MICROCLIMATIC ALTERATION ON WATER PRODUCTIVITY OF CHILLI (*Capsicum annum L*) UNDER FERTIGATION

by

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THESIS

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DECLARATION

I, hereby declare that this thesis entitled **"Microclimatic alteration on water productivity of Chilli (*Capsicum annum L*) under fertigation"** is a bonafide record of research work done by me during the course of research and the thesis has not previously formed the basis for the award to me of any degree, diploma, associateship, fellowship or other similar title, of any other university or Society.

Place : Vellanikkara

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CERTIFICATE

Certified that this thesis entitled **"MICROCLIMATIC ALTERATION ON WATER PRODUCTIVITY OF CHILLI (*Capsicum annum L*) UNDER FERTIGATION"** is record of research work done independently by **Ms. GOUTHAMI DEEP K.P** (2012-20-109) 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.

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EXTERNAL EXAMINER

Affectionately Dedicated

To

Mentor,

My Parents

Mr. Pradeep Kumar P. V and Mrs. I. Kavitha Devi Pillai

Brother

&

My Betterhalf

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SYMBOLS AND ABBREVIATIONS

%	Percent
@	At the rate of
°C	Degree Celsius
B: C	Benefit cost ratio
cm	Centimeter
DAP	Days after planting
et al	And others
FYM	Farm Yard Manure
Ha	Hectare
i.e	That is
K	Potassium
KAU	Kerala Agricultural University
Kg	Kilogram
kg ha-1	Kilogram per hectare

N	Nitrogen
NS	Not significant
P	Phosphorus
PAR	Photosynthetically active radiation
POP	Package Of Practice
RBD	Randomaized Block Design

INTRODUCTION

CHAPTER 1

INTRODUCTION

Water is the most important and critical input in agriculture. The pressure for the most efficient use of water for agriculture is intensifying with the increased competition for water resources among various sectors with escalating population.

Kerala is thought to be water-plenty state as it gets six months of rainfall, 2.5 times higher than the national average. Despite this, the state has been experiencing serious water deficit, threatening agricultural sustainability in the changing climatic scenario. Improper management of water and nutrients have contributed extensively to the current water scarcity and the pollution problems in many parts of the world, and is also a serious challenge to future food security and environmental sustainability.

Addressing these issues require an integrated approach to soil-water-plant-nutrient management at the plant-rooting zone. Higher water productivity is the only solution to provide enough food with the available water. Due to water scarcity, the available water resources should be very effectively utilized through water saving irrigation technologies.

Potential advantages of micro irrigation includes increased efficient use of water, enhanced plant growth and yield, reduced salinity hazard, improved efficiency of fertilizer and other chemicals, limited weed growth, decreased energy requirements and improved cultural practices. Maintaining available soil moisture at low water tension and almost constant during entire growth period through micro-irrigation with considerable water saving up to 50 per cent was possible with micro irrigation (Patel et al., 2007). Bringing more area under irrigation would depend largely upon efficient use of water. In this context, micro irrigation has most significant role to achieve not only higher productivity and water use efficiency but also to have sustainability with economic use and productivity.

Protected cultivation is a cropping technique where the plants are grown under controlled microclimate resulting in higher yields than that is possible under open condition during all seasons. Fertigation is for precise application of water and nutrients which help to increase nutrient and water use efficiency, crop productivity and quality under protected conditions.

Fertilizer management is the most important agro-technique, which controls development, yield and quality of a crop, fertigation is the technology wherein nutrients are applied along with the irrigation water and opens new possibilities for controlling water and nutrient supplies to crop besides maintaining the desired concentration and distribution of water and nutrients to soil with higher water productivity.

Chilli (*Capsicum annuum* L.) is an important vegetable cum spice crop cultivated extensively in India and Kerala which form a major ingredient of our daily diet. It can be grown as both rain fed and irrigated crops. Chilli being a long duration crop, it responds to split application of nutrients *i.e.,* nitrogen, phosphorus and potassium. Information on fertigation requirement of chilli grown under different micro climatic condition is meager. The present study was proposed against this backdrop with the following objectives.

1. To study the influence of microclimate and fertigation on yield.
2. To study the water productivity and profitability of chilli under open and green house condition.

REVIEW OF LITERATURE

CHAPTER 2

REVIEW OF LITERATURE

Fertigation is a new technology wherein nutrients are applied along with the irrigation water and opens new possibilities for controlling water and nutrient supplies to crop besides maintaining the desired concentration and distribution of water and nutrients to soil with higher water productivity. Chilli (*Capsicum annuum* L.) is an important vegetable cum spice crop cultivated extensively in India and Kerala which form a major ingredient of our daily diet. Fertigation is necessary for crop production under green houses to supply water and nutrients precisely, in comparison with the conventional methods, this technology provides increased nutrient content and water use efficiency, crop productivity and quality. This section contains the collection of review of various researchers which is relevant for the present study.

2.1 Fertigation

The practice of applying fertilizers *via* the irrigation water is called fertigation. In fertigation, timing, amounts and concentration of fertilizers application can be controlled easily. Fertigation let the landscape to absorb up to 90% of the applied nutrients, while granular or dry fertilizer application typically result in absorption rates of 10 to 40%. It ensures saving in fertilizer dose (40-60%), due to "better fertilizer use efficiency" and "reduction in leaching" (Kumar and Singh 2002).

Singh (2001) conducted some studies on the emerging scenario of micro irrigation in India and reported that drip system allows the use of fertilizers, pesticides and soluble chemicals along with the irrigation water. It can be used as a major component in precision farming.

Fertigation enables sufficient application of water and nutrients with precise timing and uniform distribution to meet the crop nutrient demand. It also ensures substantial saving in fertilizer usage and reduces leaching losses (Mmolawa and Or 2000).

Fertigation is one of the latest techniques of providing nutrients through drip irrigation system. The system permits application of several fertilizers directly in to the root zone. Fertigation system is becoming more popular because of its advantages like, higher nutrient use efficiency, increased availability of nutrient content to the plant, saves fertilizer up to a range of 20 – 40 per cent, supplies crop nutrients regularly when required, labor and energy savings and facility for application of chemicals other than fertilizers for specific purposes (Khan *et al.*, 1999)

Fertigation is the application of liquid or solid mineral fertilizers through irrigation water (Magen, 1995). For efficient and uniform distribution of nutrients, the irrigation system must have some requirements like it must be accurately designed to operate most efficiently and should confirm complete solubility of the fertilizers without leaving any more surpluses and should provide nutrient solution at constant rate and pressure from the main flow line (Nache, 1996).

According to Fertilizer Association of India (FAI, 1995) fertigation has various supremacy like higher water and fertilizer use efficiency, least loss of nutrients due to prevention of leaching, supply nutrients directly to the root zone in available form and make the best use of nutrients, control of nutrient concentration in soil solution to effect proper supply, save application money and improve soil physical and biological conditions due to proper maintenance of soil moisture.

The area under drip irrigation, which was over 3.55 lakh ha in 2002, right now, adoption of drip irrigation in our country, is increasing and about 6.0 lakh ha area is covered under drip irrigation under several crops. Among the different techniques developed for application of water, drip irrigation also referred to as micro-irrigation or trickle irrigation is achieving popularity as applying water most efficiently (Bucks *et al.,* 1982).

The major advantages of fertigation through drip system are water and labour saving, better timing, uniform distribution of water and nutrients with less damage to crop and soil and providing higher yield. Also this method gives an opportunity for precise application of water soluble fertilizers and other nutrients to the root zone at proper time with desired concentration (Kumar *et al*., 2005).

Fertigation helps in fertilizer saving and reduce labour cost. This method provides easy supply of nutrients as they are already available to plant roots more quickly than solid fertilizers applied to soil surface. The possible drawbacks of fertigation are improper laying of drip system or when low quality fertilizer materials are used (Koo, 1980).

Tickle-irrigation is a highly efficient technique of water application to crops, which substantially saves water applied to plants, which substantially saves water and nutrients, increases yield besides improving the quality of produce and reducing labours. In these years there has been a serious concern of global water deficit. It is evaluated that in India by 2025, 33 per cent of India's population will be live under severe scarcity conditions (Chauhan, 2005).

For a fertigation system to be successful, a number of essentials are, the system should be designed in such a way that each emitter must deliver same amount of water, there should not be any deposits of fertilizers and chemicals, there should be a uniform mixing of nutrients and irrigation water (Greef, 1975a)

Several factors such as plant species, media, its pH, solar radiation, temperature, humidity and water availability in the green house affect the absorption and utilization of nutrients. Hence, proper management of the media and appropriate fertigation program is essential for getting sustained productivity of crops under green house. Excessive or imbalanced application of nutrients would result in improper plant growth (Mortvedt, 1997).

Fertilizers applied through conventional methods of irrigation are not efficiently used by the crops. Through fertigation, water and fertilizers are efficiently used by the crop. Studies conducted in various commercial, horticultural and high value crops, disclosed that adoption of this method improves yield and quality of plants. It is also most beneficial to the farming community in lessening the cost production. Also it helps in sustaining the soil health for better productivity and reducing environmental risks (Manickasundaram, 2005).

The initial cost of installation of drip system could be very high, advantages in saving water, labour, non-interference with cultural operations and save fertilizers when applied through this micro irrigation system. In management practices, water and fertilizer application is a major input. Initiative farmers and scientist in earlier days have attempted to provide fertilizer through irrigation a concept which is termed as fertigation with yield advantages (Goldberg and Shamueli, 1970). Then this method of applying fertilizers through sprinklers or drip especially for horticultural crops was developed by scientists in many countries (Bester *et al.*, 1977).

Chilli crop requires good and exact amount of water for better yield and quality. In this way, micro irrigation proposes great opportunity for precise application of water and nutrients to the crop root zone. This method has proved its superiority over other conventional method of application of water, mainly in fruits and vegetable crops owing to accurate and direct application of water in the root zone (Bhella, 1988; Raina *et al.,* 1998).

A study on the speaking plant approach for automatic fertigation system in green house was conducted, in order to apply water and nutrients in the right quantity and time. Plants condition can be observed on CCD camera which is attached to image processing facilities to build up a speaking plant approach. The developments of plants during their growing period are observed through image processing. The plant growth response in the same condition was monitored, and this response was used as input for the ferigation to switch on and off the electrical pump automatically, so the fertigation system could sustain the growth of the plants (Usman *et al.*, 2011)

In crop productivity, fertilizers are major input. Efficient uses of these nutrients are very low in conventional methods. Nitrogen consumption is very high for most of the plants. Among nitrogenous fertilizers urea is most suited for fertigation, it is highly soluble and does not react with water to form ions. In conventional method nitrogen use efficiency is about 40 – 60 per cent, but in fertigation nitrogen use efficiency is very high it is about 90 per cent. Alternate wetting and drying of flood irrigation in conventional method will also cause nitrogen loss which is practically not in fertigation (Greef, 1975b).

Singandhupe *et al.*, (2002) observed that fertigation is a practice that provide accurate amount of nutrients directly in to the root zone and the plants utilize nutrients efficiently during their critical stage of its growth. They also reported that nitrogen application through drip at 8 days interval having 10 splits saved about 20 to 40 per cent nitrogen in tomato as compared to furrow irrigation in conventional method and application of nitrogen is given as two splits.

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

Rekha and Mahavishnan (2008) observed that water and fertilizer saving in drip ferigation of vegetable crops was about 40 to 70 percent and 30 to 50 percent respectively.

Furthermore, there is good potential for adoption of drip irrigation and use of water soluble fertilizers with drip system, *i.e.* fertigation technique for achieving higher productivity and quality in several crops. The microirrigation also allow use of fertilizers, pesticides and other soluble fertilizers along with the water provide and thus enhancing the quality of produce and yield (Pandey *et al.,* 2013, Singh *et al.,* 2000).

A study carried out by *Tu et* al., (2000) in tomato found that fertigation was much better than soil application of fertilizers. They found that yield were higher when soil application of fertilizers replaced with fertigation. The studies on fertigation in various vegetable crops showed that it is the most effective way applying water and fertilizers into the crop root zone, which save water and nutrients and also increase vegetable yields (Hatami *et al.*, 2012).

EFFECT OF GROWING ENVIRONMENTS

The main aim on cultivation of vegetables in a protected condition are, to protect the crop against biotic (pests, diseases and weeds) and abiotic (temperature, humidity light,) stresses and to certain round the year production of better quality vegetables like capsicum specially, during the off-season. Vegetable cultivation in polyhouse, increases the productivity and quality of vegetables and now it is practicing in more than fifty countries all over the world.In India, it is a latest technology and is still in its initial stage (Singh, 1998; Singh *et al*, 1999; Phookan and Saikia, 2003; Rai et al, 2004; Singh and Asrey, 2003)

Production of better quality capsicum under open field condition is not that as easy because of specific climatic needs. Lower night temperature, high rainfall, hails, frost, water logging, higher relative humidity and cold wind are major limiting factors for successful cultivation of capsicum under open field condition. However, it can successfully be cultivated under protected condition in Uttarakhand (Chandra *et al.*, 2000 and Singh *et al.*, 2010). In order to get the maximum output form capsicum under naturally ventilated polyhouse, optimum nutrient management through fertigation and management of hydrothermal regime in the soil was also very important.

Thangam *et al.*, (2002) conducted an experiment on tomato growth under open and poly house , shaded conditions and observed that early flowering and fruiting were noticed in open field when compared to shade for various genotypes of tomato also crop grown under shaded condition have better growth, increased plant growth and dry matter production compared to open field condition.

Under open field condition relative humidity was lower than that of poly house. Relative humidity fluctuation could affect growth and development of cucumber (Chaugale *et al.*, 1990).

In arid region use of green house lowers the crop water requirement by decreasing evapotranspiration by 65 to 80 % compared to open field (Fernades *et al.*, 2003).Vegetable crops under protected cultivation was suitable for domestic purpose and export needs could be more efficient alternative for land use and other resources (Sanwal *et al.*, 2004).

Sethi *et al.* (2003) noted that inside the green house growth of muskmelon was higher than that of open field. It was reported that the average growth rate of plants was 4 mm per day and 2 mm per day inside and outside, respectively.

Narayanankutty *et al.* (2013) observed that varieties of cucumber grown under green house for a low temperature and low light environment of spring and winter season so the warm humid climate of Kerala is suited for cucumber cultivation.

When transplanting was done earlier under poly house, the interaction between effect of time of transplanting and environment interaction showed a significant increase in fruit length (18.5), number of fruits (12,6), and yield (5.38 kg/plant) (Sharma *et al.*, 2006).

Patel *et al.* (2003) observed that the poly house performed better than the open field crop in terms of total rose flower production (4776 Nos.), weight per flower (22.05 gm), number of flowers per plant (66.33), number of flower per unit area (65.55) and average stalk length received (47.25). It was also reported that the yield potential of poly house is about 1.5 times more than that of open field.

Effect of growing condition on growth characters

Pandey *et al.* (2005) studied on comparison of glass house condition with polyhouse and open field condition for raising capsicum and observed that glasshouse having ventilation in the roof and side windows was found more superior than open field and polyhouse condition for the production of capsicum.

Impact of nitrogen substitution levels through organic and inorganic sources on capsicum under poly house condition showed higher root growth (Naik, 2005). Capsicum showed better growth characters, like plant height, number of leaves and number of branches under naturally ventilated poly house compared to shade house (Yellavva, 2008).

Kumar and Arumugam (2010) chillies grown under poly house performed better on growth characters includes plant height (165.84 cm), number of branches

(47.21) and inter nodal length (12.12 cm) compared with open field condition (80.33 cm, 35.50 and 7.86 cm, respectively).

Sriharsha (2001) reported the highest tomato yield of 35.27 t ha^{-1} in medium cost green house followed by low cost green house (31.98 t ha^{-1}) and least production was under open field condition (24.38 t ha^{-1}).

Thangam and Thamburaj (2008) observed the comparative performance of tomato varieties and hybrids under shade and open field condition and reported that plants grown under shade showed improved growth and dry matter production compared to those grown in open field.

Singh *et al.* (2003) reported that higher yield of tomato (93.2 t/ha) and capsicum (76.4 t/ha) inside poly house was mainly due to higher temperature (4-9°C) compared to outside which is observed over the month of December to February and high rate of utilization of carbon dioxide inside greenhouse. Another observation was observed on capsicum was that the crop was well suited to microclimate of greenhouse due to its peculiar characters like medium height, lateral spreading and fruit set at comparatively lower temperature. Similarly, tomato production inside greenhouse with training and pruning has facilitated better spreading with 2 – 3 branches and consequently higher yield.

Megharaja (2000) conducted a study on capsicum cv. Indira under both polyhouse and open conditions. Significantly higher plant height (94.36 cm) and number of branches (31.94) observed under poly house condition compared to the plants grown under open field condition.

Zende (2008) conducted a study in capsicum cv. Orobelle under two growing conditions *viz.*, naturally ventilated poly house and shade house . In naturally ventilated poly house maximum plant height observed than under shade house and

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the days to 50 per cent flowering was early under naturally ventilated poly house than shade house.

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

Sharma *et al.* (2010) conducted a study on the performance of capsicum genotypes in poly tunnel *vis-à-vis* in open field condition and recorded that plants grown under shade showed better growth in terms of plant height compared crops under open field. Capsicum cv. California Wonder recorded the highest plant height (67.25 cm) among the nine genotypes under shade house.

Nagalakshmi *et al.* (2001) conducted a study on effect of growing condition in tomato, capsicum and cauliflower. Crops grown under polyhouse showed better plant height, number of branches, earlier flowering and fruiting compared to the crop grown under open field condition.

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

Papadopoulos and Ormorod (1991) found that better growth rate of tomato under green house. The growth and development at earlier stages in tomato found to be faster in protected condition than open place (Chowdhury and Bhuyan, 1992).

Naik (2005) conducted a study on three growing conditions, medium cost polyhouse, low cost polyhouse and net house. Crop grown in medium cost polyhouse recorded increased yield. The favourable environmental condition prevailing in medium cost polyhouse not only helped in better growth of roots and shoots but also helped in better vegetative growth.

Dixit (2007) conducted a study to find out the performance of leafy vegetables like amaranthus, spinach, oriander and fenugreek under poly house and open field and find out that higher plant height, number of leaves per plant, number of branches, length and breadth of leaves at poly house compared to open field. Kavitha *et al*, (2009) also found that growth characters like plant height and number of primary branches were higher under poly house compared to open field.

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

Harish (2011) conducted a studied in tomato (*Solanum lycopersicum* L.) that the naturally ventilated poly house condition exhibited higher plant height (37.63 cm, 71.88 cm and 55.72 cm), number of branches (3.25,8.10 and 9.07) at 30, 60 and 90 DAT, respectively and less number of days to 50 percent flowering as compared to open field condition.

Parvej *et al.* (2010) studied on tomato and reported that plant height, number of branches per plant, leaf area expansion rate and LAI were showed better growth under poly house when compared with natural enviroment . Prabhu *et al.* (2009) reported that plant height and leaf production were very high under protected condition.

Wajaszek *et al.* (1979) observed that enrichment of CO2 (1500ppm) under greenhouse increased the yields (45.2%) of tomato as compared to normal atmosphere (27°C). Singh *et al.* (2003) observed that capsicum crop was suited to greenhouse due to its peculiar characters like medium height, lateral spreading and fruit set as compared to lower temperature.

Shedeed *et al.* (2009) reported that significant increase in growth parameters like, (plant height, LAI, fruit dry weight, total dry weight), yield components (number of fruits /plant, mean fruit weight, fruit yield / plant) and total fruit yield in tomato with the application of 100 per cent RDF through fertigation and soil application of fertilizers on furrow method.

Canadas *et al.* (1985) reported that fresh pepper have improved leaf area and leaf fresh weight in greenhouse were with greater fertigation than with flood irrigation. Fertigation let nutrient placement directly into the crop root zone during critical periods of nutrient demand. Fertigaion at weekly intervals was found to be more profitable and convenient for farmers (Bachchhav,1995).

Effect of fertigation on water use efficiency

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

Kaushal *et al.* (2011) reported that the drip irrigation adoption increased water use efficiency (60-200%), saved water (20-60%), reduced fertilization requirement

(20-33%) through fertigation, produced better quality crop and increased yield (7-25%) as compared with conventional irrigation.

At Udaipur a study on drip irrigation shows that an increase in production and water use efficiency of potato and also reported that it minimize loss of water , increased yield of potato tubers and reduced weed growth in drip irrigation compared to surface irrigation (Singh *et al.*, 2001).

Farshi (2001) reported an increased WUE of 5.2 kg m-3 from drip irrigated cucumber compared to 1.2 kg m^{-3} in surface irrigation. Foster (1989) examined moisture regime and growth of vegetables under drip irrigation system and conventional furrow irrigation. The results reported better water savings and higher yields under drip. Micro irrigation gave highest water use efficiency in round guard (5.10 q ha^{-1} cm) and water melon (10.3 q ha^{-1} cm) than furrow irrigation system (3.70 q ha^{-1} cm).

Chartzoulakis and Michelakis (1996) obtained that water use efficiency for cucumber was largest with drip compared to furrow method, micro tube drip, porous clay tube and porous plastic tube. Komamura *et al.* (1990) conducted a study on effect of irrigation method on poly house cucumber found that perforate pipe system maintained adequate soil moisture than drip irrigation system.

Srinivas (1986) studied on water requirement of water melon reported that among two different drip irrigation treatments one emitter per two plants recorded slightly higher yields (34 t ha-1). Comparison between bubbler and drip methods in bitter gourd (KAU, 1997) with an irrigation schedule at 100 per cent evaporation in bubbler gave increased yield of 28.33 kg ha^{-1} with water use of 320 mm compared with drip. Also studies in okra showed that bubbler works with the pressure less than that of sprinkler with uniform distribution and increase in water use efficiency. Field experiment on oriental pickling melon by Gebremedhin

(2001) drip irrigation saved irrigation water by 37 per cent than conventional method.

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

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

Atre *et al.* (2003) conducted a study on yield and water use efficiency of capsicum grown under poly house. More application of water, provided improved yield in capsicum and the water use efficiency was higher with application of water equivalent to 70 per cent of pan evaporation through micro irrigation system in poly house.

EFFECT OF FERTIGATION ON GROWTH AND YIELD OF CROP

Hyness (1988) observed increased vegetative growth in chilli when applied 75 kg ha^{-1} of nitrogen through fertigation compared to hand application. Like that in Nendran banana application of about 200 g N per plant through drip irrigation gave a higher number of bunch weight compared to 200 g N applied to soil (KAU, 1997).

In Egypt tomatoes grown under arid conditions in sandy soils produced more yield under high fertigation frequency about 2 days interval, than under low once in a week (Ibrahim, 1992).

Improved growth and yield of vegetable crops under fertigation have been recorded by many scientists (Bafina *et al.,* 1993; Malik *et al.*, 1994; Bresler, 1997 and Razzaque *et al.,* 2004). Fertigation in tomato and brinjal gave encouraging results in terms of yield and economic return The highest tomato fruit yield was obtained with fertilizer doses N100 P55 K120 under fertigation and irrigated at two days interval through drip systems (Razzaque *et al.,* 2004).

Growth characters like, number of leaves, number of internodes and plant height improved by the application of 100 kg of nitrogen per hectare as compared to control. The varieties tested and analyzed that Parbhani kranti was found to be highly vigorous than selection 2-2 (Chaudhari *et al.*, 1995).

Highest yield (29.83 t/ha) and fruit weight of melons (1.1 kg) were obtained with nitrogen at 70 kg, P_2O_5 at 60 kg and K_2O at 90 kg per hectare when applied through irrigation water (Harnandez and Aso, 1991).

130-200 kg ha^{-1} nitrogen increased fresh marketable tomato production by increasing its fruit size; it was due to loss of nutrients reduced under drip irrigation (Karlen *et al.*, 1985). Jeevansab (2000) recorded that the fruit yield of capsicum varies significantly with the growing environments and obtained highest fresh fruit yield (30.50 t/ha) under polyhouse than open condition (12.00 t/ha).

Chilli responds well to 11 to 22 split fertilizer applications in terms of increased growth and yield properties besides, higher water and fertilizer expense efficiencies compared to conventional methods of application of fertilizer. Pungency and colour are two important factors liked by consumers. Nitrogen is an essential part of nucleic acid and has been suggested to improve the growth of vegetative structures and also yield (Glass, 1989).

Raman *et al.* (2000) conducted a study on effect of fertigation on growth and yield of gherkins having four fertigation with different soluble fertilizer combinations at two levels (100 and 75% NPK) compared with recommended dose of solid fertilizers applied through band application in soil. Application of 75 per cent of recommended dose of NPK with soluble fertilizers through drip irrigation system gave greater yields and saved 25 per cent saving of fertilizers, than band application.

Guler and Ibrikci (2002) recorded higher yield (7.8 t ha^{-1}) from drip irrigated plant compared to furrow irrigated plant (7.2 t ha^{-1}). Ochigbu and Harris (1989) studied on tomato under both polyethylene film covered green house and open field conditions to compare the fruit yield. The tomato grown under polyethylene film covered greenhouse conditions gave more total fruit yield (9.4 kg/m^2) than open field condition (7.35 kg/m^2).

Kataria and Michael (1990) studied that under drip irrigation in Delhi a high yield of tomato as obtained which was about 47.4% over furrow method of irrigation.

Bernan (1989) recorded yield of pepper per acre was maximum (13.4 t/ac) under drip irrigation with the amount of water 65.5 cm and it was 10.4 t per acre under furrow irrigation with 70.75 cm.

Alcantar *et al.* (1999) conducted a field study with two fertigation treatments one with conventional irrigation and fertilizer and other as fertigation treatment. Dry matter production was always higher in fertigated plants than in those conventionally irrigated and fertilized. Fruit production and quality parameters (size, firmness and soluble sugars) were consistently enhanced by fertigation.

Bhatnagar *et al.* (1990) compared the yield of tomato between green house and open field conditions and observed that maximum fruit yield (507 q/ha) under greenhouse as compared to no yields under open field condition, as no plants were survived due to severe frost during winter in hilly region of Uttar Pradesh. It was also reported that during winter in the hilly region of Uttar Pradesh, capsicum grown under greenhouse higher yield of 50 quintal per hectare as compared to open fields (24 q/ha).

Patel and Patel (2010) conducted an experiment on cultivation of capsicum in net house, greenhouse and open field. The production was reported highest in greenhouse, but due to huge consumption of electric energy the cultivation of crop under poly house was found unprofitable.

The plant height and number of branches increased the new nodes for appearance of flower and fruit development, resulting in the increase of the total yield of chilli.(Antony and Singandhupe, 2004), Manjunatha (2001), (Cetin and Bilgel, 2002) and (Tiwari *et al.* 2003) who also reported beneficial effects of drip irrigation on growth and yield of different vegetables.

Roy *et al.* (2011) reported in capsicum the length and girth of fruit and number of fruits per plant increased significantly with increased N doses up to 100 kg N/ha and average fruit weight increased significantly with increasing levels of P up to 150 kg N/ha. Average weight of fruit and yield increased significantly with increasing levels of P up to the treatment 30 kg P/ha, whereas length and number of fruits per plant was increased significantly up to the 60 kg P/ha. The combination of nitrogen and phosphorus was recorded higher yield in the treatment combination of 150 kg N and 30 kg P /ha

Beyaert *et al.* (2007) reported that micro irrigation coupled with fertigation showed significant advantages in terms of yield and economic returns of cucumber compared to overhead irrigation and conventional fertilization practices.

Basavaraja *et al.* (2003) studied on the microclimatic conditions in poly house and got the higher yield from the poly house condition was due to the favourable air temperature, optimum relative humidity and light intensity present in the structure, which had helped in good vegetative growth and reproductive characters in capsicum.

More *et al.* (1990) observed on cucumber variety under two growing conditions, polyhouse and open field in North India and reported that higher yield of 1.70 kg per plant under polyhouse compared to open field condition (0.85 kg per plant) during winter months under North Indian conditions due to low temperature.

A field experiment in Haryana, in the year 1997- 1998 during spring-summer on sandy loam soil for to know the effect of irrigation and nitrogen on okra. They observed that while applying 150 kg N and 200 kg N applied in 3 times basal, 30 and 45 days after sowing) uptake of nitrogen increased when the intensity of irrigation and level of nitrogen supply increased. The highest fruit yield can be obtained when supply moderate irrigation (Verma and Batra, 2001).

In drip irrigation system the use of fertigation was studied by Hynes (1985). The benefit of fertigation in a drip irrigation system contains increased fertilizer use efficiency and ease of fertilizer application also reduced labour. During the critical period of nutrient demand fertigation provides nutrients directly the plant root zone (Mikkelsen, 1989).

Prasad (2001) compared the yield of bell pepper under both greenhouse and open field condition and recorded that the maximum total yield (82.31 t/ha) of bell pepper was reported under greenhouse than that of open field condition (19.89 t/ha).

Singh *et al.* (2003) observed that the improved productivity of tomato (93.20 t/ha) and capsicum (76.40 t/ha) inside greenhouse was observed mainly due to higher temperature (4 – 9 °C) than the Outside condition during month of December to February and high rate of utilization of carbon-dioxide inside greenhouse. Microclimate inside greenhouse during winter months was mainly responsible for higher yield due to their beneficial effects on flowering and fruiting.

Nimje *et al.* (1990) studied on three varieties of sweet pepper to understand the suitability under greenhouse and open field conditions. Among three varieties of sweet pepper, California Wonder variety was best suited for green house cultivation as it yielded 445 qha^{-1} compared to 164 qha^{-1} under open field condition. Further, in the sequence of cropping system of two crops of sweet pepper and one crop of ladies finger, the ladies finger crop produced maximum yield (1053 q/ha/year) under greenhouse than normal field condition (385 q/ha/year).

A field experiment to study the water and nutrient use efficiency of sprouting Broccoli grown on sandy loam soil under fertigation found that yield obtained indicated that a fertilizer savings up to an extend 20-40 per cent (Anil *et al.*, 2001).

A study conducted during summer season in Lucknow, UP in RBD in order to get suitable dose (40, 80 and 120 kg N) of nitrogen in two conditions with and without Azotobacter a bio fertilizer in okra cv . Arka Anamika. Obtained that with Azotobacter about 120 kg/ha N gave a very high yield in okra (Meena et al., 2008).

Nagalakshmi *et al.* (2001) observed that tomato, S-1 variety and capsicum Green Gold variety grown under polyhouse recorded better number of fruits per plant, fruit weight, fruit yield per plant and per hectare compared to the crops grown under open condition

A study on effect of irrigation water and nitrogen fertilizer on total canopy and wetted area basis of Capsicum annum based on yield, water saving and WUE showed that increased yield of 3.03 kg/ha was reported when applied water on total area basis along with 180 kg N/ha. The study recommends that it is much more effective to schedule irrigation at 0.8 of E pan evaporation and apply on canopy area basis in combination with 180 kg of N per hectare to increase the production (Singh *et al.*, 2001).

A field experiment during the kharif seasons of 2007 and 2008 in order to study the effect of nitrogen and phosphorus (0, 80, 120 and 140 kg ha$^{-1)}$ and (0, 120 and 140 kg ha$^{-1)}$, respectively under different plant spacing (50 × 30 and 50 ×40 cm) on growth and yield of okra at Kanpur, UP, India. The vegetative growth including height and girth of the plant, number of leaves and nodes and leaf area increased with application of nitrogen 140 kg ha^{-1} and followed by 120 and 80 kg per hectare, and more P (100 kg ha^{-1}) promoted these growth parameters followed by 80 kg ha^{-1} in this year's (Singh *et al.*, 2008).

Veeranna et al. (2001) conducted a study on chilli to know the effect of broadcast application with normal application of fertilizers and fertigation with soluble fertilizers at 3 rates through furrow and drip irrigation methods to study the its impact on yield , water and fertilizer use efficiency. The application of normal fertilizers 100 per cent suggested level in furrow method gave a yield of 24.7 percent and through fertigation with 80%water soluble fertilizers provide higher yield of about 31 with 20% and 36% saving in fertilizers and irrigation water.

Soumkuwar *et al.* (1997) studied that application of 75 kg N/ha improved vegetable growth, number and weight of fruit per plant and yield per hectare in okra varieties Parbhani Kranthi, Selection 2-2 and Punjab-7. Among these two varieties Parbhani Kranthi recorded betterr yield (77.70 q/ha).

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

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

Bhella and Wilcox (1986) studied efficient use of nitrogen in muskmelon under drip irrigation. It showed improved stem growth, early maturity and total yields obtained with pre-plant N fertilization rates. The plants were more responsive to increasing N fertigation than without fertilizer application. Fertigation responses were reduced in regimes that received 67 or 100 kg N per hectare.

The highest and significant fresh fruit yield (30.5 t/ha) was obtained under green house than open condition (12 t/ha). capsicum fruits produced from poly house had a higher ascorbic acid and total soluble solids (TSS) compared to fruits collected from open field (Jeevansab, 2000).

Effect of NPK on growth and yield of chilli

The application of nitrogen at greater levels increased plant height of chilli and maximum height was recorded at 100 kg N per ha (Nathulal and Pundrik, 1971). Nitrogen application improved synthesis of chlorophyll which causes an increase in carbohydrate production. It is responsible for higher vegetative growth. Similarly, Das and Mishra (1972) recorded the highest plant height with the highest nitrogen levels (180 and 150 kg N/ha, respectively).

Singh *et al.* (1986) studied non-significant increase in the fruit length with potassium application in chilli cv. Hort Portugal. With highest level of potassium application (75 kg K_2O/ha) produced maximum fruit length (7.67 cm).

Chougule and Mahajan (1979) studied that number of fruits in chilli was not influenced by potassium levels. Singh *et al.* (1986) reported significantly higher number of fruits per plant with potassium application in chilli cv. Hort Portugal. The maximum number of fruits per plant (22.19) were obtained with 25 kg K_2O per ha, then increase in potassium levels reduced number of fruits in chilli. Shukla *et al.* (1987) conducted a fertilizer trial in Bell pepper cv. California Wonder and reported that yield was not affected by potassium application.

Singh and Srivastava (1988) reported the increased number of branches (20) in chilli cv. Pant C-1 at 120 kg N per ha compared to control (8.58) without fertilizer application.

Jayaram and Balasubramanian (1988) observed that application of high amount of potassium up to 105 kg per ha resulted in increased yield and yield attributess in chilli (1616 kg/ha) and also, reduction in attack of aphids, thrips and chilli mosaic disease. Belichki (1988) reported that application of NPK at 320:320:80 or 320:320:60 kg per ha were the most effective treatments economically and it increased total yield by 67.4 and 43.3 per cent, respectively.

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Hegde (1988) applied 0, 60, 120 and 180 kg nitrogen per ha to study the effect of nitrogen. Increased amount of nitrogen applied to the plants improved dry matter production significantly from 13.5 g (control) to 28.7 g (180 kg N/ha) per plant. In chilli cv. Sindhur *et al.*, (1993) reported highest dry matter production of 1377.4 kg per ha at 100 kg N per ha compared to control (840.9 kg/ha) without any fertilizer.

Sharma (1995) observed linear response on yield and yield components of chilli up to an application of 125 kg N, 75 kg P_2O_5 and 110 kg K_2O per ha. At Jabalpur, Sharma *et al.* (1996) concluded that the best treatment to promote yield and profitable in chilli was 120 kg N + 30 kg P_2O_5 per ha.

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MATERIALS AND METHODS

CHAPTER 3

MATERIALS AND METHODS

The present investigation entitled ***'Microclimatic alteration on water productivity of Chilli (Capsicum annum L) under fertigation'*** was taken up at the Water Management Research Unit (WMRU) a sub center of Agronomic Research Station (ARS) Chalakudy, Vellanikkara, Thrissur, Kerala, during February 2017 to August 2017. The details of the materials used and methods adopted during the course of investigation are described in this chapter.

3.1 EXPERIMENTAL SITE

The experiment was conducted at Water Management Research Unit located at Vellanikkara in Thrissur district of Kerala state. This station is geographically situated at 10° 33' 10" N latitude and 76° 16' 46" E longitude at an altitude of 12.192 m above mean sea level. Typical warm humid tropical climate prevails in this area.

3.1.1 Soil

The soil of the experimental region was sandy loam and acidic in reaction. Prior to the experiment, composite soil samples were collected from 0 - 15 cm layer of the soil, both from inside the poly house and open field condition and analyzed its chemical properties. The data on the chemical properties of the soil are presented in Table 1.

3.1.2 Cropping history of the field

The area was under a bulk crop of oriental pickling melon before the experiment.

3.1.3 Season

The experiment was conducted during the summer season, from 4th February 2017 to 15th August 2017.

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Table 1. Chemical properties of the soil

Sl. No.	Parameter	Open field condition	Inside poly house	Procedure adopted
1	Organic carbon (%)	1.68	2.07	Walkley and black rapid titration method (Jackson, 1973)
2	Available phosphorus (kg ha^{-1})	36.13	18.32	Bray colorimetric method (Jackson, 1973)
3	Available potassium (kg ha^{-1})	292.38	244.94	Ammonium acetate method (Jackson, 1973)
4	Soil reaction (pH)	4.67	4.79	1:2.5 Soil solution ratio using pH meter with glass electrode (Jackson, 1973)

3.1.4 Weather

The weekly averages of maximum and minimum temperatures, relative humidity, and rain fall in open field condition are given in Appendix 1 and graphically presented in Fig. 1a. The maximum and minimum temperature and relative humidity inside the poly house are given in Appendix 2 and illustrated in Fig. 1b.

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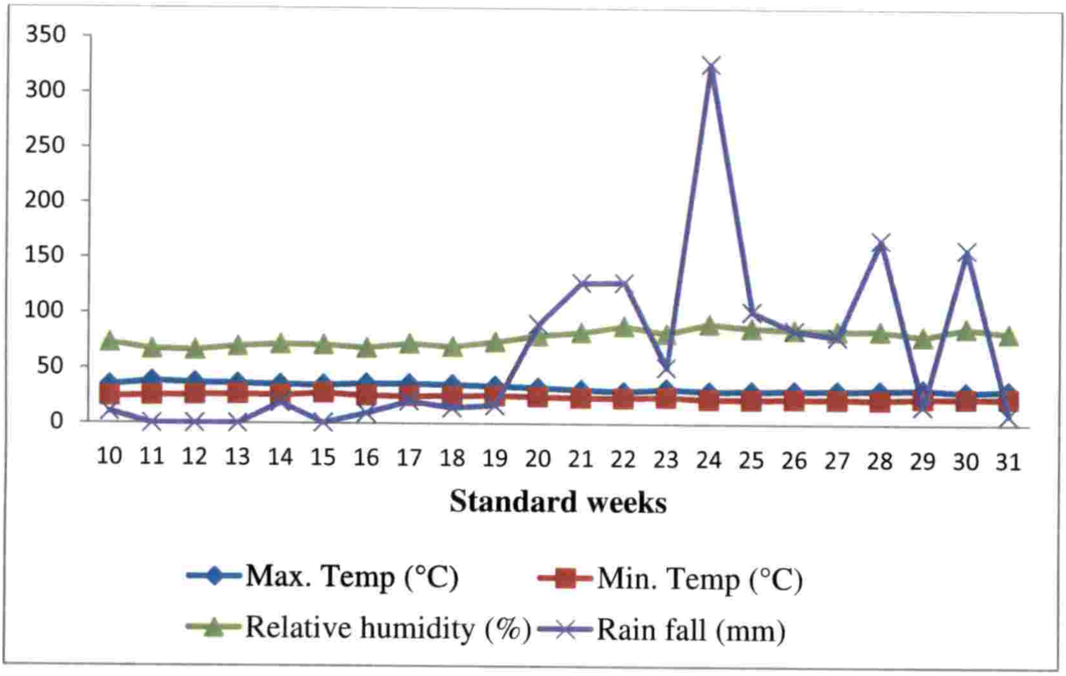

Fig. 1a: Weather parameters in open field during the cropping period (15th March – 15th August, 2017)

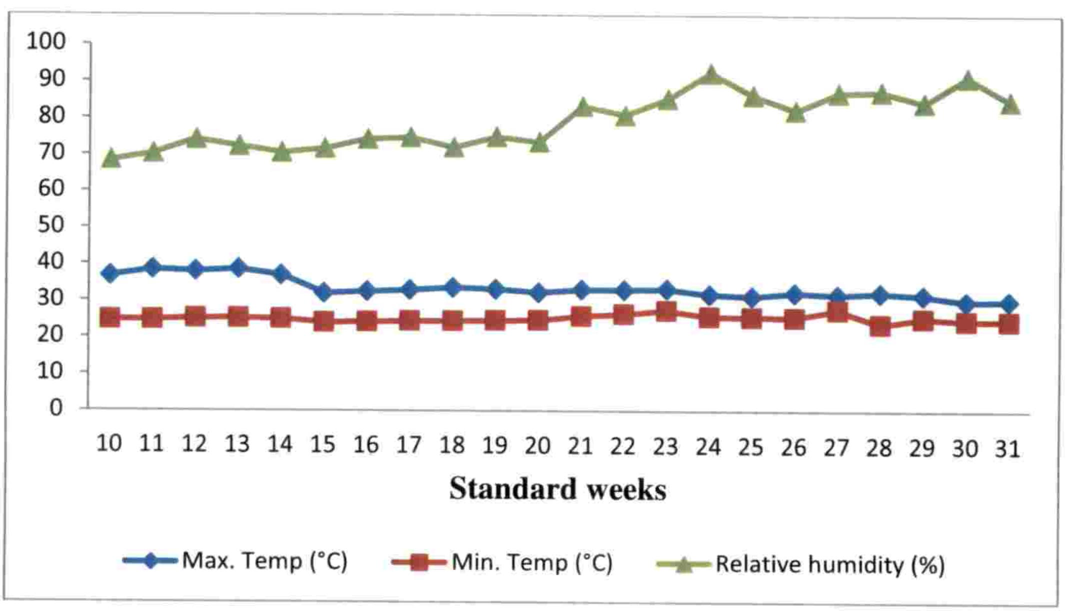

Fig. 1b: Weather parameters in poly house during the cropping period (15th March – 15th August, 2017)

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3.2 MATERIALS

3.2.1 Variety

The chilli variety used for this experiment was Ujwala, a high yielding bacterial wilt resistant variety developed by Department of Olericulture, Kerala Agricultural University (KAU), Vellanikkara. The fruits of Ujwala are long, dark green in colour when young and turn red on maturing with high degree of pungency. They come to harvest in 75 days after planting. The variety can be used both as dry and green chilli. Spacing for chilli was adopted as 45 cm × 40 cm.

3.2.2 Manures and fertilizers

Farm yard manure (1.0 % N, 0.5 % P_2O_5, 1.0 % K_2O) was used for the experimental plots as the organic source. Urea (46 % N), Rajphos (20 % P_2O_5), MOP (60 % K_2O), 19:19:19 and sodium ammonium phosphate were used as the inorganic sources for the study.

3.3 METHODS

3.3.1 Design and layout

The experiment was laid out in randomized block design (RBD) with four replications (Fig.2) and (Fig.3). The details of the layout are given below.

3.3.2 Outline of the technical programme

Two growing conditions, with four levels of treatments and one variety called Ujwala.

Design	: Randomized block design (RBD)
Replication	: 4
Plot size	: 3.0 m × 3.0 m
Spacing	: 45 cm × 40 cm

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Crop : Chilli

Variety : Ujwala

3.3.3 Treatments

I Growing condition (P) — 2

P_1 - Open condition

P_2 - Green house condition

II Fertigation (T) — 4

T_1 – 100% N, P & K through fertigation with no basal application

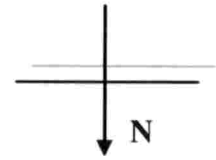
T_2 –25% NPK of 100% NPK as basal and remaining NPK through fertigation

T_3 – 75% N, P&K through fertigation with no basal application

T_4 – 25%NPK of 75% as basal and remaining NPK through fertigation

III Control (C)

C – 100% NPK through conventional fertilizers & method.



R_1T_1	R_1T_2	R_1T_3	R_1T_4	R_1C
R_2T_1	R_2T_2	R_2T_3	R_2T_4	R_2C
R_3T_1	R_3T_2	R_3T_3	R_3T_4	R_3C
R_4T_1	R_4T_2	R_4T_3	R_4T_4	R_4TC

Fig.2(a): Layout of the experiment for open field

R_1T_1	R_1T_2	R_1T_3	R_1T_4
R_2T_1	R_2T_2	R_2T_3	R_2T_4
R_3T_1	R_3T_2	R_3T_3	R_3T_4
R_4T_1	R_4T_2	R_4T_3	R_4T_4

Fig.2(b): Layout of the experiment for polyhouse

3.4 CULTURAL OPERATIONS

The various cultural operations carried out for this study are described below.

3.4.1 Nursery

The soil was brought to fine tilth and a mixture of coir pith compost and soil was used as medium for planting in a pot trays. Single chilli seed was sown in each hole of pot tray. The seeds were sown on 4/2/2017. The seedlings were watered twice daily. Plant protection measures and hand weeding were done as and when required. The seedlings were ready for transplanting in 30 – 45 days.

3.4.2 Land preparation

The experimental fields both at open field and inside the poly house were thoroughly ploughed and weeds were removed. Plots were laid out as per the layout plan. Each plot was levelled and beds were formed. Pre emergent weedicide, Oxyfluorfen @750 ml ha^{-1} applied at the time of bed preparation and then healthy seedling of 30-45 days old was transplanted.

3.4.3 Manure and fertilizer application

Lime @ 350 kg ha^{-1} applied and FYM @ 25 t ha^{-1} was applied as basal as per POP recommendation of KAU. Fertilizers used were Urea, Rajphos, MOP, 19:19:19 and Ammonium phosphate. Nutrient recommendation for chilli was 75 kg N, 40 kg P_2O_5 and 25 kg K_2O as per KAU POP. Quantity of fertilizer required for each treatment was worked out based on the soil test value of nutrients for both open and ployhouse. Based on the soil test value nutrient recommendation for open field was 56.25 kg/ha N, 10 kg/ha P_2O_5 and 12.25kg/ha K_2O and 56.25 kg/ha N, 28 kg/ha P_2O_5, and 15 kg/ha K_2O for ployhouse.

Quantity of fertilizers applied to open field and poly house for each treatment is given in Table 2 and Table 3, respectively. Schedule of fertilizers application is given in Table 4.

Table 2. Quantity of fertilizers required for open field for each treatments (kg/ha)

Treatments	Fertilizer requirements (kg/ha) for open field						
	Conventional fertilization			Fertigation			
	Urea	MP	MOP	19:19:19	12:61: 0	0:0: 60	urea
100 % N, P & K through fertigation with no basal application				64			119
25 % NPK of 100 % NPK as basal and remaining NPK through fertigation	31	13	4.9	48			90
75 % N, P & K through fertigation with no basal application				48			90
25 % NPK of 75 % as basal and remaining NPK through fertigation	23	9	4	36			67
100% NPK through Conventional fertilizers & method (Control)	124	50	19.6				

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Table 3. Quantity of fertilizers required for poly house for each treatments (kg/ha)

Treatments	Fertilizer Requirements (kg/ha) for poly house						
	Conventional fertilization			Fertigation			
	Urea	MP	MOP	19:19:19	12: 61: 0	0: 0: 60	urea
100 % N, P & K through fertigation with no basal application				78	21		85
25 % NPK of 100 % NPK as basal and remaining NPK through fertigation	31	35	6	59	16		64
75 % N, P & K through fertigation with no basal application				59	16		64
25 % NPK of 75 % as basal and remaining NPK through fertigation	23	26	5	44	12		48

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Table 4. Schedule of fertilizer application

Weeks	Percent nutrient applied	
1st and 2nd	5% each	10%
3rd and 4th	10% each	20%
5th and 8th	15% each	60%
9th and 10th	5% each	10%
Total		100%

3.4.4 Irrigation

Water was applied through the drip irrigation system in open field and polyhouse. Drip lines laid at a spacing of 45cm and emitters at a distance of 40 cm. The water requirement of chilli was calculated by taking the average pan evaporation as 6mm and quantity of water applied per plant was 1.080 litre day^{-1}.

3.4.5 Gap filling

Gap filling was done with healthy seedlings in both open field and poly house at week after transplanting in order to get optimum plant population.

3.4.6 Weeding

Hand weeding was done for both poly house and open field at 30 to 45 days after planting (DAP).

Plate 1: General field view of polyhouse

Plate 2: General field view of open field

Plate 3: General field view of conventional method

3.4.7 Plant protection

Plant protection measures were adopted for pest and diseases control as and when required as per Kerala Agricultural University, Package of Practice Recommendation.

3.4.8 Harvest

The crop was ready for its first harvest after 75 DAP in both poly house and open field and subsequent harvest was made at 10 – 15 days intervals (7 pickings in open field and 4 pickings in poly house).

3.5 OBSERVATIONS

Five plants were selected randomly from each plot both from open field and poly house for taking the biometric observations

3.5.1 Biometric observations

3.5.1.1 *Plant height*

The height of five observational plants was recorded from each plot using the measuring tape. Height was measured from the soil surface to the growing tip of the plant at 30, 60, 90, 120, 150 DAP and at harvest from both open field and poly house. The mean height of the five samples were worked out and expressed in cm.

3.5.1.2 *Number of branches per plant*

Number of branches from the five sample plants from each plot were counted at 30, 60, 90, 120 and 150 DAP and at harvest from both open field and poly house and mean worked out from the data.

3.5.1.3 ***Number of leaves per plant***

Number of leaves from each plant was counted from the five observational plants from both open field and poly house at 5 stages, include 30, 60, 90, 120, 150 DAP and at harvest. The mean number of leaves was worked out.

3.5.1.4 ***Leaf area***

For the determination of leaf area, leaf length and breadth of one leaf was measured from each observational plant at 5 stages 30, 60, 90, 120, 150 DAP and at harvest from both growing conditions.

3.5.1.5 ***Root depth***

Length of tap root measured from the plants and mean worked out and expressed in cm.

3.5.1.6 ***Lateral root spread***

Length of the lateral root on the both sides of tap root was measured from the collected plants from each plot and mean worked out and expressed in centimetre.

3.5.1.7 ***Dry matter production (DMP)***

The samples collected from both the field at different stages 30, 60, 90, 120, 150 DAP and at harvest were dried to constant weight in a hot air oven at a temperature of 70°C. The dry weight of the completely dried plants was measured in gram and mean worked out and expressed in kilogram.

3.5.1.7 ***Days to 50 % Flowering***

Number of days taken for 50% of blooming in each plot was observed and recorded for all treatment and mean calculated and found out earlier flowering from both growing conditions.

3.5.1.8 *Relative leaf water content*

Selected the top-most fully expanded leaf receiving sunlight from the five observational plants. Leaf sampling was be achieved as quickly and efficiently as possible. Collected leaves were immediately transferred in to closed containers and then obtained fresh weight (FW) of the leaf sample, then added distilled water in to each sample. The leaf samples taken out from the container, and quickly and carefully blot dried with paper towel and measured turgid weight (TW) and leaf samples were dried at 70 °C for 24 hours, then dry weight of sample obtained.

The Relative Leaf Water Content was calculated by the following formula and expressed in percentage (%).

$$\mathbf{RWC\ (\%) = [(FW\text{-}DW) / (TW\text{-}DW)] \times 100,}$$

Where,

FW – Sample fresh weight
TW – Sample turgid weight
DW – Sample dry weight

3.5.1.9 *Determination of water use efficiency*

The fruit yield obtained from each treatment was divided with the quantity of water applied for each treatment. Water Use Efficiency (WUE) computed and expressed in kg/ha and amount of water applied expressed in mm.

$$\mathbf{WUE = \ Fruit\ yield\ (kg\ ha^{-1)} / Total\ amount\ of\ water\ applied\ (mm)}$$

3.5.1.10 *Determination of nutrient use efficiency*

The nutrient use efficiency computed using the formula

NUE = Yield (kg ha^{-1}) / Total quantity of nutrient applied (kg ha^{-1})

3.5.2 Yield and Yield Attributes

3.5.2.1 *Number of fruits per plant*

Total number of fruits of all harvest from the five observational plants was recorded and the mean worked out.

3.5.2.2 *Fruit weight per plant*

The weight of mature fruits were taken from the observational plants at different harvest and total weight of the fruits from each plant worked out and mean weight of fruits was calculated and expressed as kg $plant^{-1}$.

3.5.2.3 *Yield*

Total weight of fruits harvested from net per plot area of both poly house and open field was calculated and expressed as kg ha^{-1}.

Plate 4: Open field layout of drip system

Plate 5: Polyhouse layout of drip system

3.5.3 Plant Analysis

Plant samples collected from each plots at 30, 60, 90, 120 and 150 DAP from both poly house and open field were shade dried, oven dried at 70 °C to constant weight. The samples were then ground to pass through a .5 mm mesh sieve. Then 0.5g of samples were weighed out, digested and nutrient content was estimated as per standard procedure

3.5.3.1 *Uptake of nitrogen*

The nitrogen content estimated from the plant sample was obtained by the modified micro kjeldhal method (Jackson, 1973) and uptake of nitrogen was calculated by multiplying the nitrogen content with the total dry weight of plant sample. The values were expressed in kg ha^{-1}.

3.5.3.2 *Uptake of phosphorus*

The collected samples were digested using nitric-perchloric (9:4) and kept for pre digestion and then phosphorus content was obtained colorimetrically using Vandomolybdo phosphoric yellow colour method (Jackson, 1973) using the instrument spectrophotometer by adjusting the wave length 470 mm. Multiplying the phosphorus content with the total dry weight of plants, uptake of phosphorus obtained and expressed in kg ha^{-1}.

3.5.3.3 *Uptake of potassium*

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

3.5.4 Soil analysis and soil characteristics

The soil samples were collected from each plot before and after the conduct of experiment. The samples collected were dried in shade and sieved through 0.2 mm sieve and analysed.

3.5.4.1 *Organic Carbon Content*

The soil carbon content was determined using 'Walkley and Black's rapid titration method (Jackson, 1973). The values were expressed in per cent (%).

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3.5.4.2 *Available phosphorus content*

The available phosphorus content in the soil samples was determined using Dickman and Bray's molybdenum blue method using Bray No. 1 as reagent used for extraction and instrument used was spectrophotometer (Jackson, 1973). The values were expressed in kg ha^{-1}.

3.5.4.3 *Available potassium content*

The available K content in the soil samples was determined using neutral ammonium acetate extract and readings taken from Flame photometer (Jackson, 1973). The values were expressed in kg ha^{-1}.

3.5.4.4 *Soil pH*

Soil pH measured using p^H meter after mixing soil and water in the ratio 1:2.5 (Jackson, 1958).

3.5.4.5 *Soil moisture content*

Soil samples were collected at a depth of 0 - 15 cm using auger at two weeks interval for obtaining soil moisture content. Moisture content was determined using gravimetric method and expressed as percentage.

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Plate 6: Crops grown under polyhouse at 60 DAP

Plate 7: Crops grown under open field at 60 DAP

Plate 8: Crops grown under conventional method at 60 DAP

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Plate 9: Crops grown under polyhouse at 120 DAP

Plate 10: Crops grown under open field at 120 DAP

Plate 11: Crops grown under conventional method at 120 DAP

3.5.5 Meteorological Parameters

Weather parameters including maximum temperature, minimum temperature, relative humidity, rain fall, soil temperature, photo synthetically active radiation, and crop canopy temperature were recorded.

3.5.5.1 *Maximum and minimum temperature (°C)*

Daily maximum and minimum air temperature inside the poly house was recorded, by using mercury thermometer. Daily maximum and minimum air temperature for the open field was collected from the meteorological observatory.

3.5.5.2 *Relative humidity (%)*

The relative humidity inside the poly house was recorded by using wet and dry bulb thermometer. Relative humidity of the open field was collected from the meteorological observatory.

3.5.5.3 *Rainfall (mm)*

Rain fall data was collected from Department of Meteorology, College of Horticulture, Vellanikkara.

3.5.5.4 Soil temperature (°C)

Soil temperature was recorded using glass soil thermometers installed at a depth of 5 cm at an angle of 45°. Observations were taken at 8. 30 A.M in both open field and polyhouse in two weeks interval.

3.5.5.5 Photo-synthetically Active Radiation (PAR)

Line quantum sensor was used to measure integrated PAR. Photo-synthetically active radiation was recorded as millimoles of light energy per square meter (μmol s^{-1} m^{-2}). PAR was measured in two weeks interval.

3.5.5.6 Canopy temperature (°C)

Infrared thermometer was used to measure canopy temperature of the plant in one week interval. Observations were taken at 11:00 AM.

3.5.6 Economic Analysis

Economics of production were calculated for the experiment by considering the labour and input cost prevailing for the period and market price of chilli.

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

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

3.5.7 Statistical analysis

Data relating to different characters were compiled, tabulated and analysed statistically by applying the technique of analysis of variance (Gomez and Gomez, 1984) and significance was tested by Duncan's Multiple Range Test.(DMRT) (Duncan, 1955).

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RESULTS

CHAPTER 4

RESULTS

An investigation titled "Microclimatic alteration on water productivity of Chilli (*Capsicum annum L*) under fertigation" was conducted to study the influence of microclimate and fertigation on yield, water productivity and profitability of chilli under open and green house condition. The results obtained from the experiment are presented below.

4.1 BIOMETRIC OBSERVATIONS

4.1.1 Plant height

Effect of growing condition and fertigation levels on plant height at different growth stages is given in Table 4.1.1.Growing conditions had significant influence on plant height at 30 and 60 DAP. Crops grown under poly house recorded significantly higher plant height (29.53 cm, 49.25 cm) as compared to open field condition (22.59 cm, 41.51 cm) at 30 DAP and 60 DAP. At 90, 120 and 150 DAP effect of growing condition was found to be non-significant. Fertigation levels had significant influence on plant height at 30, 120 and 150 DAP. At 30 DAP application of 75 % NPK with no basal and 75 % NPK with 25% as basal resulted in same plant height. Application of 100% NPK given as fertigation with no basal dose produced significantly higher plant height at 120 and 150 DAP. At 60, and 90 DAP fertigation levels was found to be non-significant. Crops grown under conventional fertilizer application showed superior plant height (81.70 cm) during all growth stages compared to fertigated crops. (Table 4.1). The interaction effect was found to be non- significant at 30 DAP while significant difference was recorded at 60, 90, 120 and 150 DAP. Poly house plants receiving 100% NPK with no basal recorded significantly higher plant height compared to other fertigation levels at 60, 90, 120 and 150 DAP. But under open field condition fertigation levels showed significant effect on plant height at the above growth stages. G_2F_4 showed the highest value at all the stages.

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Table 4.1: Effect of growing condition and fertigation levels on plant height at different growth stages

Treatments	Plant height (cm)				
	Days after planting (DAP)				
	30	60	90	120	150
Growing conditions					
G1- Poly house	29.53	49.25	58.64	65.86	67.76
G2- Open field	22.59	41.51	59.94	65.18	66.44
CD (0.05%)	**1.55**	**1.90**	**NS**	**NS**	**NS**
Fertigation levels					
F1-100% NPK with no basal	25.35	47.28	63.65	69.73	71.95
F2-100% NPK with 25% as basal	24.55	43.95	58.21	63.3	66.23
F3-75% NPK with no basal	27.15	45.7	58.63	67.75	66.89
F4-75% NPK with 25% as basal	27.18	44.6	56.68	61.3	63.33
CD (0.05%)	**2.2**	**NS**	**NS**	**5.25**	**4.67**
Control	27.05	48.95	75.25	78.90	81.70
Interaction effects	**NS**	**3.79**	**7.41**	**7.42**	**6.60**

Table 4.1(a): Interaction effects on growing condition and fertigation levels on plant height at 60 DAP

	F1	F2	F3	F4
G1	55.35	48.8	48.8	44.05
G2	39.2	39.1	42.6	45.15
CD (0.05%)		**3.79**		

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Table 4.1(b): Interaction effect of growing condition and fertigation levels on plant height at 90 DAP

	F1	F2	F3	F4
G1	66.9	59.313	57.4	50.95
G2	60.4	57.1	59.85	62.4
CD (0.05%)	**7.41**			

Table 4.1(c) Interaction effects on growing condition and fertigation levels on plant height at 120 DAP

	F1	F2	F3	F4
G1	75.3	64.8	67.9	55.45
G2	64.15	61.8	67.6	67.15
CD (0.05%)	**7.42**			

Table 4.1(d): Interaction effects on growing condition and fertigation levels on plant height at 150 DAP

	F1	F2	F3	F4
G1	77.75	68.4	68.14	56.75
G2	66.15	64.05	65.65	69.9
CD (0.05%)	**6.60**			

4.1.2 Number of branches

Growing conditions had significant influence on production of branches (Table 4.2). Crops grown under open field had significantly higher number of branches compared to poly house. Chilli grown under conventional method of fertilizer application produced more number of branches during entire growth stages. Fertigation levels had no significance on number of branches. Interaction effects on growing condition and fertigation levels had significance only at 60 DAP. In open field 75% NPK with 25% as basal had superior production of branches (Table 4.2(a)).

Table 4.2: Effect on growing condition and fertigation levels on number of branches at different growth stage

Treatments	NUMBER OF BRANCHES				
	Days after planting (DAP)				
	30	**60**	**90**	**120**	**150**
Growing conditions					
G1- Poly house	0.35	3.83	4.95	6.55	4.96
G2- Open field	2.46	7.93	8.59	14.19	15.13
CD (0.05%)	**0.51**	**0.96**	**0.90**	**1.61**	**1.31**
Fertigation levels					
F1-100% NPK with no basal	1.23	5.25	7.65	10.00	11.23
F2-100% NPK with 25% as basal	1.23	6.05	6.65	10.80	9.68
F3-75% NPK with no basal	1.63	6.20	6.65	10.55	9.88
F4-75% NPK with 25% as basal	1.55	6.00	6.13	10.13	9.40
CD (0.05%)	**NS**	**NS**	**NS**	**NS**	**NS**
Control	5.05	16.3	9.05	17.25	20.7
Interaction effects	**NS**	**1.92**	**NS**	**NS**	**NS**

Table 4.2(a): Interaction effects on growing condition and fertigation levels on number of branches at 60 DAP

	F1	**F2**	**F3**	**F4**
G1	2.75	5	4.55	3
G2	7.75	7.1	7.85	9
CD (0.05%)	**6.60**			

4.1.3 Number of leaves

Leaf production of chilli was found significantly influenced by growing condition (Table.4.3). Plants grown under open condition produced significantly higher number of leaves during all growth stages when compared to poly house. Fertigation levels had significance only at 30 DAP and in other growing stages it was not significant. Application of 75% NPK with 25% as basal had higher number of leaves (20) at 30 DAP. Plants grown under conventional fertilizer application produced more number of leaves at all growth stages compared to poly house and open field condition with fertigation. Interaction effects on number of leaves were found significant at 60 and 120 DAP. Production of leaves was higher in open field in these growing stages than poly house. Application of 75% NPK with 25% as basal resulted in higher production of leaves in open field.

Table 4.3: Effect of growing condition and fertigation levels on number of leaves at different growth stages

Treatments	NUMBER OF LEAVES				
	Days after planting (DAP)				
	30	60	90	120	150
Growing conditions					
G1- Poly house	16.79	28.39	46.96	48.63	45.16
G2- Open field	18.96	78.23	142.86	174.85	269.64
CD (0.05%)	**1.57**	**6.11**	**17.26**	**16.13**	**19.78**
Fertigation levels					
F1-100% NPK with no basal	16.35	51.50	102.18	117.95	167.20
F2-100% NPK with 25% as basal	16.15	52.68	87.13	103.15	146.40
F3-75% NPK with no basal	19.00	50.88	96.28	100.08	149.78
F4-75% NPK with 25% as basal	20.00	58.18	94.08	125.78	166.23
CD (0.05%)	**2.23**	**NS**	**NS**	**NS**	**NS**
Control	41.6	169.7	185.75	261.5	466.3
Interaction effects	**NS**	**12.22**	**NS**	**32.26**	**NS**

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Table 4.3(a): Interaction effect of growing condition and fertigation levels on number of leaves at 60 DAP

	F1	F2	F3	F4
G1	30.9	34.3	26.6	21.75
G2	72.1	71.05	75.15	94.6
CD (0.05%)	**12.22**			

Table 4.3(b): Interaction effect of growing condition and fertigation levels on number of leaves at 120 DAP

	F1	F2	F3	F4
G1	55.85	55.65	47.7	35.3
G2	180.05	150.65	152.45	216.25
CD (0.05%)	**32.26**			

4.1.4 Leaf area

Leaf area production had significance at 30, 60, 90 and 150 DAP (Table 4.4). Under growing conditions plants under open field had significantly higher leaf area during all growth stages except at 30 DAP. At 120 DAP leaf area was found to be not significant. Fertigation levels had significance on leaf area at 30 and 60 DAP and had no significance during the later stages. At 30 DAP 75% NPK with no basal resulted in higher leaf area and 100% NPK with no basal had significantly higher leaf area (1002.42 cm^2) at 60 DAP. Conventional method of water and fertilizer application had significantly superior leaf area compared to poly house and open field with fertigation. Interaction effects on leaf area was found to be significant at 60, 90 and 120 DAP. Application of 75% NPK with 25% as basal had lower leaf area under poly house than open field at all these stages. At 30 and 150 DAP interaction effect was not significant. In poly house G_1F_1 was superior at 60 and 120 DAP and G_1F_2 at 90 DAP. In the open G_2F_4 recorded significantly higher leaf area at 60 and 120 DAP and at 90 DAP, G_2F_1 was the best.

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Table 4.4: Effect of growing condition and fertigation levels on leaf area at different growth stages

Treatments	LEAF AREA (cm2)				
	Days after planting (DAP)				
	30	**60**	**90**	**120**	**150**
Growing conditions					
G1- Poly house	350.8	643.52	1,394.1	1,856.5	1,292.78
G2- Open field	127.8	971.459	2,077.7	2,425.7	9,799.46
CD (0.05%)	**40.77**	**159.71**	**446.41**	**NS**	**1,448.86**
Fertigation levels					
F1-100% NPK with no basal	214.2	1,002.4	2,118.4	2,046.3	5,975.23
F2-100% NPK with 25% as basal	189.8	711.16	1,817.5	1,783.5	5,234.00
F3-75% NPK with no basal	283.9	657.52	1,575.3	2,346.5	5,017.09
F4-75% NPK with 25% as basal	269.2	858.86	1,432.6	2,388.1	5,958.16
CD (0.05%)	**57.66**	**225.86**	**NS**	**NS**	**NS**
Control	572.2	2697.2	3,077.5	4,994	19,372.14
Interaction effects	**NS**	**319.41**	**892.82**	**1,314.0**	**NS**

Table 4.4(a): Interaction effect of growing condition and fertigation levels on leaf area at 60 DAP

	F1	**F2**	**F3**	**F4**
G1	1,159.16	620.70	501.65	292.57
G2	845.67	801.62	813.39	1,425.16
CD (0.05%)	**319.41**			

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Table 4.4(b): Interaction effect of growing condition and fertigation levels on leaf area at 90 DAP

	F1	F2	F3	F4
G1	1,447.49	1,748.87	1,615.35	764.73
G2	2,789.32	1,886.07	1,535.19	2,100.39
CD (0.05%)	**892.82**			

Table 4.4(c): Interaction effect of growing condition and fertigation levels on leaf area at 120 DAP

	F1	F2	F3	F4
G1	2,501.48	2,038.14	1,846.04	1,040.27
G2	1,591.12	1,528.77	2,846.98	3,736.00
CD (0.05%)	**1314.04**			

4.1.5 Root spread (cm)

Root spread had significant difference at 30, 60, 90 and 150 DAP. Root spread was significantly superior under poly house condition compared to open field. Lowest root spread recorded in conventional method (8.13 cm) at 30 DAP. Fertigation levels and interaction effect had no significance on root spread.

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Table 4.5: Effect of growing condition and fertigation levels on root spread at different growth stages

Treatments	ROOT SPREAD (cm)				
	Days after planting (DAP)				
	30	60	90	120	150
Growing conditions					
G1- Poly house	22	30.5	38.38	41	51.88
G2- Open field	11.88	11.69	26.31	36.19	43.13
CD (0.05%)	**4.89**	**5.22**	**4.35**	**NS**	**6.74**
Fertigation levels					
F1-100% NPK with no basal	13.13	18.63	30.13	37.75	52.13
F2-100% NPK with 25% as basal	14.75	21.50	28.88	38.13	49.25
F3-75% NPK with no basal	17.75	21.25	37.00	44.38	42.88
F4-75% NPK with 25% as basal	22.13	23.00	33.38	34.13	45.75
CD (0.05%)	**NS**	**NS**	**NS**	**NS**	**NS**
Control	8.13	12.25	32.75	24.50	35.75
Interaction effects	**NS**	**NS**	**NS**	**NS**	**NS**

4.1.6 Root depth (cm)

Growing conditions and fertigation levels had no significant effect on root depth in different growth stages. Fertigation levels and interaction effect was also found to be not significant.

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Table 4.6: Effect of growing condition and fertigation levels on root depth at different growth stages

Treatments	ROOT DEPTH (cm)				
	Days after planting (DAP)				
	30	60	90	120	150
Growing conditions					
G1- Poly house	5.31	4.25	13.63	10.94	11.81
G2- Open field	4.09	4.31	13.13	11.38	13
CD (0.05%)	**1.06**	**NS**	**NS**	**NS**	**NS**
Fertigation levels					
F1-100% NPK with no basal	4.13	4.63	13	9.25	13.25
F2-100% NPK with 25% as basal	4.56	4.5	13.75	11.25	11.38
F3-75% NPK with no basal	4.44	4	13.25	12.75	12
F4-75% NPK with 25% as basal	5.69	4	13.5	11.38	13
CD (0.05%)	**NS**	**NS**	**NS**	**NS**	**NS**
Control	4.5	4.25	14.5	10.25	13.5
Interaction effects	**NS**	**NS**	**NS**	**NS**	**NS**

4.1.7 Dry matter production (kg/ha)

Effect of growing conditions and fertigation levels on dry matter production at different stages was given in Table 4.8. Growing conditions had significance on dry matter production at 60, 120 and 150 DAP and during the initial growth period at 60 DAP dry matter production was significantly higher under poly house. During 120 and 150 DAP dry matter production was significantly higher under open field. Dry matter production was not significantly influenced by fertigation levels. None of the interaction effect showed significance on dry matter production.

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Table 4.7: Effect of growing condition and fertigation intervals on dry matter production at different growing stages

Treatments	DRY MATTER PRODUCTION (kg/ha)				
	Days after planting (DAP)				
	30	60	90	120	150
Growing conditions					
G1- Poly house	33.75	329.89	543.71	815.97	1109.37
G2- Open field	27.05	117.26	617.70	1309.02	2093.73
CD (0.05%)	**NS**	**84.93**	**NS**	**390.80**	**341.98**
Fertigation levels					
F1-100% NPK with no basal	25.35	244.65	505.97	1222.21	1690.96
F2-100% NPK with 25% as basal	23.82	255.07	625.97	1052.07	1690.96
F3-75% NPK with no basal	30.76	186.25	683.40	1114.57	1722.21
F4-75% NPK with 25% as basal	41.67	208.33	507.50	861.11	1302.07
CD (0.05%)	**NS**	**NS**	**NS**	**NS**	**NS**
Control	16.95	240.83	1,005.4	3,291.64	3,499.97
Interaction effects	**NS**	**NS**	**NS**	**NS**	**NS**

4.1.8 Relative leaf water content

Relative leaf water content was found to be significant at 30, 90 and 120 DAP under the growing conditions (Table.4.1.8). At 30 and 120 DAP relative leaf water content was significantly higher under open field condition than polyhouse. Fertigation levels had significance only at 150 DAP and in other stages found to be not significant. Application of 100% NPK with 25% as basal had significantly higher relative leaf water content. Crops grown under conventional fertilizer application had significantly superior relative leaf water content (77.89%) at 120 DAP compared to fertigated crops raised under polyhouse and open field. Interaction effects on relative leaf water content was found to be significant at 90

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and 120 DAP. Application of 75% NPK with 25% as basal resulted in superior relative leaf water content under polyhouse condition. In the open field 100% NPK with 25 % basal was superior to other fertigation levels.

Table 4.8: Effect of growing condition and fertigation levels on relative leaf water content at different growing stages

Treatments	Relative leaf water content (%)				
	Days after planting (DAP)				
	30	**60**	**90**	**120**	**150**
Growing conditions					
G1- Poly house	68.63	62.66	74.60	63.41	66.08
G2- Open field	74.45	63.42	68.50	70.60	66.44
CD (0.05%)	**4.45**	**NS**	**3.38**	**4.04**	**NS**
Fertigation levels					
F1-100% NPK with no basal	72.45	61.52	71.57	65.42	63.05
F2-100% NPK with 25% as basal	73.60	61.44	70.60	69.13	69.77
F3-75% NPK with no basal	72.08	63.77	71.68	66.80	65.41
F4-75% NPK with 25% as basal	68.03	65.43	72.35	66.67	66.82
CD (0.05%)	**NS**	**NS**	**NS**	**NS**	**4.575**
Control	75.58	68.72	71.82	77.89	62.30
Interaction effects	**NS**	**NS**	**6.75**	**8.08**	**NS**

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Table 4.8(a): Interaction effect of growing condition and fertigation intervals on relative leaf water content at 90 DAP

	F1	F2	F3	F4
G1	72.34	68.97	77.81	79.30
G2	70.80	72.24	65.55	65.40
CD (0.05%)	6.75			

Table 4.8(b): Interaction effect of growing condition and fertigation levels on relative leaf water content at 120 DAP

	F1	F2	F3	F4
G1	66.36	66.92	60.89	59.48
G2	64.48	71.35	72.70	73.86
CD (0.05%)	8.08			

4.1.9 Yield and yield attributes

4.1.9.1 Days to 50% flowering

Growing conditions and fertigation levels had significant influence on days to 50% flowering (Table.4.9).Crops raised under poly house condition showed earlier flowering compared to open field crops with fertigation. Fertigation levels had significance on days to 50% flowering. Application of 75% NPK with no basal was resulted in earlier flowering. Interaction effect had no significant influence on the time of 50% flower.

4.1.9.2 Number of fruits

Production of fruits in chilli was found significantly influenced by the growing conditions (Table 4.9). Plants grown under open field condition produced significantly more number of fruits (473.13) compared to poly house (44.44). Highest fruit production noticed in conventional method of fertilizer application compared to poly house and open field under fertigation. Fertigation levels and interaction effects was found to be not significant on number of fruits.

4.1.9.3 Fruit weight (g/fruit)

Effect of growing condition and fertigation levels was found to be not significant on fruit weight. Interaction effects were also not significant on fruit weight.

Table 4.9: Effect of growing conditions and fertigation levels on yield attributes

Treatments	Days to 50% flowering	Number of fruits	Fruit weight (g/fruit)
Growing conditions			
G1- Poly house	46.75	44.44	1.78
G2- Open field	53.94	473.13	1.86
CD (0.05%)	**1.82**	**94.44**	**NS**
Fertigation levels			
F1-100% NPK with no basal	54.75	317.13	1.76
F2-100% NPK with 25% as basal	55.00	195.88	1.84
F3-75% NPK with no basal	45.38	266.00	1.84
F4-75% NPK with 25% as basal	46.25	256.13	1.83
CD (0.05%)	**2.57**	**NS**	**NS**
Control	42.25	806	2.03
Interaction effects	**NS**	**NS**	**NS**

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4.1.9.4 Per plant yield (kg/plant)

Growing condition had significance on per plant yield given in Table 4.10. Under growing conditions, significantly higher per plant yield was obtained from open field (0.85 kg/plant) than crops grown under poly house (0.08 kg/plant). Per plant yield was higher for conventional method of fertilizer application compared to poly house and open field. Fertigation levels and interaction effect had no significance on per plant yield.

4.1.9.5 Yield (kg/ha)

Yield obtained from chilli under different growing conditions are presented in table 4.10. Crops grown under open field had significantly higher yield (7643.70 kg/ha) than under poly house condition. Effect of fertigation levels was found not significant on yield. Chilli grown under conventional method of water and fertilizer application resulted in significantly superior yield (15,345.32 kg/ha) compared to poly house and open field under fertigation. Interaction effects had significance on yield. Open field had significantly higher yield at all fertigation levels compared to poly house. Application of 75% NPK with 25% as basal resulted significantly superior yield in open field condition.

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Table 4. 10: Effect of growing conditions and fertigation levels on yield

Treatments	Per plant yield (kg/plant)	Yield (kg/ha)
Growing conditions		
G1- Poly house	0.08	799.742
G2- Open field	0.85	7,643.70
CD (0.05%)	**0.18**	**639.15**
Fertigation levels		
F1-100% NPK with no basal	0.53	4,130.33
F2-100% NPK with 25% as basal	0.36	3,703.80
F3-75% NPK with no basal	0.49	4,139.52
F4-75% NPK with 25% as basal	0.47	4,913.23
CD (0.05%)	**NS**	**NS**
Control	1.60	15,345.42
Interaction effects	**NS**	**1,278.30**

Table 4.10(a): Interaction effects of growing condition and fertigation levels on yield (kg/ha)

	F1	F2	F3	F4
G1	827.447	845.663	1,087.45	438.411
G2	7,433.21	6,561.95	7,191.59	9,388.06
CD (0.05%)	**1278.3**			

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4.1.10 Water productivity (kg/hacm)

Effect of growing conditions and fertigation levels on water productivity of chilli is given in table 4.11. Chilli grown under open field condition showed significantly higher water productivity compared to poly house. Fertigation levels had significance on water productivity. Application of 75% NPK with 25% as basal resulted in significantly higher water productivity compared to other fertigation levels. Crops under conventional method of water and fertilizer application had significantly superior water productivity 210.03 kg/hacm. Interaction effect was found to be significant on water productivity. Application of 75% NPK with 25% as basal recorded the highest water productivity under open field condition.

4.1.11 Nutrient use efficiency (kg/kg NPK)

Nutrient use efficiency was found to be significant under growing conditions given in table 4.11. Crops under open field condition showed significantly higher nutrient use efficiency (97.37 kg/kg NPK) compared to poly house. Fertigation levels had significance on nutrient use efficiency. Application of 75% NPK with 25% as basal had significantly higher nutrient use efficiency compared to other fertigation levels. Conventional method of fertilizer application under open field resulted in significantly superior nutrient use efficiency 195.48. Interaction effect was found to be significant on nutrient use efficiency. Application of 75% NPK with 25% as basal was recorded the highest nutrient use efficiency under open field condition.

Table 4.11: Effect of growing conditions and fertigation levels on Water productivity and Nutrient Use Efficiency (NUE)

Treatments	Water productivity (kg/ha-cm)	Nutrient use efficiency (kg/kg NPK)
Growing conditions		
G1- Poly house	10.16	8.06
G2- Open field	141.82	97.37
CD (0.05%)	**11.32**	**7.89**
Fertigation levels		
F1-100% NPK with no basal	74.22	51.51
F2-100% NPK with 25% as basal	66.25	46.06
F3-75% NPK with no basal	73.62	51.28
F4-75% NPK with 25% as basal	89.88	62.01
CD (0.05%)	**16.01**	**11.16**
Control	210.03	195.48
Interaction effects	**22.65**	**15.78**

Table 4.11(a): Interaction effects of growing condition and fertigation levels on water productivity (kg/ha-cm)

	F1	F2	F3	F4
G1	10.51	10.75	13.82	5.57
G2	137.92	121.75	133.43	174.19
CD (0.05%)	**22.65**			

Table 4.11(b): Interaction effects of growing condition and fertigation levels on nutrient use efficiency

	F1	F2	F3	F4
G1	8.34	8.52	10.96	4.42
G2	94.69	83.59	91.61	119.60
CD (0.05%)	**15.78**			

4.2 SOIL CHARACTERISTICS

4.2.4 Soil pH

Effect of growing condition and fertigation levels on soil pH is given in Table 4.12. Initial soil pH was found to be more acidic than post soil pH. Under growing conditions soil pH was significantly higher under poly house compared to open field. Fertigation levels had significance on soil pH. Application of 100% NPK with 25% as basal had significantly higher soil pH. Interaction effect was not significant on soil pH.

4.2.1 Soil organic carbon content (%)

Effect of growing condition and fertigation levels on organic carbon content is given in table 4.12. Under growing conditions significantly higher organic carbon content was found under open field compared to poly house. Fertigation levels had significant influence on soil organic carbon. Application of 100% NPK with no basal was resulted in significantly higher organic carbon content. Soil under conventional method of fertilizer application had significantly superior organic carbon (0.99%) than that of soil under fertigation. Organic carbon content in the soil became highly reduced under poly house and open field after the conduct of experiment. Interaction effect was found not significant on organic carbon content in the soil.

4.2.2 Phosphorus content (kg/ha)

Growing condition had significance influence on phosphorus content in the soil Table.4.12. Soil taken after the trial from open field had significantly higher phosphorus content than that of the soil from poly house. Fertigation levels had significance on phosphorus level in the soil after the trial. Application of 75% NPK with 25% as basal resulted in significantly higher phosphorus in the soil. Soil under conventional method of fertilizer application had significantly higher phosphorus content (34.87 kg/ha) than that of the fertigated soil after the trial. After the conduct of experiment soil phosphorus declined from initial phosphorus level. Interaction effects of growing condition and fertigation levels were significant on post soil phosphorus content. Application of 100% NPK with no basal resulted in significantly higher phosphorus content under open field condition than soil taken from poly house.

4.2.3 Potassium content (kg/ha)

Potassium content in the soil was significantly influenced by the growing conditions (Table 4.12). Soil taken from open field had significantly higher potassium content than poly house. Fertigation levels and interaction effects were not significant on post soil potassium content. Final potassium content was higher than that of the initial soil K content.

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Table4.12: Effect of growing conditions and fertigation levels soil pH, organic carbon and nutrient status of the soil

Treatments	Soil pH	Final O.C content (%)	Phosphorus content (kg/ha	Potassium content (kg/ha)
Growing conditions				
G1- Poly house	6.02	0.83	12.28	324.47
G2- Open field	5.42	0.92	26.13	387.35
CD (0.05%)	**0.22**	**0.06**	**1.63**	**59.11**
Fertigation levels				
F1-100% NPK with no basal	5.38	0.95	20.02	370.35
F2-100% NPK with 25% as basal	5.93	0.81	17.89	351.15
F3-75% NPK with no basal	5.76	0.82	16.89	371.63
F4-75% NPK with 25% as basal	5.81	0.90	22.03	330.51
CD (0.05%)	**0.31**	**0.09**	**2.31**	**NS**
Control	5.05	0.99	34.87	375.34
Interaction effects	**NS**	**NS**	**3.26**	**NS**
Initial soil analysis				
G1- Poly house	4.79	2.07	18.32	244.94
G2- Open field	4.67	1.68	36.13	292.38

Table 4.12(a): Interaction effect of growing condition and fertigation levels on Phosphorus (kg/ha) in soil

	F1	F2	F3	F4
G1	10.69	9.48	8.37	20.59
G2	29.34	26.29	25.42	23.45
CD (0.05%)	**3.26**			

4.2.5 Soil moisture content (%)

Soil moisture content had significant difference at two weeks intervals of soil sampling from two growing conditions and on second interval it was not significant (Table 4.13). Under growing conditions poly house had higher soil moisture content at first interval and on later intervals higher soil moisture content was found under open field. Fertigation levels had significance on soil moisture only at IIIrd and IVth intervals. Application of 100% NPK with no basal had significantly superior soil moisture at third and fourth intervals. Interaction effect was found to be significant on soil moisture only at first interval. Application of 100% NPK with 25% as basal resulted in higher soil moisture under poly house.

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Table 4.13: Effect of growing condition and fertigation levels on soil moisture at different intervals

Treatments	Soil moisture content (%)				
	15 days	**30 days**	**45 days**	**60 days**	**75 days**
Growing conditions					
G1- Poly house	16.82	16.186	13.168	10.137	9.522
G2- Open field	12.893	15.124	15.906	13.486	12.899
CD (0.05%)	**2.984**	**NS**	**1.51**	**1.176**	**1.963**
Fertigation levels					
F1-100% NPK with no basal	13.436	14.659	16.365	13.08	13.379
F2-100% NPK with 25% as basal	18.089	15.205	14.174	11.31	11.264
F3-75% NPK with no basal	12.874	16.545	14.281	12.298	10.363
F4-75% NPK with 25% as basal	15.028	16.211	13.328	10.558	9.839
CD (0.05%)	**NS**	**NS**	**2.136**	**1.663**	**NS**
Control	12.273	13.103	10.53	10.165	9.715
Interaction effects	**5.968**	**NS**	**NS**	**NS**	**NS**

Table 4.13(a): Interaction effect of growing condition and fertigation levels on soil moisture at first interval

	F1	**F2**	**F3**	**F4**
G1	13.535	24.275	15.103	14.368
G2	13.338	11.903	10.645	15.688
CD (0.05%)	**5.97**			

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4.3 WEATHER OBSERVATIONS

4.3.1 Soil temperature (°C)

Effect of growing condition and fertigation levels on soil temperature at two weeks intervals is given in Table 4.14. Under growing condition significantly higher soil temperature was recorded under open field at all intervals than poly house. Fertigation levels had significance on soil temperature at third interval only. Application of 100% NPK with 25% as basal resulted in slightly higher soil temperature and other fertigation levels had almost same soil temperature. Interaction effect was found to be significant on soil temperature at fourth interval. Other intervals found to be not significant.

Table 4.14: Effect of growing condition and fertigation levels on soil temperature at different intervals

Treatments	Soil temperature (°C)				
	15 days	**30 days**	**45 days**	**60 days**	**75 days**
Growing conditions					
G1- Poly house	29.25	29.63	29.73	28.98	31.13
G2- Open field	29.94	30.18	30.08	31.10	32.58
CD (0.05%)	**0.39**	**0.29**	**NS**	**0.44**	**0.56**
Fertigation levels					
F1-100% NPK with no basal	29.65	29.80	29.99	30.01	31.44
F2-100% NPK with 25% as basal	29.65	30.00	30.19	30.04	31.81
F3-75% NPK with no basal	29.73	30.00	30.04	30.40	32.06
F4-75% NPK with 25% as basal	29.36	29.81	29.40	29.70	32.11
CD (0.05%)	**NS**	**NS**	**0.559**	**NS**	**NS**
Control	30.6	30.3	30.425	30.45	31.5
Interaction effects	**NS**	**NS**	**NS**	**0.89**	**NS**

Table 4.14(a): Interaction effect on growing condition and fertigation levels on soil temperature at 60 days

	F1	F2	F3	F4
G1	28.625	28.875	28.475	29.925
G2	31.4	31.2	32.325	29.475
CD (0.05%)	**0.89**			

4.3.2 Maximum temperature (°C)

Growth parameters such as plant height, number of branches, number of leaves, leaf area, root depth and dry matter production was negatively correlated with maximum temperature during the cropping period (Table.4.15). Increase in maximum temperature inside the poly house decreased these growth parameters. But root spread showed positive correlation with maximum temperature. Increase in maximum temperature, increased spread of roots of the plants inside the poly house with fertigation than open field with fertigation and conventional fertilizer application. Yield and yield attributes were also found to be negatively correlated with maximum temperature (Table.4.16). Increase in maximum temperature decreased production of chilli under poly house with fertigation than open field with both fertigation and conventional fertilizer application.

4.3.3 Minimum temperature (°C)

Minimum temperature was found to be negatively correlated with growth parameters, yield and yield attributes (Table.4.15) and (Table 4.16) except root spread which showed positive correlation with minimum temperature. Increase in minimum temperature decreased the production of all growth parameters inside the polyhouse which in turn decreased the production of yield attributes there by the production of chilli.

4.3.4 Relative humidity (%)

Relative humidity was found to be negatively correlated with growth and yield parameters except root spread which showed positive correlation with relative humidity. Increase in relative humidity inside the poly house decreased growth parameters, such as plant height, production of leaves, number of branches, leaf area and dry matter production. This in turn decreased the production of yield attributes and yield of chilli under polyhouse than chilli under open field condition.

4.3.5 Rain fall (mm)

Growth and yield parameters were found to be positively correlated with rain fall except root spread which was found to be negatively correlated with rain fall. Crops grown under open field received south west monsoon during the cropping period which was absent in chilli under poly house. So chilli receiving more amount of water through rain fall showed increase in growth parameters and yield attributes under open field with and without fertigation. Thus increase in production of chilli under open field with conventional method of fertilizer application and open field with fertigation than chilli under polyhouse with fertigation.

4.3.6 Soil temperature (°C)

Growth parameters such as plant height, root spread and root depth showed negative correlation with soil temperature (Table. 4.15). Increase in soil temperature decreased plant height of crops grown under open field with fertigation than chilli grown under open field with conventional method of fertilizer application and polyhouse with fertigation. Like that decrease in soil temperature increased root spread of the crop under poly house with fertigation. Other growth parameters and yield and yield attributes found to be in positive correlation with soil temperature.

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4.3.7 Canopy temperature (°C)

Canopy temperature showed negative correlation with growth and yield parameters except root spread which was found to be in positive correlated with canopy temperature. Increase in leaf temperature inside the poly house with fertigation decreased production of growth contributing parameters which negatively reflected in reduction in production of chilli than chilli under open field.

4.3.8 Photo synthetically Active Radiation (PAR) (μmol m^2 s^{-1})

PAR showed positive correlation with growth parameters such as number of leaves, production of branches, leaf area, root depth and dry matter production. Increase in photo synthetically active radiation under open field condition increased all these parameters. Plant height and root spread showed negative correlation with PAR. Yield and yield attributes showed positive correlation with PAR. Increase in PAR under open field increased the production of chilli under open field with fertigation and open field with conventional method of fertilizer application than poly house with fertigation.

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Table. 4.15: Effect of weather parameters on growth parameter

	Maximum Temperature (°C)	Minimum Temperature (°C)	Relative humidity (%)	Rain fall (mm)	soil temperature (°C)	Canopy Temperature (°C)	PAR (µmol m2 s-1)
Plant height (cm)	-0.43	-0.43	-0.43	0.43	-0.35	-0.26	-0.17
Number of branches	-0.94	-0.94	-0.94	0.94	0.40	-0.86	0.57
Number of leaves	-0.88	-0.88	-0.88	0.88	0.28	-0.79	0.45
Leaf area (cm2)	-0.85	-0.85	-0.85	0.85	0.21	-0.74	0.39
Root spread (cm)	0.89	0.89	0.60	-0.89	-0.29	0.79	-0.46
Root depth (cm)	-0.96	-0.96	-0.96	0.96	-0.29	-0.89	0.62
Dry matter production (kg/ha)	-0.81	-0.81	-0.81	0.81	0.15	-0.69	0.33

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Table. 4.16: Effect of weather parameters on yield and yield attributes

	Maximum Temperature (°C)	Minimum Temperature (°C)	Relative humidity (%)	Rain fall (mm)	soil temperature (°C)	Canopy Temperature (°C)	PAR (µmol m2 s-1)
Days to 50% flowering	-0.13	-0.13	-0.13	0.13	0.80	-0.31	0.68
Number of fruits	-0.90	-0.90	-0.90	0.90	0.31	-0.81	0.49
Per plant yield (kg/plant)	-0.87	-0.87	-0.87	0.87	0.25	-0.77	0.43
Yield (kg/ha)	-0.85	-0.85	-0.85	0.85	0.21	-0.74	0.39

4.4 PLANT ANALYSIS

4.4.1 Nitrogen uptake in plants (kg/ha)

Growing condition had significant influence on nitrogen uptake by plants at 150 DAP Table.4.4. Plants grown under open field condition had significantly higher nitrogen uptake compared to poly house. At 90 and 120 DAP effect of growing condition was not significant on nitrogen uptake. Crops raised under conventional method of fertilizer application showed superior nitrogen content compared to poly house and open field under fertigation (Table 4.17). Fertigation levels had no significant effect on nitrogen uptake in all growth stages. Interaction effects were found to be significant only at 90 DAP. Application of 75% NPK with no basal resulted in significantly higher nitrogen uptake by plants under poly house.

Table 4.17: Effect of growing conditions and fertigation levels on nitrogen uptake (kg/ha) in plants at different growing stages

Treatments	NITROGEN UPTAKE IN PLANTS (kg/ha)		
	Days after planting (DAP)		
	90	120	150
Growing conditions			
G1- Poly house	15.63	20.49	29.50
G2- Open field	14.42	24.15	42.90
CD (0.05%)	**NS**	**NS**	**9.98**
Fertigation levels			
F1-100% NPK with no basal	12.22	28.66	41.51
F2-100% NPK with 25% as basal	15.89	18.50	38.85
F3-75% NPK with no basal	20.15	23.27	36.61
F4-75% NPK with 25% as basal	11.83	18.85	27.85
CD (0.05%)	**NS**	**NS**	**NS**
Control	27.68	78.71	56.19
Interaction effects	**11.44**	**NS**	**NS**

Table 4.17(a) Interaction effects of growing condition and fertigation levels on nitrogen uptake in plants at 90 DAP

	F1	F2	F3	F4
G1	8.055	14.053	28.77	11.645
G2	16.38	17.733	11.528	12.023
CD (0.05%)	**11.44**			

4.4.2 Phosphorus uptake by plants (kg/ha)

Phosphorus uptake by plants was found significantly influenced by the growing conditions (Table 4.18). At 120 and 150 DAP, plants grown under open field had significantly higher phosphorus uptake when compared with poly house. Fertigation levels had no significance on all growth stages. Crops under conventional method of fertilizer application exhibited significantly superior uptake of phosphorus compared to poly house and open field under fertigation. Interaction effect was found significant at 150 DAP and at other growing stages found to be not significant. Application of 75% NPK with no basal dose had significantly higher phosphorus uptake under open field condition compared to poly house.

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Table 4.18: Effect of growing conditions and fertigation levels on phosphorus uptake (kg/ha) in plants at different growing stages

Treatments	PHOSPHORUS UPTAKE IN PLANTS (kg/ha)		
	Days after planting (DAP)		
	90	**120**	**150**
Growing conditions			
G1- Poly house	1.72	2.98	4.08
G2- Open field	2.18	6.94	8.20
CD (0.05%)	**NS**	**1.87**	**1.81**
Fertigation levels			
F1-100% NPK with no basal	2.04	5.95	5.83
F2-100% NPK with 25% as basal	2.23	5.41	5.61
F3-75% NPK with no basal	2.26	5.19	8.01
F4-75% NPK with 25% as basal	1.27	3.31	5.12
CD (0.05%)	**NS**	**NS**	**NS**
Control	5.33	14.27	15.81
Interaction effects	**NS**	**NS**	**3.61**

Table 4.18(a): Interaction effects of growing condition and fertigation levels on phosphorus uptake in plants (kg/ha) at 150 DAP

	F1	**F2**	**F3**	**F4**
G1	2.978	6.558	4.2	2.588
G2	8.673	4.658	11.81	7.643
CD (0.05%)	**3.61**			

4.4.3 Potassium uptake by plants (Kg/ha)

Effect of growing condition and fertigation levels on potassium uptake by plants is given in Table.4.19. Growing conditions had significant influence on potassium uptake at 120 and 150 DAP. Plants raised under open field condition w showed significantly higher potassium uptake at these growing stages compared to poly house. Conventional method of fertilizer application resulted in significantly superior uptake of potassium by the plants grown under poly house and open field with fertigation. Fertigation levels were not significant on potassium uptake at any of the stages. Interaction effect was found to be significant only at 150 DAP and at other stages was not significant. Application of 100% NPK with no basal had significantly higher and lower values under open field and poly house conditions respectively.

4.19 Effect of growing conditions and fertigation levels on potassium uptake (kg/ha) in plants at different growing stages

Treatments	POTASSIUM UPTAKE IN PLANTS (kg/ha)		
	Days after planting (DAP)		
	90	120	150
Growing conditions			
G1- Poly house	22.36	36.16	46.03
G2- Open field	20.20	52.19	100.10
CD (0.05%)	**NS**	**15.6**	**24.37**
Fertigation levels			
F1-100% NPK with no basal	21.21	49.53	81.62
F2-100% NPK with 25% as basal	17.79	50.63	73.25
F3-75% NPK with no basal	27.31	43.46	81.56
F4-75% NPK with 25% as basal	18.81	33.07	55.83
CD (0.05%)	**NS**	**NS**	**NS**
Control	41.97	190.52	148.04
Interaction effects	**NS**	**NS**	**48.73**

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Table 4.19(a): Interaction effects of growing conditions and fertigation levels on potassium uptake in plants (kg/ha) at 150 DAP

	F1	F2	F3	F4
G1	26.275	72.573	53.28	31.983
G2	136.958	73.933	109.84	79.683
CD (0.05%)	**48.73**			

4.5 ECONOMICS OF CHILLI PRODUCTION

The data pertaining to the economics of production of chilli in terms of total variable cost, gross return, net return and B : C ratio were significantly influenced by different treatments and growing conditions is given in table 4.20. The cost of cultivation of chilli was significantly higher in conventional method of fertilizer application followed by poly house. Application of 75% NPK with 25% as basal showed significantly lower cost.

The crops grown under open field had significantly higher gross return than poly house. Fertigation levels were not significant on gross return. Interaction effect was found to be significant. Application of 75% NPK with 25% as basal provided significantly the highest gross return.

Net returns from the crop was found to be significantly higher under open field condition compared to poly house. Crops grown under conventional method of irrigation and fertilizer application had significantly superior net return (855,559 Rs ha^{-1}) than open field with fertigation. Fertigation levels were found to be not significant on net return.. Interaction effect was significant on net return from chilli production. Application of 75% NPK with 25% as basal resulted in significantly higher net return from chilli produced under open field condition.

Benefit cost ratio was significantly influenced by growing conditions and fertigation levels. B:C ratio was found to be significantly higher under open field than poly house. Fertigation levels also had significant influence on B:C ratio.

Application of 75% NPK with 25% as basal had significantly higher benefit cost ratio. Crops under conventional method of fertilizer application had significantly superior benefit cost ratio compared to open field with fertigation. Interaction effect was found to be significant on benefit cost ratio. Application of 75% NPK with 25% as basal had significantly higher benefit cost ratio under open field condition.

Table 4.20: Effect of growing conditions and fertigation levels on economics of production

Treatments	Cost (Rs/ha)	Gross return (Rs/ha)	Net return	B : C Ratio
Growing conditions				
G1- Poly house	62329	47985	-14344	0.766
G2- Open field	59599	458622	399023	7.715
CD (0.05%)		**38349**	**38349**	**0.647**
Fertigation levels				
F1-100% NPK with no basal	63777	247820	184043	3.99
F2-100% NPK with 25% as basal	61011	222228	161217	3.709
F3-75% NPK with no basal	60612	248371	187760	4.165
F4-75% NPK with 25% as basal	58456	294794	236338	5.099
CD (0.05%)		**NS**	**NS**	**0.915**
Control	65166	111393	855559	14.13
Interaction effects		**76698**	**76698**	**1.294**

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Table 4.20(a): Interaction effect of growing conditions and fertigation levels on gross return

	F1	F2	F3	F4
G1	49,647	50,740	65,247	26,305
G2	445,993	393,717	431,495	563,283
CD (0.05%)	**76,698**			

Table 4.20(b): Interaction effects of growing conditions and fertigation levels on net return

	F1	F2	F3	F4
G1	-16,204	-11,645	3,330	-32,856
G2	384,291	334,080	372,189	505,532
CD (0.05%)	**76,698**			

Table. 4.20(c): Interaction effects of growing conditions and fertigation levels on B:C Ratio

	F1	F2	F3	F4
G1	0.753	0.815	1.053	0.445
G2	7.228	6.603	7.278	9.753
CD (0.05%)	**1.29**			

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DISCUSSION

Chapter 5

DISCUSSION

The present investigation entitled **"Microclimatic alteration on water productivity of Chilli (*Capsicum annum* L) under fertigation"** was conducted at Water Management Research Unit (WMRU), Vellanikkara, a sub centre of Agronomic Research Station (ARS) Chalakudy, during 4th February 2017 to 15th August 2017. The experiment was conducted in two growing conditions i.e., open field and poly house with four different ferigation levels and having one control with conventional method of irrigation and fertilizer application with 100% NPK as per POP. The experiment was laid out in RBD with four replications. The result of the study was discussed under the following as two sections.

5.1 Effect of growing condition on water productivity of chilli

5.2 Effect of fertigation levels on water productivity of chilli

5.1 Effect of growing conditions on water productivity of chilli

The result of the study revealed that growing conditions had significant influence on the yield and water productivity of chilli. Chilli grown under open field condition with fertigation as well as conventional method of fertilizer application produced significantly higher yield compared to crops grown under polyhouse with fertigation. Conventional method of water and nutrient application recorded the highest yield (15.35 t/ha) followed by open field condition with fertigation (Fig. 1). This may be due to higher quantity of irrigation water applied to the conventional method. Irrigation was given in conventional method of fertilizer application to wet the entire field and for fertigation treatments water was applied at 100% PE. The quantity of water applied under conventional method was 35.57% higher compared to fertigated fields. It was observed that all the growth parameters of number of branches (Fig. 2), number of leaves, leaf area (Fig. 3) and dry matter production (Fig.4) were superior under open field condition with fertigation and conventional fertilizer application with normal irrigation (Table

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4.1 to Table 4.4) than under polyhouse with fertigation. Improved growth parameters helped to tap more solar radiation and resulted in the production of more number of yield contributing characters such as number of fruits and per plant yield. Improved growth parameters coupled with yield parameters resulted in higher productivity of chilli under open condition. Kumar and Arumugam (2010) reported chillies grown under poly house performed better on growth characters like plant height and number of branches compared to open field condition during December 2009 to April 2010. In contrast to this report chilli grown under open field recorded higher growth and yield parameters. This may be due to micro climatic condition and water stress experienced during growing period under poly house condition. Under polyhouse, maximum and minimum temperature and canopy temperature were higher when compared to open field condition. The quantity of water applied to fertigate the crops under open field and poly house was based on 100% pan evaporation and the quantity of water applied was 1 litre per plant per day.

Crops raised under polyhouse recorded higher plant height during initial stages and then decreased at later stages. This may be due to the reason that initial water requirement could be met from the initial water supply but when the growing stages advanced water requirement under polyhouse was not sufficient for the growth due to higher temperature. Other growth parameters like number of branches, number of leaves and leaf area which recorded value in polyhouse resulted in reduced photosynthesis and dry matter production. All this parameters resulted in reduced yield under poly house condition with fertigation.

Plants grown under polyhouse condition significantly had higher root spread compared to open field. Increased root growth is on indication of the moisture stress during the period. Higher root spread noticed under polyhouse (Table. 4.5) also emphasised the stress condition prevailed in the polyhouse. Under this situation the plants produced more roots to tap the available moisture. Bauerle (2008) also reported that moisture stressed roots continue to grow in to deeper

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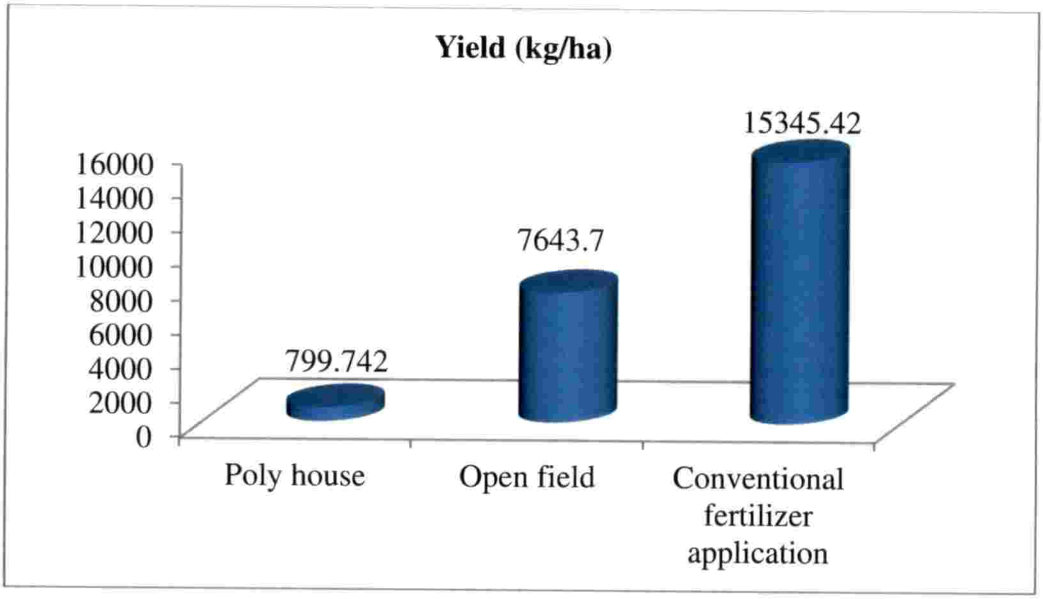

Fig. 1 Effect of growing condition on yield

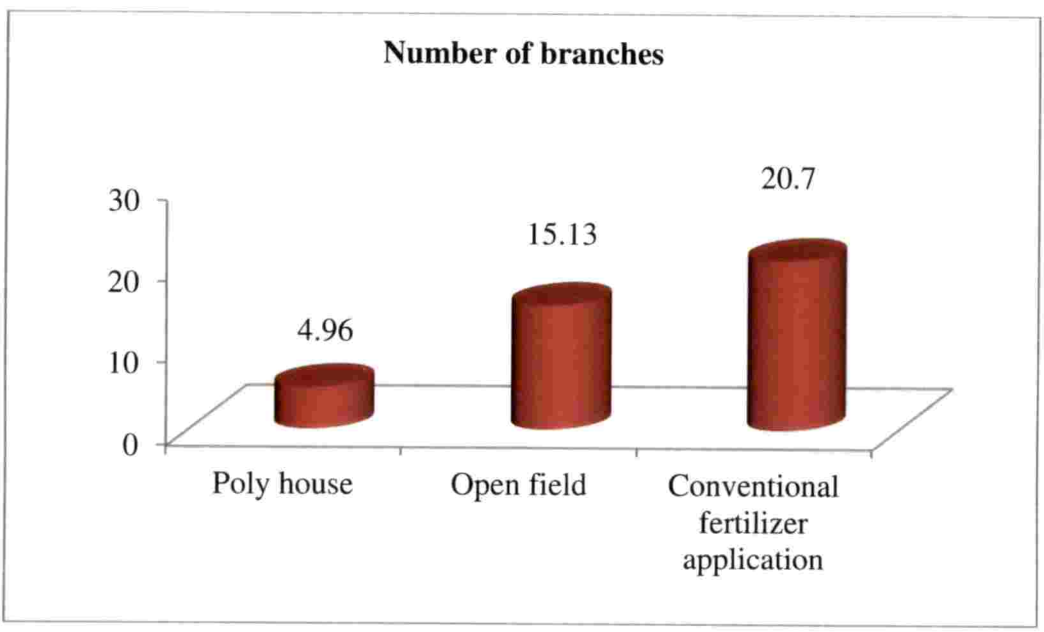

Fig.2. Effect of growing conditions on production of leaves

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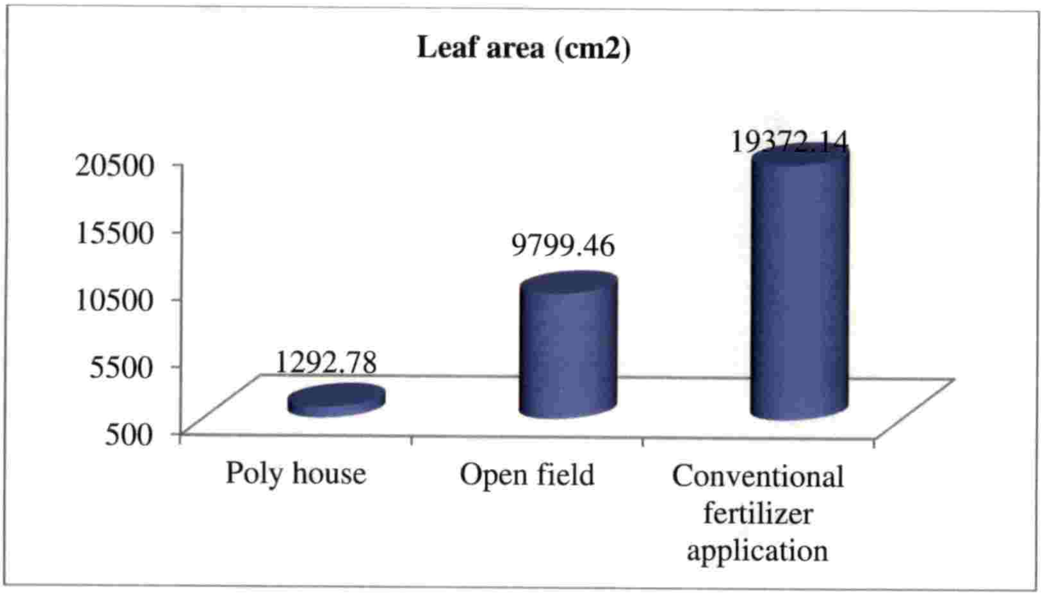

Fig.3 Effect of growing conditions on leaf area cm^2

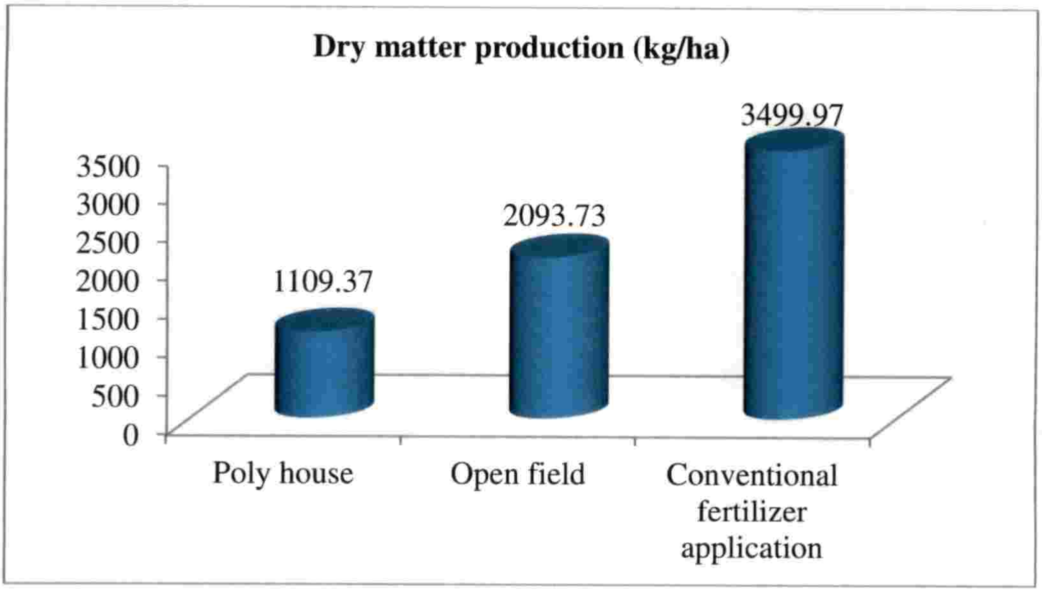

Fig.4 Effect of growing conditions on dry matter production

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strata of the soil in search of moisture, while the roots of the plants irrigated directly proliferate or spread in soil. The maximum temperature inside the polyhouse during the cropping period was found to be higher compared to open field weather condition (Fig.5). During the initial growing stages minimum temperature was found to be lesser in polyhouse but at the final stage it showed an increasing trend compared to open filed (Fig. 6). Relative humidity was found to be in same trend under open field and polyhouse condition (Fig. 7).

Soil moisture content inside the polyhouse was found to be higher at initial and it was found to be lower at later stages compared to open field with fertigation. It may be due to higher evaporation demand under the poly house. The soil temperature was found to increase from initial to later stage. The crop leaf temperature measured from polyhouse and open field using infra red thermometer showed higher value inside the polyhouse and this indicate a water stressed conditions (Fig. 8). In this experiment the growth period extended up to August, therefore during the fruiting stage the plants under open field with fertigation and conventional method of fertilizer application received South – West monsoon but the crops under poly house received only irrigation water. This might have also contributed more water stress under poly house.

Better tapping of sunlight with increased leaf area resulted in increased dry matter production in conventionally fertilized plants (Table 4.7) (Fig. 4). The high yield obtained from conventional method of fertilizer application showed that providing adequate nutrients at its initial stage helpful for better increase in all growth parameters. Higher leaf number and leaf area which increased photosynthetic surface and could capture more sunlight for better photosynthesis which resulted in more production of yield attributing characters like number of fruits, per plant yield and fruit yield under open field especially conventionally irrigated and fertilized crops.

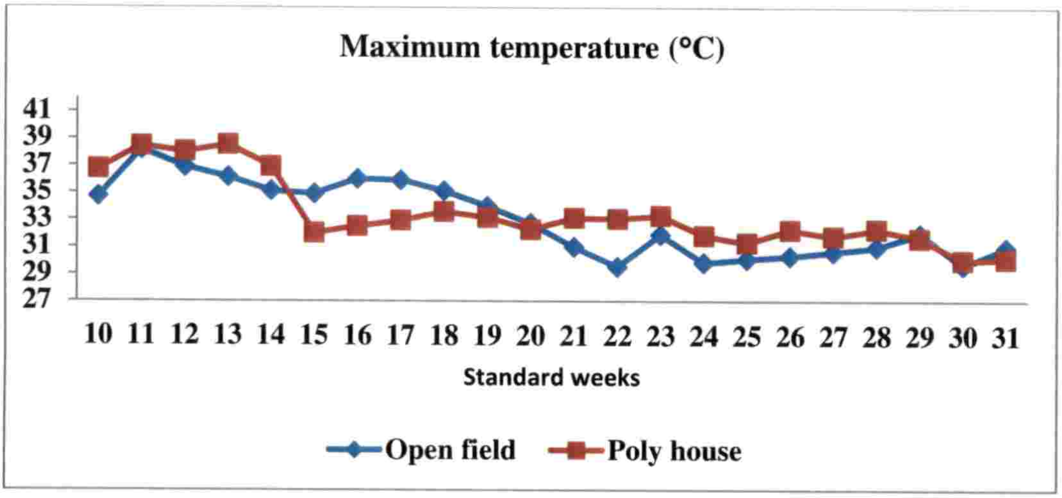

Fig. 5 Maximum temperature under open field and poly house during the experiment

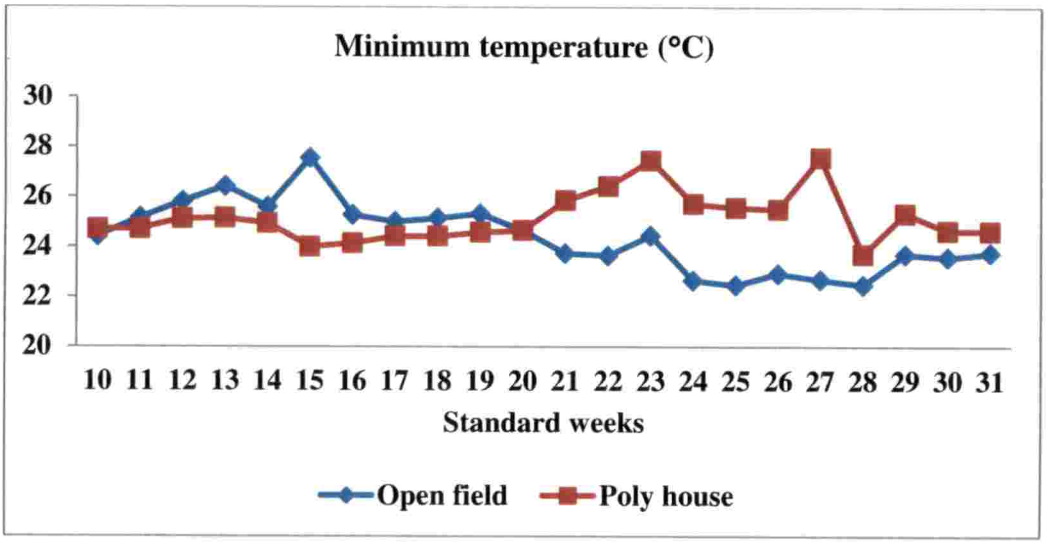

Fig. 6 Minimum temperature under open field and poly house during the experiment

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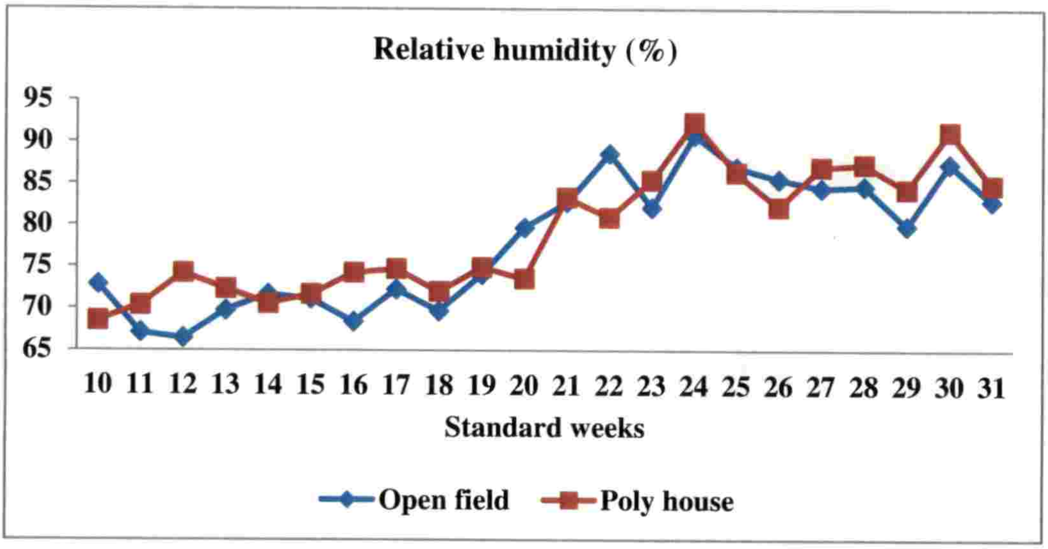

Fig. 7 Relative humidity under open field and poly house during the experiment

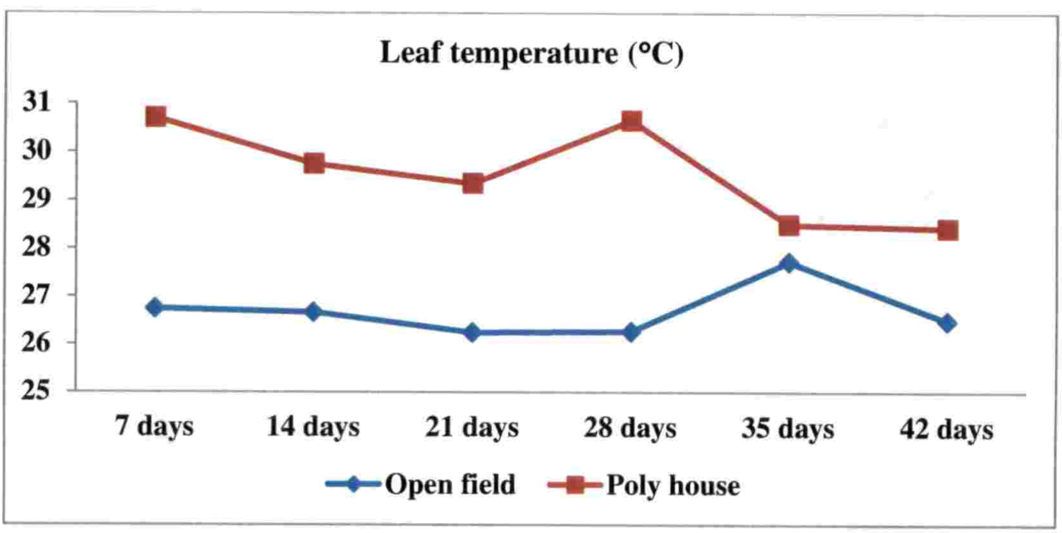

Fig. 8 Leaf temperature under open field and poly house

Total nutrients provided are effectively utilized by the plants under open field which further resulted in significantly superior yield in open field with conventional fertilizer.

The nutrients uptakes of plants were also higher under open field condition. Nutrient use efficiency was significantly superior for crops under control (195.48). This was due to the higher yield produced by plants under conventional method of fertilizer application.

From this result it is inferred that the growth and yield of chilli is better when the plants receive higher quantity of water. The quantity of water was fixed based on 100% PE for the fertigation. It was not sufficient to meet the growth requirement and to meet the evaporation demand of crop under poly house condition.

Soil organic carbon and available phosphorus after the experiment was found lesser under open field and poly house compared to initial soil O.C and soil phosphorus. Potassium content in the soil after the trial significantly increased in open field with fertigation and conventional method of fertilizer application and poly house with fertigation.

Water productivity and nutrient use efficiency (Fig. 11) under conventional method of irrigation and fertilizer application followed by open field with fertigation was found significantly higher compared to poly house plants receiving fertigation. This was due to the higher yield under open field condition.

Result of the study indicated that microclimatic condition prevailed during the growth period had significant influence on the growth and yield parameter of chilli.

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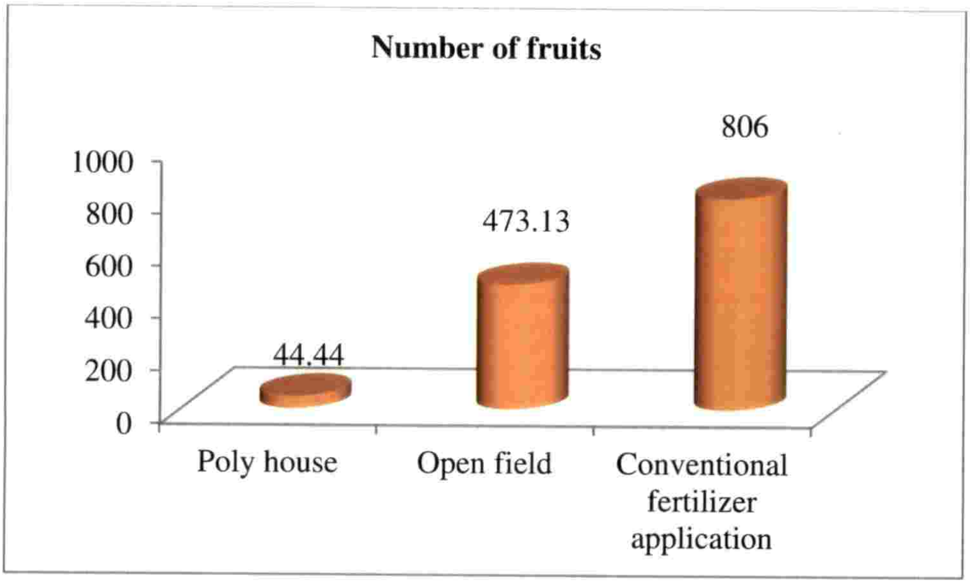

Fig.9 Effect of growing condition on production of fruits

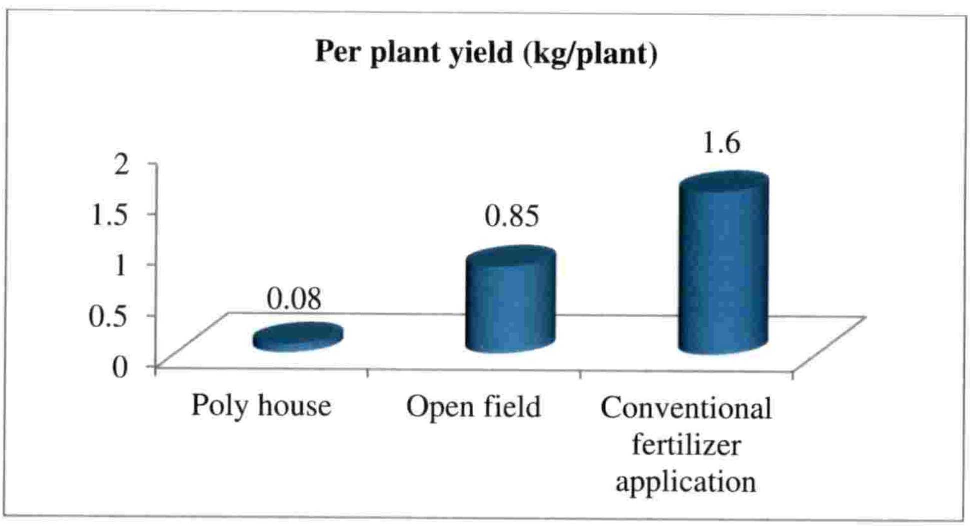

Fig. 10 Effect of growing condition on per plant yield

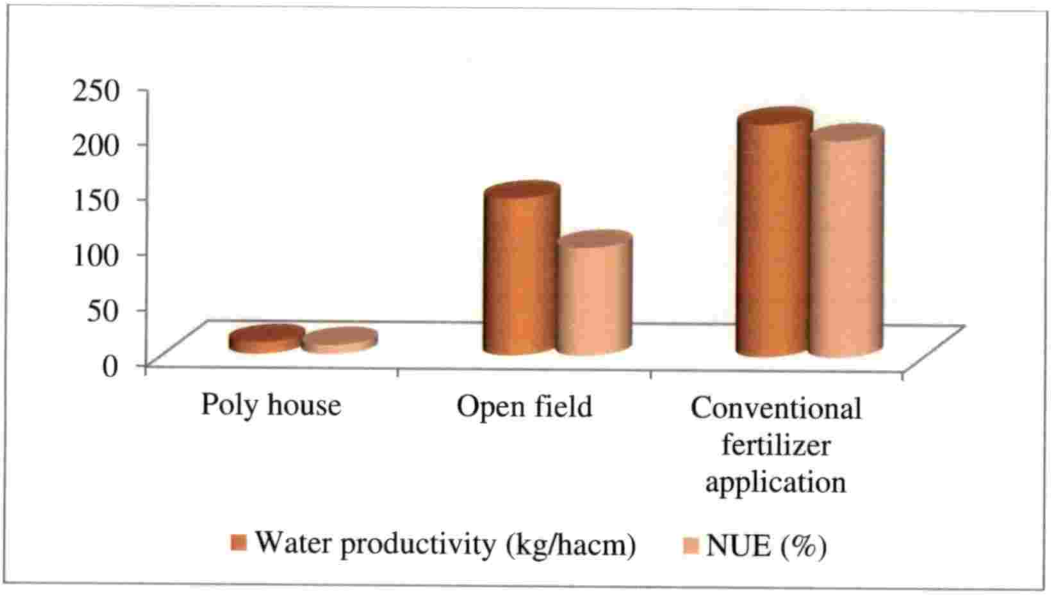

Fig.11 Effect of growing conditions on water productivity and nutrient use efficiency

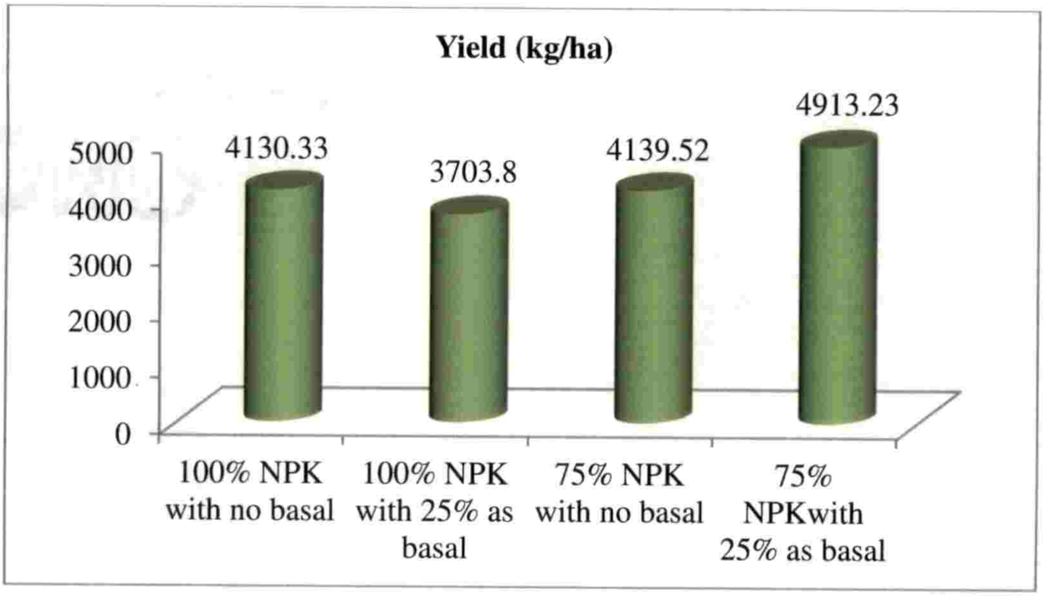

Fig. 12 Effect of fertigation levels on yield

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5.2 Effect of fertigation levels on water productivity of chilli

Results indicated that levels of fertigation showed no significant influence on the yield of chilli (Fig. 12). In this study four levels of fertigation that is application of 100% NPK with no basal, 100% NPK with 25% as basal, 75% NPK with no basal and 75% NPK with 25% as basal was given at 100% PE to open field and poly house plants with fertigation.

Growth characters, like plant height had significance only at 30, 120 and 150 DAP (Table.4.1). Production of branches per plant, production of leaves and leaf area (Fig. 14) had similar effect by the application of different fertigation levels. In this study it was observed that application of 100% NPK with no basal or with 25% as basal and application of 75% NPK with no basal or with 25% as basal had no significance on production of branches (Fig. 13).

Root spread, root depth and dry matter production (Fig. 15) also showed no significance difference with fertigation levels. Hence the yield (Fig. 12) was found on par with different fertilizer application.

Fertilizer application of 75% NPK with 25% as basal recorded significantly higher water productivity (89.88 kg/ha-cm) under open field compared to poly house. Conventional method of fertilizer application showed significantly higher yield which resulted in better water productivity (210.3 kg/ha.cm) and nutrient use efficiency (195.48kg/kg NPK) (Fig. 16).

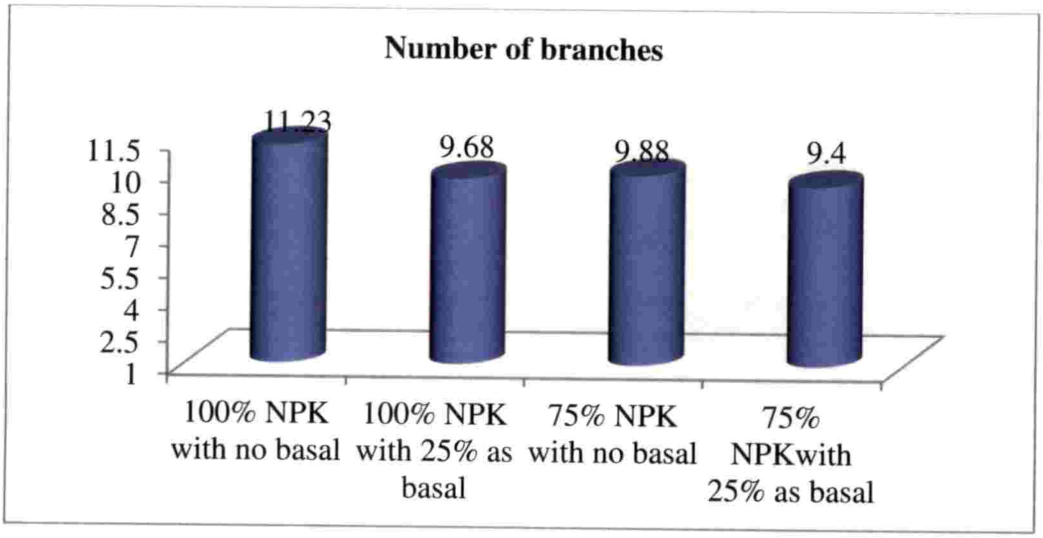

Fig.13 Effect of fertigation levels on production of branches

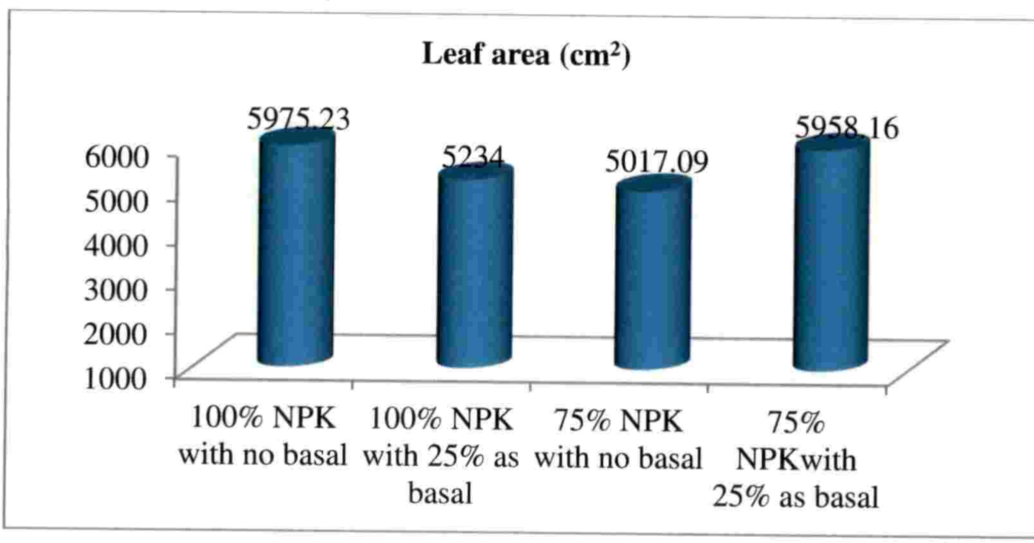

Fig. 14 Effect of fertigation levels on leaf area cm^2

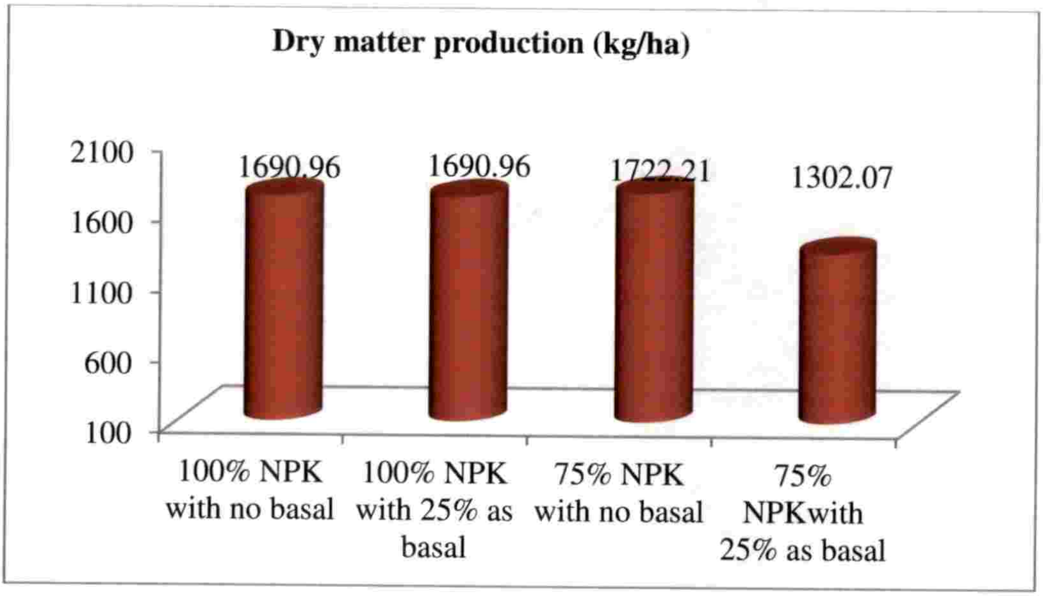

Fig.15 Effect of fertigation levels on dry matter production

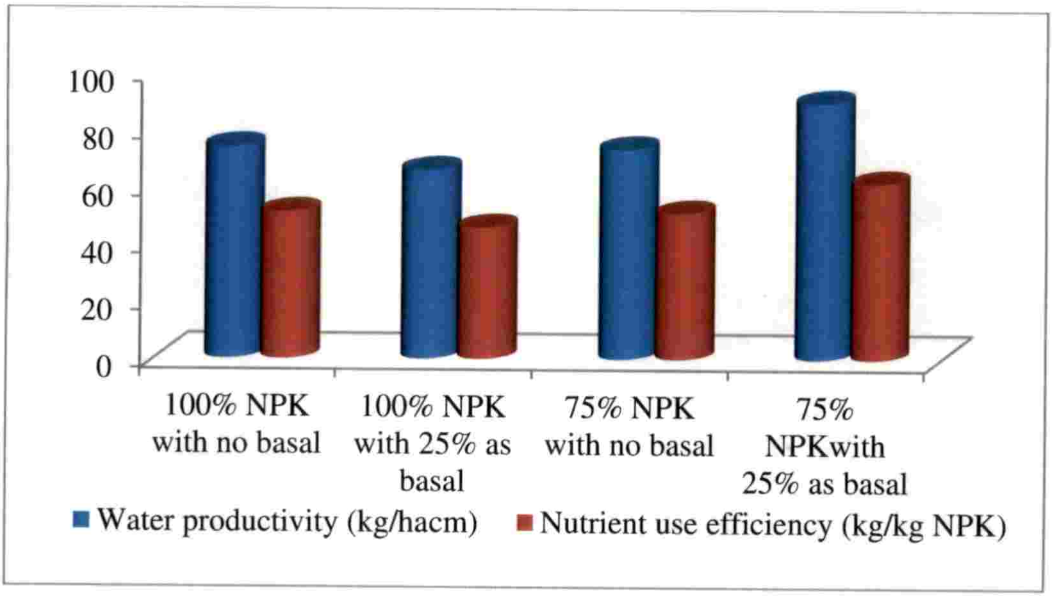

Fig. 16 Effect of fertigation levels on Water productivity and Nutrient use efficiency

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Uptake of NPK with different levels of fertilizer application showed no significant difference. Through fertigation providing lesser nutrients that is application of 75% NPK with 25% as basal is enough for the maximum production. So there will be a reduction of 25% of nutrients.

Interaction effects of growing conditions and fertigation levels had significant influence on growth parameters such as, number of branches, number of leaves and leaf area. The above parameters showed significantly higher production under open field with the application of 75% NPK with 25% as basal compared to poly house.

Increase in such growth parameters improved better vegetative growth of the crop thus in return produced better yield in open field compared with poly house. Interaction effects of growing condition and fertigation levels had no significance on root spread, root depth and also in dry matter production.

Application of 100% NPK with 25% as basal showed significantly higher soil moisture content inside the poly house compared to open field. Under poly house condition significantly higher plant water status found for the crops at 90 DAP having fertilizer application of 75% NPK with 25% as basal which is also similar for open field crops at 120 DAP.

Higher nutrient use efficiency was also found under open field condition having fertilizer application of 75% NPK with 25% as basal.

The yield, water productivity and nutrient use efficiency were not affected by the levels of fertigation. Hence it indicated that by giving fertigation we can reduce 25% of the fertilizer.

Interaction effects of growth and fertigation levels showed that fertigation levels having 75% NPK with 25% as basal resulted in higher yield under open field

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compared to poly house, while under poly house condition application of 75% NPK with no basal produced significantly higher yield. (Table 4.9)

Cost of production was significantly higher for conventional method of irrigation and fertilizer application under open field followed by poly house. The soluble fertilizers significantly had higher cost per kilogram, like 19:19:19 and ammonium phosphate. Gross return was significantly higher for crop grown under open field with conventional method of fertilizer application. Net return was also found to be significantly higher under open field with conventional method of fertilizer application followed by open field with fertigation. Benefit cost ratio was found to be significantly superior for conventional method of fertilizer application compared to poly house.

SUMMARY

Chapter 6

SUMMARY

A field experiment was conducted at Water Management Research Unit (WMRU) Vellanikkara, a sub centre of Agronomic Research Station (ARS) Chalakudy, during February 4 2017 to August 15 2017 to study the influence of Microclimatic alteration on water productivity of Chilli (*Capsicum annum* L) under fertigation.

The experiment was laid out in Randomised Block Design (RBD) with four replications. The treatments consisted of four fertigation levels with 100% NPK with no basal and with 25% as basal application, 75% NPK with no basal and with 25% as basal application under two growing conditions and having one control with conventional method of irrigation and fertilizer application with 100% NPK as per POP. Hence totally it consisted of nine treatment combinations.

The salient findings of the investigation are summarised below.

- Growing conditions significantly influenced the growth parameters of chilli. Chilli grown under conventional method of water and fertilizer application produced higher plant height, more number of branches, number of leaves and leaf area compared to chilli grown under open field received fertigation and chilli grown under poly house receiving fertigation.
- Production of leaves was significantly higher under open field condition than poly house. Maximum number of leaves (466.3) was recorded for the chilli grown under open field with conventional method of fertilizer application followed by open field with fertigation than poly house with fertigation.
- Leaf area was significantly higher for chilli grown under open field with fertigation and conventional method of fertilizer application. Maximum leaf area (19,372.14 cm^2) was recorded under conventional method of irrigation and fertilizer application followed by open field (9799.46 cm^2) with fertigation having 100% PE.

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- Root spread of chilli was found significantly higher under poly house conditions compared to open field with fertigation. It may be due to the moisture stress prevailed in the poly house condition.
- Dry matter production was significantly influenced by the growing conditions. Maximum dry matter production (3499.9 kg/ha) was recorded under open field with copious amount of water and 100% NPK through conventional method. Lowest dry matter production was recorded under poly house with fertigation.
- Earlier flowering is recorded for the crops grown under poly house condition than open field with fertigation. But yield contributing characters like number of fruits and per plant yield were higher under open field with conventional method of fertilizer application and were significantly superior to open field and poly house with fertigation.
- Maximum yield (15345.4 kg/ha) was recorded under conventional method of irrigation and fertilizer application followed by open field with fertigation. Chilli grown under conventional method of irrigation received more quality of water compared to chilli grown under fertigation either is the open field and poly house. Even though the quantity of water applied to conventional method was higher, water productivity and nutrient use efficiency was higher for conventional method of irrigation and fertilizer application due to significantly higher yield obtained. From the result it was observed that for better yield performance of chilli more quantity of water is needed. That is water application at100% PE is not sufficient to meet the water requirement.
- Soil pH, organic carbon and nutrient status of the soil were significantly influenced by the growing conditions. Soil pH and potassium content in the soil after the experiment was higher than that of the initial soil under both open field and poly house. Organic carbon and phosphorus content in the soil after the trial were found to be lesser than that of the initial value in two growing conditions.
- Weather parameters such as maximum temperature, minimum temperature, relative humidity and canopy temperature, PAR were found higher inside poly

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house than open field condition. Canopy temperature was higher under poly house (29.56°C) than open field (26.56°C) but photo synthetically active radiation was higher at the open field (4624.85 μmol m2 s-1) than poly house. Maximum soil temperature (32.58°C) was recorded in the open field with fertigation and lowest soil temperature (31.13°C) was found under poly house with fertigation. Higher maximum temperature, minimum temperature and canopy temperature etc might have reduced the yield of chilli under poly house.

- Nutrient uptake by the plants was significantly influenced by the growing conditions. Maximum uptake of nutrients, nitrogen, phosphorus and potassium (56.19 kg/ha, 15.81kg/ha and 148.04 kg/ha respectively) was recorded under open field with conventional method of fertilizer application than open field and poly house with fertigation.
- Fertigation levels given to chilli grown under either open field or poly house showed no significance variation on growth and yield performance. Growth parameter such as plant height, number of branches, number of leaves, leaf area, root spread, root depth, dry matter production and yield parameters such as number of fruits and per plant yield and yield of chilli were not significantly different under different fertigation levels. Hence the application of fertilizer through fertigation can be reduced by 25% without affecting the productivity of chilli.
- Fertigation levels significantly influenced the water productivity and nutrient use efficiency. Significantly higher WP (89.88 kg/hacm) and NUE (62.01kg/kg NPK) was recorded under fertigation with 75% NPK with 25% as basal.
- Nutrient uptake, soil pH, O.C, P and K of soil after the experiment was not affected by the application of different levels of fertigation.
- Net return and benefit cost ratio was found higher when chilli was grown under conventional method of fertilizer application followed by open field with fertigation. Net return was not significantly different under different fertigation levels. Benefit cost ratio was found significant by varying under

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fertigation levels. Application of 75% NPK with 25% as basal showed significantly higher B:C ratio.

- From the result it can be summarised that growth parameters, yield and water productivity had significant effect on chilli grown under open field condition during summer season.
- Growing of chilli by giving copious water with conventional fertilizer application as per POP had better production and water productivity.
- Fertigation given in poly house and open field was based on 100% PE. So providing more water than 100% PE in both the growing conditions may increase the yield and water productivity.
- Result of the study indicated that microclimatic alteration in the growing conditions significantly influenced the growth, productivity and profitability of chilli. Chilli grown with copious amount of water under conventional method produces more yields. To realize higher productivity and profitability of chilli need more quantity of water than water applied at 100% PE is needed for both open field and poly house condition. Application of fertilizer through fertigation resulted in the saving of 25% of the NPK requirement without affecting the WP and profitability of chilii.

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APPENDIX-I

Weather data in open field for the experimental period (15-03-2017 to 15-09-2017 - weekly average)

Standard week No.	Date and month	Temperature (°C)		Relative humidity (%)	Rain fall (mm)
		Max. temp.	Min. temp.		
10	15/03-21/03	34.68	24.41	72.78	10.5
11	22/03-28/03	38.17	25.15	67.07	0
12	29/03-04/04	36.87	25.8	66.42	0
13	05/04-11/04	36.13	26.41	69.71	0
14	12/04-18/04	35.1	25.58	71.64	18.6
15	19/04-25/04	34.9	27.54	71.07	0.5
16	26/04-02/05	36	25.27	68.35	9.3
17	03/05-09/05	35.9	25	72.21	20.2
18	10/05-16/05	35.1	25.14	69.64	14.2
19	17/05-23/05	33.97	25.31	74	16.6
20	24/05-30/05	32.7	24.64	79.64	90.1
21	31/05-06/06	30.97	23.74	82.71	127.7
22	07/06-13/06	29.51	23.65	88.57	127.8
23	14/06-20/06	31.87	24.44	82.07	51.2
24	21/06-27/06	29.81	22.66	90.78	326.9
25	28/06-04/07	30.08	22.47	86.92	101.7
26	05/07-11/07	30.3	22.93	85.5	84.9
27	12/07-18/07	30.6	22.69	84.42	79.2
28	19/07-25/07	30.95	22.48	84.64	167.2
29	26/07-01/08	31.95	23.7	79.85	16.8
30	02/08-08/08	29.62	23.58	87.35	158.7
31	09/08-15/08	30.92	23.76	82.85	8.7

APPENDIX-II

Weather data in polyhouse for the experimental period (15-03-2017 to 15-09-2017 - weekly average)

Standard week No.	Date and month	Temperature(°C)		Relative humidity (%)
		Max. temp.	Min. temp.	
10	15/03-21/03	36.72	24.71	68.46
11	22/03-28/03	38.44	24.71	70.33
12	29/03-04/04	38.02	25.12	74.15
13	05/04-11/04	38.52	25.14	72.28
14	12/04-18/04	36.92	24.94	70.52
15	19/04-25/04	32	24	71.62
16	26/04-02/05	32.5	24.14	74.21
17	03/05-09/05	32.92	24.42	74.68
18	10/05-16/05	33.57	24.42	71.97
19	17/05-23/05	33.14	24.57	74.86
20	24/05-30/05	32.27	24.65	73.51
21	31/05-06/06	33.11	25.85	83.29
22	07/06-13/06	33.05	26.42	80.87
23	14/06-20/06	33.28	27.45	85.37
24	21/06-27/06	31.81	25.72	92.37
25	28/06-04/07	31.28	25.57	86.28
26	05/07-11/07	32.24	25.5	82.14
27	12/07-18/07	31.75	27.57	86.95
28	19/07-25/07	32.28	23.71	87.28
29	26/07-01/08	31.62	25.34	84.28
30	02/08-08/08	30	24.65	91.24
31	09/08-15/08	30.11	24.64	84.78

APPENDIX-III

Cost of cultivation of Chilli (Ujwala)

ITEMS	T1	T2	T3	T4	T5	T6	T7	T8	T9
Materials									
Ujwala seedlings (ha)	1500	1500	1500	1500	1500	1500	1500	1500	1500
FYM (t)	10000	10000	10000	10000	10000	10000	10000	10000	10000
Lime	3500	3500	3500	3500	3500	3500	3500	3500	3500
Application cost	3000	3000	3000	3000	3000	3000	3000	3000	3000
Fertilizers									
Urea	459	513	345	383	642	653	486	486	669
Mussorie phos		183		136		68		47	262.5
Muriate of potash		117		98		96		78	384
19:19:19	10920	8260	8260	6160	8960	6720	6720	5040	
Mono ammonium phosphate	4872	3712	3712	2784					
Application cost	3000	3000	3000	3000	3000	3000	3000	3000	3500
PP Chemicals	1000	1000	1000	1000	750	750	750	750	750
Application cost	2500	2500	2500	2500	2000	2000	2000	2000	2000
Land preparation	4600	4600	4600	4600	4600	4600	4600	4600	4600
Planting	7500	7500	7500	7500	7500	7500	7500	7500	7500
Weeding	7500	7500	7500	7500	7500	7500	7500	7500	7500
Irrigation	1250	1250	1250	1250	1250	1250	1250	1250	12500
Harvesting fruits	4250	4250	4250	4250	7500	7500	7500	7500	7500
TOTAL COST	**65851**	**62385**	**61917**	**59161**	**61702**	**59637**	**59306**	**57751**	**65165.5**

Cost of inputs			
Seedlings		**Fertilizers**	
Ujwala seedlings	Rs. 1 $Plant^{-1}$	Urea	Rs. 5.4 kg^{-1}
		Mussorie phos	Rs. 5.25 kg^{-1}
		Muriate of potash	Rs. 19.6 kg^{-1}
		FYM	Rs. 500 t^{-1}
		19:19:19	Rs. 140 kg^{-1}
		12:61:0	Rs. 232 kg^{-1}

Labour cost	
Men	Rs. 300 day^{-1}
Women	Rs. 250 day^{-1}

Price of produce	
Fruits	Rs. 60 kg^{-1}

MICROCLIMATIC ALTERATION ON WATER PRODUCTIVITY OF CHILLI (*Capsicum annum L*) UNDER FERTIGATION

by

GOUTHAMI DEEP KP

(2012 - 20 - 109)

ABSTRACT OF THE THESIS

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ABSTRACT

An investigation entitled 'Microclimatic alteration on water productivity of Chilli (*Capsicum annum L*) under fertigation' was conducted at Water management research unit (WMRU) Vellanikkara, a sub centre of agronomic research station (ARS) Chalakudy, during March 15 2017 to August 15 2017. The experiment was conducted in two growing conditions of open field and poly house with four ferigation levels and having one control with conventional method of irrigation and fertilizer application with 100% NPK as per POP.

From this study result revealed that under Kerala condition during February 2017 to August 2017 better performance of growth parameters and yield contributing characters resulted in higher yield under open field condition with conventional method of irrigation and fertilizer application than open field and poly house with fertigation.

The study revealed that the growth and yield of chilli was better for plants receiving higher quantity of water. The quantity of water fixed was 100% PE for the fertigation. It was not sufficient to meet the growth requirement and to meet the evaporation demand of crop under poly house condition. Water productivity and nutrient use efficiency under conventional method of irrigation and fertilizer application followed by open field with fertigation was found higher compared to poly house plants receiving fertigation. This was due to the higher yield under open field condition. Result of the study indicated that microclimatic condition prevailed during the growth period had significant influence on the growth and yield parameter of chilli.

The yield, water productivity and nutrient use efficiency were not affected by the levels of fertigation. Through fertigation, providing lesser nutrients that is application of 75% NPK with 25% as basal is enough for the maximum production. So there will be a reduction of 25% of nutrients.

Net return and Benefit cost ratio were found to be much higher under conventional method of fertilizer application compared to open field and poly house with fertigation.