)	Jwala mukhi (V_3)	Mean	Vellayani Athulya (V_1)	Anugraha (V_2)	Jwalam ukhi (V_3)	Mean
g_1f_1	2.65	5.35	1.65	3.22	6.05	6.15	4.45	5.55
g_1f_2	2.60	3.60	1.90	2.70	6.15	4.90	2.70	4.58
g_2f_1	2.20	2.85	1.95	2.33	4.55	4.85	3.25	4.22
g_2f_2	2.70	4.05	1.75	2.83	5.20	5.90	2.80	4.63

	G x F	G x F x V	G x F	G x F x V
SE m ±	0.267	0.603	0.245	0.447
CD(0.05)	NS	NS	0.784	NS

NS- Not significant

g_1f_1 - Poly house + Fertigation
g_1f_2 - Poly house + Without fertigation
g_2f_1 - Open condition + Fertigation
g_2f_2 - Open condition + Without fertigation

Table 10. Effect of different growing conditions, fertigation and varieties on number of branches at 90 and 120 DAT

Treatments	90 DAT				120 DAT			
	Vellayani Athulya (V_1)	Anugraha (V_2)	Jwala-mukhi (V_3)	Mean	Vellayani Athulya (V_1)	Anugraha (V_2)	Jwala-mukhi (V_3)	Mean
G_1 (Poly house)	8.98	8.28	6.78	8.01	10.95	10.38	9.33	10.22
G_2 (Open condition)	7.05	8.08	5.63	6.92	9.53	10.30	8.60	9.48
F_1 (With fertigation)	8.08	8.28	6.65	7.67	11.48	11.50	9.10	10.69
F_2 (Without fertigation)	7.95	8.08	5.75	7.26	9.00	9.18	8.83	9.00
Mean	8.01	8.18	6.20		10.24	10.34	8.96	

	G	F	V	G x V	F x V	G	F	V	G x V	F x V
SE m ±	0.187	0.187	0.186	0.372	0.372	0.210	0.210	0.188	0.376	0.376
CD(0.05)	0.598	NS	0.770	NS	NS	0.672	0.672	0.777	NS	1.099

NS- Not significant

Table 11. Interaction effect of growing conditions, fertigation and varieties on number of branches at 90 and 120 DAT

Treatments	90 DAT				120 DAT			
	Vellayani Athulya (V_1)	Anugraha (V_2)	Jwala-mukhi (V_3)	Mean	Vellayani Athulya (V_1)	Anugraha (V_2)	Jwala-mukhi (V_3)	Mean
g_1f_1	9.10	9.00	7.25	8.45	11.90	10.40	9.00	10.43
g_1f_2	8.85	7.55	6.30	7.57	10.00	10.35	9.65	10.00
g_2f_1	7.05	7.55	6.05	6.88	11.05	12.60	9.20	10.95
g_2f_2	7.05	8.60	5.20	6.95	8.00	8.00	8.00	8.00

	G x F	G x F x V	G x F	G x F x V
SE m ±	0.264	0.528	0.297	0.532
CD(0.05)	NS	NS	0.95	NS

NS- Not significant

g_1f_1 - Poly house + Fertigation
g_1f_2 - Poly house + Without fertigation
g_2f_1 - Open condition + Fertigation
g_2f_2 - Open condition + Without fertigation

Table 12. Effect of growing conditions, fertigation and varieties on number of branches at 150 and 180 DAT

Treatments	150 DAT				180 DAT #			
	Vellayani Athulya (V_1)	Anugraha (V_2)	Jwala-mukhi (V_3)	Mean	Vellayani Athulya (V_1)	Anugraha (V_2)	Jwala-mukhi (V_3)	Mean
G_1 (Poly house)	12.63	13.88	11.38	12.63	12.83	13.95	11.98	12.92
G_2 (Open condition)	12.08	12.95	12.85	12.29	12.18	13.25	12.05	12.49
F_1 (With fertigation	12.05	14.10	12.65	12.65	12.25	14.95	11.95	13.05
F_2 (Without fertigation)	12.65	12.73	11.43	12.27	12.65	13.13	11.83	12.54
Mean	12.35	13.41	11.61		12.48	13.82	11.95	12.75

	G	F	V	G x V	F x V
SE m ±	0.208	0.208	0.218	0.436	0.436
CD(0.05)	NS	NS	0.900	NS	NS

Data statistically not analyzed

NS- Not significant

Table 13. Interaction effect of growing condition, fertigation and varieties on number of branches at 150 DAT

Treatments	150 DAT			
	Vellayani Athulya (V_1)	Anugraha (V_2)	Jwalamukhi (V_3)	Mean
g_1f_1	12.65	15.35	11.65	13.22
g_1f_2	12.60	12.40	11.10	12.03
g_2f_1	11.45	12.85	11.95	12.08
g_2f_2	12.70	13.05	11.75	12.50

	G x F	G x F x V
SE m ±	0.295	0.617
CD(0.05)	0.944	NS

NS- Not significant

g_1f_1 - Poly house + Fertigation
g_1f_2 - Poly house + Without fertigation
g_2f_1 - Open condition + Fertigation
g_2f_2 - Open condition + Without fertigation

Interaction between levels of fertigation and varieties (F x V) showed significant influence on leaf area index at 30 DAT. Maximum LAI was reported in Vellayani Athulya grown with fertigation (f_1v_1) (0.26) and Anugraha grown with fertigation (f_1v_2) (0.26) which were on par with Anugraha grown without fertigation (f_2v_2) (0.21), Vellayani Athulya grown without fertigation (f_2v_1) (0.19) and Jwalamukhi grown without fertigation (f_2v_3) (0.13). The minimum LAI was observed in Jwlamukhi grown with fertigation (f_1v_3) (0.12) and was on par with Jwalamukhi grown without fertigation (f_2v_3) (0.13), Vellayani Athulya grown without fertigation (f_2v_1) (0.19) and Anugraha grown without fertigation (f_2v_2) (0.21).

The interaction effect of G x F x V didn't cause significant influence on LAI at any stages of growth.

4.1.4. Length of Tap Root (cm)

Average length of tap root recorded at harvest is presented in table 20 and 21.

The perusal of the data revealed that different levels of growing condition significantly influenced the length of tap root. Plants grown under poly house (G_1) recorded maximum length of tap root (29.83 cm).

Fertigation levels had significant impact on length of tap root. Plants grown with fertigation (F_1) showed maximum length of tap root (29.23 cm).

Varieties significantly influenced the length of tap root. Maximum length of tap root was shown by Vellayani Athulya (V_1) (32.85 cm) followed by Anugraha (V_2) (28.38 cm). The lowest length of tap root was recorded by Jwalamukhi (V_3) (23.00 cm).

The G x F (growing conditions and fertigation), G x V (growing conditions and varieties), F x V (fertigation levels and varieties) and G x F x V (growing conditions, fertigation levels and varieties) interaction failed to produce any significant effect on length of tap root.

4.1.5 Root Spread (cm)

Average root spread recorded at harvest is presented in table 20 and 21.

Table 14. Effect of growing conditions, fertigation and varieties on leaf area index at 30 and 60 DAT

Treatments	30 DAT				60 DAT			
	Vellayani Athulya (V_1)	Anugraha (V_2)	Jwala-mukhi (V_3)	Mean	Vellayani Athulya (V_1)	Anugraha (V_2)	Jwala-mukhi (V_3)	Mean
G_1 (Poly house)	0.28	0.32	0.17	0.26	1.52	1.16	1.17	1.28
G_2 (Open condition)	0.17	0.15	0.08	0.13	1.11	0.86	0.55	0.84
F_1 (With fertigation)	0.26	0.26	0.12	0.22	1.45	1.22	1.00	1.22
F_2 (Without fertigation)	0.19	0.21	0.13	0.17	1.19	0.80	0.72	0.90
Mean	0.23	0.23	0.13		1.32	1.01	0.86	

	G	F	V	G x V	F x V	G	F	V	G x V	F x V
SE m ±	0.033	0.033	0.023	0.045	0.045	0.050	0.050	0.059	0.119	0.119
CD(0.05)	0.107	NS	0.094	NS	0.133	0.159	0.159	0.246	NS	NS

NS- Not significant

Table 15. Interaction effect of growing conditions, fertigation and varieties on leaf area index at 30 and 60 DAT

Treatments	30 DAT				60 DAT			
	Vellayani Athulya (V_1)	Anugraha (V_2)	Jwala-mukhi (V_3)	Mean	Vellayani Athulya (V_1)	Anugraha (V_2)	Jwala-mukhi (V_3)	Mean
g_1f_1	0.43	0.43	0.17	0.34	1.52	1.16	1.17	1.28
g_1f_2	0.11	0.18	0.07	0.12	1.11	0.86	0.55	0.84
g_2f_1	0.28	0.20	0.09	0.19	1.45	1.22	1.00	1.22
g_2f_2	0.07	0.14	0.22	0.15	1.19	0.80	0.72	0.90

	G x F	G x F x V	G x F	G x F x V
SE m ±	0.047	0.064	0.070	0.168
CD(0.05)	NS	NS	NS	NS

NS- Not significant

g_1f_1 - Poly house + Fertigation
g_1f_2 - Poly house + Without fertigation
g_2f_1 - Open condition + Fertigation
g_2f_2 - Open condition + Without fertigation

Table 16. Effect of growing conditions, fertigation and varieties on leaf area index at 90 and 120 DAT

Treatments	90 DAT				120 DAT			
	Vellayani Athulya (V_1)	Anugraha (V_2)	Jwala-mukhi (V_3)	Mean	Vellayani Athulya (V_1)	Anugraha (V_2)	Jwala-mukhi (V_3)	Mean
G_1 (Poly house)	3.32	3.00	3.98	3.44	4.08	4.05	2.56	3.57
G_2 (Open condition)	2.39	1.74	1.53	1.88	3.06	2.80	2.54	2.80
F_1 (With fertigation	2.84	2.30	2.76	2.63	4.85	4.95	3.67	4.49
F_2 (Without fertigation)	2.87	2.44	2.75	2.69	2.29	1.90	1.43	1.87
Mean	2.85	2.37	2.75		3.57	3.42	2.55	

	G	F	V	G x V	F x V	G	F	V	G x V	F x V
SE m ±	0.147	0.147	0.117	0.234	0.234	0.143	0.143	0.136	0.271	0.271
CD(0.05)	0.470	NS	NS	0.684	NS	0.457	0.457	0.560	NS	NS

NS- Not significant

Table 17. Interaction effect of growing conditions, fertigation and varieties on leaf area index at 90 and 120 DAT

Treatments	90 DAT				120 DAT			
	Vellayani Athulya (V_1)	Anugraha (V_2)	Jwala-mukhi (V_3)	Mean	Vellayani Athulya (V_1)	Anugraha (V_2)	Jwala-mukhi (V_3)	Mean
g_1f_1	3.64	3.23	4.17	3.68	5.96	5.34	3.77	5.02
g_1f_2	3.14	2.88	4.24	3.42	2.33	2.07	1.46	1.96
g_2f_1	3.06	1.86	1.70	2.21	3.79	4.17	3.92	3.96
g_2f_2	2.01	1.47	1.48	1.65	1.49	2.22	1.64	1.78

	G x F	G x F x V	G x F	G x F x V
SE m ±	0.207	0.331	0.202	0.384
CD(0.05)	NS	NS	0.646	NS

NS- Not significant

g_1f_1 - Poly house + Fertigation
g_1f_2 - Poly house + Without fertigation
g_2f_1 - Open condition + Fertigation
g_2f_2 - Open condition + Without fertigation

Table 18. Effect of growing conditions, fertigation and varieties on leaf area index at 150 and 180 DAT

Treatments	150 DAT				180 DAT#			
	Vellayani Athulya (V_1)	Anugraha (V_2)	Jwala-mukhi (V_3)	Mean	Vellayani Athulya (V_1)	Anugraha (V_2)	Jwala-mukhi (V_3)	Mean
G_1 (Poly house)	5.29	5.25	3.84	4.79	3.02	2.46	1.98	2.49
G_1 (Poly house)	1.63	1.10	0.75	1.16	0.00	0.00	0.00	0.00
G_2 (Open condition)	3.48	3.21	2.45	3.04	1.38	1.13	1.05	1.19
F_1 (With fertigation)	3.44	3.15	2.14	2.91	1.64	1.33	0.94	1.30
F_2 (Without fertigation)	3.46	3.18	2.29		1.51	1.23	0.99	

	G	F	V	G x V	F x V
SE	0.296	0.296	0.250	0.500	0.500
CD(0.05)	0.948	0.948	NS	NS	NS

Data statistically not analyzed

NS- Not significant

Table 19. Interaction effect of growing conditions, fertigation and varieties on leaf area index at 150 DAT

Treatments	150 DAT			
	Vellayani Athulya (V_1)	Anugraha (V_2)	Jwalamukhi (V_3)	Mean
g_1f_1	4.65	4.72	4.41	4.60
g_1f_2	7.14	2.91	3.45	4.50
g_2f_1	2.32	0.77	0.57	1.22
g_2f_2	0.91	0.86	0.79	0.85

	G x F	G x F x V
SE m ±	0.419	0.708
CD(0.05)	NS	NS

NS- Not significant

g_1f_1 - Poly house + Fertigation
g_1f_2 - Poly house + Without fertigation
g_2f_1 - Open condition + Fertigation
g_2f_2 - Open condition + Without fertigation

Different levels of growing conditions significantly influenced the root spread. Maximum root spread of 48.2 cm recorded by the plants grown under poly house (G_1).

Root spread was significantly influenced by the fertigation levels. The maximum root spread was shown by the plants grown with fertigation (F_1) with an average root spread of about 46.30 cm.

Varieties caused significant variation in root spread. The maximum root spread was observed in Vellayani Athulya (V_1) (46.70 cm) followed by Anugraha (V_2) (42.20 cm). The lowest root spread was shown by Jwalamukhi (V_3) (36.70 cm) and was on par with V_2.

Interaction effect of G x F, G x V, F x V and G x F x V had no significant influence on the root spread.

4.1.6 Root Shoot Ratio

Aaverage root shoot ratio recorded at harvest is presented in table 20 and 21.

The root shoot ratio was observed to vary significantly with different growing conditions. The highest value of root shoot ratio (0.40) was observed in chilli plants grown under open field condition (G_2).

The different fertigation levels, varieties and interactions effect of G x F, G x V, F x V and G x F x V had no significant influence on the root shoot ratio.

4.2 YIELD ATTRIBUTES AND YIELD

4.2.1 Number of Fruits Plant^{-1}

Average number of fruits is presented in table 22 and23.

Different levels of growing condition had significant influence on number of fruits plant^{-1}. The plants grown under poly house recorded maximum fruit number (110.67) compared to those grown under open field condition.

The results revealed that number of fruits plant^{-1} showed significant variation due to different levels of fertigation. The plants with fertigation (F_1) recorded maximum number of fruits plant^{-1} (113.49).

Table 20. Effect of different growing conditions, fertigation and varieties on root characters of chilli

Treatments	Length of tap root (cm)				Root spread (cm)				Root shoot ratio			
	Vellayani Athulya (V_1)	Anu-graha (V_2)	Jwala-mukhi (V_3)	Mean	Vellayani Athulya (V_1)	Anu-graha (V_2)	Jwala-mukhi (V_3)	Mean	Vellayani Athulya (V_1)	Anug-raha (V_2)	Jwala-mukhi (V_3)	Mean
G_1 (Poly house)	34.99	30.50	24.00	29.83	52.00	45.90	46.60	48.20	0.11	0.13	0.17	0.14
G_2(Open condition)	30.71	26.26	22.00	26.32	43.80	45.70	27.40	39.00	0.32	0.50	0.39	0.40
F_1 (With fertigation	33.92	29.47	24.30	29.23	54.50	37.10	47.30	46.30	0.26	0.28	0.28	0.27
F_2 (Without fertigation)	31.77	27.29	21.71	26.92	36.30	39.90	25.50	33.90	0.25	0.23	0.22	0.23
Mean	32.85	28.38	23.00		46.70	42.20	36.70		0.24	0.28	0.27	

	G	F	V	G x V	F x V	G	F	V	G x V	F x V	G	F	V	G x V	F x V
SE m ±	0.620	0.620	0.710	1.421	1.421	1.656	1.656	1.804	3.608	3.608	0.024	0.024	0.028	0.056	0.056
CD(0.05)	1.985	1.985	2.937	NS	NS	5.302	5.302	7.457	NS	NS	0.076	NS	NS	NS	NS

NS- Not significant

Table 21. Interaction effect of growing conditions, fertigation and varieties on root characters of chilli

Treatments	Length of tap root (cm)				Root spread (cm)				Root shoot ratio			
	Vellayani Athulya (V_1)	Anu graha (V_2)	Jwala-Mukhi (V_3)	Mean	Vellayani Athulya (V_1)	Anu graha (V_2)	Jwala-Mukhi (V_3)	Mean	Vellayani Athulya (V_1)	Anu graha (V_2)	Jwala-Mukhi (V_3)	Mean
g_1f_1	36.15	31.65	25.09	30.97	58.07	47.56	50.01	51.88	0.09	0.16	0.14	0.13
g_1f_2	33.82	29.36	22.91	28.70	45.99	44.26	43.11	44.45	0.13	0.11	0.21	0.15
g_2f_1	31.70	27.28	23.50	27.49	51.00	26.64	44.59	40.74	0.44	0.40	0.42	0.42
g_2f_2	29.72	25.23	20.50	25.15	40.49	28.25	36.78	35.17	0.56	0.39	0.24	0.4

	G x F	G x F x V	G x F	G x F x V	G x F	G x F x V
SE m ±	0.877	2.013	2.342	5.111	0.333	0.079
CD(0.05)	NS	NS	NS	NS	NS	NS

NS- Not significant

g_1f_1 - Poly house + Fertigation
g_1f_2 - Poly house + Without fertigation
g_2f_1 - Open condition + Fertigation
g_2f_2 - Open condition + Without fertigation

G x F interaction caused significant influence on number of fruits plant^{-1}. Maximum number of fruits plant^{-1} was reported in plants grown under poly house with fertigation (g_1f_1) (118.34) and the lowest number of fruits plant^{-1} was obtained from plants grown in open condition without fertigation (g_2f_2) (85.02).

Varieties have shown significant influence on number of fruits plant^{-1}. Among three varieties, Anugraha (V_2) had maximum number of fruits plant^{-1} (154.21) followed by Vellayani Athulya (V_1) (86.56). The lowest number of fruits plant^{-1} was recorded by Jwalamukhi (V_3) (70.47).

G x V interaction caused significant influence on number of fruits plant^{-1}. Maximum number of fruits plant^{-1} was reported in Anugraha grown under poly house (g_1v_2) (169.75) and the lowest number of fruits plant^{-1} was obtained from Jwalamukhi grown under open condition (g_2v_3) (66.57) and was on par with Jwalamukhi grown under poly house (g_1v_3) (74.37).

F x V interaction caused significant influence on number of fruits plant^{-1}. Maximum number of fruits plant^{-1} was reported in Anugraha grown with fertigation (f_1v_2) (169.42) and the lowest number of fruits plant^{-1} was obtained from Jwalamukhi grown without fertigation (f_2v_3) (66.39) and was on par with Jwalamukhi grown with fertigation (f_1v_3) (74.55).

G x F x V interaction had significant influence on number of fruits plant^{-1}. Maximum number of fruits plant^{-1} (179.50) was obtained from Anugraha grown under poly house with fertigation ($g_1f_1v_2$). The lowest number of fruits plant^{-1} was observed in Jwalamukhi grown under open condition without fertigation ($g_2f_2v_3$) (59.31).

4.2.2 Length of the Fruit (cm)

Average length of fruit is presented in table 22 and23.

Length of fruit showed significant variation due to different levels of growing condition. Maximum length of fruit (11.77 cm) was observed in plants grown under poly house (G_1).

Fertigation levels had significant influence on length of fruit. Plants grown with fertigation (F_1) recorded maximum length of fruit (11.55 cm).

Table 22. Effect of growing conditions, fertigation and varieties on yield and yield attributing characters of chilli

Treatments	Number of fruits plant^{-1}				Length of fruit (cm)			
	Vellayani Athulya (V_1)	Anugraha (V_2)	Jwala-mukhi (V_3)	Mean	Vellayani Athulya (V_1)	Anugraha (V_2)	Jwala-mukhi (V_3)	Mean
G_1 (Poly house)	87.88	169.75	74.37	110.67	12.91	12.29	10.10	11.77
G_2 (Open condition)	85.25	138.67	66.57	96.83	12.72	11.01	8.55	10.76
F_1 (With fertigation	96.50	169.42	74.55	113.49	13.67	11.89	9.09	11.55
F_2 (Without fertigation)	76.63	139.00	66.39	94.00	11.96	11.41	9.56	10.98
Mean	86.56	154.21	70.47		12.82	11.65	9.33	

	G	F	V	G x V	F x V	G	F	V	G x V	F x V
SE m ±	1.526	1.526	1.489	2.979	2.979	0.039	0.039	0.065	0.129	0.129
CD(0.05)	4.888	4.888	6.158	8.709	8.709	0.125	0.125	0.267	0.378	0.378

NS- Not significant

Table 23. Interaction effect of growing conditions, fertigation and varieties on yield and yield attributing characters of chilli

Treatments	Number of fruits plant^{-1}				Length of fruit (cm)			
	Vellayani Athulya (V_1)	Anugraha (V_2)	Jwala-mukhi (V_3)	Mean	Vellayani Athulya (V_1)	Anugraha (V_2)	Jwala-mukhi (V_3)	Mean
g_1f_1	100.25	179.50	75.28	118.34	14.38	12.17	9.50	12.02
g_1f_2	75.50	160.00	73.47	102.99	11.45	12.41	10.70	11.52
g_2f_1	92.75	159.35	73.83	108.64	12.96	11.61	8.67	11.08
g_2f_2	77.75	118.00	59.31	85.02	12.48	10.41	8.42	10.44

	G x F	G x F x V	G x F	G x F x V
SE m ±	2.159	2.220	0.055	0.183
CD(0.05)	6.913	12.316	NS	0.534

NS- Not significant

g_1f_1 - Poly house + Fertigation
g_1f_2 - Poly house + Without fertigation
g_2f_1 - Open condition + Fertigation
g_2f_2 - Open condition + Without fertigation

Length of the fruit was significantly influenced by varietal effect. The maximum length of fruit was recorded by Vellayani Athulya (V_1) (12.82 cm) followed by Anugraha (V_2) (11.65 cm) and the minimum length of the fruit was reported by Jwalamukhi (V_3) (9.33 cm).

The G x V interaction had significant influence on length of the fruit. The maximum length of fruit was recorded from g_1v_1 (Vellayani Athulya grown under poly house) (12.91 cm) and it was on par with Vellayani Athulya grown in open field condition (g_2v_1) (12.72 cm). The minimum length of fruit was observed in Jwalamukhi grown in open field condition (g_2v_3) (8.55 cm) and it was on par with Jwalamukhi grown under poly house (g_1v_3) (10.10 cm).

Length of fruit was also significantly influenced by F x V interaction. The maximum length of fruit was recorded from Vellayani Athulya grown with fertigation (f_1v_1) (13.67 cm). The lowest length of fruit was observed in Jwalamukhi grown with fertigation, f_1v_3 (9.09 cm).

G x F x V interaction showed significant variation on length of the fruit. Maximum length of fruit was recorded from Vellayani Athulya grown under poly house with fertigation ($g_1f_1v_1$) (14.38 cm) and the minimum length of fruit was recorded in Jwalamukhi grown in open field condition without fertigation ($g_2f_2v_3$) (8.42 cm) and was on par with Jwalamukhi grown in open field condition with fertigation ($g_2f_1v_3$) (8.67cm).

G x F interaction didn't show significant influence on length of fruit.

4.2.3 Fruit Yield Plant^{-1} (g)

Average fruit yield plant^{-1} is presented in table 24 and 25.

The results revealed that different levels of growing conditions had significant influence on fruit yield plant^{-1}. Maximum fruit yield plant^{-1}(604.08 g) was recorded by the plants grown under polyhouse (G_1).

Levels of fertigation have shown significant influence on fruit yield plant^{-1}. Plants grown with fertigation (F_1) have recorded highest fruit yield plant^{-1} (591.92 g).

Different varieties also showed significant variation in fruit yield plant^{-1}. Maximum fruit yield plant^{-1} (665.18 g) was observed in Vellayani Athulya (V_1)

followed by Anugraha (V_2) (574.70 g) and the lowest value was reported in Jwalamukhi (V_3) (465.80 g).

Interaction effect of G x F, G x V, F x V and G x F x V had no significant influence on fruit yield plant^{-1}.

4.2.4 Total Fruit Yield (t ha^{-1})

Total fruit yield is presented in table 24 and 25.

The results revealed that different levels of growing conditions had significant influence on total fruit yield. Highest fruit yield was recorded by plants grown under polyhouse (G_1) (29.54 t ha^{-1}).

Levels of fertigation have shown significant influence on total fruit yield. Plants grown with fertigation (F_1) have recorded highest fruit yield (26.27 t ha^{-1}).

Total fruit yield was significantly influenced by varietal effect. Maximum fruit yield (28.41 t ha^{-1}) was observed in Vellayani Athulya (V_1) followed by Anugraha (V_2) (26.00 t ha^{-1}) and the lowest value was reported by Jwalamukhi (V_3) (22.00 t ha^{-1}).

The interaction effect of G x F, G x V, F x V and G x F x V interaction had no significant influence on number of fruits plant^{-1}.

4.3 QUALITY ASPECTS OF CHILLI

4.3.1 Shelf Life (days)

Shelf life is presented in table 26 and 27.

Shelf life of chilli showed significant variation due to different levels of growing condition. Green chilli fruits obtained from plants grown under poly house (G_1) recorded maximum shelf life (10.29 days).

Different levels of fertigation have shown significant influence on shelf life of chilli fruit. Green chilli fruits obtained from plants grown with fertigation (F_1) has recorded more shelf life (10.00 days).

The G x F interaction had significant influence on shelf life of fruit. The maximum shelf life of fruit was recorded by the interaction effect of poly house and with fertigation (g_1f_1) (11.08 days) followed by interaction effect of poly house and without fertigation (g_1f_2) (9.50 days) and it was on par with interaction effect of open field condition and without fertigation (g_2f_2) (9.08 days). The

Table 24. Effect of growing conditions, fertigation and varieties on yield and yield attributing characters of chilli

Treatments	Fruit yield plant^{-1} (g)				Total fruit yield (t ha $^{-1}$)			
	Vellayani Athulya (V_1)	Anugraha (V_2)	Jwala-mukhi (V_3)	Mean	Vellayani Athulya (V_1)	Anugraha (V_2)	Jwalamukhi (V_3)	Mean
G_1 (Poly house)	708.47	617.73	486.05	604.08	33.61	29.88	25.13	29.54
G_2 (Open condition)	621.89	531.68	445.55	533.04	23.21	22.13	18.88	21.41
F_1(With fertigation)	686.97	596.74	492.04	591.92	29.42	26.59	22.80	26.27
F_2(Without fertigation)	643.39	552.67	439.56	545.21	27.40	25.42	21.21	24.67
Mean	665.18	574.70	465.80		28.41	26.00	22.00	

	G	F	V	G x V	F x V	G	F	V	G x V	F x V
SE m ±	12.557	12.557	14.384	14.384	28.773	0.299	0.299	0.414	0.829	0.829
CD(0.05)	40.205	40.205	59.476	59.476	NS	0.956	0.956	1.714	NS	NS

NS- Non significant

Table 25. Interaction effect of growing conditions, fertigation and varieties on yield and yield attributing characters of chilli

Treatments	Fruit yield plant^{-1} (g)				Total fruit yield (t ha^{-1})			
	Vellayani Athulya (V_1)	Anugraha (V_2)	Jwalamukhi (V_3)	Mean	Vellayani Athulya (v_1)	Anugraha (v_2)	Jwalamukhi (v_3)	Mean
g_1f_1	732.09	640.99	508.12	627.06	36.15	31.65	25.09	30.97
g_1f_2	684.85	594.47	463.99	581.10	33.82	29.36	22.91	28.70
g_2f_1	641.85	552.50	475.96	556.77	31.70	27.28	23.50	27.49
g_2f_2	601.93	510.87	415.14	509.31	29.72	25.23	20.50	25.15

	G x F	G x F x V	G x F	G x F x V
SE m ±	17.758	40.758	0.749	3.227
CD(0.05)	NS	NS	NS	NS

NS- Not significant

g_1f_1 - Poly house + Fertigation
g_1f_2 - Poly house + Without fertigation
g_2f_1 - Open condition + Fertigation
g_2f_2 - Open condition + Without fertigation

minimum shelf life of fruit was observed from interaction effect of open field condition and with fertigation (g_2f_1) (8.92 days). Shelf life of chilli fruits was observed to differ significantly among different varieties. V_1 (Vellayani Athulya) showed maximum shelf life of 10.19 days and was followed by V_2 (Anugraha) (9.44 days). The lowest shelf life was recorded by V_3 (Jwalamukhi) (9.31 days) and it was on par with V_2.

G x V interaction had significant influence on shelf life of fruit. The maximum shelf life of fruit was recorded by the Vellayani Athulya grown under poly house (g_1v_1) (10.88 days). The minimum shelf life of fruit was observed in Jwalamukhi grown in open field condition (g_2v_3) (8.63 days) and was on par with Anugraha grown in open field condition (g_2v_2) (8.88 days).

Shelf life of fruit was found to be significantly influenced by the interaction effect of growing conditions, fertigation levels and varieties (G x F x V). The maximum shelf life was recorded by Vellayani Athulya grown under poly house with fertigation ($g_1f_1v_1$) (12.00 days) followed by Jwalamukhi grown under poly house with fertigation $g_1f_1v_3$ (11.00 days) and it was on par with Anugraha grown under poly house with fertigation ($g_1f_1v_2$) (10.25 days). The minimum shelf life was recorded by Jwalamukhi grown in open field condition with fertigation ($g_2f_1v_3$) (8.00 days) and was on par with Anugraha grown in open field condition without fertigation ($g_2f_2v_2$) (8.75 days).

F x V interaction found to have no significant influence on shelf life of chilli fruit.

4.3.2 Ascorbic Acid Content (mg $100g^{-1}$)

Ascorbic acid content is presented in table 26 and 27.

The results revealed that different levels of growing conditions had significant influence on ascorbic acid content of green chilli. Maximum ascorbic acid content (98.28 mg $100g^{-1}$) was recorded by plants grown under polyhouse (G_1).

The ascorbic acid content was observed to differ significantly among the various levels of fertigation. F_1 (fertigation) recorded maximum ascorbic acid content of 97.39 mg $100g^{-1}$.

Interaction effect of growing conditions and fertigation levels (G x F) had significant influence on ascorbic acid content of green chilli. The maximum ascorbic acid content was recorded by the interaction effect of poly house and with fertigation (g_1f_1) (101.11 mg 100 g^{-1}) followed by the interaction effect of poly house and without fertigation (g_1f_2) (95.46 mg 100 g^{-1}), which was on par with interaction effect of open field condition and without fertigation (g_2f_2) (93.87 mg 100 g^{-1}) and the minimum ascorbic acid content was recorded by the interaction effect of open field condition and with fertigation (g_2f_1) (93.67 mg 100 g^{-1}) and it was on par with g_2f_2.

Varieties showed significant influence on ascorbic acid content of chilli fruits. V_1 (Vellayani Athulya) showed maximum ascorbic acid content of 98.71 mg $100g^{-1}$ and it was followed by V_3 (Jwalamukhi) (96.63 mg $100g^{-1}$). The lowest ascorbic acid content was recorded by V_2 (Anugraha) (92.74 mg $100g^{-1}$).

G x V interaction has shown significant influence on ascorbic acid content of green chilli. The maximum ascorbic acid content was recorded in Vellayani Athulya grown under poly house (g_1v_1) (102.78 mg $100g^{-1}$) and was followed by Jwalamukhi grown under poly house (g_1v_3) (98.26 mg $100g^{-1}$). The minimum ascorbic acid content was recorded by the interaction between open field and Anugraha (g_2v_2) (91.67 mg $100g^{-1}$) and it was followed by Vellayani Athulya in open field condition (g_2v_1) (94.64 mg $100g^{-1}$) and Jwalamukhi in open field condition (g_2v_3) (94.99 mg $100g^{-1}$).

The ascorbic acid content of green chilli was observed to vary significantly by interaction effect of fertigation levels and varieties (F x V). The maximum ascorbic acid content was recorded by Vellayani Athulya with fertigation (f_1v_1) (101.69 mg $100g^{-1}$) and it was followed by Jwalamukhi with fertigation (f_1v_3) (97.25 mg $100g^{-1}$). The minimum ascorbic acid content was recorded by Anugraha without fertigation (f_2v_2) (92.27 mg $100g^{-1}$) and was on par with that of Anugraha with fertigation (f_1v_2) (93.22 mg $100g^{-1}$).

G x F x V interaction have recorded significant influence on ascorbic acid content of green chilli. The maximum ascorbic acid content was recorded in Vellayani Athulya grown with fertigation under poly house ($g_1f_1v_1$)

(108.74 mg 100 g^{-1}) and the minimum ascorbic acid content was recorded in Anugraha grown with fertigation under open field condition ($g_2f_1v_2$) (91.09 mg 100 g^{-1}) and it was on par with Anugraha grown without fertigation under open field condition ($g_2f_2v_2$) (92.26 mg 100 g^{-1}) and Anugraha without fertigation under poly house ($g_1f_2v_2$) (92.27 mg 100 g^{-1}).

4.3.3 Capsaicin Content (per cent)

Capsaicin content is presented in table 26 and 27.

Levels of growing conditions had significant influence on capsaicin content of fruit. Maximum capsaicin content (1.17 per cent) was recorded by plants grown under polyhouse (G_1).

The capsaicin content was observed to differ significantly among the various levels of fertigation. F_1 (fertigation) recorded maximum capsaicin content of 1.16 per cent.

Capsaicin content was significantly influenced by varietal effect. Maximum capsaicin content of 1.38 per cent was observed in Jwalamukhi (V_3) and it was followed by Vellayani Athulya (V_1) (1.25 per cent) and the lowest value was reported by Anugraha (V_3) (0.81 per cent).

F x V interaction also had significant influence on capsaicin content of chilli fruit. The maximum capsaicin content was recorded by Jwalamukhi with fertigation (f_1v_3) (1.40 per cent) and it was followed by Jwalamukhi without fertigation (f_2v_3) (1.36 per cent). The minimum capsaicin content was recorded by Anugraha without fertigation (f_2v_2) (0.79 per cent).

G x F x V interaction have shown significant influence on capsaicin content of chilli fruit. The maximum capsaicin content was recorded by Jwalamukhi with fertigation under poly house ($g_1f_1v_3$) (1.43 per cent) and was followed by Jwalamukhi without fertigation under poly house $g_1f_2v_3$ (1.39 per cent). The minimum capsaicin content was recorded by Anugraha without fertigation under open field condition ($g_2f_2v_2$) (0.77 per cent) and was followed by Anugraha with fertigation under open field condition ($g_2f_1v_2$) (0.79 per cent).

Interaction effect of G x F and G x V had no significant influence on capsaicin content of green chilli.

Table 26. Effect of growing conditions, fertigation and varieties on fruit quality aspects of chilli

Treatments	Shelf life (days)				Ascorbic acid (mg $100g^{-1}$)				Capsaicin content (%)			
	Vellayani Athulya (V_1)	Anugraha (V_2)	Jwala-mukhi (V_3)	Mean	Vellayani Athulya (V_1)	Anu graha (V_2)	Jwala-mukhi (V_3)	Mean	Vellayani Athulya (V_1)	Anugra-ha (V_2)	Jwalam-ukhi (V_3)	Mean
G_1 (Poly house)	10.88	10.00	10.00	10.29	102.78	93.81	98.26	98.28	1.27	0.84	1.41	1.17
G_2(Open condition)	9.50	8.88	8.63	9.00	94.64	91.67	94.99	93.77	1.22	0.78	1.35	1.12
F_1 (With fertigation	10.88	9.63	9.50	10.00	101.69	93.22	97.25	97.39	1.25	0.83	1.40	1.16
F_2 (Without fertigation)	9.50	9.25	9.13	9.29	95.73	92.27	96.00	94.66	1.24	0.79	1.36	1.13
Mean	10.19	9.44	9.31		98.71	92.74	96.63		1.25	0.81	1.38	

	G	F	V	G x V	F x V	G	F	V	G x V	F x V	G	F	V	G x V	F x V
SE m ±	0.176	0.176	0.126	0.252	0.252	0.282	0.282	0.263	0.527	0.527	0.002	0.002	0.002	0.004	0.004
CD(0.05)	0.563	0.563	0.520	0.735	NS	0.902	0.902	1.089	1.540	1.540	0.007	0.007	0.007	NS	0.010

NS- Not significant

Table 27. Interaction effect of growing conditions, fertigation and varieties on fruit quality aspects of chilli

Treatments	Shelf life (days)				Ascorbic acid (mg $100g^{-1}$)				Capsaicin content (per cent)			
	Vellayani Athulya (V_1)	Anugraha (V_2)	Jwalamukhi (V_3)	Mean	Vellayani Athulya (V_1)	Anugraha (V_2)	Jwalamukhi (V_3)	Mean	Vellayani Athulya (V_1)	Anugraha (V_2)	Jwalamukhi (V_3)	Mean
g_1f_1	12.00	10.25	11.00	11.08	108.74	95.36	99.23	101.11	1.27	0.87	1.43	1.19
g_1f_2	9.75	9.75	9.00	9.50	96.81	92.27	97.30	95.46	1.27	0.82	1.39	1.16
g_2f_1	9.75	9.00	8.00	8.92	94.65	91.09	95.28	93.67	1.23	0.79	1.37	1.13
g_2f_2	9.25	8.75	9.25	9.08	94.64	92.26	94.70	93.87	1.21	0.77	1.33	1.11

	G x F	G x F x V	G x F	G x F x V	G x F	G x F x V
SE m ±	0.249	0.356	0.398	0.746	0.003	0.005
CD(0.05)	0.796	1.040	1.275	2.178	NS	0.015

NS- Not significant

g_1f_1 - Poly house + Fertigation
g_1f_2 - Poly house + Without fertigation
g_2f_1 - Open condition + Fertigation
g_2f_2 - Open condition + Without fertigation

4.4 PLANT ANALYSIS

4.4.1 Nitrogen Uptake (Kg ha^{-1})

Nitrogen uptake is presented in table 28 and 29.

Levels of growing conditions had significant influence on nitrogen uptake. Maximum nitrogen uptake (69.52 kg ha^{-1}) was recorded by plants grown under polyhouse (G_1).

Nitrogen uptake was observed to differ significantly among the levels of fertigation. Plants with fertigation (F_1) recorded maximum nitrogen uptake (58.21 kg ha^{-1}).

Varieties had significant influence on nitrogen uptake. Maximum nitrogen uptake was observed in Vellayani Athulya (V_1) (60.73 kg ha^{-1}) and it was on par with Anugraha (V_2) (55.00 kg ha^{-1}).

Interaction effects didn't cause significant influence in nitrogen uptake.

4.4.2 Phosphorus Uptake (Kg ha^{-1})

Phosphorus uptake is presented in table 28 and 29.

Different growing conditions caused significant variation in phosphorus uptake. Plants grown under polyhouse (G_1) registered maximum phosphorus uptake (14.92 kg ha^{-1}).

Treatments like fertigation and varieties and interactions like G x F, G x V, F x V and G x F x V didn't cause significant influence on phosphorus uptake.

4.4.3 Potassium Uptake (Kg ha^{-1})

Potassium uptake is presented in table 28 and 29.

Different growing conditions caused significant variation in potassium uptake. Plants grown under polyhouse (G_1) showed maximum potassium uptake (39.62 kg ha^{-1}).

Treatments like fertigation, varieties and interactions like G x F, G x V, F x V and G x F x V didn't cause significant influence on potassium uptake.

4.5 SOIL ANALYSIS

4.5.1 Organic Carbon Content (per cent)

Organic carbon content is presented in table 30 and 31.

Table 28. Effect of different growing conditions, fertigation and varieties on nutrient uptake, kg ha^{-1}

Treatments	N				P				K			
	Vellayani Athulya (V_1)	Anu-graha (V_2)	Jwala-mukhi (V_3)	Mean	Vellaya ni Athulya (V_1)	Anu-graha (V_2)	Jwala-mukhi (V_3)	Mean	Vellay ani Athuly a (V_1)	Anu-graha (V_2)	Jwala-mukhi (V_3)	Mean
G_1(Poly house)	73.07	74.17	61.33	69.52	15.18	15.62	13.96	14.92	40.81	40.52	37.52	39.62
G_2 (Open condition)	48.38	35.83	26.40	36.87	11.94	8.85	10.95	10.58	22.19	26.51	32.59	27.10
F_1(With fertigation)	68.63	56.29	49.72	58.21	15.29	12.12	14.89	14.10	40.03	35.72	33.24	36.33
F_2(Without fertigation)	52.82	53.71	38.02	48.18	11.84	12.35	10.01	11.40	22.97	31.31	36.87	30.38
Mean	60.73	55.00	43.87		13.56	12.23	12.45		31.50	33.52	35.06	

	G	F	V	G x V	F x V	G	F	V	G x V	F x V	G	F	V	G x V	F x V
SE m ±	2.717	2.717	2.379	4.759	4.759	1.123	1.123	0.964	1.927	1.927	2.452	2.452	3.022	6.046	6.046
CD(0.05)	8.700	8.700	9.836	NS	NS	3.596	NS	NS	NS	NS	7.852	NS	NS	NS	NS

NS- Not significant

Table 29. Interaction effect of different growing conditions, fertigation and varieties nutrient uptake, kg ha^{-1}

Treatments	N				P				K			
	Vellayani Athulya (V_1)	Anu-graha (V_2)	Jwa-lamukhi (V_3)	Mean	Vellayani Athulya (V_1)	Anu-graha (V_2)	Jwala-mukhi (V_3)	Mean	Vellayani Athulya (V_1)	Anu-graha (V_2)	Jwalam u-khi (V_3)	Mean
g_1f_1	76.35	84.24	74.54	78.38	17.60	15.03	15.20	15.94	51.30	44.36	37.59	44.42
g_1f_2	69.78	64.09	48.13	60.67	12.77	16.21	12.71	13.90	30.31	36.69	37.45	34.81
g_2f_1	60.91	28.34	24.89	38.05	12.98	9.20	14.58	12.25	28.75	27.08	28.88	28.24
g_2f_2	35.85	43.32	27.91	35.69	10.91	8.49	7.32	8.91	15.62	25.94	36.30	25.95

	G x F	G x F x V	G x F	G x F x V	G x F	G x F x V
SE m ±	3.843	6.741	1.589	2.730	3.468	8.564
CD(0.05)	NS	NS	NS	NS	NS	NS

NS- Not significant

g_1f_1 - Poly house + Fertigation
g_1f_2 - Poly house + Without fertigation
g_2f_1 - Open condition + Fertigation
g_2f_2 - Open condition + Without fertigation

Table 30. Effect of growing conditions, fertigation and varieties on organic carbon content of soil, percent

Treatments	Organic carbon content			
	Vellayani Athulya (V_1)	Anugraha (V_2)	Jwalamukhi (V_3)	Mean
G_1 (Poly house)	1.37	1.35	1.59	1.44
G_2 (Open condition)	1.50	1.36	1.38	1.42
F_1 (With fertigation)	1.49	1.35	1.44	1.43
F_2 (Without fertigation)	1.39	1.36	1.53	1.43
Mean	1.44	1.35	1.48	

	G	F	V	G x V	F x V
SE m ±	0.082	0.082	0.054	0.109	0.109
CD(0.05)	NS	NS	NS	NS	NS

NS- Not significant

g_1f_1 - Poly house + Fertigation
g_1f_2 - Poly house + Without fertigation
g_2f_1 - Open condition + Fertigation
g_2f_2 - Open condition + Without fertigation

Table 31. Interaction effect of growing conditions, fertigation and varieties on organic carbon content of soil, percent

Treatments	Organic carbon content			
	Vellayani Athulya (V_1)	Anugraha (V_2)	Jwalamukhi (V_3)	Mean
g_1f_1	1.44	1.51	1.79	1.58
g_1f_2	1.30	1.18	1.39	1.29
g_2f_1	1.54	1.18	1.09	1.27
g_2f_2	1.47	1.55	1.66	1.56

	G x F	G x F x V
SE m ±	0.116	0.154
CD(0.05)	NS	NS

NS- Not significant

g_1f_1 - Poly house + Fertigation
g_1f_2 - Poly house + Without fertigation
g_2f_1 - Open condition + Fertigation
g_2f_2 - Open condition + Without fertigation

Table 32. Effect of growing conditions, fertigation and varieties on available nutrient status of soil, kg ha^{-1}

Treatments	N				P				K			
	Vellayani Athulya (V_1)	Anu-graha (V_2)	Jwala-mukhi (V_3)	Mean	Vellayani Athulya (V_1)	Anu graha (V_2)	Jwala-mukhi (V_3)	Mean	Vellayani Athulya (V_1)	Anu-graha (V_2)	Jwala-mukhi (V_3)	Mean
G_1(Poly house)	378.34	384.63	390.65	384.54	64.83	61.89	61.30	62.68	40.38	42.54	41.44	41.45
G_2 (Open condition)	383.91	390.00	397.54	390.48	68.59	68.44	65.56	67.53	.37.64	42.80	41.75	40.73
F_1 (With fertigation)	386.26	398.16	395.18	393.20	69.23	62.24	52.68	61.38	40.71	42.77	40.59	41.35
F_2 (Without fertigation)	375.99	376.46	393.01	381.82	64.19	68.09	74.18	68.82	37.31	42.57	42.60	40.83
Mean	381.12	387.31	394.09		66.71	65.17	63.43		39.01	42.67	41.60	

	G	F	V	G x V	F x V	G	F	V	G x V	F x V	G	F	V	G x V	F x V
SE m ±	6.020	6.020	9.670	19.342	19.342	0.942	0.942	1.365	2.731	2.731	2.446	2.446	1.852	3.704	3.704
CD(0.05)	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS

NS-Not significant

Table 33. Interaction effect of growing conditions, fertigation and varieties on available nutrient status of soil, kg ha^{-1}

Treatments	N				P				K			
	Vellayani Athulya (V_1)	Anug-raha (V_2)	Jwala-mukhi (V_3)	Mean	Vellayani Athulya (V_1)	Anu-graha (V_2)	Jwala-mukhi (V_3)	Mean	Vellaya ni Athulya (V_1)	Anu-graha (V_2)	Jwala-mukhi (V_3)	Mean
g_1f_1	380.43	376.23	423.65	393.43	64.49	68.13	48.35	60.32	42.91	42.63	40.31	41.95
g_1f_2	376.26	393.03	357.65	375.65	65.18	55.66	74.25	65.03	37.85	42.45	42.58	40.96
g_2f_1	392.09	420.10	366.70	392.96	73.97	56.36	57.01	62.45	38.50	42.90	40.88	40.76
g_2f_2	375.73	359.90	428.38	388.00	63.20	80.53	74.10	72.61	36.78	42.70	42.63	40.70

	G x F	G x F x V	G x F	G x F x V	G x F	G x F x V
SE m ±	8.514	3.650	1.332	3.868	3.459	5.247
CD(0.05)	NS	NS	NS	NS	NS	NS

NS- Not significant

g_1f_1 - Poly house + Fertigation
g_1f_2 - Poly house + Without fertigation
g_2f_1 - Open condition + Fertigation
g_2f_2 - Open condition + Without fertigation

Neither the treatments nor their interaction effect have significant influence on organic carbon content in soil.

4.5.2 Available NPK Status in Soil (Kg ha^{-1})

Available NPK status is presented in table 32 and 33.

There was no significant difference on available NPK content in soil with different levels of growing conditions, fertigation, varieties and their interaction effects.

4.6 SCORING OF PEST AND DISEASE

4.6.1 Scoring of Thrips and Mite incidence

Scoring of leaf curl complex caused by thrips and mite was done (Table 34).

Pest attack was not reported inside poly house throughout the period of plant growth and under open condition, leaf curl complex caused by thrips and mite was reported at 60 DAT.

Disease incidence was also not reported under poly house condition while, under open condition, incidence of anthracnose and wilt was noticed but not found to infect the crop beyond the economic threshold level demanding control measures.

4.7 ECONOMIC ANALYSIS

4.7.1 Net Return (Rs lakhs ha^{-1})

Net return calculated is presented in table 35 and 36.

Growing condition caused significant influence on net return. Maximum net return was obtained from poly house, G_1 (Rs 5.22 lakhs ha^{-1}) compared to open field situation, G_2 (Rs 3.31 lakhs ha^{-1}).

Fertigation caused significant influence on net return. Maximum net return was obtained from plants grown with fertigation, F_1 (Rs 4.46 lakhs ha^{-1}) compared to those grown without fertigation, F_2 (Rs 4.07 lakhs ha^{-1})

Net return was significantly influenced by varieties. Vellayani Athulya (V_1) recorded maximum net return (Rs 4.95 lakhs ha^{-1}). Lowest maximum return was recorded in Jwalamukhi (V_3) (Rs 3.48 lakhs ha^{-1}).

Table 34. Effect of growing conditions, fertigation and varieties on pest incidence, score

Treatments	Leaf curl index (60 DAT)			
	Vellayani Athulya (V_1)	Anugraha (V_2)	Jwalamukhi (V_3)	Mean
G_1 (Poly house)	0	0	0	0
G_2 (Open condition)	1.38	1.28	1.28	1.31
F_1 (With fertigation	1.25	1.1	1.1	1.15
F_2 (Without fertigation)	1.2	1.45	1.45	1.06
Mean	0.9575	0.9575	0.9575	

Data statistically not analyzed

Table 35. Effect of different growing conditions, fertigation and varieties on net returns and benefit-cost ratio

Treatments	Net returns (Rs lakhs ha^{-1})				Benefit-cost ratio			
	Vellayani Athulya (V_1)	Anugraha (V_2)	Jwa-lamukhi (V_3)	Mean	Vellayani Athulya (V_1)	Anugraha (V_2)	Jwalamukhi (V_3)	Mean
G_1 (Poly house)	6.15	5.22	4.28	5.22	2.76	2.35	2.15	2.42
G_2 (Open condition)	3.76	3.49	2.68	3.31	1.84	1.71	1.32	1.62
F_1 (With fertigation	5.16	4.45	3.76	4.46	2.34	2.03	1.94	2.10
F_2 (Without fertigation)	4.75	4.25	3.20	4.07	2.26	2.03	1.53	1.94
Mean	4.95	4.35	3.48		2.30	2.03	1.73	

	G	F	V	G x V	F x V	G	F	V	G x V	F x V
SE m ±	0.072	0.072	0.103	0.206	0.206	0.063	0.063	0.062	0.125	0.125
CD(0.05)	0.229	0.229	0.425	NS	NS	0.200	NS	0.258	NS	NS

NS-Not significant

Table 36. Interaction effect of growing conditions, fertigation and varieties on on net returns and benefit-cost ratio

Treatments	Net returns (Rs lakhs ha^{-1})				Benefit-cost ratio			
	Vellayani Athulya (V_1)	Anugraha (V_2)	Jwalamu-khi (V_3)	Mean	Vellayani Athulya (v_1)	Anugraha (v_2)	Jwalamu-khi (v_3)	Mean
g_1f_1	6.91	5.03	4.83	5.59	2.76	2.17	2.36	2.43
g_1f_2	4.91	5.12	4.14	4.72	2.76	2.53	1.93	2.41
g_2f_1	4.47	3.85	2.59	3.63	1.92	1.90	1.51	1.78
g_2f_2	3.53	3.20	2.45	3.06	1.76	1.53	1.12	1.47

	G x F	G x F x V	G x F	G x F x V
SE m ±	0.101	0.291	0.088	0.176
CD(0.05)	NS	NS	NS	NS

NS- Not significant

g_1f_1 - Poly house + Fertigation
g_1f_2 - Poly house + Without fertigation
g_2f_1 - Open condition + Fertigation
g_2f_2 - Open condition + Without fertigation

Interactions like G x F, G x V, F x V and G x F x V didn't cause significant influence on net ruturn.

4.7.2 BC Ratio

BC ratio calculated is presented in table 35 and 36.

BC ratio was significantly influenced by growing condition. Maximum B: C ratio (2:42) was obtained from poly house (G_1) compared to open field situation (G_2) (1.62).

BC ratio significantly varied with varieties. Maximum BC ratio was reported in Vellayani Athulya (V1) (2.30) followed by Anugraha (V_2) (2.03) and Jwalamukhi (V_3) (1.73).

Fertigation and interactions like G x F, G x V, F x V and G x F x V didn't cause significant influence on BC ratio.

DISCUSSION

5. DISCUSSION

An experiment was conducted to study the performance of chilli varieties and the effect of fertigation on productivity of chilli (*Capsicum annuum* L.) under protected cultivation. The experimental findings detailed in the previous chapter have been briefly discussed here in the light of published information, fundamental theoretical knowledge and acquired information from the investigation.

5.1 EFFECT OF GROWING CONDITIONS, FERTIGATION AND THEIR INTERACTIONS ON GROWTH AND YIELD ATTRIBUTING CHARACTERS

5.1.1 Growth Characters

Different growing conditions caused significant variation in plant height at all growth stages (Fig. 3). Plants grown under poly house were taller compared to that grown under open situation at all stages of plant growth. Similar increase in plant height under shade due to long internodal length and the etiolating effect of shade on the plants was reported by Sharma and Tiwari (1993). Growth retardation under open environment may be due to the exposure of plants to the ultra violet and infrared radiations which are not beneficial for the crop growth, as they bring changes in molecular level which leads to cellular disorganization of the crops and the excellent growth under poly house could be due to the UV and infrared radiations absorbing property of covering structures (Hazra and Some, 1999). Increased plant height of capsicum due to favourable micro-climatic conditions that prevailed in the polyhouse, which enhanced plant metabolic activities like photosynthesis and respiration was reported by Zende (2008). Similar explanation for increased plant height under polyhouse was also given by Megharaja (2000) and Yellavva (2008) in capsicum and Parvej *et al.* (2010) in tomato. Increase in height of bell pepper due to higher temperature inside the tunnel compared to unprotected condition was reported by Singh *et al.* (2013). Increase in plant height of capsicum under shade house condition was reported by Ganiger (2010). Maximum plant height under shade

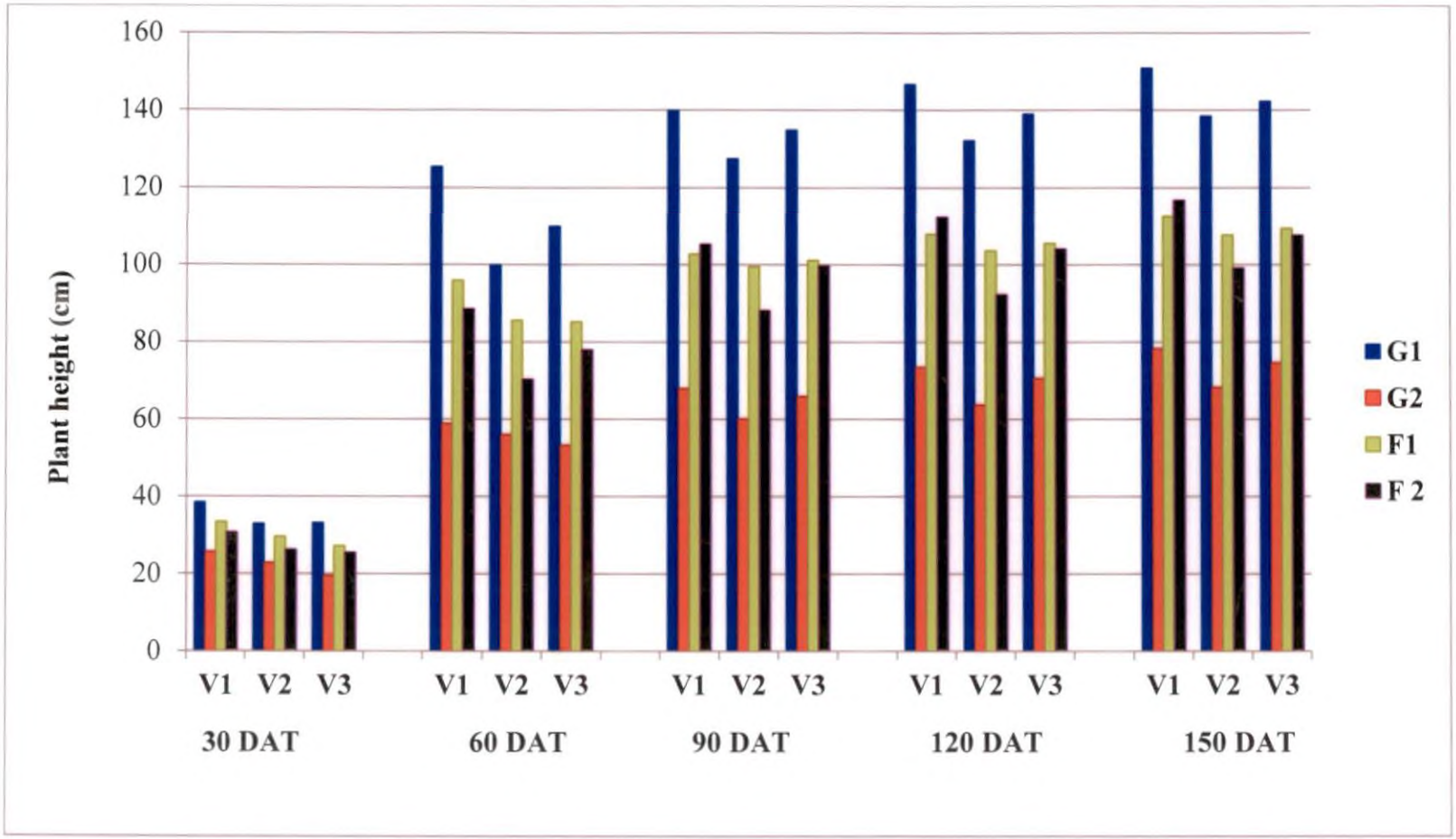

Fig. 3. Effect of growing conditions, fertigation and varieties on height of the plant at 30, 60, 90, 120 and 150 DAT

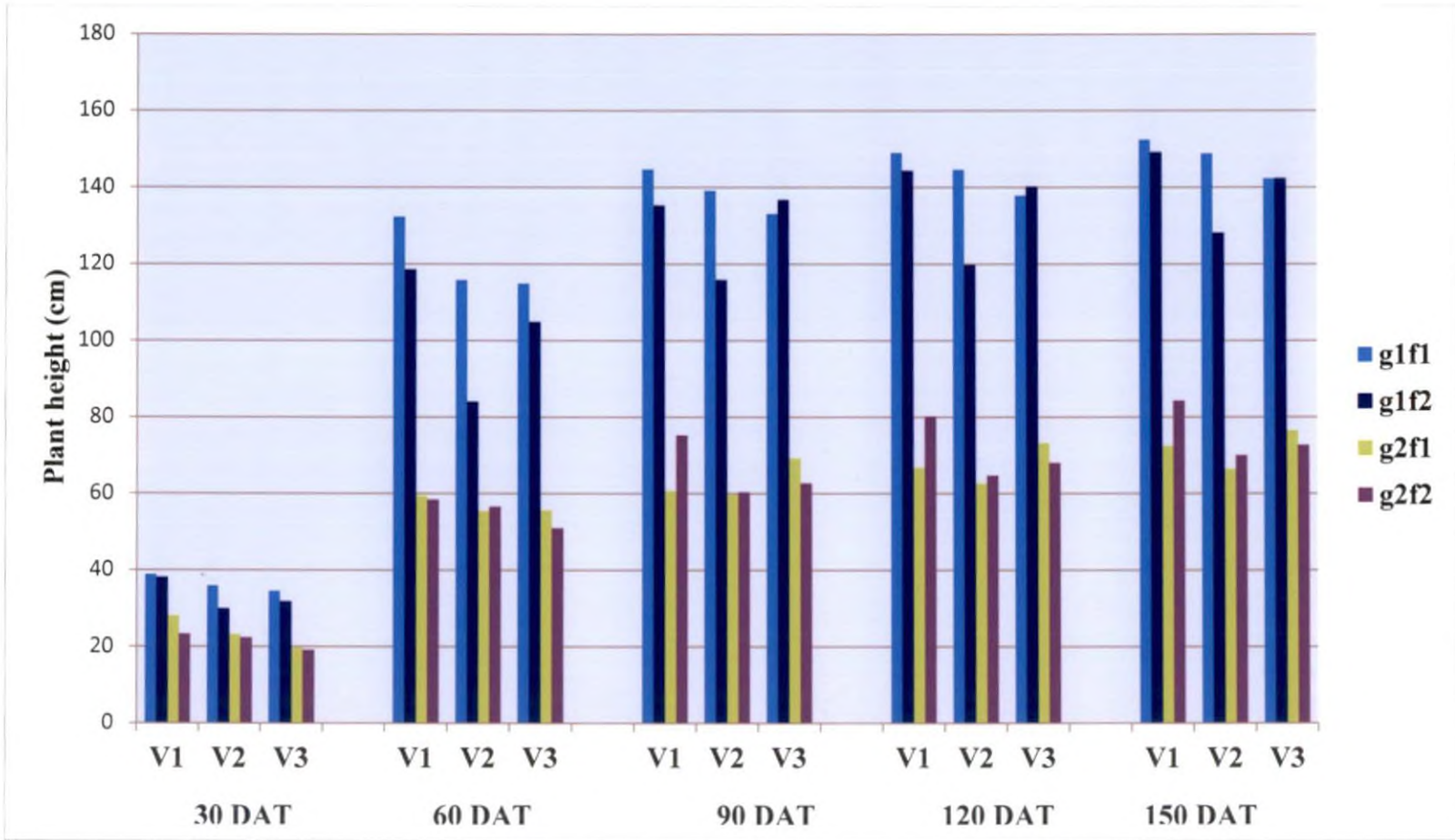

Fig. 4. Interaction effect of growing conditions, fertigation and varieties on height of the plant at 30, 60, 90, 120 and 150 DAT

net cover was due to low light intensity and better environmental conditions (Prabhu *et al.*, 2009).

Different fertigation levels caused significant variation in plant height (Fig. 3) at 60 DAT, where plants grown with fertigation were taller. Similar results of increased plant height through fertigation was reported by Tumbare (1999) in okra, Shashidhara (2006) in chilli, Savitha *et al.* (2010) in onion, Singandhupe *et al.* (2003) and Brahma *et al.* (2010) in tomato. Increased plant height of red chilli due to split application of nitrogen and potassium through drip irrigation was reported by Ashoka (2005).

Irrespective of the non significance at 30 and 150 DAT, maximum number of branches (Fig. 5) were showed by plants grown under poly house at all growth stages. Similar results of maximum number of branches plant^{-1} under poly house were also reported by Megharaja (2000) and Zende (2008) in bell pepper, Kavitha *et al.* (2009) and Parvej *et al.* (2010) in tomato and Dixit (2007) in leafy vegetables. Different fertigation levels caused significant variation in number of branches (Fig. 5) at all growth stages except at 60 and 120 DAT, where plants grown with fertigation showed maximum number of branches. Increased number of branches of red chilli due to split application of nitrogen and potassium through drip irrigation was observed by Ashoka (2005). Interaction effect of growing condition and fertigation caused significant variation in number of branches (Fig. 6) at 60, 120 and 150 DAT. Plants grown under poly house with fertgation recorded more number of branches. Increased number of branches with fertigation and mulching in sweet pepper was reported by Kanwar *et al.* (2013).

The perusal of the data revealed that different growing conditions caused significant variation in LAI all growth stages (Fig.7). Higher LAI was shown by the plants grown under poly house. The higher LAI under poly house might be due to the availability of optimum climatic condition inside poly house which lead to more cell division and cell elongation and leaf area. Similar results of increased LAI in poly house were reported by Parvej *et al.* (2010). The increased LAI in poly house situation might also be due to the higher number of leaves plant^{-1}, increased number of branches and the congenial microclimate that

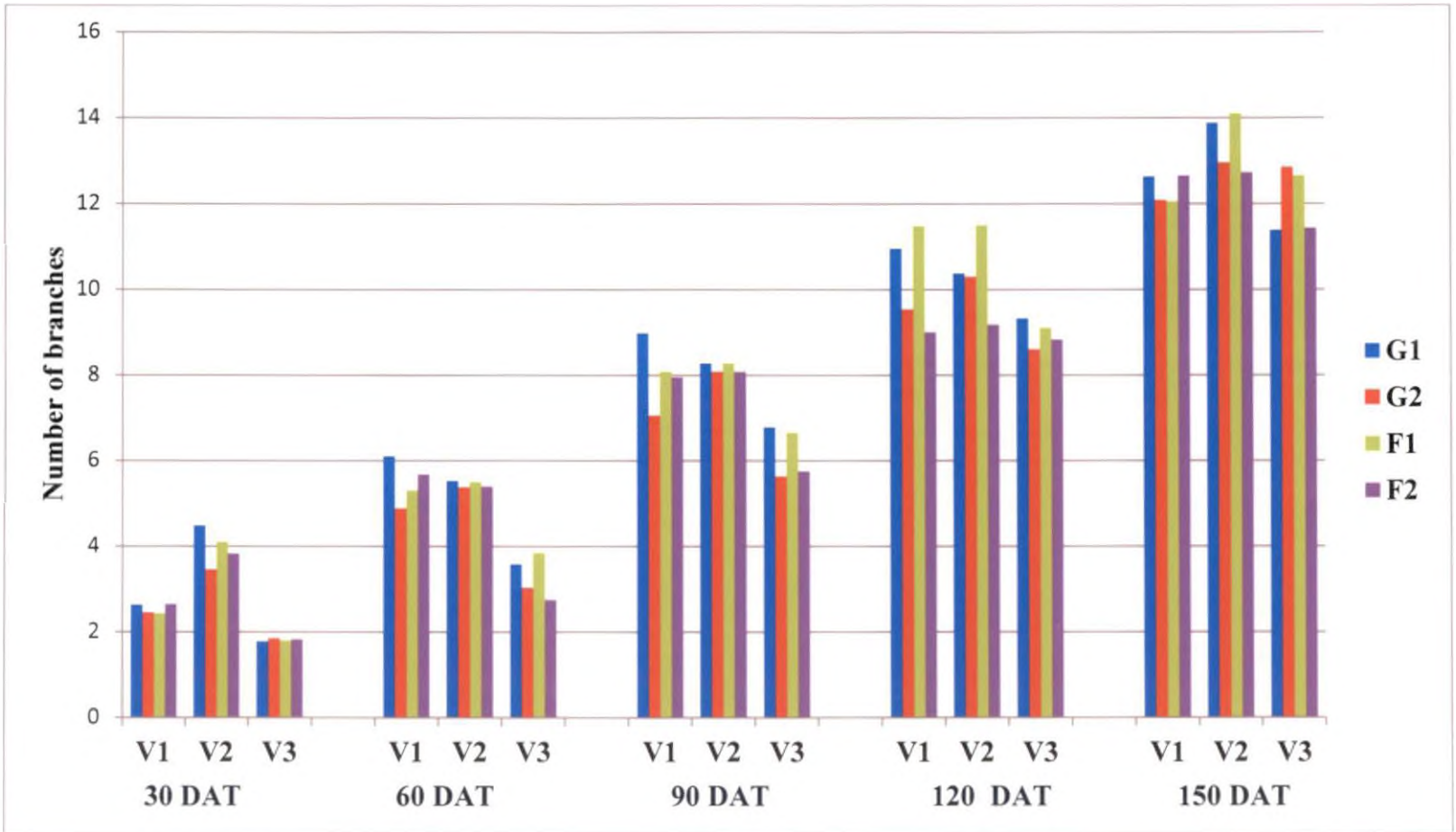

Fig. 5. Effect of growing conditions, fertigation and varieties on number of branches at 30, 60, 90, 120 and 150 DAT

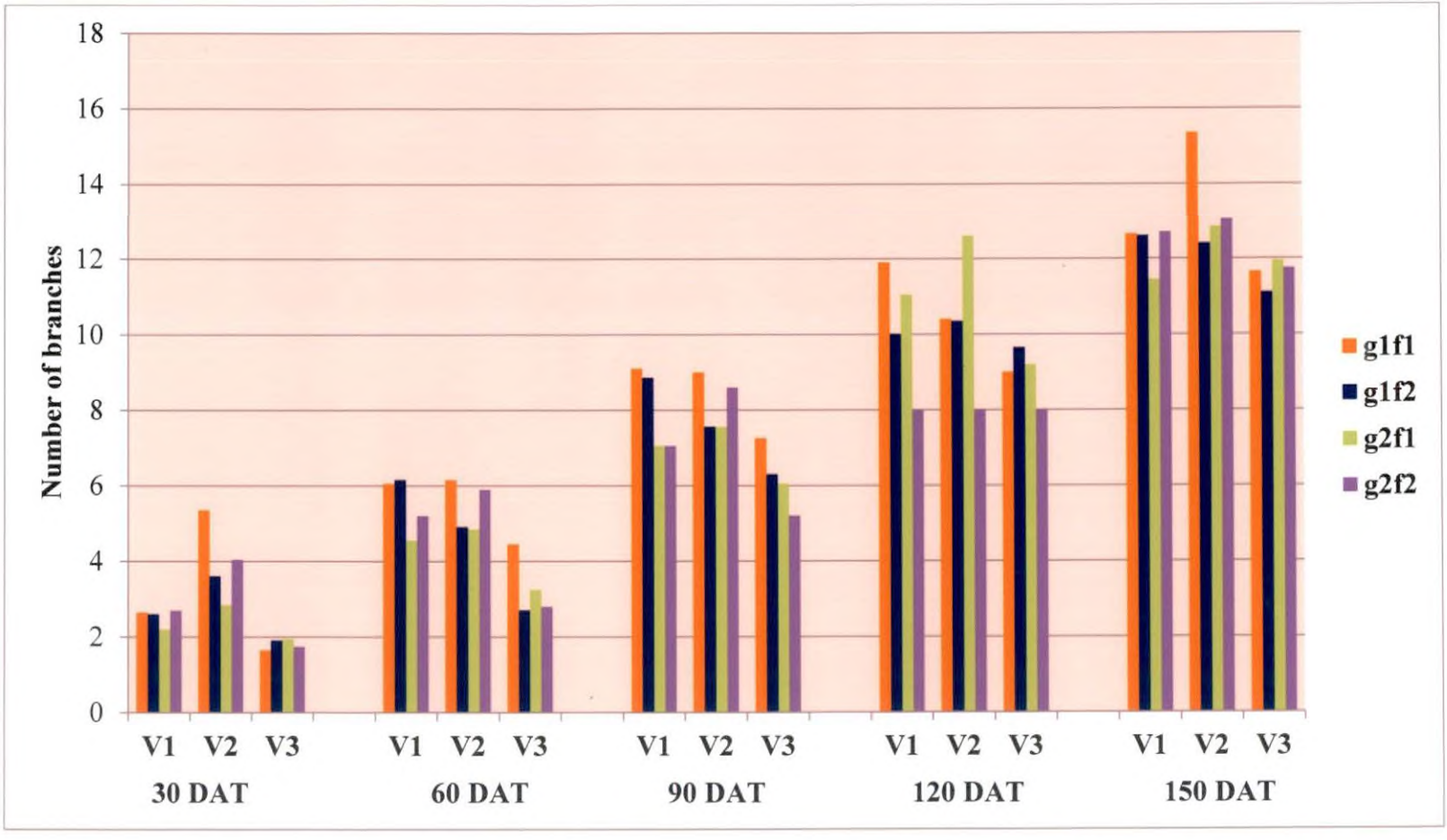

Fig. 6. Interaction effect of growing conditions, fertigation and varieties on number of branches at 30, 60, 90, 120 and 150 DAT

prevailed inside the polyhouse favouring increased growth rate of plants. This is in conformity with the findings of Zende (2008) and Yellavva (2008) in capsicum. Maximum number of leaves under shade net cover due to low light intensity and better environmental conditions was also reported by Prabhu *et al.* (2010) in tomato, capsicum, cucumber, bottle gourd, bitter gourd and sponge gourd. Fertigation caused significant variation in LAI at 60 and 120 DAT. Plants grown with fertigation (Fig. 7) showed maximum LAI (1.22) at 60 DAT and (4.49) at 120 DAT. Higher LAI with fertigation might be due to the increased photosynthetic capacity of plants due to the continuous availability of nitrogen and potassium through drip irrigation. Similar result was reported by Ashoka (2005) in red chilli. Similarly, higher LAI through fertigation was also reported by Hebbar *et al.* (2004) in tomato and Shashidhara (2006) in chilli. Crops grown under poly house condition with fertigation (Fig. 8) recorded higher LAI (5.02) followed by plants grown in open field condition with fertigation (3.96).

Different levels of growing condition significantly influenced the length of tap root (Fig.9) and root spread (Fig. 9). Maximum length of taproot (29.83 cm) and maximum root spread (48.20 cm) were observed from plants grown under poly house. The favourable environmental conditions prevailing in poly house might have helped in better growth of roots of capsicum (Naik, 2005). Fertigation levels had significant impact on length of tap root and root spread. Plants grown with fertigation showed maximum length of tap root (29.23 cm) and root spread (46.30 cm). Increased root length with fertigation was reported by Savitha *et al.* (2010) in onion.

The root shoot ratio was observed to vary significantly with different growing conditions (Fig.10). The highest value of root shoot ratio (0.40) was observed in plants grown under open field condition. Increase in root shoot ratio under open condition might be due to the decrease in shoot dry weight due to the decreased growth attributes like plant height, number of branches and LAI under open condition.

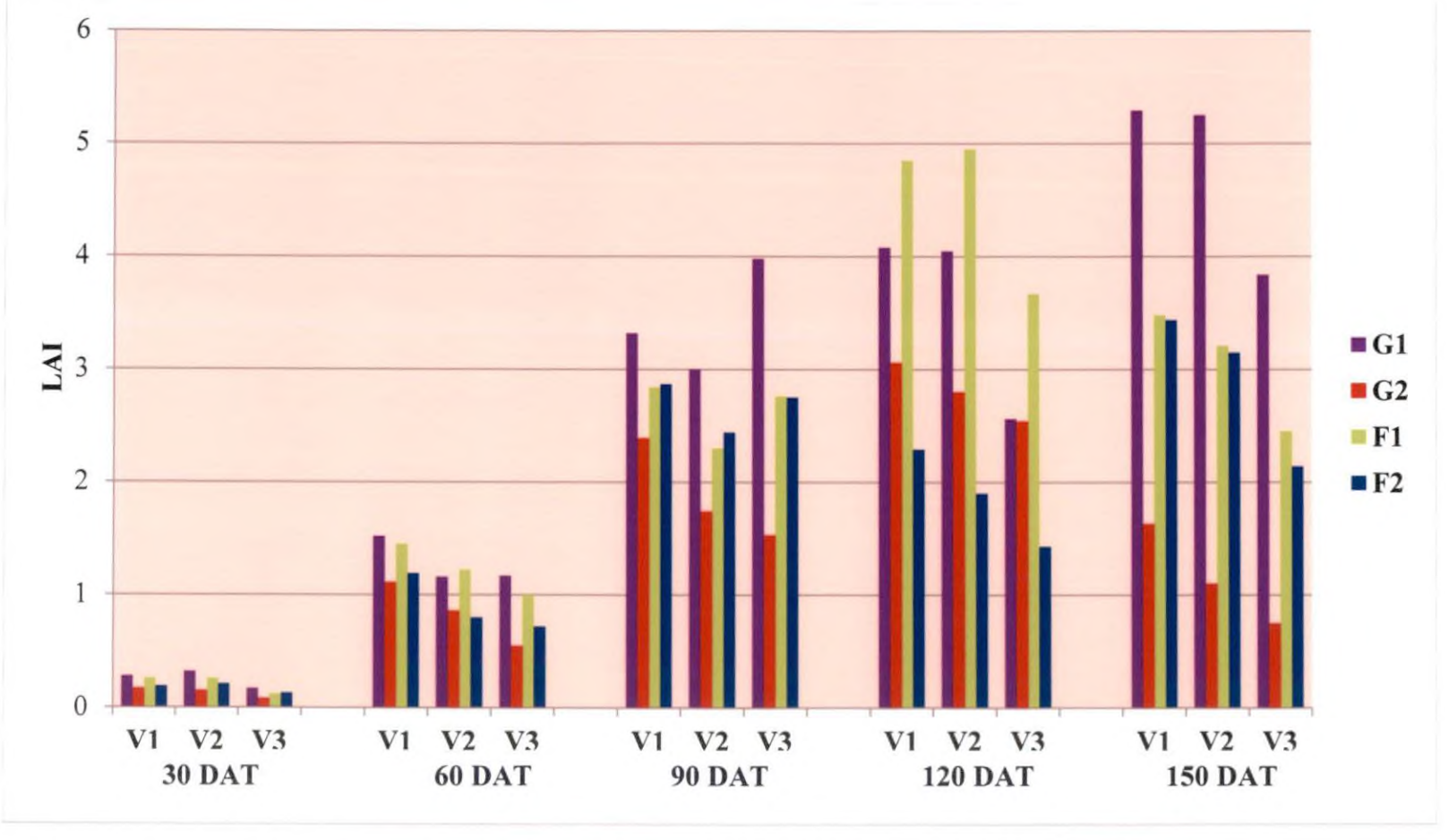

Fig. 7. Effect of growing conditions, fertigation and varieties on LAI at 30, 60, 90, 120 and 150 DAT

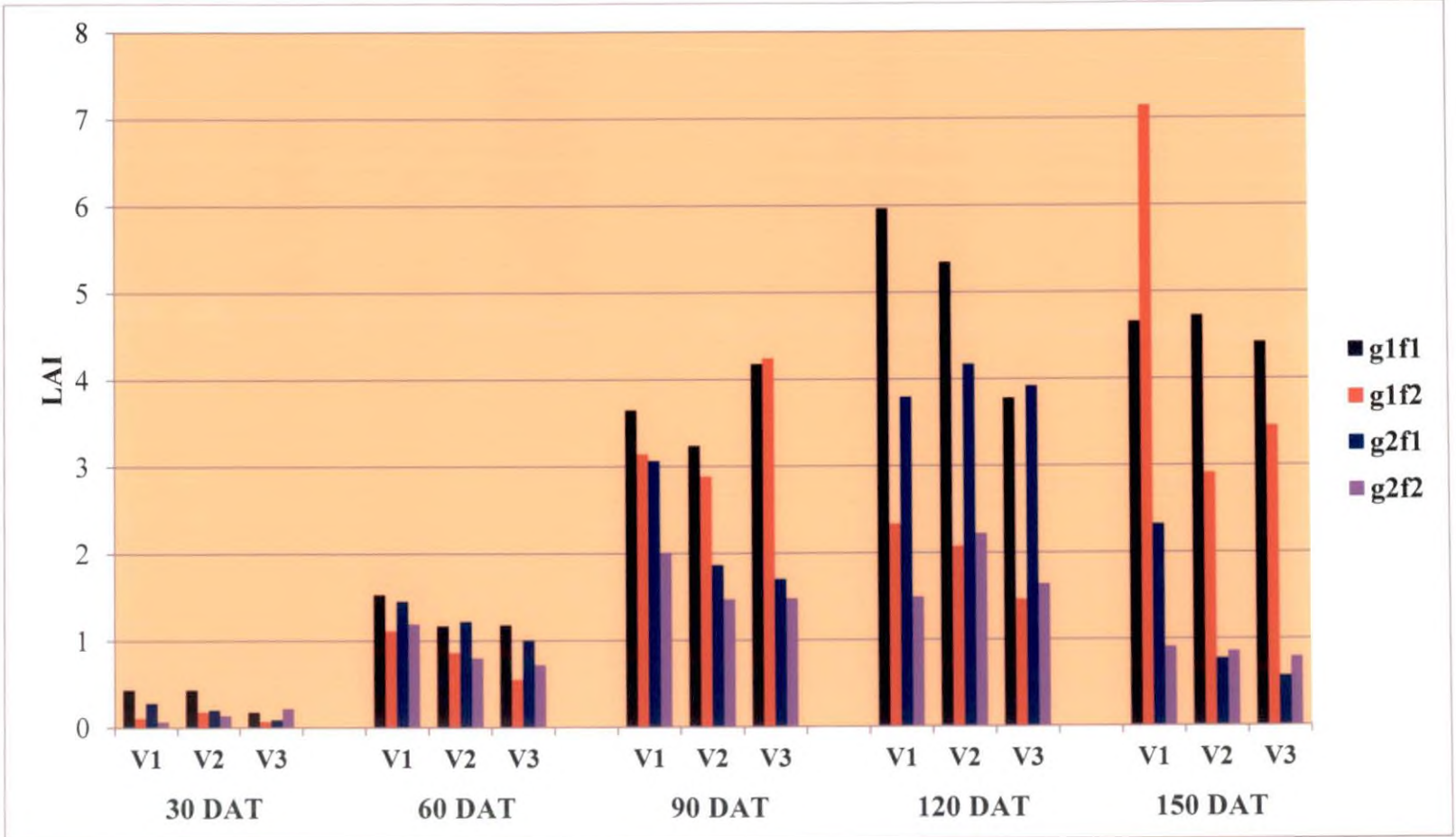

Fig. 8. Interaction effect of growing conditions, fertigation and varieties on LAI at 30, 60, 90, 120 and 150 DAT

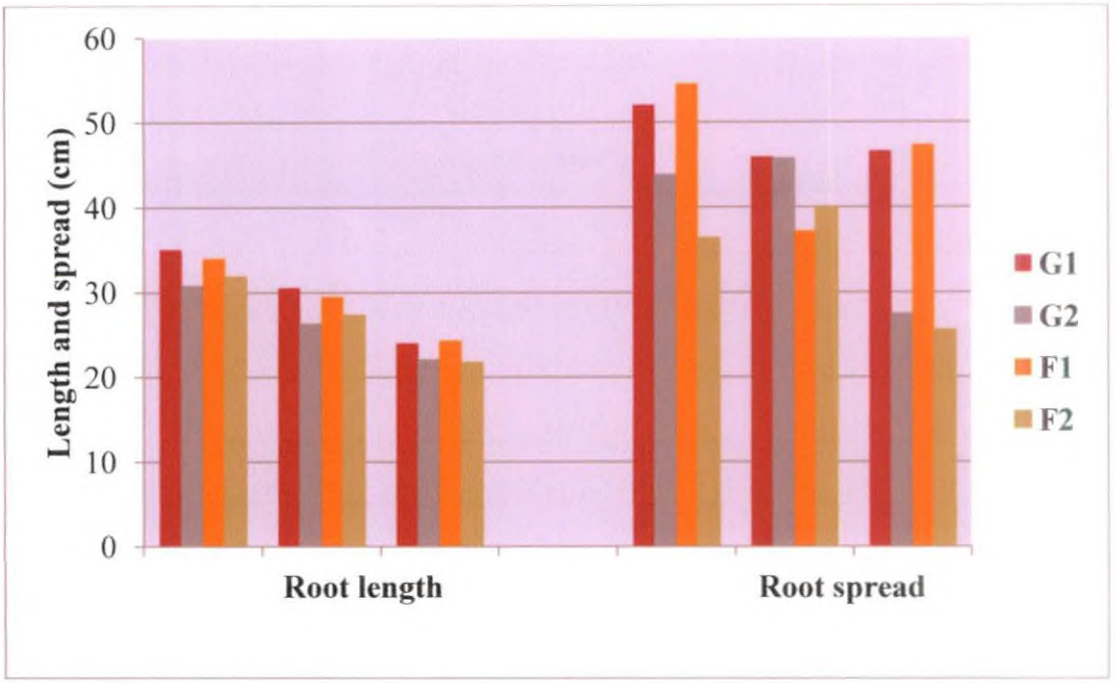

Fig. 9. Effect of different growing conditions, fertigation and varieties on tap root length and root spread of chilli

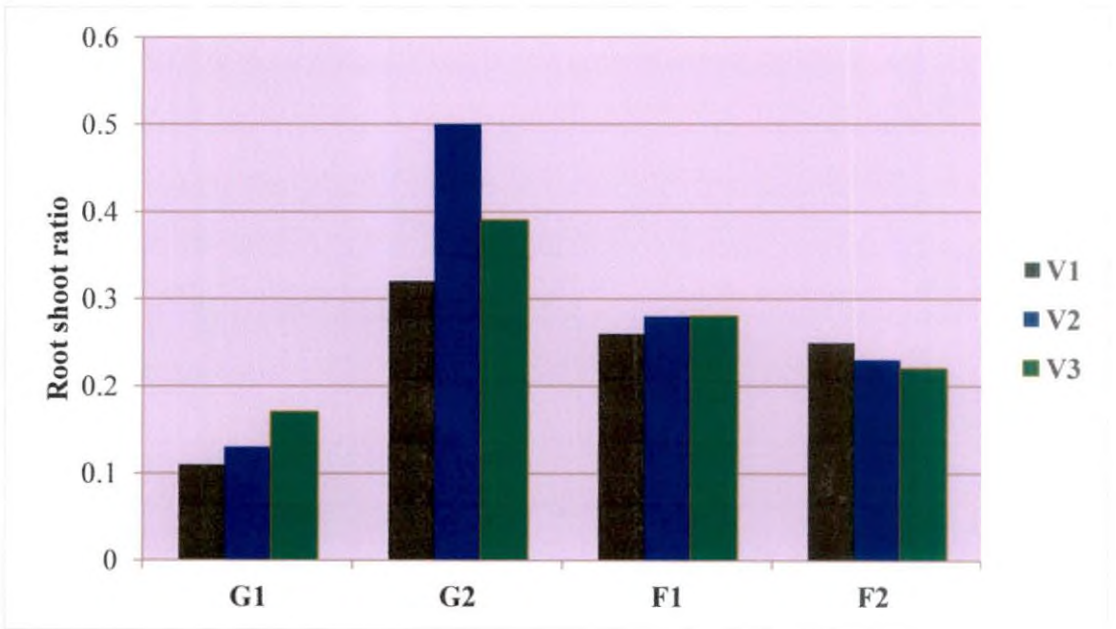

Fig. 10. Effect of different growing conditions, fertigation and varieties on root shoot ratio

5.1.2 Yield and Yield Attributing Characters

Different growing condition had significant influence on number of fruits plant^{-1} (Fig.11), length of fruit (Fig. 13), fruit yield plant^{-1} (Fig. 15) and total fruit yield (Fig. 17). The plants grown under poly house recorded maximum number of fruits plant^{-1} (110.67) , length of fruit (11.77 cm) , fruit yield plant^{-1} (604.08 g) and total fruit yield (29.54 t ha^{-1}) and these were 11.70 per cent, 9.30 per cent, 13.30 per cent and 37.90 per cent more respectively, compared to those grown under open field condition. Reduction in number of fruits plant^{-1} under open field condition might be due to poor fruit set under high temperature and low humidity and high temperature might have caused dehydration in cells causing permanent injury to the plant and cessation of growth (Venthamoni and natarajan, 2008). Similar findings of increased number of fruits plant^{-1} under poly house was reported by Singh *et al.* (2011) in capsicum. Higher length of fruits of capsicum recorded under naturally ventilated polyhouse might be due to the translocation of more photosynthates from source to sink and also favourable microclimate that prevailed in the naturally ventilated polyhouse throughout the crop growth period. This result corroborate with the findings of Zende (2008) and Naik (2005) in capsicum. Ganiger (2010) also reported higher fruit length for capsicum under shaded condition compared to open field condition. Increased fruit number plant^{-1}, fruit yield plant^{-1} and total fruit yield might be due to the increased harvesting span of chilli plants grown in poly house, production of more flowers plant^{-1} as there was less interference of adverse climatic and weather condition like rainfall and wind velocity during crop growth and development. In this experiment, thirteen harvests were obtained from poly house whereas; it was limited to ten in open condition. Similar increase in fruit number plant^{-1} and total fruit yield due to increase in harvesting span was reported by Singh *et al.* (2013) in bell pepper. Increased yield under shade due to increased number of branches and highest number of fruits per capsicum plant was also reported by Venthamoni and Natarajan (2008). Higher yields obtained from the poly house was due to the favourable air temperature, RH and light intensity present in the structure which had helped in achieving better vegetative growth and that

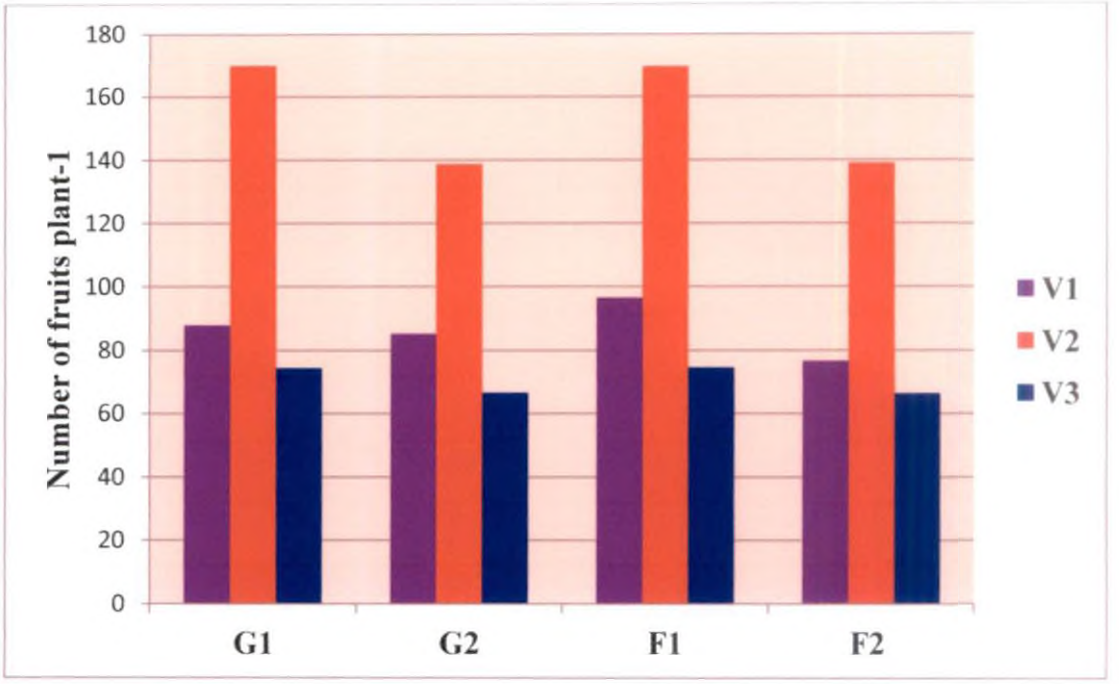

Fig. 11. Effect of different growing conditions, fertigation and varieties on number of fruits plant^{-1}

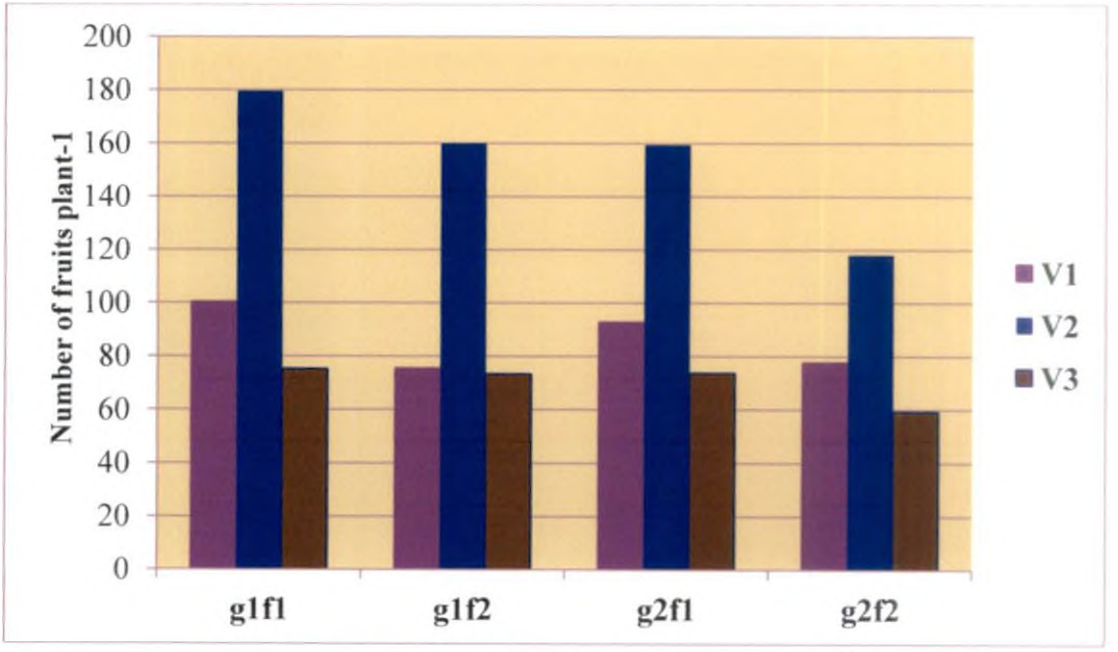

Fig. 12. Interaction effect of different growing conditions, fertigation and varieties on number of fruits plant^{-1}

reflected in better reproductive characters in chilli. Zende (2008) also reported that higher percentage of fruit set and more number of fruits under polyhouse was due to less interference of adverse climatic and weather condition. Similar results of higher fruit yield plant^{-1} under polyhouse was also reported by Naik (2005), Yellavva (2008) and Singh *et al.* (2011) in capsicum and increase in yield plant^{-1} with shade was reported by Mashego (2001) in tomato and Ganiger (2010) in capsicum. Higher values of all the yield components and yield of crop grown under poly house than open field might be due to the taller plants and much number of branches with greater LAI. Similar results were obtained by Parvej *et al.* (2010) in tomato. Increased fruit yield plant^{-1} under polyhouse condition compared to open field condition due to minimum incidence of pest and insects under polyhouse was reported by Singh *et al.* (2012) in tomato, capsicum and strawberry. In this study, crop inside poly house was comparatively free from pest and disease incidence. A similar finding was given by Hazara and Some (1999). Higher yield is generally realized in the crops grown under greenhouse, because the covering structures have the property of absorbing UV and infrared radiations (Hazra and Some, 1999). The higher yield of capsicum recorded from shade house condition might be due to the congenial growing environment which prevailed inside the shade house that helped the plant in better utilization of solar radiation and nutrients (N uptake- 69.52 Kg ha^{-1}, P uptake- 14.92 Kg ha^{-1} and K uptake-39.62 Kg ha^{-1}) (Fig. 24) for the production of photosynthates and transformation of metabolites in to economic parts like fruits. Further, the moderate temperature (21.45^{0}C- 27.71^{0}C) in combination with higher RH (88.50 per cent) prevailing in poly house might have helped in fast multiplication of cells and cellular elongation resulting in a better growth of roots, shoots, number of branches and leaf area which directly helped in a better vegetative growth finally improving the yield attributing parameters. This is in line with findings of Ganiger (2010) in capsicum. Due to erratic behavior of weather, the crops grown in open field are often exposed to fluctuating levels of temperature, humidity, wind flow etc. which ultimately resulted in 27.50 per cent reduction in yield under open condition.

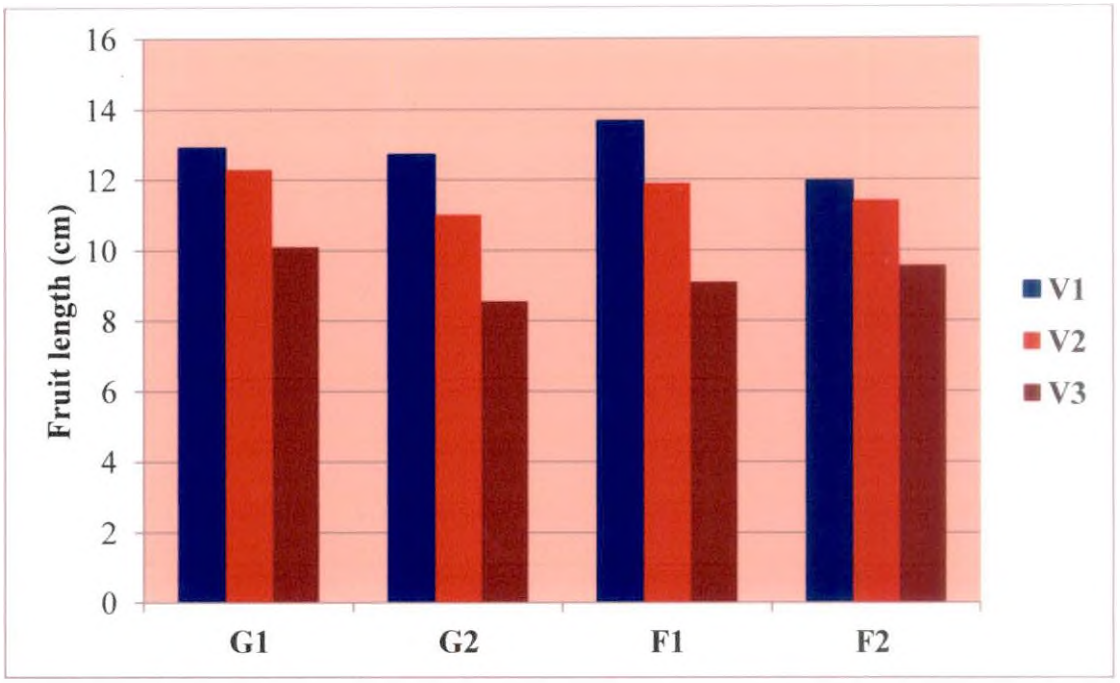

Fig. 13. Effect of different growing conditions, fertigation and varieties on fruit length

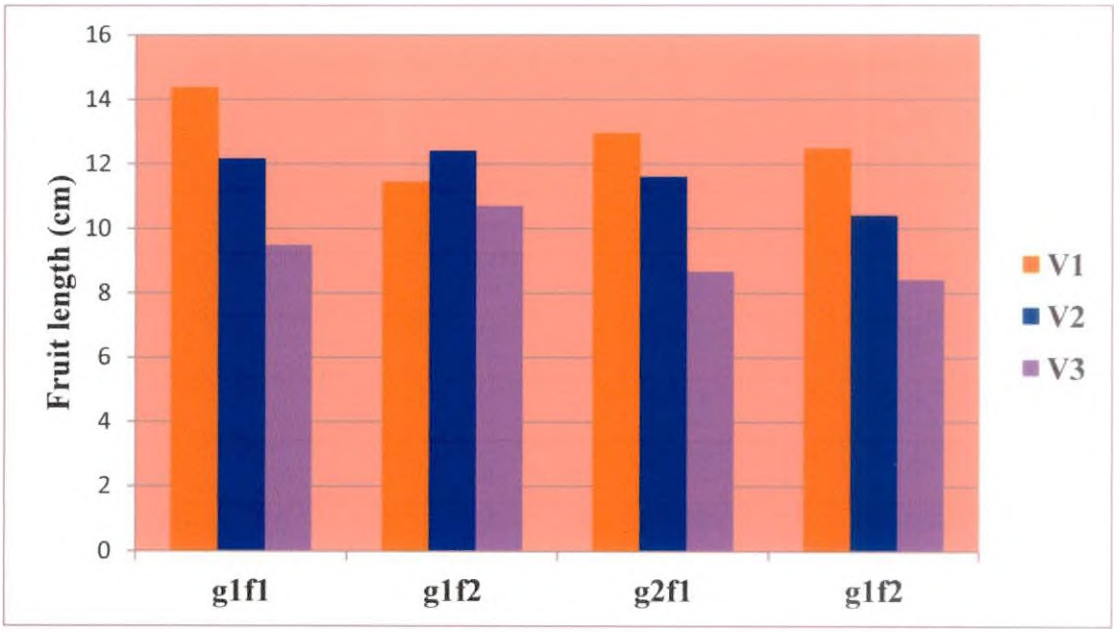

Fig. 14. Interaction effect of different growing conditions, fertigation and varieties on fruit length

Number of fruits plant^{-1}, length of fruit, fruit yield plant^{-1} and total fruit yield showed significant variation with fertigation. The plants grown with fertigation recorded maximum number of fruits plant^{-1} (113.49), maximum length of fruit (11.55 cm), fruit yield plant^{-1} (591.92 g) and highest fruit yield (26.27 t ha^{-1}). Similar results of increased fruit number with fertigation has been reported earlier by Shashidhara (2006) in chilli, Brahma *et al.* (2010) and Singandhupe et al. (2005) in tomato. Maximum fruit length through fertigation was reported by Gupta *et al.* (2010) in chilli and Brahma *et al.* (2010) in tomato. The increased yield and yield attributing characters of chilli under fertigation might be due to the efficient use of nutrients at various stages of crop growth without leaching of nutrients in the form of runoff. This is in line with findings of Gupta *et al.* (2010) in chilli. Confined application of fertilizers to rhizosphere where the active roots are concentrated leads to better utilization of nutrients and thereby contributed to the higher yield. This is in conformity with the findings of Brahma *et al.* (2010) in tomato. The better availability of plant nutrients and water throughout the crop growth period through fertigation lead to higher yield attributing characters. This is in accordance with the findings of Savitha *et al.* (2010) in onion. Increase in average fruit weight through fertigation was reported by Gupta *et al.* (2010) and Shashidhara (2006) in chilli. Increased fruit yield of red chilli by split application of nitrogen and potassium through drip irrigation was reported by Ashoka (2005).

Maximum number of fruits plant^{-1} (Fig. 12) was reported in plants grown under poly house with fertigation (118.34). Increased number of fruits with the interaction effect of shade with 100% water soluble fertilizers was reported by Kavitha *et al.* (2009) in tomato.

Present investigation found that growing condition had influence on growth and yield of chilli. The higher yield obtained under poly house situation might be due to congenial microclimate which prevailed inside poly house.

Average moderate max. temperature (27.71°C) and min. temperature (21.45°C) in combination with high RH (88.50 per cent) and low light intensity (67.50 K. lux) prevailing inside poly house (appendix I) might have helped in the

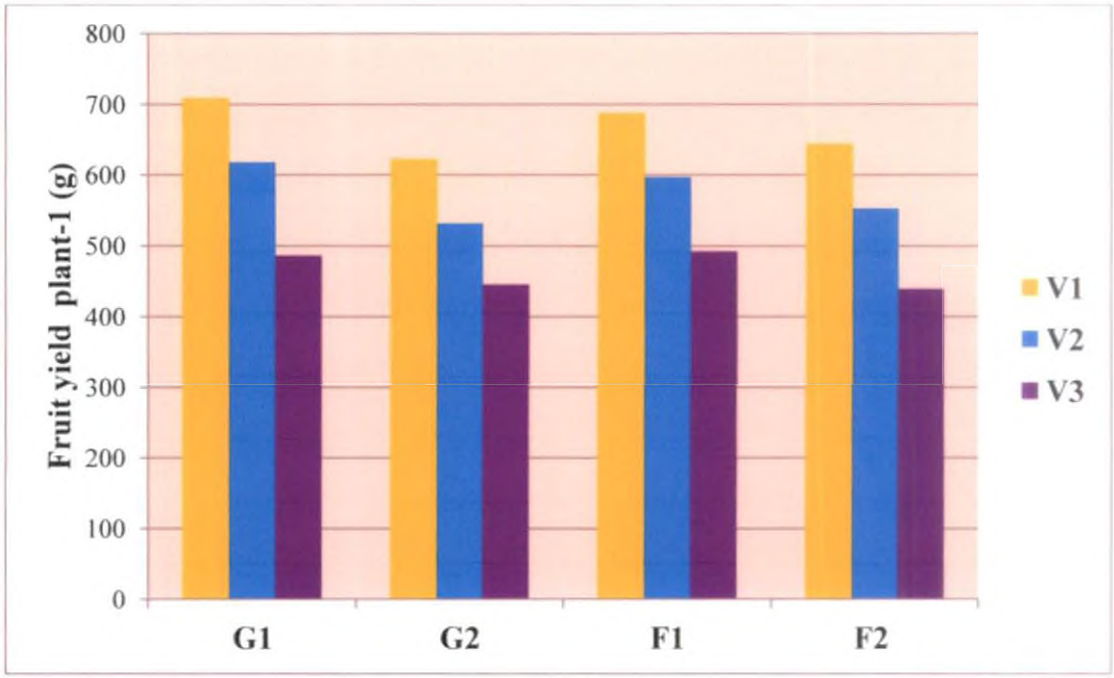

Fig. 15. Effect of different growing conditions, fertigation and varieties on fruit yield plant^{-1}

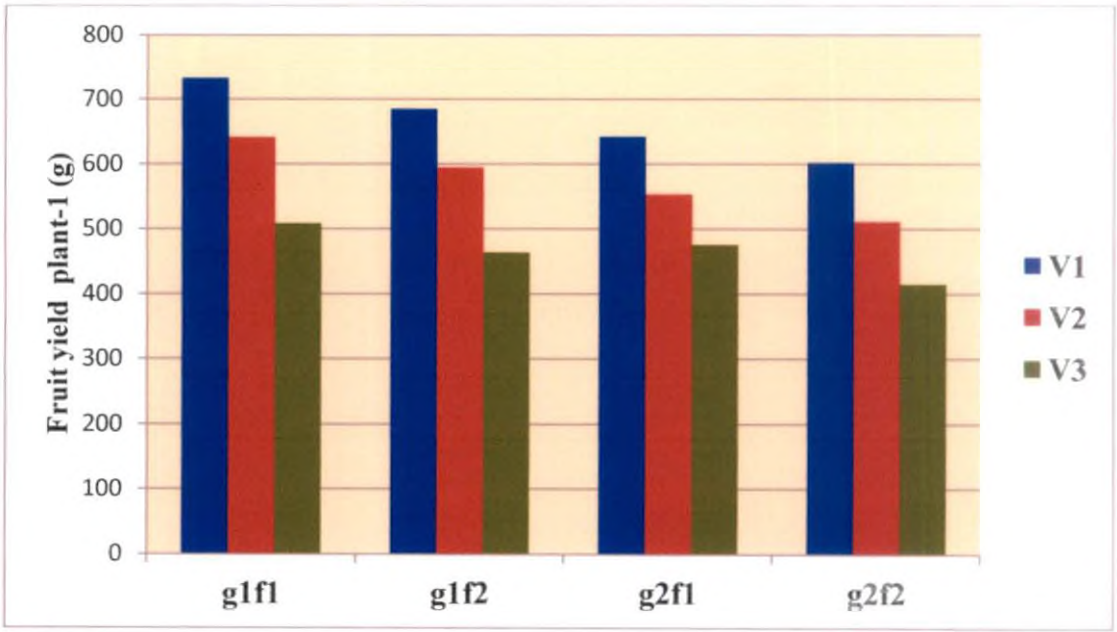

Fig. 16. Interaction effect of different growing conditions, fertigation and varieties on fruit yield plant^{-1}

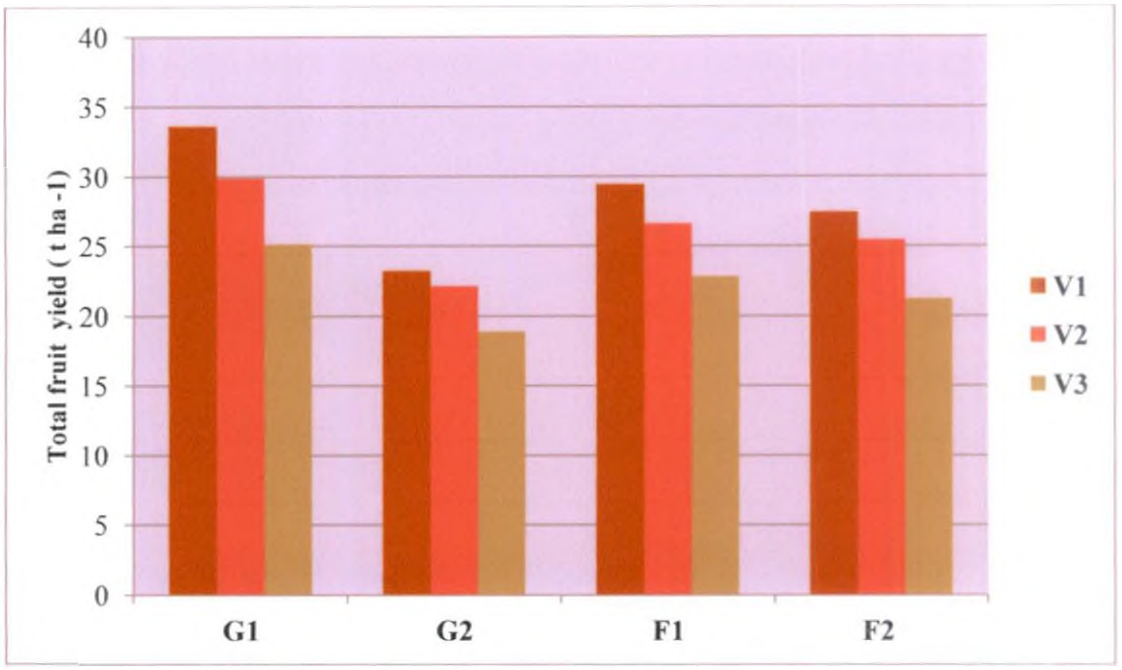

Fig. 17. Effect of different growing conditions, fertigation and varieties on total fruit yield (t ha $^{-1}$)

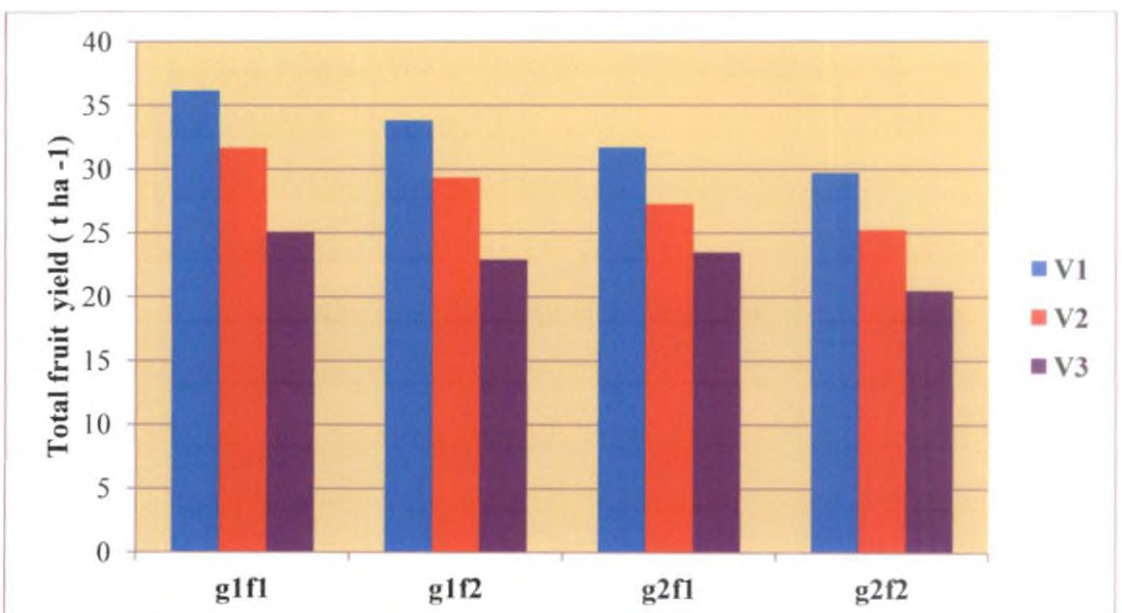

Fig. 18. Interaction effect of different growing conditions, fertigation and varieties on total fruit yield (t ha $^{-1}$)

fast multiplication of cells and cellular elongation resulting in a better growth of roots, shoots, number of branches and leaf area which directly helped in better vegetative growth (plant height, number of branches and LAI) and thereby improved yield attributing characters (Fig. 19) like fruit bearing period, number of fruits plant^{-1}, length of fruit, fruit yield plant^{-1} resulting in total fruit yield. According to Yellavva (2008) excellent growth and higher yield is generally realized in the crops grown under greenhouse, because the covering structure has the property of absorbing UV and infrared radiations. Burt (2005) reported that the day temperature of 24 to 30°C was optimum for growth and fruit set of chilli. In this study also, temperature was maintained at optimum level inside poly house.

Plants grown in open condition had experienced stressed condition throughout growth period due to unfavourable weather parameters like high max. temperature (30.60°C) and min. temperature (23.90°C), low RH (86.70 per cent) and high light intensity (86.50 K. lux), which is evidenced by the poor performance in growth and yield attributing characters. The higher temperatures have more adverse influence on net photosynthesis than lower temperature leading to decreased production of photosynthates above a certain temperature (Bhatt and Rao, 1993). The results of the study showed, 37.90 per cent increase in total fruit yield of chilli on growing under poly house. This reduction in yield was may be due to unfavourable weather parameters prevailed during crop growing period under open condition.

5.2 EFFECT OF VARIETIES AND ITS INTERACTION WITH DIFFERENT GROWING CONDITIONS AND FERTIGATION ON GROWTH AND YIELD ATTRIBUTING CHARACTERS

5.2.1 Growth Characters

Vellayani Athulya recorded significantly higher plant height (Fig. 3) at 60 and 150 DAT (92.15 cm and 114.58 cm, respectively) and significantly higher LAI (Fig. 7) (1.32) at 60 DAT. Anugraha recorded similar plant height compared to vellayani Athulya at 30 DAT, similar number of branches at 60, 90 and 120 DAT and similar LAI at 30 and 120 DAT. These better growth attributes was

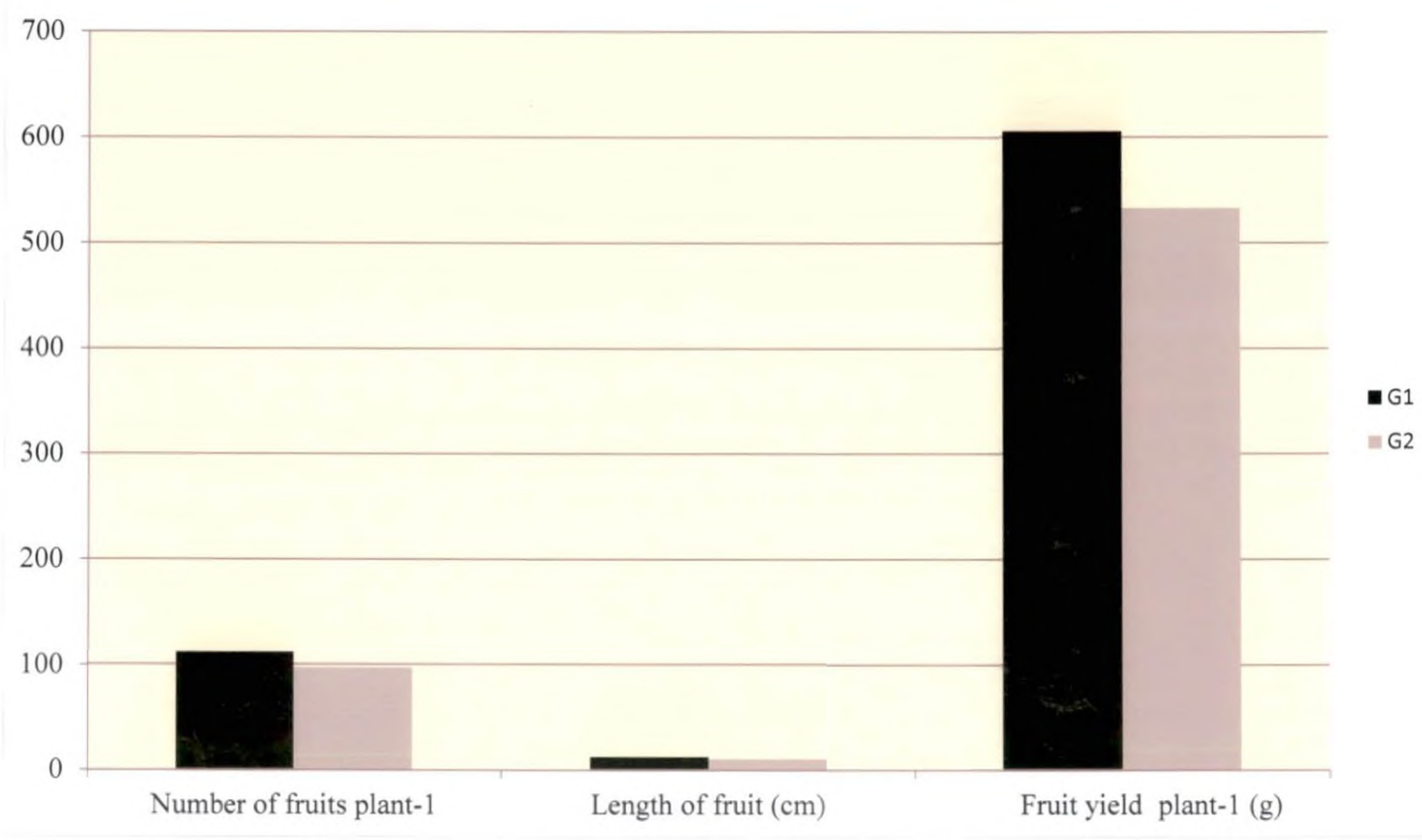

Fig. 19. Effect of different growing conditions, fertigation and varieties on yield attributing characters

mainly due to genetic makeup of varieties. Maximum length of tap root (32.85 cm) and root spread (46.7 cm) (Fig. 9) were shown by Vellayani Athulya followed by Anugraha (28.38 cm and 42.2 cm, respectively). This better root growth might have promoted nutrient uptake and might have resulted in better growth attributes. Varietal effect on plant height was also reported by Parvej *et al.* (2010) and Kengar (2011) in tomato, Shivkumar (2005) in chilli and Yellavva (2008) in capsicum. Varietal effect on growth has been explained by Ganiger (2010) in capsicum. Varietal effect on number of branches was reported by Shivkumar (2005) in chilli. Varietal effect on number of leaves was reported by Yellavva (2008) in capsicum.

G x V interaction caused significant influence on plant height (Fig. 3) at 60 DAT with maximum value of 125.43 cm by Vellayani Athulya grown under poly house. The favourable interaction effect of shade house and variety on increased plant height of capsicum was reported by Ganiger (2010). At 90 DAT, Jwalamukhi and Vellayani Athulya grown under poly house (Fig.7) recorded maximum LAI. The interaction effect of poly house and varieties on number of leaves was also reported by Sharma *et al.* (2004) and Yellavva (2008) in capsicum.

Anugraha grown with fertigation recorded maximum number of branches (11.50) and it was on par with Vellayani Athulya grown with fertigation (11.48) at 120 DAT. Positive interaction effect of fertigation and varieties on number of branches was reported by Gupta *et al.* (2009) in capsicum. Maximum LAI was reported in Vellayani Athulya grown with fertigation (0.26) and Anugraha grown with fertigation (0.26) which were on par with Anugraha grown without fertigation (0.21), Vellayani Athulya grown without fertigation (0.19) and Jwalamukhi grown without fertigation (0.13).

G x F x V interaction caused significant influence on plant height at 150 DAT and maximum value for plant height was observed from Vellayani Athulya grown under poly house with fertigation (152.49 cm) and it was comparable with Vellayani Athulya grown under poly house without fertigation (149.17 cm), Anugraha grown under poly house with fertigation (148.87 cm),

Jwalamukhi grown under poly house with fertigation (142.33 cm) and Jwalamukhi grown under poly house without fertigation (142.31 cm).

5.2.2 Yield and Yield Attributing Characters

Maximum number of fruits plant^{-1} (154.21) was obtained from Anugraha while, maximum length of fruit (12.82 cm), fruit yield plant^{-1} (665.18 g) and total fruit yield (28.41 t ha^{-1}) was obtained from Vellayani Athulya. Varietal effect on number of fruits plant^{-1}, fruit yield plant^{-1} and total fruit yield was reported by Yellavva (2008) in capsicum hybrids. Varietal effect on fruit yield plant^{-1} was also reported by Kengar (2011) in tomato. Varietal effect on number of fruits plant^{-1} and length of fruit was also reported by Shivkumar (2005) in chilli. Results of varietal effect on total fruit yield were also reported by Ganiger (2010) in capsicum.

G x V interaction had significant influence on length of the fruit (Fig. 13) and number of fruits plant^{-1}(Fig. 11). The maximum length of fruit was recorded by Vellayani Athulya grown under poly house (12.91 cm), which was on par with (Vellayani Athulya grown in open condition) (12.72 cm). Maximum number of fruits plant^{-1} was reported in Anugraha grown under poly house (169.75). Interaction effect of varieties and plastic house on fruit length was studied by Aruna and Sudagar (2009) in sweet pepper. Increased number of fruits plant^{-1} of tomato varieties under controlled environment conditions was reported by Wahudeniya *et al.* (2006). Interaction effect of shade and varieties on fruit length of sweet pepper was reported by Venthamoni and Natarajan (2008). Positive interaction effect of shade house and varieties on length of fruit of capsicum was reported by Ganiger (2010). Eventhough G x V interaction didn't cause significant influence on total fruit yield. Vellayani Athulya grown under poly house (33.61t ha^{-1}) recorded maximum total fruit yield compared to other varieties under poly house. Increase in yield of Vellayani Athulya under poly house compared to open condition was about 44.80 per cent where as percentage increase in yield was 35.02 per cent in Anugraha and 33.10 per cent in Jwalamukhi. Increase in total fruit yield of Vellayani Athulya under poly house

compared to open condition might be due to increased fruit yield plant^{-1}(13.92 per cent) and number of fruits plant^{-1}(3.08 per cent).

F x V interaction also had significant influence on length of fruit (Fig. 13) and number of fruits plant^{-1} (Fig. 11). The maximum length of fruit was recorded by Vellayani Athulya grown with fertigation (13.67 cm). Interaction effect of fertigation and varieties on length of fruit was reported by Gupta *et al.* (2009) in capsicum. Maximum number of fruits plant^{-1} was reported in Anugraha grown with fertigation (169.42).

G x F x V interaction showed significant variation on length of the fruit and number of fruits plant^{-1}. Maximum length of fruit was recorded by Vellayani Athulya grown under poly house with fertigation (14.38 cm). Maximum number of fruits plant^{-1}(179.50) was obtained from Anugraha grown under poly house with fertigation.

5.3 EFFECT OF GROWING CONDITIONS, FERTIGATION, VARIETIES AND THEIR INTERACTIONS ON QUALITY ASPECTS OF FRUITS

Different growing condition had significant influence on keeping quality (shelf life) (Fig. 20), ascorbic acid content (Fig. 22) and capsaicin (Fig. 20). Maximum shelf life (10.29 days), ascorbic acid content (98.28 mg 100g^{-1}) and capsaicin content (1.17 per cent) was recorded by plants grown under poly house and it was about 14.3 per cent, 4.80 per cent and 4.46 per cent, respectively more compared to open condition. Higher shelf life of tomato under naturally ventilated polyhouse with bigger fruits having thick pericarp thickness had been reported by Zende (2008). A similar result of increased shelf life in capsicum was also reported by Yellavva (2008). The capsicum fruit from poly house situation grown well under ambient weather condition with less physiological loss in weight and recorded high ascorbic acid content compared to fruits obtained from open field conditions. This is in conformity with the findings of Ganiger (2010). The biological function of ascorbic acid is based on its ability to donate electrons, which provides intra and extra cellular reducing power for a variety of biological reaction. Substantially high cellular levels of ascorbic acid provide antioxidant protection against photosynthetically generated free radicals and this might have

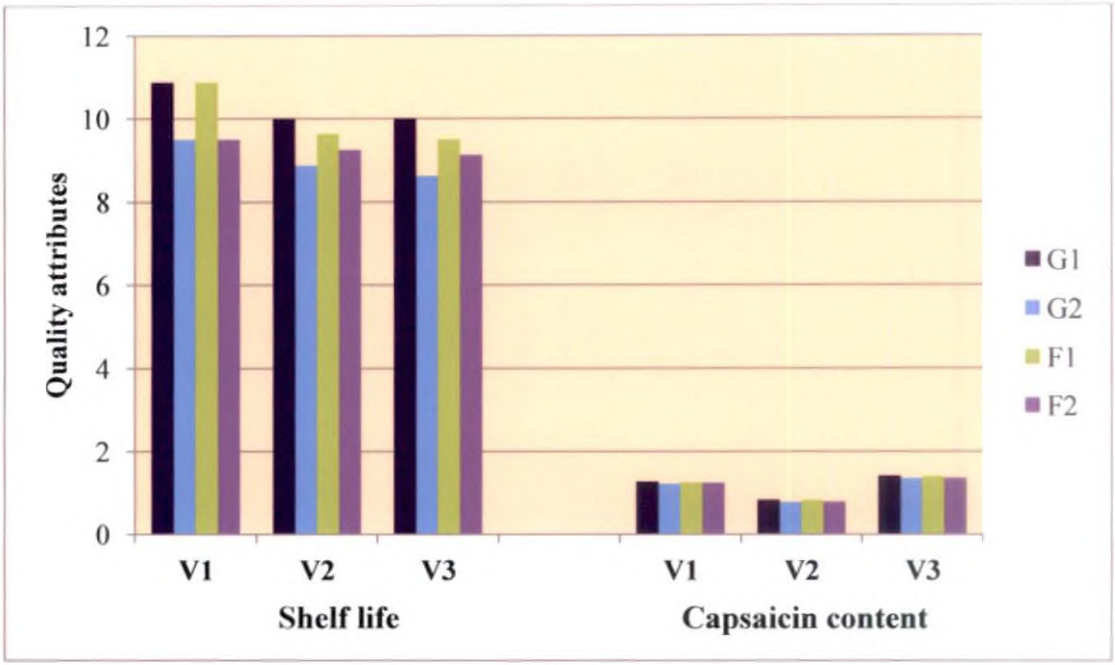

Fig.20. Effect of different growing conditions, fertigation and varieties on shelf life (days) and capsaicin content (per cent)

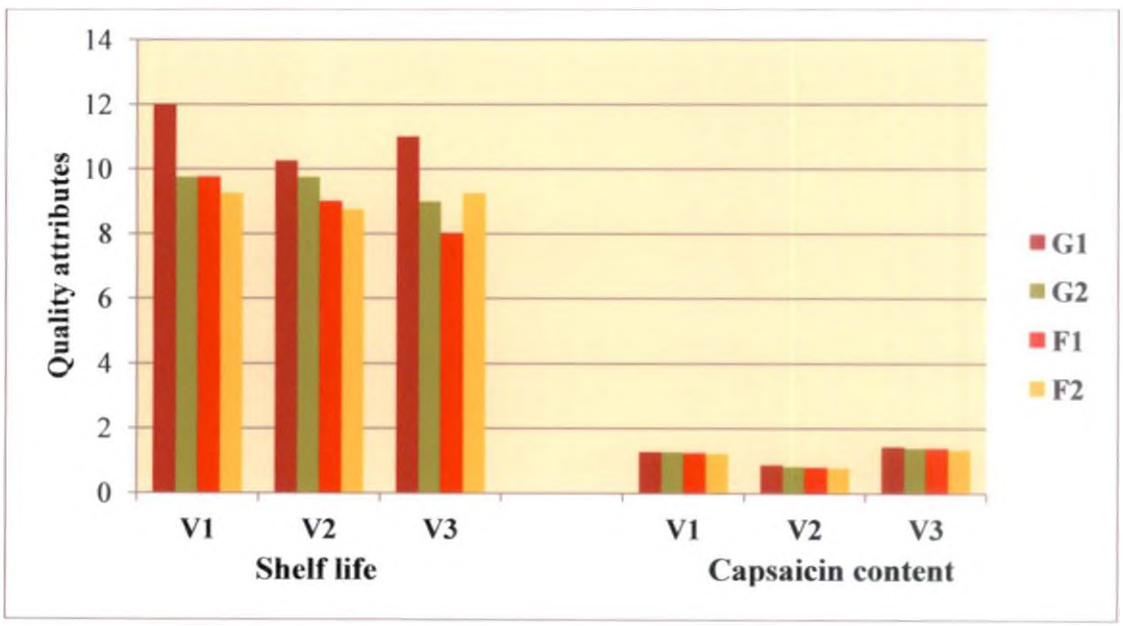

Fig.21. Interaction effect of different growing conditions, fertigation and varieties on shelf life (days) and capsaicin content (per cent)

increased the shelf life of chilli fruits in poly house situation which had high ascorbic acid content. Higher ascorbic acid content in capsicum fruits obtained from poly house was reported by Jeevansab (2000). Effect of shade on capsaicin content was reported by Rahman and Inden (2012).

The ascorbic acid content (Fig. 22), shelf life (Fig. 20) and capsaicin content (Fig. 20) were observed to differ significantly among the various levels of fertigation. Plants grown with fertigation recorded maximum ascorbic acid content (97.39 mg $100g^{-1}$), shelf life (10.00 days) and capsaicin content (1.16 per cent). Improved quality with fertigation might be due to the better utilization of water and nutrients, lower leaching losses and more controllable application of nutrients during the growing season as compared to other methods of water and nutrient supply. Similar findings of improved quality with fertigation have been reported by Gupta *et al.* (2010). Improvement in ascorbic acid content through fertigation was reported by Shashidhara (2006) and Ramachandrappa *et al.* (2010) in chilli, Rana *et al.* (2005) in capsicum and Hebbar *et al.* (2004) and Brahma *et al.* (2010) in tomato.

G x F interaction had significant influence on ascorbic acid content (Fig. 23) and shelf life (Fig. 21) of green chilli. Plants grown under poly house with fertigation recorded maximum shelf life (11.08 days) and ascorbic acid content (101.11 mg 100 g^{-1}). Positive influence of green house and fertigation on ascorbic acid of tomato was reported by Mahajan and Singh (2006).

Varieties had significant influence on shelf life (Fig. 20), ascorbic acid content (Fig. 22) and capsaicin content (Fig. 20) of chilli. Vellayani Athulya showed maximum shelf life of 10.19 days and ascorbic acid content of 98.71 mg 100 g^{-1}. The thicker pericarp of Vellayani Athulya might have resulted in more shelf life. Kengar (2011) also reported higher keeping quality with increased pericarp thickness. Varietal effect on shelf life was also reported by Yellavva (2008) in capsicum. Jwalamukhi recorded maximum capsaicin content (1.38 per cent). Varietal effect on capsaicin content was reported by Nwokem *et al.* (2010) and Ozguven and Yaldiz (2011) in caspicum,

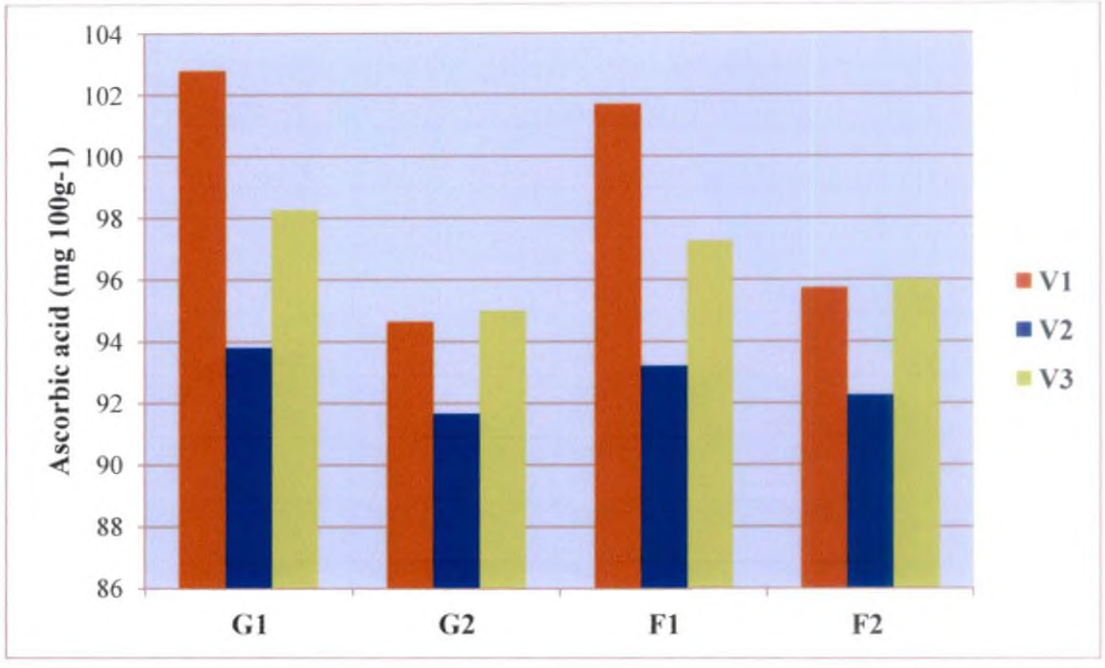

Fig.22. Effect of different growing conditions, fertigation and varieties on ascorbic acid (mg $100g^{-1}$)

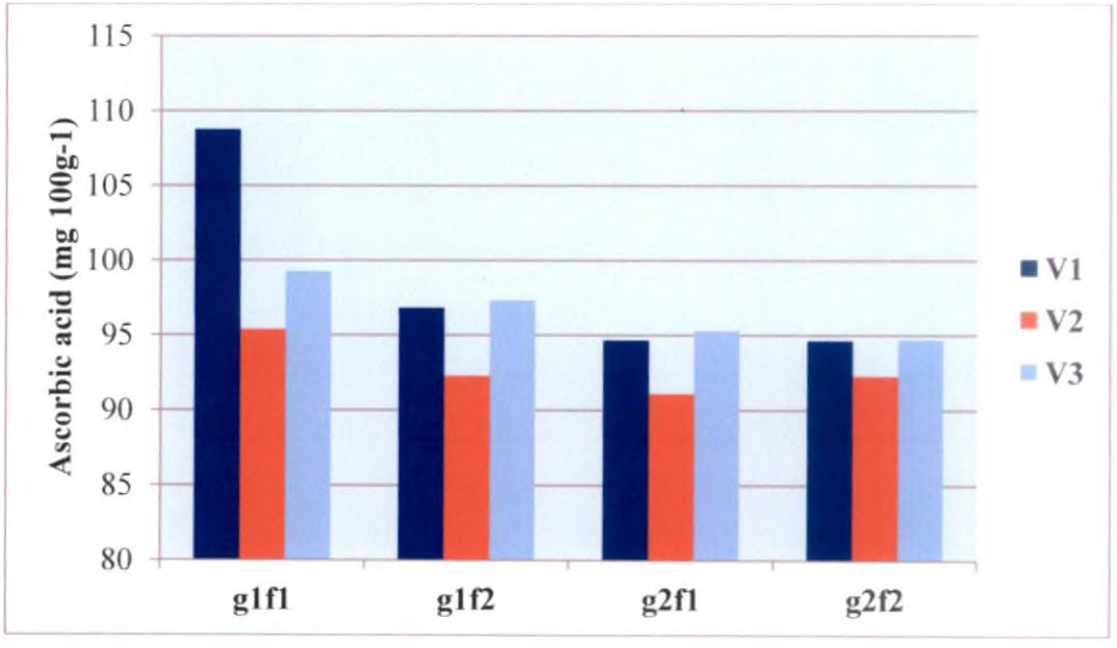

Fig.23. Interaction effect of different growing conditions, fertigation and varieties on ascorbic acid (mg $100g^{-1}$)

Hundal and Khanna (2002) among chilli culture. Capsaicin content of pepper fruits varied according to ontogenetic variety (Hundal and Khanna, 2002).

G x V interaction had significant influence on shelf life and ascorbic acid content of green chilli. Vellayani Athulya under poly house recorded maximum shelf life of fruit (10.88 days) and ascorbic acid content (102.78 mg $100g^{-1}$). Interaction effect of polyhouse and varieties on shelf life was also reported by Yellavva (2008) in capsicum. Interaction effect of shade house condition and varieties on ascorbic acid of capsicum was reported by Ganiger (2010).

F x V interaction had significant influence on ascorbic acid content and capsaicin content of green chilli. The maximum ascorbic acid content was recorded by Vellayani Athulya grown with fertigation (101.69 mg $100g^{-1}$). The maximum capsaicin content was recorded by Jwalamukhi grown with fertigation (1.40 per cent).

G x F x V interaction had significant influence on shelf life, ascorbic acid content and capsaicin content. The maximum shelf life was recorded by Vellayani Athulya grown under poly house with fertigation (12.00 days). The maximum ascorbic acid content was recorded by Vellayani Athulya with fertigation under poly house (108.74 mg 100 g^{-1}). The maximum capsaicin content was recorded by Jwalamukhi with fertigation under poly house (1.43 per cent).

5.4 EFFECT OF GROWING CONDITIONS, FERTIGATION, VARIETIES AND THEIR INETRACTION ON NUTRIENT UPTAKE

Levels of growing conditions had significant influence on nutrient uptake. (Fig.24). Maximum N (69.52 kg ha^{-1}), P (14.92 kg ha^{-1}), K (39.62 kg ha^{-1}) uptake was recorded by plants grown under polyhouse. An increased uptake of around 88.50 per cent of nitrogen, 41.00 per cent of phosphorus and 46.10 per cent of potassium compared to open field was recorded plants grown under poly house. The enhanced root production, more vegetative growth along with higher dry matter production might have resulted in increased uptake of these nutrients. Increased dry matter production inside green house compared to open field crop

with slightly higher temperature inside green house was reported by Tiwari and Chaudhury (1986).

Nitrogen uptake was observed to differ significantly among the levels of fertigation (Fig. 24). Plants with fertigation recorded maximum nitrogen uptake (58.21 kg ha^{-1}). The increased nitrogen availability of nitrogen through drip irrigation in splits resulted in higher nitrogen uptake. This is in conformity with the findings Alcantar *et al.* (1999) and Singandhupe (2003) also reported increased uptake of N in tomato through fertigation compared to conventional method of application. Silber *et al.* (2003) reported that frequent fertigation improved the uptake of nutrients through continuous replenishment of nutrients in the depletion zone in the vicinity of the root or medium interface and enhanced transport of dissolved nutrients by mass flow. The continuous availability of nutrients through drip irrigation resulted in accelerated leaf expansion along with overall dry matter production which ultimately resulted in higher nutrient uptake. Increased N in plants through fertigation was reported by Wabel *et al.* (2006) in cucumber and Shashidhara (2006) in chilli.

Fertigation levels and their interaction with growing condition didn't cause significant influence on phosphorus uptake and potassium uptake.

Varieties had significant influence on nitrogen uptake (Fig. 24). Maximum nitrogen uptake was observed in Vellayani Athulya (60.73 kg ha^{-1}) and it was on par with Anugraha (55.00 kg ha^{-1}). The higher plant height along with higher LAI with higher DMP in Vellayani Athulya and the higher number of branches with higher DMP resulted in higher nutrient uptake for Anugraha. Interaction effects didn't cause significant influence in nitrogen uptake.

5.5 EFFECT OF GROWING CONDITIONS, FERTIGATION AND THEIR INETRACTION WITH VARIETIES ON PEST INCIDENCE

No incidence of pest were reported inside poly house throughout the period of plant growth while, leaf curl complex caused by thrips and mite was reported at in open field condition (Table 34). Lower incidence of pest under green house compared to open field condition was reported by Yellavva (2008) in capsicum and Singh *et al.* (2009) in tomato. No incidence of pests under

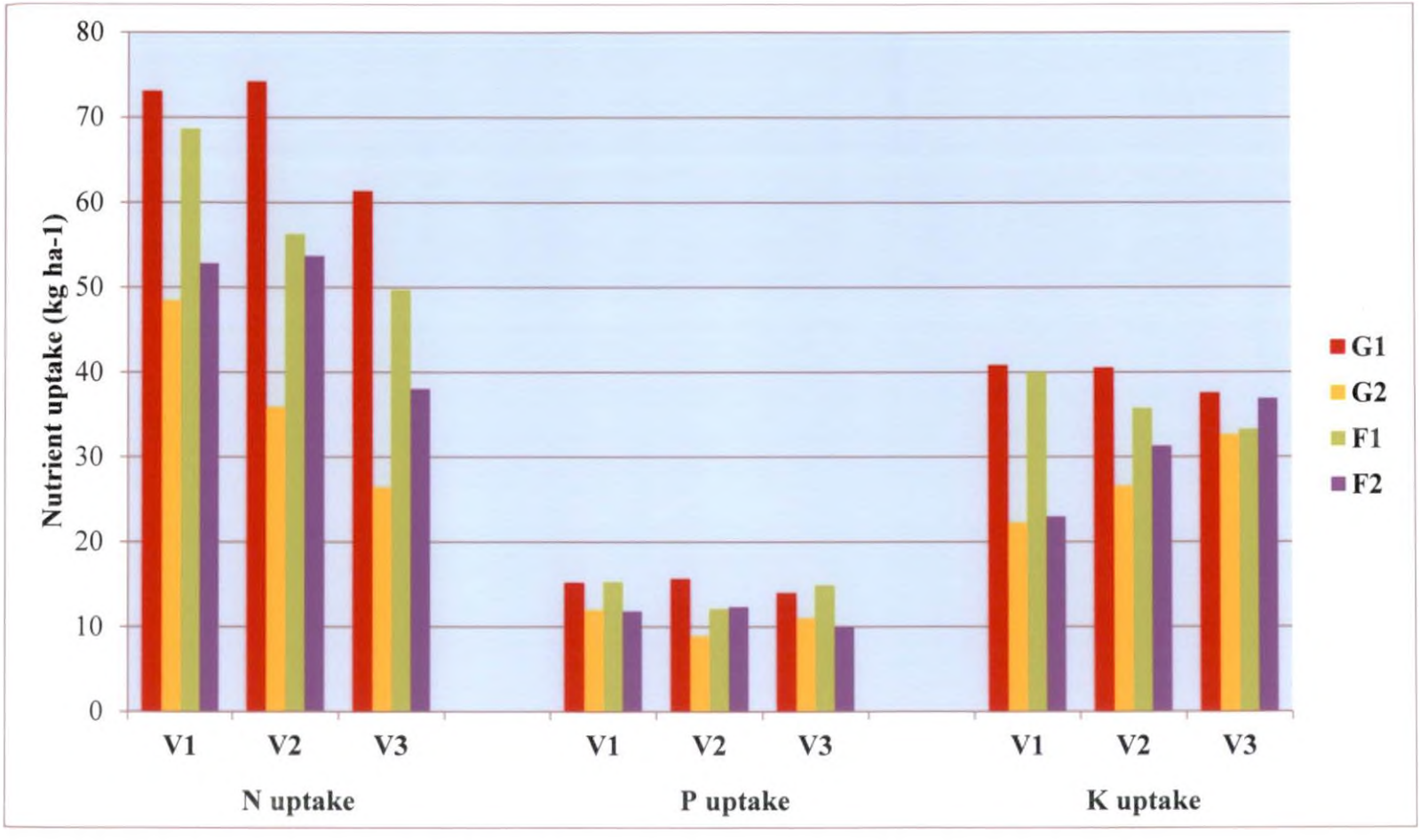

Fig.24. Effect of different growing conditions, fertigation and varieties on nutrient uptake (kg ha^{-1})

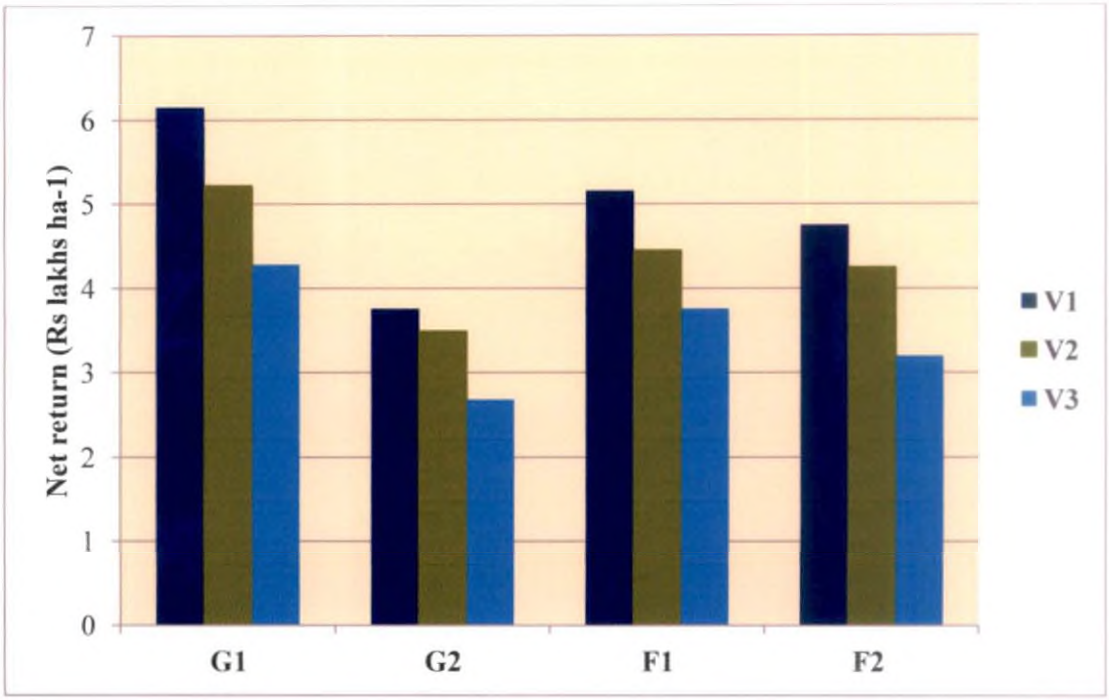

Fig.25. Effect of different growing conditions, fertigation and varieties on net returns (Rs lakhs ha^{-1})

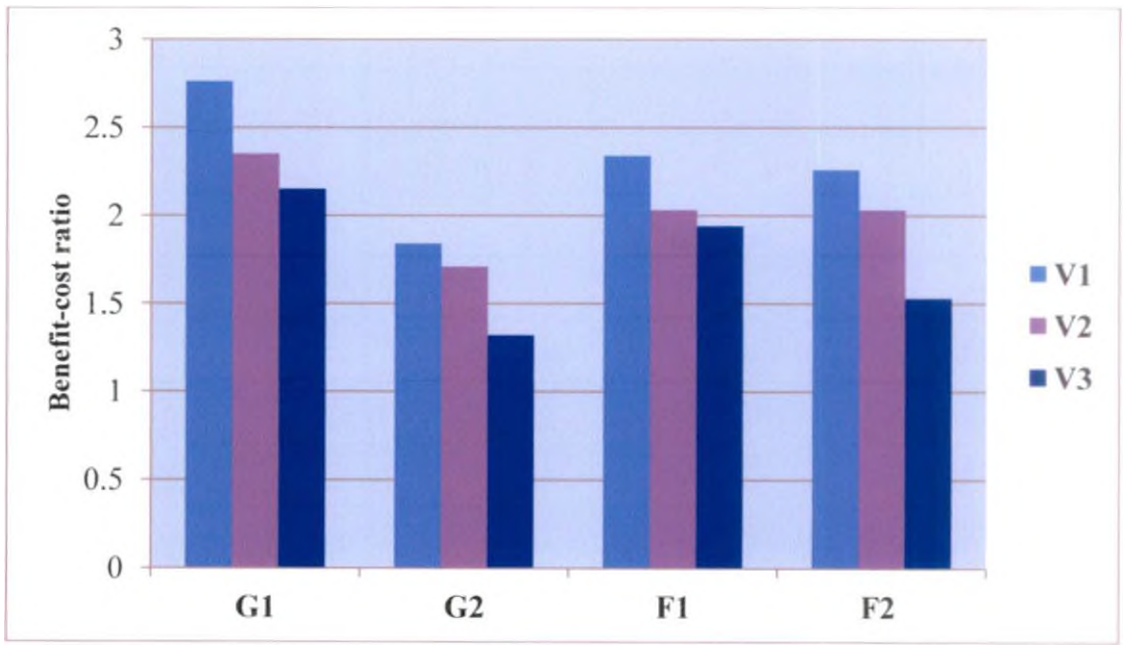

Fig.26. Effect of different growing conditions, fertigation and varieties on BC ratio

polyhouse situation due to physical barrier and maximum incidence in open field condition due to the absence of physical barrier were reported by Singh *et al.* (2012) in tomato, capsicum and strawberry.

5.6 EFFECT OF GROWING CONDITIONS, FERTIGATION, VARIETIES AND THEIR INETRACTION ON ECONOMICS

Growing condition caused significant influence on net return (Fig. 25) and BC ratio (Fig. 26). Maximum net return was obtained from poly house (Rs 5.22 lakhs ha^{-1}) compared to open field situation (3.31 lakhs ha^{-1}). Percentage of increase in net return from poly house was about 57.70 per cent over open field. Similar results of higher net profit from capsicum grown under green house compared to open condition were reported by Megharaja (2000) and Ganiger (2010). Higher gross income and net income for growing capsicum under naturally ventialted polyhouse had also been reported by Yellavva (2008) and Singh *et al.* (2011) and Singh *et al.* (2012) in tomato, capsicum and strawberry. Maximum B: C ratio (2.42) was obtained from poly house compared to open field situation (1.62). Percentage of increase in B: C ratio inside poly house was about 49.38 per cent over open field. Similar results higher B: C ratio for cultivation of capsicum under green house compared to open condition was reported by Megharaja (2000) and Singh *et al.* (2011).

Fertigation caused significant influence on net return (Fig. 25). Maximum net return was obtained from plants grown with fertigation (Rs 4.46 lakhs ha^{-1}) compared to those grown without fertigation (4.07 lakhs ha^{-1}). Higher net return through fertigation in chilli was reported by Ramachandrappa (2010).

B: C ratio was significantly varied with varieties (Fig. 26). Maximum B: C ratio was reported in Vellayani Athulya (2.60) followed by Anugraha (2.30) and Jwalamukhi (1.80). Maximum net return (4.95 lakhs ha^{-1}) was recorded in Vellayani Athulya. Varietal effect on B: C ratio and net return was reported by Singh *et al.* (2011) among capsicum varieties.

SUMMARY

6. SUMMARY

A field investigation was conducted during March 2013 to September 2013 at Instructional Farm, College of Agriculture, Vellayani, to study the performance of chilli varieties and the effect of fertigation on the productivity of chilli under protected cultivation and also to work out the economics.

The experiment was laid out in split plot design with main plot treatment as the combination of growing condition (two levels - G_1 (poly house) and G_2 (open condition)) and fertigation (two levels – F_1 (with fertigation) and F_2 (without fertigation)) and the sub plot treatment was three varieties (V_1- Vellayani Athulya, V_2- Anugraha, V_3- Jwalamukhi). The findings of the investigation are summarized below.

Maximum plant height, number of branches and LAI were recorded by the plants grown under poly house (G_1). Maximum length of tap root and root spread were also observed in plants grown under poly house, while maximum root shoot ratio was observed in plants grown under open condition (G_2). Fertigation (F_1) resulted in significantly superior plant height at 60 DAT, number of branches at 120 DAT and LAI at 60 and 120 DAT. Maximum tap root length and root spread were attained with fertigation. Among varieties, Vellayani Athulya (V_1) recorded maximum plant height, tap root length and root spread. At later stages, Anugraha (V_2) recorded maximum number of branches while, maximum LAI was observed in both Vellayani Athulya (V_1) and Anugraha (V_2).

Plant height, number of branches, LAI, tap root length and root spread were observed to vary significantly among the different treatment combinations. The interaction effect of g_1f_1 (poly house with fertigation) recorded maximum number of branches and LAI. The g_1v_1 (Vellayani Athulya grown under poly house) recorded maximum plant height at 60 DAT and at 90 DAT, while g_1v_1 and g_1v_3 (Jwalamukhi grown under poly house) recorded maximum LAI at 90 DAT. F x V interaction caused significant influence on number of branches and LAI at 120 DAT and 30 DAT, respectively. Maximum number of branches was recorded by f_1v_2 (Anugraha grown with fertigation) and it was on par with f_1v_1 (Vellayani

Athulya grown with fertigation). Maximum LAI was reported in Vellayani Athulya grown with fertigation (f_1v_1) and Anugraha grown with fertigation (f_1v_2) which were on par with Anugraha grown without fertigation (f_2v_2), Vellayani Athulya grown without fertigation (f_2v_1) and Jwalamukhi grown without fertigation (f_2v_3). G x F x V caused significant variation in plant height at 150 DAT. Maximum plant height was recorded by Vellayani Athulya grown under poly house with ($g_1f_1v_1$) and without fertigation ($g_1f_2v_1$), Anugraha grown under poly house with fertigation ($g_1f_1v_2$) and Jwalamukhi grown under poly house with ($g_1f_1v_3$) and without fertigation ($g_1f_2v_3$).

Highest number of fruits plant^{-1}, length of fruit, fruit yield plant^{-1} and total fruit yield were obtained from the plants grown under poly house and plants grown with fertigation. Among varieties, Vellayani Athulya (V_1) recorded maximum length of fruit, fruit yield plant^{-1} and total fruit yield while, Anugraha (V_2) recorded maximum number of fruits.

Various treatment combinations recorded significant influence on length of fruit. G x F interaction caused significant influence on number of fruits plant^{-1}. Maximum number of fruits plant^{-1} was reported in plants grown under poly house with fertigation (g_1f_1). G x V interaction caused significant influence on fruit length and number of fruits plant^{-1}. Maximum fruit length was reported in g_1v_1 (Vellayani Athulya grown under poly house) and was on par with g_2v_1 (Vellayani Athulya grown in open condition). Maximum number of fruits plant^{-1} was reported in Anugraha grown under poly house (g_1v_2). Vellayani Athulya grown with fertigation (f_1v_1) recorded maximum fruit length while, maximum number of fruits plant^{-1} was reported in Anugraha grown with fertigation (f_1v_2). Vellayani Athulya grown under poly house with fertigation ($g_1f_1v_1$) recorded maximum fruit length while, maximum number of fruits plant^{-1} was obtained from Anugraha grown under poly house with fertigation ($g_1f_1v_2$).

Maximum shelf life, ascorbic acid and capsaicin content were realized in plants grown under poly house (G_1). Plants grown with fertigation (F_1) recorded maximum shelf life, ascorbic acid and capsaicin content. Vellayani Athulya (V_1)

recorded maximum shelf life and ascorbic acid content while, maximum capsaicin content was observed in Jwalamukhi (V_3).

Various treatment combinations recorded significant influence on quality of fruit. Maximum shelf life and ascorbic acid content were observed in plants grown under poly house with fertigation (g_1f_1). Vellayani Athulya grown under poly house (g_1v_1) recorded maximum shelf life and ascorbic acid content. Vellayani Athulya grown with fertigation (f_1v_1) recorded maximum ascorbic acid content while, Jwalamukhi grown with fertigation (f_1v_3) recorded maximum capsaicin content. Vellayani Athuyla grown under poly house with fertigation ($g_1f_1v_1$) recorded maximum shelf life and ascorbic acid content while, Jwalamukhi grown under poly house with fertigation ($g_1f_1v_3$) recorded maximum capsaicin content.

Growing condition caused significant influence on NPK uptake. Maximum NPK uptake was observed in plants grown under poly house (G_1). Plants grown with fertigation (F_1) recorded maximum N uptake. Among varieties, Vellayani Athulya (V_1) recorded maximum N uptake and was on par with Anugraha (V_2).

There was no significant difference on available NPK and organic carbon content in soil with different growing conditions, fertigation, varieties and their interaction effects.

No pest and disease incidence were reported inside poly house (G_1) throughout the period of plant growth, while under open condition leaf curl complex caused by thrips and mite were reported at 60 DAT.

Growing condition caused significant influence on net return. Maximum net return was obtained from plants grown under poly house situation (G_1) and also plants grown with fertigation (F_1). Among varieties, Vellayani Athulya (V_1) recorded maximum net return.

B: C ratio was significantly influenced by growing condition. Maximum B: C ratio was obtained from poly house (G_1). Among varieties, maximum B: C ratio was obtained from Vellayani Athulya (V_1).

Future line of work:

- Studies have to be conducted for standardizing suitable fertigation schedule for chilli.
- Suitability of chilli hybrids also have to be evaluated under poly house.
- Standardization of spacing for chilli under poly house has to be done.

REFERENCES

7. REFERENCES

Aberkain, K., Gosselin, A., Vineberg, S. and Dorais, M. 2006. Effects of insulating foams between double polyethylene films on light transmission, growth and productivity of greenhouse tomato plants grown under supplemental lighting. *Acta Hortic.* 711: pp.449-454.

Ahluwalia, M. S., Singh, B. and Singh, B. 1996. Effect of raising nursery in plastic greenhouse on yield, water use efficiency and quality of tomato crop. *Indian J. Ecol.* 23 (2): pp.93-98.

Akhilesh, O., Mishra, S., Singh, R. V. and Ram, H. 2001. Character association in capsicum (*Capsicum annum* L.) genotypes. *Prog. Hortic.* 33: pp.138-143.

Alcantar, G.,Villareal, M. R. and Aguilar, A. S. 1999. Tomato growth (*Lycopersicon esculentum* Mill) and nutrient utilization in response to varying fertigation programs. *Acta Hortic.* 481: pp.385-391.

Amarananjundeswara, H., Khan, M. M., Krishnamanohar, R., Kariyanna., Sreerama, R. and Mallikarjun, B. 1999. Effect of sources and levels of fertigation on productivity of potato. In: *Proceedings of National Seminar on Problems and Prospects of Micro and Sprinkler Irrigation – A Critical Appraisal*, November 19-20, Bangalore, India, 213p.

Amjad, M., Anjum, M. A. and Ali, A. 2001. Impact of phosphorus and planting geometry on growth, yield and quality of green pods in okra. *Int. J. Agirc. Biol.* 3: pp.341-344.

Antony, E. and Singandhupe, R. B. 2004. Impact of drip and surface irrigation on growth, yield and WUE of capsicum (*Capsicum annuum* L.) *Agric. Water Manag.* 65: pp.121-132.

Appireddy, G. K., Saha, S., Mina, B. L., Kundu, S., Selvakumar, G. and Gupta, H. S. 2008. Effect of organic manures and integrated nutrient management on yield potential of bell pepper (*Capsicum annuum)* varieties and on soil properties. *Arch. Agron. Soil Sci.* 54 (2): pp.127-137.

Aruna, P. and Sudagar, I. P. 2009. Evaluation of capsicum varieties under poly house conditions. *Asian J. Hortic.* 4 (2): pp. 336-337.

Ashoka, H. R. 2005. Effect of split application of nitrogen and potassium on growth, yield and quality of red chilli under drip irrigation system. M.Sc.(Ag.) thesis, University of Agricultural Sciences, Dharwad, 37p.

Balasubrahmanyam, V. R., Dhake, A. V. and Moitra, P. 2001. Micro irrigation and fertigation in onion. In: Singh, H. P., Kaushish, S. P., Kumar, A., Murthy, T. S. and Samuel, J. C. (eds), *Micro-irrigation.* Central Board of Irrigation and Power, New Delhi, Publ. No. 282, pp 455-460.

Basavaraja, N., Nandi, V. R. and Jholgikar, P. 2003. Protected cultivation of capsicum and bhendi. In: *Proc. of all India on Sem. Potential and Prospects for Protective Cultivation,* 12-13 December 2003, Institute of Engineers, Ahmednagar, pp. 197-199.

Battilani, A. 2003. Processing tomato water and nutrients integrated crop management: state of the art and future horizons. *Acta Hortic.* 613: pp.63-73.

Bhatnagar, P. R., Vedprakash, R. C. and Srivastav, R. C. 1990. Production of vegetables in poly house greenhouse during winters in mid hills of Uttar Pradesh. *Prog. Hortic.* 22: pp.97-100.

Bhatt, R. M. and Rao, N. K. S. 1993. Response of bell pepper to photo- synthesis, growth flower and fruit setting to night temperature. *Photosynthetica.* 28: pp.127-132.

Bouyoucos, C.J. 1962. Hydrometer method improved for making particle size analysis of soil. *Agron. J.* 54: 464-465.

Bowen, P. and Frey, B. 2002. Response of plasticultured bell pepper to staking, irrigation frequency and fertigated nitrogen rate. *Hortic. Sci.* 37: pp. 95-100.

Brahma, S., Phookan, D. B., Barua, P. and Saikia, L. 2010. Effect of drip-fertigation on performance of tomato under Assam conditions. *Indian J. Hort.* 67 (1): pp.56-60.

Buczkowska, H. 1990. Evaluation of yield of six sweet pepper cultivars grown in an unheated foil tunnel and in the open field. *Folia Hortic.* 2: pp.29-39.

Burt, J. 2005. Growing capsicums and chillies [on-line]. Available: http:/archive.agric.wa.gov.au/objtwr/importedassets/content/hort/veg/cp/capsicum/f06499.pdf.

Canadas, M. M. A., Sanchez, M. F., Sevilla, F. and Alcaraz, C. F. 1985. Leaf development of sweet pepper growing in a greenhouse. *Anales de Edafologica Agrobiol.* 44 (6): pp.873-888.

Chandra, P. and Gupta, M. J. 2003. Cultivation in hi-tech green houses for enhanced productivity of natural resources to achieve the objective of precision farming. In: Singh, H. P., Singh, G. and Samuel, J.C (eds), *Precision farming in Horticulture*. National committee on plastics application in Horticulture, Precision farming development center, Central Institute of Subtropical Horticulture, Lucknow, pp. 64-74.

Cheema, D. S., Kaur, P. and Kaur, S. 2004. Off-season cultivation of tomato under net house conditions. *Acta Hortic.* 659: pp.177-181.

Chowdhury, A. R. and Bhuyan, M. A. J. 1992. Effect of shading and 'atonik'-A plant stimulant on growth and yield of tomato in summer. *Panjab. Veg. Grow.* 27: pp.1-5.

Dixit, A. 2007. Performance of leafy vegetables under protected environment and open field condition. *Asian J. Hortic.* 2 (1): pp.197-200.

Fen, M. X. and Mackenzie, A. F. 1993. Urea and phosphate interactions in fertilizer micro sites: Ammonia volatilization and pH changes. *Soil Sci. Soc. Am. J.* 57: pp.839-845.

Ganesan and Subhasini. 2001. Study on Biometric characteristics of tomato grown in poly green house and open field conditions. *IE(J).- AG.* 89: pp.72-76.

Ganesan, M. 2002a. *Effect* of poly-greenhouse on plant micro climate and fruit yield of tomato. *Karnataka J. Agric. Sci.* 15 (4): pp.750-752.

Ganesan, M. 2002b. Effect of poly-greenhouse models on plant growth and yield of tomato (*Lycopersicon esculentum*). *Indian J. Agric. Sci.* 72 (10): pp.586-588.

Ganesan, M. 2004. Effect of poly-greenhouse on plant microclimate and fruit yield of tomato. *IE (I).* J. –AG. 80: pp.12-16.

Ganiger, V. M. 2010. Response of bell pepper to organic nutrition under different environments. *Karnataka J. Agric. Sci.* 23 (5): pp. 840-845.

Gent, M. P. N. 1990. Factors affecting harvest date of tomato grown under floating row cover. *Appl. Agric. Res.* 5: pp.112-118.

Gimenes, E. S., Streck, N. A., Buriol, G. A., Garcia, D. C. and Rico, J. C. 1994. Effect of reduction in incident solar radiation on lettuce growth. *Ciencia Rural.* 24: pp.241-246.

Gupta, A. J., Ahmad, M. F. and Bhat, F. N. 2010. Studies on yield, quality, water and fertilizer use efficiency of capsicum under drip irrigation and fertigation. *Indian J. Hortic.* 67 (2): pp.213-218.

Gupta, A. J., Chattoo, M. A. and Bhat, F. N. 2009. Techno-economic evaluation of drip irrigation and fertigation practices in capsicum under Kashmir conditions. *Veg. Sci.* 36 (3): pp.309-314.

Hazara, p. and Some, M. G. 1999. *Technology for vegetable production and improvement.* Nayaprokash, Calcutta (India). pp.168-169.

Hazarika, T. K. and Phookan, D, B. 2005. Performance of tomato cultivars for poly house cultivation during spring summer in Assam. *Indian J. Hortic.* 62 (3): pp.268-271.

Hebbar, S. S., Ramachandrappa, B. K., Nanjappa, H. V. and Prabhakar, M. 2004. Studies on NPK drip fertigation in field grown tomato. *European J. Agron.* 21 (1): pp.117-127.

Hundal, J. S., Khanna, D. S. 2002. A new hybrid of chili "Ch-3" – suitable for processing. *J. Res. Punjab Agric. Univ.* 39 (2): 326p.

Imas, P. B., Yosef, B., Kaftkafi, U. and Neuman, R. G. 1997a. Release of carboxylic anions and protons by tomato roots in response to ammonium nitrate ratio and pH in solution culture. *Plant and Soil.* 191: pp.27-34.

Imas, P. B., Yosef, B., Kaftkafi, U. and Neuman, R. G. 1997b. Phosphate induced carboxylate and proton release by tomato roots. *Plant and Soil.* 191: pp.27-34.

Jackson, M. L. 1973. *Soil Chemical Analysis* (2nd Ed.). Prentice Hall of India, New- Delhi, 498p.

Jaloud, A. A., Baig, M. S., Errebhi, M. A., Gadir, A. H. A. and Sarhan, H. B. 2006. The Effect of Fertigating Different Levels of Nitrogen, Phosphorus and Potassium on Greenhouse Cucumber Yield. *Acta Hortic.* 710: pp.359-363.

Jeevansab, 2000. Effect of nutrient sources on growth, yield and quality of capsicum grown under different environments. M.Sc.(Ag.) thesis, University of Agricultural Sciences, Dharwad, Karnataka, India, 73p.

Kamaruddin, R., Shahid, M. and Abdullah, F. 2006. Response of fertigation on capsicum growth under naturally ventilated tropical greenhouse. *Acta Hort.* 710: pp.275-280.

Kanwar, D. P. S., Dikshit, S. N., Sharma, G. L., Patel, K. L., Agrawal, R. and Sarnaik, D. A. 2013. Studies on effect of fertigation on growth and yield attributing characters of sweet pepper (*Capsicum annuum* L.) under black polythene mulch. 23 (1): pp.73-77.

Kavitha, M., Natarajan, S., Pugalendhi, L. and Meenekshi, N. 2008. Influence of shade and fertigation on physiological and yield parameters of tomato (*Lycopersicon esculentum* Mill). *Orissa J. Hortic.* 36 (2): pp.1-7.

Kavitha, M., Natarajan, S., Pugalendhi, L. and Meenakshi, N. 2009. Protected cultivation of tomato (*Solanum lycopersicon* L.) under shade net. In: *Proceedings on national workshop cum seminar on status and future strategies of horticulture development in A& N islands*, 23-25 January 2009, Port Blair, Andaman, 170 p.

Kengar, I. 2011.Performance of tomato (*Solanum lycopersicum*) hybrids under shade house condition. M.Sc.(Ag) thesis, University of Agricultural Sciences, Dharwad, 133p.

Kittas, C., Rigakis, N., Katsoulas, N. and Bartzanas, T. 2009. Influence of shading screens on microclimate, growth and productivity of tomato. *Acta Hortic.* 807: pp.97-102.

Kumar, S. R. and Arumugam, T. 2010. Performance of vegetables under naturally ventilated poly house condition. *Mysore J. Agric. Sci.* 44 (4): pp.770-776.

Kumari, S. and Sharma, M. K. 2011. Exploitation of heterosis for yield and its contributing traits in tomato (*Solanum lycopersicum* L.). *Int. J. Farm Sci.* 1 (2): pp.45-55.

Lange, A. J. and Combark, N. J. J. 1997. Microclimate and yield of seedless watermelon as affected by plant covers and soil mulches. *Appl. Plant Sci.* 11: pp.1- 6.

Leonardi, C., Scuderi, D., Caturano, E. and Giuffrida, F. 2009. Nutrient uptake of tomato grown under protected cultivation. *Acta Hort.* 807: pp.341-346.

Madile, A. K., Singh, P. K., Sharma, H. C. Singh, R. P. and Joshi, G. 2012. Tensiometer based drip irrigation scheduling for enhancing water productivity of capsicum (Capsicum annum L.) under poly house. *Indian J. Soil Conserv.* 40 (1): pp.41-45.

Mahajan, G. and Singh, K. G. 2006. Response of greenhouse tomato to irrigation and fertigation. agricultural water management. 84 (2): pp. 202-206.

Mahajan, G., Singh, K. G. Sharda, R. and. Siag, M. 2007. Response of red hot pepper (*Capsicum annum* L.) to water and nitrogen under drip and check basin method of irrigation. *Asian J. Plant Sci.* 6 (5): pp.815-820.

Marsin, N. and Osvald, J. 1997. The influence of different cover materials of green houses on growth and development of pepper (*Capsicum annuum* L.). *Zbornic- Biotehniske-Fakultete-Univerze-v-Ljubljani,-Kmetijstvo.* 69: pp.141-46.

Mashego, D. C. 2001. The production of vegetable crops under protection for small scale farming situations. [on-line]. Available: http://www.alldissertations.com/full.

Mathew, A. G., Nambudiri, E. S., Ananthakrishna, S. M., Krishnamurthy, N. and Lewis, Y. S. 1971. An improved method for estimation of capsaicin in capsicum oleoresin. Lab. Pr. 1: pp.23-26.

Mawalagedera, S. M. M. R., Weerakkody, W. A. P. and Premaratne, K. P. 2012. Circulation culture of tomato for efficient nutrient uptake and high yield in tropical greenhouses. Trop. Agric. Res. 23 (3): pp. 204–217.

Megharaja, K. M. 2000. Studies on the effect of growing conditions and growth regulators on growth and productivity of hybrid capsicum cv. Indira. M.Sc.(Ag) thesis, University of Agricultural Sciences, Bangalore, Karnataka, 67p.

Mishra, G. P., Singh, N., Kumar, H. and Singh, S. B. 2010. Protected Cultivation for Food and Nutritional Security at Ladakh. *Def. Sci.* J. 61 (2): pp.219-225.

Monaghan, J. M., Rahn, C. R., Hilton, H. W. and Wood, M. 2010. Improved efficiency of nutrient and water use for high quality field vegetable production using fertigation. *Acta Hort: pp.*145-151.

Munij. J. O. and Almedia, J. I., De, L. 1998. Performance of capsicum cultivars, *Horticultura Brasileira.* 6 (1): 18-19.

Muralidhar, A. P. 1998. Effect of fertigation with normal and water soluble fertilizers compared to drip and furrow systems in capsicum-maize-sunflower cropping system. Ph.D. thesis, University of Agricultural Sciences, Bangalore, 75p.

Murthy, D. S., Prabhakar, B. S., Hebbar, S. S., Srinivas, V. and Prabhakar, M. 2009. Economic feasibility of vegetable production under poly house: a case study of capsicum and tomato. *J. Hortic. Sci.* 4 (2): pp.148-150.

Nagalakshmi, S., Nandakumar, N., Palaniswamy, D. and Sreenarayana, V. V. 2001. Naturally ventilated poly house for vegetable cultivation. *S. Indian Hortic.* 49: pp.345-346.

Nagoata, M., Takahashi, K., Arai, K., Hanada, T. and Yoshioka, H. 1979. Effects of light intensity,night temperature and CO2 concentration on the growth and yield of glass house tomato. *Bull. Veg. Orn. Crops Res. Stn.* 6: pp.105-122.

Naik, R. K. 2005. Influence of N-substitution levels through organic and inorganic sources on growth, yield and post-harvest quality of capsicum under protected condition. Ph.D. thesis, University of Agricultural Sciences, Dharwad, Karnataka, India, 65p.

Narda, N. K. and Lubana, S. P. 1999. Growth dynamics studies of tomatoes under sub-surface drip irrigation. *J. Res. Punjab Agric. Univ.* 36 (4): pp.222-223.

Navale, A. V., Nandagude, S. B., Pawar, A. G., Ghodke, H. M. and Bhosale, A. D. 2003. Comparative study of skirting and top covering effect in low cost greenhouse. In: *Proceedings of All India Seminar on Potential and Prospects for Protective Cultivation*, 12-13 December 2003, Institute of Engineers, Ahmednagar, p. 97.

Nimje, P. M. and Shyam, N. 1991. Greenhouse as an alternative technology for commercial vegetable crop production. *Indian J. Agric. Sci.* 61: pp.185-189.

Nwokem, C. O., Agbaji, E. B., Kagbu, J. A. and Ekanem, E. J. 2010. Determination of capsaicin content and pungency level of five different peppers grown in Nigeria. *New York Sci. J.* 3 (9): pp.17-21.

Ochigbu, A. A. and Harris, G. P. 1989. Effect of film plastic cover on the growth and yield of bush tomato grown in a bed system. *J. Hortic. Sci.* 64 (1): pp.300-302.

Olsen, J. K., Lyons, P. J. and Kelly, M. M. 1993. Nitrogen uptake and utilization by bell pepper in sub-tropical Australia. *J. Plant Nutr.* 16 (1): pp.177-193.

Ozguven, M. and Yaldiz, G. 2011. Capsaicin contents of different *capsicum* (red peppers) populations and varieties. *Adv. Environ. Biol.* 5 (7): pp.1991-1995.

Papadopoulos, A. P. and Ormorod, D. P. 1991. Plant spacing effect on growth and development of green house tomato. *Can. J. Plant. Sci.* 71: pp.297-304.

Pareya, F.J. 1992. Fertigation in Washington State Horticultural Association. In: *Proceedings of the 88th Annual Meeting*, 7-9 December 1992, Yakima, Washington, WSA, pp. 289-291.

Parvej, M. R., Khan, M. A. H. and Awal, M. A. 2010. Phonological development and production potentials of tomato under poly house condition. *J. Agric. Sci.* 5 (1): pp.19-24.

Prabhu, M., Kumar, A. R., Balasubramanian, V., Jagadeesan, R. and Ponnuswami, V. 2009. Protected cultivation of vegetables. *Asian J. Hortic.* 4 (2): pp.529-533.

Rahman, A. S. Z. and Sheikh, E. T. M. 1994. A comparative study on some sweet pepper cultivation grown under plastic house conditions for yield and storability. *Egyptian J. Hortic.* 21 (2): pp.213-225.

Rahman, M. J. and Inden, H. 2012. Effect of nutrient solution and temperature on capsaicin content and yield contributing characteristics in six sweet pepper (*Capsicum annuum* L.) cultivars. *Food, Agric. Environ.* 10 (1): pp.524-529.

Ramachandrappa, B. K., Nanjappa, H.V., Soumya, T.M. and Mudalagiriyappa. 2010. Effect of fertigation with sources and levels of fertilizer on yield, quality and use efficiency of water and fertilizer in green chilli (*Capsicum annuum* L.). *Indian J. Dryland Agric. Res. Dev.* 25 (2): pp.33-39.

Rana, R.S., Krishna devi. and Verma, I.M. 2005. Fertigation studies in hybrid tomato *(Lycopersicon esculentum Mill.). Ann. Agric. Biol. Res.*10 (1): pp.87-90.

Rumpel, T. and Grudzien, K. 1990. Suitability of non woven poly propylene for a fiat covering is sweet pepper cultivation. *Acta Hortic.*, 267: pp.53-58.

Rylski, I. and Spigelman, M. 1986. Effect of shading on plant development, yield and fruit quality of sweet pepper grown under conditions of high temperature and radiation. *Scientia Hortic.* 29 (2): pp.31-35.

Sadasivam, S. and Manickam, A. 1992. *Biochemical Methods for Agricultural Sciences.* Wiley Eastern Ltd., New Delhi, p.246.

Sari, N., Guler, H.Y., Abak, K., Pakyurek, Y., Babik, I. and Rumpel, J. 1994. Effect of mulch and tunnel on the yield and harvesting period of cucumber and squash. Seventh International symposium on timing field production of vegetables. *Acta Hort.* 371: pp. 305-310.

Satpathy, S., Rai, S. and Kapoor, K. S. 1998. Integerated management of vegetable pest. In: *National Symposium on Emerging Scenarios in*

vegetable research and Development, 1998. Indian Institute of Vegetable Research, Varanasi, pp. 123-130.

Savitha, B. K., Paramaguru, P. and Pugalendhi, L. 2010. Effect of drip fertigation on growth and yield of onion. *Indian J. Hortic.* 67: pp.334-336.

Sharma, H. G., Narendra-Agarwal., Dubey, P. and Dixit, A. 2004. Comparative performance of capsicum under controlled environment and open field condition. *Ann. Agric. Res.* 25 (4): pp.638-640.

Sharma, N. K. and Tiwari, R. S. 1993. Effect of shade on growth contributing characters and factors in relation to yield of tomato cv. Pusa Ruby. *Prog. Hortic.* 25: pp.180-184.

Shashidhara, K. G. 2006. Response of chilli to drip irrigation and fertigation on a vertisol of malaprabha command area. Msc (Ag) thesis, University of Agricultural Sciences, Dharwad, 65p.

Shinde, P. P., Ramteke, J. R., More, V. G. and Chavan, S.A. 2002. Evaluation of micro irrigation systems and mulch for summer chilli production. *J. Maharashtra Agric Univ.* 27: pp.51-54.

Shivkumar. 2005. Biometrical studies in chilli (*Capsicum annuum* L.). M.Sc.(Ag) thesis, University Of Agricultural Sciences, Dharwad, 143p.

Siddeque, A., Saika, S. and Deepa, B. P. 1993. Protected cover cultivation for high humid region. *Natl. Conf. Plast. Agric.* 52: pp.55-93.

Silber, A., Xu, G., Levkovitch, I., Soriano, S., Bilu, A. and Wallach, R. 2003. High fertigation frequency: the effects on uptake of nutrients, water and plant growth. *Plant and Soil.* 253 (2): pp.467-477.

Singandhupe, R. B., Antony, E. and Behera, M. S. 2005. Effect of fertigation on field grown tomato (Lycopersicon esculentum). *Indian J. Agric. sci.* 75 (6): pp.329-402.

Singandhupe, R. B., Rao, G. G. S. N., Patil, N. G. and Brahmanand, P.S. 2003. Fertigation studies and irrigation scheduling in drip irrigation system in tomato crop (*Lycopersicon esculentum* L.). *Eur. J. Agron.*19: pp.327-340.

Singh, A. K., Shrivastava, R., Gupta, M. J. and Chandra, P. 2005. Effect of protected and unprotected condition on biotic stress, yield and economics of spring summer vegetables. *Indian J. Agric. Sci.* 75: pp.485-487.

Singh, B. 1998. Vegetable production under protected condition: Problem and prospects. In: *National Symposium on Emerging Scenarios in Vegetable Research and Development*, 1998. Indian Institute of Vegetable Research, Varanasi, pp. 90-95.

Singh, B. 2003. Greenhouse vegetable production in India: Problems and future prospects. In: *Proc. All India Seminar on Potentials and Prospects for Protective Cultivation*, 12-14 December 2003. Institute of Engineers, Ahmednagar, India, pp. 55.65.

Singh, B. and Kumar, M. 2006. Techno-economic feasibility of israeli and indigenously designed naturally ventilated greenhouses for year-round cucumber cultivation. *Acta Hortic.* 710: pp.449-454.

Singh, R., Asrey, R. and Nangare, D. D. 2003. Studies on the performance of tomato and capsicum under medium cost greenhouse. In: *Proceedings of All India Sem. On Potential and Propsects for Protective Cultivation,* 12-13 December 2003. Institute of Engineers, Ahmednagar, pp. 158-161.

Singh, S. K., Tiwari, P. S., Singh, G. R., Singh, B. R. and Singh, D. 2009. Economics of naturally ventilated greenhouse (svbpu model) for tomato production in northern plain of india. *Prog. Agric.* 9 (1): pp.130-133.

Singh, A. K., Chandra, P. and Srivastava, R. 2010. Response of micro-irrigation and fertigation on high-value vegetable crops under control conditions. *Indian J. Hortic.* 67 (3): pp.418-420.

Singh, A. K., Singh, A. K., Gupta, M.J. and Shrivastav, R. 2003. Effect of poly house on insect pest incidence, fruit quality and production of vegetable and fruit crops. In: *Proceeding of the National Symposium on Frontier areas of Entomological Research,* IARI, New Delhi, pp 45-47.

Singh, A. K., Singh, B. and Gupta, R. 2011. Performance of sweet pepper (*Capsicum annum*) varieties and economics under protected and open field conditions in Uttarakhand. *Indian J. Agric. Sci.* 81 (10): pp.973–975.

Singh, A. K., Singh, B., Sindhu, S. S., Singh, J. P. and Savir N. 2012. Study of protected v/s open field conditions on insect pest incidence to minimize insecticide application for quality production of high value horticultural crops. *Int. J. Plant Prot.* 5 (1): pp.75-80.

Singh, K., Singh, R., Khurana, D. S. and Singh, J. 2013. Effect of low- tunnel on the growth, yield and harvesting span of sweet pepper. *Hortic. flora. Res. spectrum.* 2 (1): pp.45-49.

Singh, Y. V and Saxena, A. 2001. Chilli yield as related to water and nutrient management under drip irrigation system. In: Singh, H. P., Kaushish, S. P., Kumar, A., Murthy, T. S. and Samuel, J. C. (eds), *Micro-irrigation.* Central Board of Irrigation and Power, New Delhi, pp. 468-471.

Smith, I.E., Savage, M.J. and Mills, P. 1984. Shading effects on greenhouse tomatoes and cucumbers. *Acta Hortic.* 148: pp.229-237.

Snedecor, G. W. and Cohran, W. G. 1975. *Statistical Methods.*Oxford and IBH Publishing Company, New Delhi, 593p.

Srichandran, S., Panda, S.C., Sahu, G. S., Mahapatra, P. and Mishra, R. C. 2006. Effect of shade net on growth and yield of cauliflower. *Orissa J. Hortic.* 34(1): pp.28-31.

Subbaiah, B.V. and Asija, G.L. 1956. A raphid procedure for determination of available nitrogen in soil. *Curr. Sci.* 25: 259-260.

Suh, H. D. 1999. Quality improvementof chinese cabbage using rain shelter and fertigation system in summer production. *Acta Hortic.* 483: pp.199-207.

Thangam, M. and Thamburaj, S. 2008. Comparative performance of tomato varieties and hybrids under shade and open conditions. *Indian J. Hortic.* 65(4): pp.429-433.

Tiwari, R. N. and Chaudhury, B. 1986. Solaneceous crops. In: Bose, T.K. and Som, M.G. (eds), *Vegetable crops of India.* Naya Pradesh, Calcutta, pp.258-260.

Tiwari, R. N., Mishra, M., Choudhary, B. and Plani, S. K. 2002. Tomato *Veg. Crops.* 1: pp.49- 51.

Tumbare, A.D. 1999. Effect of liquid fertilizer through drip irrigation on growth and yield of okra (Hibiscus esculentus). *Indian J. Agron.* 44 (1): pp.176-178.

Tumbare, A.D. and Bhoite, S. 2002. Effect of solid soluble fertilizer applied through fertigation on growth and yield of chilli (Capsicum annum). *Indian. J. Agric. Sci.* 72: pp.109-111.

Veeranna, H. K., Khalak, A. A. A., Farooqhi and Sujith, G. M. 2001. Effect of fertigation with normal and water soluble fertilizers compared to drip and furrowmmethods on yield, fertilizer and irrigation water use efficiency in chilli. *Micro Irrig.* 34: pp. 461-466.

Venthamoni, P. I. and Natarajan, S. 2008. Cultivation of sweet pepper cultivars (Capsicum annuum var. grossum)under shade net in tropical plains of Tamil Nadu. *Asian J. Hortic.* 3 (2): pp.372-376.

Wabel, M. I., Jaloud A. A., Hussan, G. and Karimula, S. 2006. Fertigation as a Tool to Improve Nitrogen Use Efficiency and Yield. *Acta Hortic.* 710: pp.295-300.

Wahundeniya, W.M.K.B., Ramanan, R., Wickramatunga, C. and Weerakkodi, W.A.P. 2006. Comparison of Growth and Yield Performances of Tomato (*Lycopersicon esculentum* mill.) Varieties Under Controlled Environment Conditions. *Ann. Sri Lanka Dep. Agric.* 8:251-262.

Watson, D. J. 1947. The physiological basis of variation in field. Advances in Agronomy, Academic press. Inc. New York, USA, 4:101-145.

Yadav, J., Singh, N. and Kumar, N. 1999. Nutritional values of off-season leafy vegetables grown in trench under cold arid conditions of Leh. *Agric. Sci. Digest.* 19 (2): pp. 103-04.

Yellavva, K. 2008. Evaluation of capsicum hybrids under different protected structures. M.Sc.(Ag.) thesis, University of Agricultural Sciences, Dharwad. 12-48p.

Zende, U. M. 2008. Investigation on production techniques in capsicum under protected cultivation. M.Sc.(Ag) thesis, University of Agricultural Sciences, Dharwad. 143p.

ABSTRACT

PRODUCTION TECHNOLOGY OF CHILLI (*Capsicum annuum* L.) UNDER PROTECTED CULTIVATION

by

PINTU ROY VATTAKUNNEL

(2012 - 11 - 139)

ABSTRACT

Submitted in partial fulfilment of the

requirements for the degree of

MASTER OF SCIENCE IN AGRICULTURE

Faculty of Agriculture

Kerala Agricultural University

DEPARTMENT OF AGRONOMY

COLLEGE OF AGRICULTURE

VELLAYANI, THIRUVANANTHAPURAM – 695 522

KERALA, INDIA

2014

8. ABSTRACT

The field experiment entitled "Production technology of chilli (*Capsicum annuum* L.) under protected cultivation" was conducted at Instructional Farm, College of Agriculture, Vellayani during March 2013 to September 2013 to study the performance of chilli varieties and the effect of fertigation on productivity of chilli (*Capsicum annuum* L.) under protected cultivation.

The main plot treatments were a combination of growing conditions (poly house and open field) and fertigation (with fertigation and without fertigation) and the subplot treatments consisted of three varieties (Vellayani Athulya, Anugraha and Jwalamukhi).

The study revealed that plants grown under poly house situation recorded significantly higher fruit length (11.77cm), number of fruits plant^{-1} (110.67), fruit yield plant^{-1} (604.08 g) and total fruit yield (29.54 t ha^{-1}). Plants grown with fertigation registered higher number of fruits plant^{-1} (113.49), length of fruit (11.55 cm), fruit yield plant^{-1} (591.92 g) and total fruit yield (26.27 t ha^{-1}).

Maximum length of fruits (12.82 cm), fruit yield plant^{-1} (665.18 g) and total fruit yield (28.41 t ha^{-1}) were obtained from Vellayani Athulya while, highest number of fruits plant^{-1} (154.21) was from Anugraha.

Maximum length of fruits was observed in Vellayani Athulya grown under both poly house (12.91 cm) and open field situation (12.72 cm). Vellayani Athulya grown with fertigation also recorded maximum fruit length (13.67 cm).

Vellayani Athulya recorded maximum shelf life (10.19 days) and ascorbic acid content (98.71 mg 100 g^{-1}) where as maximum capsaicin content (1.38 per cent) was recorded by Jwalamukhi. Vellayani Athulya grown under poly house registered maximum shelf life (10.88 days) and ascorbic acid content (102.78 mg 100 g^{-1}). Vellayani Athulya with fertigation recorded maximum ascorbic acid content (101.69 mg 100 g^{-1}) while, Jwalamukhi grown with fertigation recorded maximum capsaicin content (1.40 per cent). Vellayani Athulya grown under poly house with fertigation recorded higher shelf life

(12.00 days). Vellayani Athulya grown under poly house with fertigation recorded maximum ascorbic acid (108.74 mg 100 g^{-1}). Maximum capsaicin was also recorded by Jwalamukhi grown under poly house with fertigation (1.43 per cent).

Among growing conditions, maximum net return (Rs 5.22 lakhs ha^{-1}) and B: C ratio (2.42) was obtained from poly house. On comparing with and without fertigation treatments, with fertigation treatments recorded maximum net return of Rs 4.46 lakhs ha^{-1} and among varieties, Vellayani Athulya (V_1) recorded maximum net return of Rs 4.95 lakhs ha^{-1} and B: C ratio of 2.30.

സംഗ്രഹം

"സംരക്ഷിത കൃഷിയിലെ മുളകിന്റെ ഫലോത്പാദന സാങ്കേതിക വിദ്യ" എന്ന പരീക്ഷണം വെള്ളായണി കാർഷിക കോളേജിലെ ഇൻസ്ട്രക്ഷണൽ ഫാമിന്റെ കീഴിലുള്ള പോളി ഹൗസിലും, അതിനോട് ചേർന്നുള്ള സ്ഥലത്തുമായി മാർച്ച് 2013 മുതൽ സെപ്റ്റംബർ 2013 വരെയുള്ള കാലഘട്ടത്തിൽ നടത്തി.

വളർത്ത് അവസ്ഥകളുടെയും തുള്ളിനനയിലുടെയുമുള്ള വള പ്രയോഗത്തിന്റെയും സമ്മിശ്രണമാണ് പ്രധാന ഭൂഭാഗനിരീക്ഷണം. മൂന്ന് മുളക് ഇനങ്ങളാണ് (വെള്ളായണി അതുല്യയും, അനുഗ്രഹയും കൂടെ ജ്വാലമുഖിയും) ഉപഭൂഭാഗ നിരീക്ഷണത്തിനായി തിരഞ്ഞെടുത്തത്.

പുറത്ത് കൃഷിചെയ്ത മുളക് ചെടികളുമായി താരതമ്യം ചെയ്തപ്പോൾ പോളി ഹൗസിനുള്ളിൽ കൃഷിചെയ്ത മുളക് ചെടികളിൽ നിന്നാണ് കൂടിയ കായുടെ നീളവും, കായ്കളുടെ എണ്ണവും, ഒരു ചെടിയിൽ നിന്നുള്ള വിളവും കൂടാതെ സമഗ്രമായ കായ്ഫലവും ലഭിച്ചത്.

മണ്ണിൽ നേരിട്ട് വളം നൽകി വളർത്തിയവയുമായി താരതമ്യം ചെയ്തപ്പോൾ തുള്ളിനന വഴി വളം നൽകി വളർത്തിയ മുളക് ചെടിയിൽ നിന്നാണ് കൂടിയ കായ് നീളവും, ഒരു ചെടിയിൽ നിന്നുള്ള വിളവും കൂടാതെ സമഗ്രമായ കായ്ഫലവും ലഭിച്ചത്.

പരീക്ഷണത്തിനായി തിരഞ്ഞെടുത്ത ഇനങ്ങളിൽ വെള്ളായണി അതുല്യയിൽ നിന്നാണ് കൂടിയ കായ് നീളവും, ഒരു ചെടിയിൽ നിന്നുള്ള വിളവും കൂടാതെ സമഗ്രമായ കായ്ഫലവും ലഭിച്ചത്. എന്നാൽ അനുഗ്രഹയിലാണ് കായുടെ എണ്ണം കൂടുതലായി കാണപ്പെട്ടത്.

പോളി ഹൗസിനു കീഴിൽ തുള്ളിനനയിലൂടെയുള്ള വള പ്രയോഗത്തിൽ വളർത്തിയ വെള്ളായണി അതുല്യയിൽ നിന്നുള്ള മുളകാണ് കൂടുതൽ ദിവസം കേടുകൂടാതെ സൂക്ഷിക്കാൻ സാധിച്ചത്. മേൽപറഞ്ഞതിന് കൂടുതൽ അസ്കോർബിക് അമ്ളവും ഉള്ളതായി തെളിഞ്ഞു. ഇതേരീതിയിൽ വളർത്തിയ ജ്വാലമുഖിയിലാണ് ഏറ്റവും കൂടിയ അളവിൽ കാപ്സൈസിൻ ഉള്ളതായി തെളിഞ്ഞത്.

പോളി ഹൗസിൽ വളർത്തിയ ചെടിയിൽ നിന്നാണ് കൂടുതൽ വരുമാനം ലഭിച്ചത്. വളം മണ്ണിൽ കൊടുക്കുന്നതിനെക്കാൾ തുള്ളി നനയിലൂടെ കൊടുക്കുന്നതാണ് കൂടുതൽ ലാഭകരം എന്നു തെളിഞ്ഞു. ഇനങ്ങളിൽ വെള്ളായണി അതുല്യ വളർത്തുന്നതാണ് കൂടുതൽ ആദായകരം.

Appendix- I

Weather data in poly house during the cropping period

(13th March – 13th September, 2013)-Weekly averages

Standard week	Temperature (°C)		Relative humidity (%)	Light intensity (K. lux)
	Max. temp.	Min. temp.		
11	27.50	21.60	86.00	70.30
12	28.40	21.40	84.00	66.90
13	29.60	20.40	90.10	70.70
14	28.40	20.30	89.00	69.34
15	28.30	20.00	94.00	68.80
16	28.60	20.60	79.00	72.30
17	28.00	21.90	81.00	69.80
18	27.00	20.20	86.60	68.95
19	26.20	22.20	86.40	68.20
20	25.60	21.50	92.00	69.30
21	27.70	23.70	85.40	69.49
22	25.70	22.00	91.40	67.70
23	25.20	23.00	91.60	60.30
24	28.14	22.70	88.40	61.30
25	27.20	19.00	90.60	61.50
26	27.14	22.20	89.00	59.60
27	28.30	22.50	91.00	69.40
28	28.50	24.50	94.00	66.80
29	27.20	21.00	90.00	69.10
30	28.50	20.00	89.25	70.60
31	27.70	23.00	88.20	60.06
32	27.80	21.40	90.00	71.70
33	29.00	21.30	90.00	68.10
34	28.00	21.00	89.00	69.30
35	28.00	20.00	87.00	69.40
36	28.40	20.40	89.50	66.30

Appendix- II

Weather data in open field during the cropping period

(13th March – 13th August, 2013)-Weekly averages

Standard week	Temperature (°C)		Relative humidity (%)	Light intensity (K. lux)	Rainfall (mm)
	Max. temp	Min. temp			
11	32.20	23.80	83.00	90.10	34.00
12	32.20	23.60	83.40	85.80	00.00
13	32.60	25.30	84.45	90.60	31.00
14	32.90	26.00	84.85	88.90	00.00
15	32.80	25.60	80.65	87.10	01.50
16	33.20	25.10	80.40	92.70	00.00
17	33.30	25.00	79.85	89.50	20.30
18	32.70	25.80	86.15	88.40	03.60
19	32.00	26.10	85.80	87.50	11.50
20	32.40	25.70	83.50	88.90	05.20
21	32.10	24.20	88.15	89.10	07.20
22	30.10	22.30	91.35	86.90	33.20
23	29.20	22.80	88.45	77.40	15.00
24	29.10	23.20	92.20	78.70	20.20
25	28.30	22.50	90.75	78.80	23.60
26	29.90	23.30	90.00	76.40	08.60
27	29.30	23.40	89.50	89.00	06.70
28	28.50	23.00	86.60	85.70	10.10
29	28.30	23.50	90.90	88.60	10.10
30	29.40	21.90	90.10	90.60	11.60
31	29.00	21.60	90.00	77.00	23.20
32	28.80	23.90	89.70	91.90	03.90

APPENDIX III

Cost of cultivation of chilli grown under poly house and open field for one season

Particulars	Poly house with fertigation	Poly house without fertigation	Open field with fertigation	Open field without fertigation
Cost of structure and cladding material	49351.85	49351.85	-	-
Cost of drip	18500	18500	18500	18500
Cost of manures	10,000	10,000	10,000	10,000
Cost of Cost fertilizers	8500	8500	8500	8500
Cost of Seeds	2800	2800	2800	2800
Cost of labour @317/labour	98270	114120	151526	167376
Total	192255.18	208271.85	196326	212176

- Structure (excluding cladding material) Rs. 800 m^{-2} for life span of 15 years and the depreciated cost is Rs. 11851.85
- Cladding material @ Rs. 45 m^{-2} for 10000 m2 for life span of 4 years and the depreciated cost for one season is Rs. 37500
- Drip irrigation system @ Rs. 55 m^{-2} for life span of 10 years and the depreciated cost for one season is Rs. 18333.33