COMPARATIVE EVALUATION OF NATURALLY VENTILATED POLYHOUSE AND RAINSHELTER ON THE PERFORMANCE OF TOMATO

By

POOJA B G

(2015-18-006)

Thesis

Submitted in partial fulfilment of the requirement for the award of degree of

Master of Technology

in

Agricultural Engineering

(Soil and Water Engineering)

Faculty of Agricultural Engineering and Technology

Kerala Agricultural University

Department of Land & Water Resources and Conservation Engineering

Kelappaji College of Agricultural Engineering and Technology

Tavanur - 679 573, Malappuram.

Kerala

2017

DECLARATION

I hereby declare that this thesis entitled **"Comparative Evaluation of Naturally Ventilated Polyhouse and Rainshelter on the Performance of Tomato"** 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 for any degree, diploma, associateship, fellowship or other similar title of any other university or society.

Place:Tavanur
Date: 20/7/2017

Pooja B.G.
(2015-18-006)

CERTIFICATE

Certified that this thesis entitled **"Comparative Evaluation of Naturally Ventilated Polyhouse and Rainshelter on the Performance of Tomato"** is a bonafide record of research work done independently by **Ms. Pooja B.G. (2015-18-006),** 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.

Place: Tavanur
Date: 20/7/17

20/7/17

Dr. Abdul Hakkim, V. M.
Professor and Head,
Department of Land & Water Resources
and Conservation Engineering
KCAET, Tavanur, Malappuram, Kerala

CERTIFICATE

We, the undersigned, members of the Advisory Committee of **Ms. Pooja B.G.,** a candidate for the degree of Master of Technology in Agricultural Engineering majoring Soil and Water Engineering agree that the thesis entitled **"Comparative Evaluation of Naturally Ventilated Polyhouse and Rainshelter on the Performance of Tomato"** may be submitted by **Ms. Pooja B G.,** in partial fulfillment of the requirement for the degree.

20/7/17

Dr. Abdul Hakkim, V. M.
(Chairman, Advisory Committee)
Professor and Head,
Department of LWRCE
KCAET, Tavanur.

20/07/2017

Dr. Sajeena, S.
(Member, Advisory Committee)
Assistant Professor,
KVK, Malappuram.

20/7/17

Dr. Berin Pathrose
(Member, Advisory Committee)
Assistant Professor,
Department of Entomology
KAU, Thrissur.

Rema K.P. 20/7/17

Dr. Rema, K. P.
(Member, Advisory Committee)
Professor and Head,
Dept. of IDE
KCAET, Tavanur.

20/7/17

EXTERNAL EXAMINER

ACKNOWLEDEMENT.

At the very outset, I express my deep and sincere regards, profound sense of gratitude and indebtedness to **Dr. Abdul Hakkim, V. M.,** Professor and Head, Department of Land and Water Resources Conservation Engineering, K.C.A.E.T, Tavanur for my esteemed supervisor, my cordial thanks for grooming me as a PG student, your warm encouragement, thoughtful guidance, insightful decision, critical comments and correction of the thesis. It is my proud privilege to express my heartfelt indebtedness and deepest sense of gratitude for laying out the guidelines of research work. I have real admiration and regards for full hearted support and untiring help.

It is my pleasure to pay tribute to **Dr. M.S. Hajilal**, Dean, K.C.A.E.T, Tavanur, for his advice and guidance rendered during this study.

I engrave my deep sense of gratitude to **Dr. Sajeena, S.** Assistant Professor, KVK, Mallappuaram, **Dr. Rema, K.P.** Professor & Head, Department of Irrigation and Drainage Engineering, K.C.A.E.T, Tavanur, **Dr. Berin Pathrose,** Assistant professor, and Department of Entomology, KAU, members of advisory committee for their constant encouragement and help throughout the period of the study.

My sincere thanks to **Dr. Sathian.** Professor, Department of Land and Water Resources Conservation Engineering, K.C.A.E.T, Tavanur and **Dr. Asha Joseph.** Professor, IDE, K.C.A.E.T, Tavanur, for their support and suggestion during course of work.

I am immensely thankful to **Er. Ajay Gokul,** Teaching Assistant, Department of Land and Water Resources Conservation Engineering, K.C.A.E.T, Tavanur, for his esteemed help and support offered during their study.

I wish to express my hearted thanks to my friends **Er. Pallavi S, Er. Akshaya B, Er. Ranjitha V, Er. Ramya R, Mr. Pruthvi S. Er. Tejesh** for their support and sincere help during entire period of work.

It gives me immense pleasure to express my deep sense of gratitude to all staff members of Precision Framing Development Centre (PFDC). KCAET. Tavanur for their valuable suggestion and support throughout the project work.

My sincere thanks to all my M.Tech friend. seniors and juniors for their suggestions and invaluable help during my study.

My heartfelt thanks to **Kerala Agricultural University** for having proffered me a chance to study in this institution.

I am in dearth of words to express my unboundful gratitude and love to the living gods, my grandparents Smt. **Yashodha** and Sri. **Basavaraj** and parents Smt. **Ambika** and Sri. **Gangadhar, B.S.** for their unbounding love and dedicated efforts to educate me to this level without whose encouragement brings out the best in every one of my endeavors. Also I express my thanks to my sister **Ms. Vidya** for her support and valuable prayers.

Above all, I humbly acknowledge the grace and blessings of the supreme power for enlighten my life and fulfilling this well nurtured dream.

Tavanur

Date: 20/7/2017

Pooja

Pooja B.G.

Dedicated To My

Parents &

My Sister

CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF PLATES

SYMBOLS AND ABBREVIATIONS

%	Percentage
°B	Brix
°C	Degree Celsius
µm	Micrometer
ANOVA	Analysis of Variance
B:C	Benefit Cost ratio
cc	Cubic Centimeter
cm	Centimeter
CRD	Completely Randomized Design
DAT	Days After Transplanting
DI	Drip Irrigation
dS/m	deci Siemens per meter
E	East
Ec	Electrical Conductivity
Ep	Pan Coefficient
ET	Evapotranspiration
FC	Field Capacity
FF	Fruit Firmness
g	Gram
g/kg	Gram per Kilogram
GI	Galvanized Iron
GDP	Gross domestic product
ha	Hectare
IARI	Indian Agriculture Research Institute
KAU	Kerala Agricultural University
KCAET	Kelappaji College of Agricultural Engineering and Technology
kg	Kilogram
Kg ha^{-1}	Kilogram per Hectare
kg/m^2	Kilogram per square meter

Kpa	Kilopascal
L	Liter
LDPE	Low Density Polyethylene
Lph	Litre per hour
m	Meter
m^2	Square meter
m^2/year	Meter Square per year
mm	Millimeter
N	North
NPK	Nitrogen, Phosphorous, Potassium
PE	Pan Evaporation
PFDC	Precision Farming Development Centre
pH	Negative Logarithm of Hydrgen Ion
ppm	Parts per million
PVC	Poly Vinyl Chloride
q/ha	Quintal per Hectare
Sq.km	Square Kilometer
SS	Soluble Sugar
T	Treatment
t/ha	Tonnes per Hectare
UV	Ultra Violet
VPD	Vapour Pressure Deficit
Wm^{-2}	Watt per square meter
WA	Water Applied
WUE	Water Use Efficiency
TSS	Total Soluble Salt
Y	Yield

Introduction

CHAPTER 1

INTRODUCTION

Kerala stands first in the country in terms of human development index, literacy rate and sex ratio. In recent years, the state is going ahead as a potential destination for ecotourism, information technology etc. the agro based rural economy drags back the State's economy. The state's agriculture sector including livestock contributes only 10.88 per cent of the total GDP, compared to 34.2 per cent in Madhya Pradesh, 29.3 per cent in Uttar Pradesh and Rajasthan. In 1955-56, agriculture was the main economic activity of Keralites and about 53.1 per cent of the total working population was engaged in agriculture (KAU, 2016). Poor return from agriculture and high labour cost forced many of the farmers to keep away from agriculture.

Kerala is a land of diversities which is situated between Arabian Sea at the west and Western Ghats at east, with a high population density of around 860 per sq.km, compared to the National density of 364 per sq.km. The share of State income from agriculture is only 20 per cent and this income is generated from marginal holdings of less than one hectare size with the average size being 0.18 ha. Vegetables and fruits are vital components of our daily food. Efforts are being made to encourage farmers to increase the area under these important food crops. For the cultivation of vegetables a net area of 17,472 acres are utilized out of the total 48,153 acres of agricultural land possessed by the cultivators, i.e. only 36.28 per cent of the total land owned by them is utilized for vegetable cultivation. From this land, an average income of Rs.279/- is obtained in a year. With the improvement in the living conditions and food habits of Keralites, the necessity for increasing the vegetable production from these small land holdings becomes essential.

Kerala lies in the humid tropical region belonging to warm climate and the state is blessed with an equable and pleasant climate throughout the year. The state is blessed with abundant rainfall with an average rainfall 3000 mm every year. Month of June and July receives highest rainfall, whereas summer months receive very less rainfall. The temperature range is between 28° and 32 °C over the plains and around 20 °C over the highlands.

Vegetable production scenario in the state reveals that majority of the vegetable production in the state is during winter season, that is between November to February. During winter season, in addition to tuber crops, vegetables like cowpea, tomato, okra, bitter gourd are grown in the state. High rainfall and high humidity limit the vegetable production in the monsoon season. Hence, Kerala depends on neighbouring states for its vegetable requirements during this period.

The search for new and viable methods led to the development of High- tech or precision agricultural systems. Greenhouse, the latest term in Indian agriculture, inside which the plants are grown under controlled or partially controlled environment resulting in higher yields than under open conditions.

Greenhouses are framed structures covered with transparent or translucent material and are large enough to grow crops under partial or fully controlled environmental conditions, to obtain optimum growth and production. Greenhouse protect crop from varied climatic conditions like wind, rainfall, excess solar radiation, extreme temperature conditions and also from the attack of pests and diseases. Further, cultivation of high value crops like flowers and vegetables in greenhouse during off-season or round the year is possible with improved productivity and quality of the produce there by gaining additional returns. Hence, there is need and scope for cultivation under greenhouse conditions (Manohar and Igathinathane, 2012).

Different types of structures are being used for improving the productivity and profitability of horticultural crops as well as for producing planting material throughout the year like green house, shade house, mist house etc. In modern research, green house technology can be utilized for controlling environmental parameters such as temperature, light intensity, relative humidity, CO_2 level, irrigation, nutrient supply spacing, growing medium and root development (Baghel *et al.*, 2003). The nature of growth is more of vertical due to congenial climate under cover, hence the plant density under protected condition is usually more. On the other hand, in order to optimize yield, a balance between vegetative (leaves and stems) and reproductive (flower and yield) growth must be established and maintained.

Protected structure is created locally by using different types of material. These structures are designed as per climatic requirements of the area for different set of environmental conditions. Growing of tomato under protective cover has been reported to give good quality produce with higher productivity (Wani *et al.*, 2011).

Salokhe and Shama (2012) stated that Greenhouse structures of various types are used for crop production. Although there are advantages in each type for a particular application, in general there is no single type greenhouse, which can be constituted as the best. Different types of greenhouses are designed to meet the specific needs. The different types of greenhouses are based on shape, utility, material and construction.

If the local farmers are able to take up vegetable cultivation during off season, they can achieve better income. Protected cultivation helps the farmers to grow vegetables year-round, but a hi-tech green house with sophisticated environmental control cannot be recommended to farmers with limited resources. Here comes the application of low cost technology of protected cultivation named rainshelter (Nair and George, 2014). Rainshelter is a naturally ventilated low cost greenhouse which facilitates year round production of high value crops like tomato, capsicum, cabbage, cut flowers etc. and also suitable for raising vegetable seedlings. This technology is acceptable to small scale and marginal farmers.

Rainshelter is low cost greenhouse, a simple structure constructed with locally available materials such as bamboo, timber etc. Ultra Violet (UV) stabilized film is used as cladding material. Unlike conventional or hi-tech greenhouses, no specific control device for regulating environmental parameters inside the greenhouse is provided. Simple techniques are adopted for increasing or decreasing the temperature and humidity. Even light intensity can be reduced by incorporating shading materials like nets. Temperature can be reduced during summer by opening the side walls and such structure can be used as rain shelter for crop cultivation (Pack and Mehta, 2012).

Since there are different arguments regarding the adaptability and advantages of polyhouse and rainshelter for protected cultivation, a scientific study in this regard is necessary. In the present study tomato is selected for comparing the growth and yield performance under polyhouse and rain shelter. Tomato (*Solanum lycopersicum*) belongs to the family Solanaceae. It is one of the most important vegetable crop that can be consumed as fresh and used in the processing industry. The tomato plants typically grow to 1-3 m height and have weak stem that spreads over the ground and twines to the other plants. It is native of South America, but now is grown around world for its edible fruits with thousands of cultivars having been selected with varying fruit types and for optimum growth in differing growth conditions.

Being an important vegetable crop, research on every aspect of its cultivation to improve its productivity becomes essential. Though production of tomato in Indian plains is high, it is reduced to a greater extent due to higher temperature during summer months, which necessitates exploration of advance techniques like protected cultivation to reduce the temperature in tropical regions in north and south Indian plains that can manage the higher demand of this nutritious vegetable during summer. Higher temperature during summer results in poor fruits set and yield. Hence, use of protected structure in this season will help to increase production. High day and night temperatures interfer with tomato fruit set (Berry and Uddin, 2003).

In India, tomato is mainly grown under open field conditions and yield of tomato is high during normal season, which makes high supply to the market resulting in poor profits to farmers. Whereas during summer season, high temperature results in poor fruit set and yield and also decreases quality due to insect pest. Hence, decreased production of superior quality tomatoes in summer will fetch higher price due to low availability. Hence, there is need to study about polyhouse and rainshelter condition for tomato cultivation in order to maximize production and quality of the produce.

The present study is proposed to compare the performance of tomato grown under polyhouse and rainshelter conditions with the following specific objectives:

□ To compare the growth and yield of tomato under naturally ventilated polyhouse and rainshelter for the same irrigation, fertigation schedule and cultural practices.

□ To work out the Cost Benefit (B: C) ratio for the polyhouse and rainshelter for tomato cultivation.

Review of Literature

CHAPTER 2

REVIEW OF LITERATURE

Tomato is the most important vegetable commercially cultivated and a highly remunerative vegetable crop grown in India. Cultivation of tomato is possible even during the off-season under protected structures. Agronomical practices play an important role for obtaining higher yields especially under greenhouse structures. The literature pertaining to the performance of tomato and other related vegetables under different protected structures is reviewed here.

2.1 PERFORMANCE OF TOMATO AND OTHER VEGETABLE CROPS UNDER PROTECTED STRUCTURES

Ohigbu and Harris (1989) had studied the greenhouse and open field cultivation of tomato and had reported that under polyethylene greenhouse condition, maximum yield of ripe tomato fruits was 8.6 kg/m^2 and total yield 9.4 kg/m^{2}was obtained as compared to open conditions 6.6 kg/m^2 and total yield 7.35 kg/m^2 respectively.

Bhatnagar *et al.* (1990) had reported that maximum yield of 507 q/ha were obtained in tomato in the polyhouse condition as compared to very less yields found in the open field conditions.

The experiment conducted on cucumber variety 'Poinset' gave a yield of 1.70 kg/plant under polyhouse as compared to lesser yield in open conditions, during winter months under North Indian conditions due to low temperatures (More *et al.*,1990).

Rai *et al.* (1995) had studied shelf life of capsicum grown under protected and open conditions. Six hybrids along with one open pollinated variety were grown in polyhouse and open conditions for studying their shelf life. The shelf life of capsicum fruits harvested from polyhouse was more than that of fruits harvested from open conditions. The maximum shelf life of sixteen days was recorded in Arun F1 growing in polyhouse, while it was only ten days in fruits produced in open condition.

Ganesan (1999) had conducted a study on changes in microclimate produced by polyhouse conditions on plant growth characteristics and fruit yield of tomato. The higher day temperature was observed under UV stabilized plastic film covered polyhouse than the open field condition, but at 8 AM the relative humidity was recoreded lower inside the polyhouse except from May to August. The light intensity in the open field was higher than in the polyhouse. Plant height, nodes number, inter-nodal length and fruit weight higher under polyhouse conditions as compared to open field condition. The fruit yield inside the polyhouse condition was nearly two times higher compare to open field condition.

Idris (1999) had conducted a study on the economic comparison of tomatoes production in both greenhouse and open field condition in Khartoum State. The statistical analysis of socio economic characteristics of both open field farmers and greenhouse producers were homogenous groups because almost all of them were sharing the same characteristics between cultivation practices. The results showed that in open field condition the cost structure includes transportation cost, inputs costs, and cultural operations and in greenhouse cultivation cost structure includes fixed, inputs costs, and maintenance of greenhouse. The yield of tomato was very high in green house cultivation compare to open field cultivation and also shows that the tomato crop was very profitable in green houses cultivation.

Gubbuk and Pekmezci (2004) had studied and found that protected cultivation was found to be better compared to open filed condition for banana. The study showed that the pseudo stem circumference, pseudo stem height, total number of leaves, bunch stalk circumference, number of days to harvest, number of hands, number of fingers, finger circumference, finger length, and bunch weight under protected cultivation was better over open field condition. The yield was obtained 53 per cent higher in protected cultivation (65.5 t/ha) than open field condition (42.8 t/ha).

Thangam and Thamburaj (2008) had reported that the effect of sunlight radiation on growth and quality of 6 varieties and the tomato hybrids in both greenhouse and in open field condition in summer seasons. The average fruit weight recorded under shade was 59.5 g in Rashmi hybrid. The number of fruits per plant was less in greenhouse condition than in open field. The yield under greenhouse was low compared to open field. The hybrid Avinash-2 recorded the highest yield in both open field and greenhouse conditions. The comparison between quality parameters like TSS, acidity, ascorbic acid and pH of fruit juice, recorded significant differences between greenhouse and open conditions.

Yellavva and Patil (2008) had conducted an experiment on the performance of capsicum hybrids under different protected structures during summer of 2007 at Department of Horticulture, Dharwad. The different hybrids used for this study were Orobelle, Bomby and Indra and the spacing between the plants was 45 x 60 cm with three replications comprising of a total twelve treatments. The results showed that the quality parameters fruit weight was (160 g), fruit volume (320 cc), rind thickness (0.9 cm) and shelf life (8.2 days) and yield parameters like number of fruits per plant (11.6), fruit yield per plant (3.6 kg), total fruit yield (72.5 t/ha)was significantly higher under naturally ventilated conditions compare to other structures.

Thompson and Strik (2009) had conducted an experiment on production of blackberry under high tunnel and open field cultivation. The result obtained was tunnel protection extended fruit yield by 3 weeks in two successive years. The total yield of all the treatments was higher in the tunnel than in the open field. In tunnel, total yield was significantly higher in double-tipped primo canes than all other treatments in two years. From 2006 to 2007, higher yield was obtained by double-tipping primo canes compared to the control. The total yield from double-tipped primocanes was 47 per cent less in the open field than in the tunnel. Averaged berry weight was 6.8 g and 4.7 g in the tunnel and open field respectively. This difference suggests that production in the tunnel may have led to increased berry weight.

Zende and Mathad (2009) had conducted an experiment on capsicum under protected cultivation. The results revealed that the quality parameters like fruit length (8.50 cm), individual fruit weight (147.74 g), fruit volume (268.85 cc), shelf life of capsicum (8.93 days), pericarp thickness (0.72 cm) and the yield parameters number of fruits per plant (23.44), fruit yield (6.49 kg/m^2) and total fruit yield (64.91 tonnes/ha) was higher under polyhouse than rainsheleter.

Parvej *et al.* (2010) had conducted an experiment in a covered greenhouse and compared with an open field from December 2007 to April 2008. Radiation inside the greenhouse was found as 40 per cent compared to the open field, day air temperature under greenhouse found between 31.8 to 39.1 °C and in open field found between 23.3 to 31.1 °C respectively shows that about 8°C higher temperature inside greenhouse and during that period the average temperature inside greenhouse was about 28 °C which was optimum for the growth and development of tomato plants. The microclimatic conditions inside greenhouse favoured for the plant growth through increased plant height, branches and leaf area index compared to the plants grown in open field. The results obtained that total yield from the greenhouse was 81 t/ha compared to 57 t/ha from the open field.

The studies were conducted for cultivation of vegetables under shade net house (33 per cent shade) and open field. Tomato, eggplant, chilli, cucumber, cluster bean, radish, amaranthus, coriander and capsicum were grown in the summer and winter. The microclimatic parameters like temperature, relative humidity and light intensity were studied. The result indicates that humidity was higher under shade net house than in open field. Light intensity in the shade net house was lower than in the open field. Mean temperature was higher under open field compare to the shade net house in both seasons. Lower temperature in the shade net house results increased in plant height, number of branches per plant, inter-nodal length, average fruit weight and yield per plant than in the open field (Rajasekar *et al.*, 2013).

Sam and Regeena (2014) had conducted an experiment on production potentials of tomato and capsicum under polyhouse and open field condition. Highest yield was recorded in greenhouse structures than in open field for trailing tomato and capsicum. The increase in yield was 82.84 per cent and 90.85 per cent tomato (hybrid rakshitha) and capsicum (hybrid indira) respectively. It was found that micro climatic parameters were varied between greenhouse and open field. Solar radiation inside the greenhouse 50 per cent compared to the open field. The relative humidity was less in poly house structure compared to open field (5-8 per cent). The tallest plants, maximum number of branches/plant and higher leaf area index were found in the crops grown under greenhouse than crops in open field conditions.

Malshe *et al.* (2016) had conducted an experiment on comparative study of different capsicum varieties under open and protected conditions at Agricultural Research Station, Manhattan variety recorded maximum plant height (78.44 cm) followed by California Wonder, in open conditions, California Wonder recorded significantly maximum height (51.30 cm). Under poly house conditions, the maximum fruit weight (76.48 g) open field conditions, Manhattan recorded maximum (60.84 g) fruit weight. The yield per plant was recorded maximum (2.426 kg $plant^{-1}$) by California Wonder under polyhouse while (1.588 kg per plant) in the open field conditions.

2.2 PERFORMANCE OF VEGETABLE CROPS UNDER RAIN SHELTER

A study was carried to evaluate 27 tomato varieties in north region of Assam in relation to growth, yield and quality of tomato in rain shelter during summer seasons. Among all the 27 varieties, Yash crop variety was recorded the higher yield of 1.76 kg per plant next to ArkaAhuti and ArkaAshish varieties. Yash variety recorded the maximum plant height, branch number, fruit set percentage and plant yield. The flowers number per inflorescence were found highest from cultivar BT1 compare to other varieties. On the other hand, ArkaAhuti variety recorded the highest retention of matured fruits. A wide range of variation was observed in both physical and chemical constituents of the fruits. Pusa Ruby and ArkaShreshta recorded the maximum TSS content (Hazarika and Phookan, 2005).

Mantur and Patil (2008) had conducted an experiment in 50 per cent shade net house during summer and kharif season of 2005-06 at agricultural college, Bijapur. Tomato planting was done in 1 m wide and 50 cm spacing between the beds. The plants spacing was 60cm x 30cm (S1), 60cm x 45cm (S2), 60cm x 60cm (S3) and with the branches pruned (P1) and without pruned (P0) by same cultivation practices. The results obtained that the average fruit weight was higher in S3(73.64 g and 71.36 g) in both the summer and kharif seasons and also the mean of two seasons (72.50 g) compared to S1 and S2(63.96 and 66.31g). The pruning treatment found significantly higher average fruit weight in summer and kharif seasons (74.32 g) compared to without pruning (60.83 g). The fruit yield per plant was higher in S3 treatment (3.67 kg) in both the seasons and the mean yield of two seasons was higher compared to other two treatments.

Rajendra *et al.* (2013) had conducted an experiment on different spacing levels on growth and yield of tomato grown under rainshelter. The Himsona variety was grown under rainshelter in rabi season from 2010-11 under different spacing between the plants. The spacing tomato plants between two beds were 60 x 60 cm (T1), 60 x 30 cm (T2), 60 x 45 cm (T3) and 45 x 45 cm (T4). The results showed that the 60 x 60 cm (T1) higher leaves per plant (44 number.), fruits yield per plant (3408.10 g) and fruit yield was higher (15.14 kg per meter square) was recorded in 60 cm x 30 cm (T2) compare to other treatments.

Rao *et al.* (2013) had studied the performance evolution of capsicum crop under open field condition and shade net with 50 per cent shade factor by using black shade net for the experiment at Bhopal during December to May(2011-2012). The same practices were taken under both shade net and open field condition for comparison. Frequency of irrigation and wetting pattern were collected by using drip irrigation system. Weather parameters like soil temperature, relative humidity, duration of the crop and yield were taken. The results found that yield was 80 per cent more in shade net house over than open field condition. Duration of the crop was found by 40days more under shade net cultivation.

According to Baliyan and Pal (2014), rainshelter is suitable structure to improve production of vegetables by reducing the damage by sunburn and birds. The project was planned and implemented in year 2012 in Southern Africa for improving production and income from vegetables. All the basic steps considered in designing an effective project such as situation analysis, stakeholder analysis, problem analysis, objective analysis, strategy analysis, log frame analysis, scheduling, swat analysis, budgeting, appraisal and monitoring and evaluation. The evaluation of the project results in the total vegetable production and the income has increased by 162 per cent and 103 per cent in rainshelter.

Mantur *et al.* (2014) had studied five varieties of cherry tomato under shade net during 2011-2012 at agricultural university, Dharwad. Five varieties were PAU-237, VRCT-17, HAT-121, VRCT-155 and HAT-20 five varieties were used for their performance under shade house. Five varieties of tomato crop were planted by three different spacing between the plants 60 x 45 cm, 60 x 60 cm and 60 x 75 cm. A among the five varieties, in the first experiment the results showed that the average fruit weight was higher in HAT-20 (10.20 g) compare to all other varieties of tomato and least fruit weight was found in HAT-121 (6.60 g) variety. The higher fruit yield per plant was found in VRCT -155 (2.55 kg) followed by HAT-121 (2.29 kg). While in the second experiment the higher fruit yield per plant was found in VRCT-155 (3.32 kg). least yield per plant was found in PAU-237 (2.15 kg). The yield per m^2 was higher in VRCT-155 (7.35 kg) variety followed by HAT-121 (6.63 kg). While three spacing were tried in experiment, in that higher yield per plant was founded in wider spacing of 60 x 75 cm (3.34 kg) and least was in closer spacing of 60 x 45 cm (2.09 kg).

Shao *et al.* (2015) had conducted a study to determine the effects of the combined use of rainshelter and deficit irrigation on tomato yield and quality characteristics. They conducted experiment by using two different treatments in southern china. The crops were irrigated to field capacity once average soil water content at the 0-60 cm layer in the treatment decreased to 80 per cent of field capacity under open-field (T1) and rainshelter (T2). The results showed that in rainshelter condition yield was found higher over than open field condition. The fruit firmness (FF), total soluble solids (TSS), soluble sugar (SS), and vitamin C was better in rainshelter than in open field condition.

2.3 INFLUENCE OF DIFFERENT GROWING ENVIRONMENT ON PRODUCTIVITY AND QUALITY OF VEGETABLES

The Studies were taken for cultivating capsicum and sweet pepper under low temperature. Higher number of branches and flowers were observed in capsicum plants when plants were exposed under in low temperature. The flowers and ovaries were very small in sweet pepper plants which were exposed to constant temperature of 25 ^{0}C and area were largest when plants exposed to low temperature at four leaf stages (Deli and Tiessen,1969).

Hicklenton and Jolliffe (1978) had conducted a study on enrichment of CO_2 on the yield and photosynthetic physiology of tomato plants. Tomato crops grown in greenhouses with and without CO_2 enrichment to approximately 900 ppm. Plants grown under CO_2 enrichment flowered earlier and produced 30 per cent more marketable fruit than those grown in normal air. The study indicated that the increases in growth and yield, that result from CO_2 enrichment that increases concentration gradient driving the flow of CO from the greenhouse air to the chloroplasts.

Bakker (1991) had studied on the effect of relative humidity on growth and production of glasshouse fruit vegetables and reported that humidity is a climate factor that can modify total yield and crops quality through its impact on the crops inside the glasshouse. The results obtained for responses of growth and production was maximum yield under glasshouse in which humidity range between the 0.3 to 0.9 kPa Vapour Pressure Deficit.

Bhatt and Rao (1993) had reported that the higher net photosynthetic rate, growth rate and number of flowers in bell pepper at higher night temperatures. They further noticed that at intermediate temperature, the number of four lobed fruits significantly increased and at low temperature the fruits obtained were short, blunt and unmarketable. In the greenhouse, the growth of the vegetative organs (leaves, stem and shoots) in brinjal and tomato were negatively affected by the high level of temperature (34^0C).

Willits (2003) had studied that cooling has always been an important problem in polyhouse operators in warm climates, for potentially limiting production and constraining profits. Polyhouse cooling is typically accomplished by ventilation, either mechanically, via exhaust fans or naturally and via wind.

Max *et al.* (2009) had conducted studies on effect of cooling system in greenhouse in Thailand. Tomato crop was cultivated during dry season in 2005 and

2006, Sidewalls, roof vents of two greenhouses were covered with nets and these greenhouses were mechanically ventilated when the temperature reaches above 30.8 ^{0}C using net. The two greenhouses with fan and pad cooling system were covered by polyethylene film. Air temperature was found significantly 2.5to 3.2 ^{0}C in day time and 1.4to 2.2 ^{0}C in night time in fan and pad cooling system compared to NET and outside air temperature. The relative humidity was around 20 to 30 per cent in day time and 10 to 15 per cent in night time from fan and pad cooling system than in NET or outside. Vapour pressure deficit was averaged0.25 kPa in fan and pad system 1.03 kPa in NET, 1.48 kPa outside. The crop water-consumption was found lower in fan and pad system that was 1.2 l per plant per day than in NET that was 1.8 l per plant per day, which indicates to reduce transpiration in fan and pad cooling system. Total fruit yield in NET was higher compare to fan and pad cooling system greenhouse. The results showed that the marketable yield was more in NET that was 4.5 kg per plant over fan and pad cooling system that was 3.8 kg per plant.

Bibi *et al.* (2012) had conducted a study on the effect of partial shade on yield of tomato cultivars, which was carried out at Department of Horticulture, Peshawar during 2010. The experiment was lead out by completely randomized block design using partial shade of 55 per cent and open field condition. The shade effects were studied on the basis of different tomato varieties during the months of April, May and June. The results obtained that in partial shade height of the plant noted 101 cm. Plant heights was recorded 74.5 cm in control and plant height from partial shade in May was 74.1 cm and in June 75.4 cm were same. And branches per plant was found higher in control 4.1 compared to shades of different months. The total yield was lower in partial shade condition compare to open field condition.

Chen *et al.* (2013) had conducted studies on quantitative response of greenhouse tomato yield and quality to water deficit at different growth stages because of water shortage. Two experiments with different irrigation treatments were conducted in solar greenhouse in the region of northwest China, the first experiment during winter season in 2008 to spring season in 2009 and from second experiment during winter in 2009 to spring season 2010 to investigate the tomato yield, fruit quality and water deficit. The results obtained that the application of different irrigation treatments at the level 1/3 as theT1 and 2/3 as irrigation level a at the stage of seedling which did not effects tomato water consumption, total yield and fruit quality inside the greenhouse. Water consumption of tomato and yield of tomato were lowered by the application of 1/3 treatment of full irrigation at flowering stage and development stage of fruit, this stage referred as stage 2, and 1/3 treatment 5 or 2/3 treatment 6 of irrigation at maturation stage of fruit at stage 3. And also found that no significant difference was found on total yield and quality of fruits by the application of 2/3 full irrigation at Stage 2.

The study was conducted by using drip-irrigation of varying length on tomato crop for yield and other quality parameter, relationships with properties of soil from 0-20 cm deep and ET ranges from 0-60 cm deep in a polyhouse from March - July 2012 as first season and October 2012 - April 2013 as the second season. The results obtained that properties of soil and evapo-transpiration (ET) of crops are referred as the very important factors affects the yield and quality of tomato. And also showed that yield of tomato was higher, and also significance difference in the quality parameters. The variation coefficients was found 18.1 and 11.8 for the yield, quality parameters as 8.6-14.5 and 6.3–9.8 and ET as 8.2-20.0 per cent and 9-11.4 per cent from first and second season respectively (Chen *et al.*, 2015).

Suzuki *et al.* (2015) had studied the effects of relative humidity, nutrient supply in greenhouse tomato. The tomato crop grown hydroponically at two electrical conductivity levels, one which low EC treatments (0.8–1.2 dS/m) and other one have high EC treatments (1.6–1.9 dS/m). In one greenhouse they conducted experiment by installing a humidification system, another greenhouse as control. The result observed that the area of leaves was not affected by humidity, but the high conductance increased the area of leaf. The water uptake when EC was low with mist lowered compared to that of control and also observed that humidity was higher with carbon-di-oxide which increases activity of stomata and results in the higher photosynthesis activity as well as the growth of tomato plants, and recommended that to yield increased by humidification with higher CO_2 conditions, it is important to control humidity and transpiration rate.

Yang *et al.* (2015)had studied the effect of vermi compost on yield of tomato crop reported that vermi compost contains lower soil organic matter content compare to chick compost and horse compost. The organic matter content of soil in vermin compost 17 and 12.5 per cent which was lower than that in chick compost and horse compost. Vermi compost had higher in Nitrogen and Phosphorous contents in soil compare to other treatments. Vermi compost increases the activity of phosphatase acid, catalase in the soil than the other treatments under the other water soil regimes. And results obtained were yield of tomato was increased 60-70 per cent under vermin compost.

2.4 DRIP IRRIGATION

An experiment was conducted to compare drip irrigation with surface irrigation methods and the results showed that farmers saves up to 80 per cent water, with also reduction of weed growth, improved germination of seeds and also increase in yield (Sivanappan *et al.*, 1977).

Hartmann (1986) had studied the four different levels of irrigation. The results reported that compared to lowest irrigation level, higher irrigation level increased root weight by 15 per cent and 50 per cent of leaves production.

The studies were undertaken by Mane *et al.* (1987), on comparison between the drip irrigation and irrigation by furrow for bhendi and the results obtained was irrigation by drip method found higher yield that was 17.72 t/ha compare to furrow irrigation method of irrigation was 10.25 tonnes/ha. Drip method increased the total yield by 16 per cent and also water saving of 39 per cent than the furrow method. The WUE was found doubled in the drip irrigation method compare to the furrow irrigation method.

Experiments were conducted to design and develop an automatic drip irrigation system and results showed that operational and labour cost can be reduced by this system and can achieve a highly economic and efficient irrigation application for the crops (Clemmens, 1990).

Locascio and Smajstria (1996) experiment had showed that the water application and mulching on the tomato for 3 years by the amount of water application was 0.0, 0.25, 0.50, 0.75 and 1.0 times pan evaporation per day. The results obtained that total yield was higher in drip irrigation. The total fruit yield from different treatments were observed higher in quantities of 0.75, 0.5 and 1.0 times pan evaporation and significantly lower in the 0.25 and 0.50 times pan evaporation values.

Yohannes and Tadesse (1997) had reported that higher yields and increased water use efficiency has found in drip irrigation system over than convectional furrow irrigation system. The experiment was conducted on clay loam soil during 1992 -1993 in Ethiopia. Tomato was grown under different spacing 35 cm, 50 cm and 70 cm between each plant. The result showed that higher fruit yield was obtained from drip irrigation system compare to furrow irrigation. Also water use efficiency and water application efficiency were high in drip irrigation when compared to furrow irrigation.

Singh *et al.* (2000) had conducted an experiment to study the effect of drip irrigation compared to conventional irrigation on growth and yield of Apricot, to find out its irrigation requirement. The results obtained that drip irrigation at 80 per cent evapo-transpiration of water was gave higher growth and fruit yield that was 8.6 tonnes per hectare compared to that surface irrigation. Mulching is the technique with drip irrigation further raised the fruit yield to 10.9 tonnes per hectare. Drip irrigation with 98 per cent irrigation resulted in 3.3 metric tonnes per hectare higher fruit yield.

Experiments were conducted based on the influence of drip irrigation and plastic mulching on the potato crop. The results showed that the highest WUE were recorded 3.24 t/ha compare to 2.17 t/ha in control treatment for the potato crop (Jain *et al.*, 2001).

Singh *et al.* (2001) had studied the yield, water requirement and economics of drip irrigation in litchi orchard at farmer's field in Uttar Pradesh. It was found that good quality marketable yield of litchi varied from 12.5 to 16 metric tons per hectare for drip irrigation system. The total volume of water applied was 282 mm for drip irrigation during four months of study period. The benefit cost ratio was found to be 3.91 for drip irrigated litchi orchard compared to 3.05 for surface irrigated litchi.

Singandhupe *et al.* (2003) had studied the response of tomato to urea fertilizer under drip irrigation system and conventional furrow irrigation system during 1995-1996 years. Application of nitrogen through the drip irrigation system saved up to 20 to 40 percent nitrogen as compared to the conventional furrow irrigation system. When nitrogen was applied in equal split, similarly 3.7 to 12.5 per cent higher fruit yield with 31 to 37 per cent saving of water was obtained in the drip system over than furrow irrigation.WUE in drip irrigation, the average N level was 68.0 and 76 per cent higher compare surface irrigation respectively. At a nitrogen application rate of 120 kg/ha, maximum yield of tomato fruits were obtained 27.4 and 35.2 tonnes per hectare in two consecutive years was recorded.

Mahajan and Singh (2006) conducted a study on response of tomato to irrigation and fertigation during 2002 to 2004 in Punjab Agricultural University. The study was taken to investigate the drip irrigation at 0.5 E_{pan} along with fertigation. The N application increased the total yield of tomato by 59.5 per cent compare to control which was inside the greenhouse and by 116.2 per cent outside the greenhouse. The fertigation treatment showed a saving of 48.1 per cent of irrigation water and resulted in 51.7 per cent higher fruit yield as compared to inside the greenhouse. The length of the roots was found higher in drip irrigated crop than the surface irrigated crop. The quality parameters of the fruits like TSS content, ascorbic acid and pH were found higher under greenhouse tomato than the open field and also showed that drip irrigation inside the greenhouse has significant improvement in the quality parameters of fruits.

Studies were conducted on the effects of different amount of irrigation water on the growth and yield of cucumber under a rainshelter. In the first experiment, the amount of water application were 0.50, 0.75 and 1.0 times of surface evaporation (Ep), denoted by Ep0.50, Ep0.75 and Ep1.0 and for the second experiment amount of irrigation water applied was Ep0.75, Ep1.00, Ep1.25, Ep1.50 and Ep1.75. The results indicated that the amount of water applied significantly affected the plant growth and fruit yield. The results showed that height of the plant and biomass increased, but specific leaf weight (SLW, g/m^2) decreased with increasing amount of irrigation water (Yuan *et al.*, 2006).

Sefer and Gulsum (2009) had conducted an experiment on the drip irrigation system on different levels on the yield, quality and water use characteristics of lettuce, which cultivated in solar green house. The result showed that higher yield was obtained from subsurface drip irrigation at 10 cm drip line depth and also showed that the irrigation use efficiency and water use efficiency increased as the irrigation was reduced.

A study was conducted to standardize the irrigation requirement of salad cucumber cultivated in polyhouse. The experiment design includes five irrigation treatments and six replications. The irrigation system was followed by basin system and drip system. The treatments in drip irrigation with 1, 1.5, 2 and 2.5 lit/day. The result indicated that the drip irrigation has a positive effect on growth and yield of crop. Crops drip irrigated with 1.5 l/plant/day performed well with water use efficiency. Drip irrigation has given higher yield when compare to surface irrigation system. And also drip irrigation has shown larger soil moisture content a day after irrigation, when compare to conventional surface irrigation system had least soil moisture content (Deepa *et al.*, 2010).

Experiments were conducted to determine the effect of different irrigation methods on crop yield during 2004 and 2005 in growing seasons. This study includes two irrigation methods, which were surface irrigation system (SI) and drip irrigation system (DI). The statistical results of study showed that irrigation method significantly ($P = 0.01$) affected crop yield. The maximum crop yield obtained was 27.1 t/ha in case of drip irrigation treatment and the minimum crop yield recorded was 22.5 t/ha in surface irrigation treatment (Majid and Fereydoun, 2011).

Varughese *et al.* (2014) conducted an experiment with varying irrigation level in naturally ventilated polyhouse in Tavanur, Kerala during August to December in 2012. The studies on effect of different irrigation and fertigation levels for cowpea of variety NS 621 inside polyhouse was undertaken with four irrigation treatments. The daily water requirement in the open field for a cowpea was calculated by using FAO CROPWAT software. The different treatments were selected on varying irrigation levels and fertigation levels. Daily irrigation with the estimated water requirement (2.2 l/plant/day) was found more effective. The results obtained that the maximum yield observed for the treatment T2 was 32632 kg/ha which was irrigated daily and fertigation done once in four days. The minimum yield was observed in the treatment T3 was 19428 kg/ha having alternate day irrigation and alternate day fertigation.

Debnath and Patel (2015) had developed a low cost microcontroller based automated drip irrigation system for Kinnow crop. The studies reported that the drip irrigation is one of the best techniques for enhancing crop yield per unit volume of water applied. Drip irrigation which associated with automatic irrigation scheduling technique, can save time, human labor and also minimize the wastage of water from wastage. The various parameters like soil moisture content, leaf-air temperature differential, crop canopy diameter, leaf area index were taken during the study period. The result obtained that the amount of water applied was 0.128 cubic meter water per plant per month by the developed system which was 8 per cent less than the water applied in the controlled condition based on the crop water requirement that was 0.139 m^3 per plant per month.

2.5 FERTIGATION

Mikkelsen (1989) explained the advantages of fertigation in a drip irrigation system, which include in reduction of labour cost, increased fertilizer efficiency and the increased fertilizer application rate. Fertigation which allows nutrient placement directly into the plant root zone enhances the plant growth during critical periods of nutrient demand.

Field experiments were conducted by comparing fertigation with NPK and farmer's fertilizer practice with conventional fertilizers in terms of yield, quality and net returns. Fertigation practices maintain at weekly intervals was found more convenient and economically profitable for the farmers (Bachav, 1995).

Hagin and Lowengart (1996) had reported that the frequent supply of nitrogen was required in drip irrigation system. Nutrient requirement were satisfied by applying fertilizers through irrigation water. Higher in the crop yield, quality and minimization of leaching losses below in the rooting volume may be achieved by managing the concentration of fertilizer in measured quantity of irrigation water according to crop requirement.

Prabhakar and Hebber (1996) had studied that fertigation scheduling for tomato crop and results indicates that highest fruit yield of 45.7 t/ha was obtained by the application of recommended dose fertilizers comprising polyfeed (19:19:19), MAP (12:60:0) and urea through fertigation. The yield was found 22 -27 per cent higher over to yields obtained in crop with normal fertilizers through soil application.

Field experiments were conducted to study the effect of water soluble fertilizers through drip irrigation on the growth and yield of cotton. The results revealed that growth and yield contributing characters of cotton due to normal planting was at higher magnitude compared to paired row found to be higher seed cotton yield by 7.75 per cent. Higher yield of 3.4 t/ha was obtained due to 100 per cent of recommended fertilizer dose (Shindhe *et al.*, 1997)

Neelam *et al.* (1998) had conducted field experiments with four fertilizer levels of 100, 80, 60 and 40 per cent at IARI, New Delhi. The yields of onion found under different treatments of fertigation were compared with conventional methods. By the use of fertigation resulted in 60 per cent saving of fertilizer for achieving same level of production compared to conventional method of fertilizer application.

Srinivas *et al.* (1999) had studied the application of water soluble fertilizer like urea and potash through drip irrigation can substantial savings of 20-25 per cent in fertilizer use, also minimizing the pollution of ground waters from nitrate–nitrogen leaching to a up to some extent. Fertigation also helps to uptake the nutrients matching the crop demand at different stages of crop growth.

Experiments were conducted to investigate the effects of broadcast application and fertigation of water soluble fertilizers and normal fertilizer at three rates through drip and furrow irrigation methods on yield, water and fertilizer use efficiency for chilli. The higher yield that was 31 per cent and 24 per cent was obtained in water soluble fertilizer under 80 per cent of fertigation than the soil application at 100 per cent level in furrow and drip irrigation system with 20 per cent saving of fertilizers and 36 per cent saving of irrigation water (Veeranna *et al.*, 2001).

Singandhupe *et al.* (2003) had conducted a study on response of tomato crop to the urea fertilizer with drip irrigation compare to the convectional furrow irrigation. The results showed that application of nitrogen with the drip irrigation in ten equal splits at 8 days interval saved 20- 40 per cent nitrogen over the furrow irrigation applied with two equal splits. As per recommendation 120 kgN/ ha which applied to the crop, tomato fruit yield were 27.4 t/ha and 35.2 t/ ha in 2 consecutive years was found. Total nitrogen uptake with drip irrigation was 8-11per cent higher compare to that of furrow irrigation. And also highest level of applied nitrogen (120 kgN/ha), total average N uptake of was 64.5 kg/ha and 104.7 kg/ha in the year 1995 and 1996 respectively.

Hebbar *et al.* (2004) had studied the effect of fertigation on growth, yield and fertilizer use efficiency on tomato crop in red sandy loam soil during summer season 2000-2001 at University of Agricultural Science, Bangalore. The experiment includes eight treatments under furrow irrigation system. The results indicate that the leaf area index and dry matter were higher in drip irrigation system (3.12 g and 165.8 g) compare to furrow irrigation system (2.25 and 140.2 g). The yield of tomato was found 19.9 per cent higher in drip irrigation (71.9 kg/ha) than furrow irrigation system (59.50 kg/ha). Fertigation with 100 per cent water soluble fertilizer increased the fruit yield that was 79.2 kg/ha than control.

Kaviani *et al.* (2004) had conducted an experiment with randomized block design in sandy loam texture soil with an exchangeable potassium level of 140 mg/kg. Two methods of application were used in this experiment a rate based on the soil test (K1) and twice the soil test (K2) were used. The highest yield of 39.27 t/ha was obtained with fertigation of potassium chloride at the rate based on soil test (K1) which compare to the control was 10.44 t/ha.

Anitha (2006) had conducted an experiment on nutrient management for chilli based cropping system in Kerala. Based on the cropping system nutrient levels influences on yield. Higher growth and yield of chilli, French bean and amaranthus was observed when both chilli and intercrops were given 100 per cent nutrient dose. The yield of the chilli was 8917, 5598 and 4865 kg/ha at 100, 75 and 50 per cent nutrient doses respectively.

The studies conducted at Agricultural Research Station Bhavanisagar to maximize the water and fertilizer use efficiency of drip irrigation system for brinjal crop. The experiments were randomized block design with nine treatments includes three irrigation levels 100, 75, 50 per cent of pan evaporation and with three fertigation levels 125, 100 and 75 per cent of Nitrogen and Potassium application by fertigation which replicated thrice. The results observed that higher yields with maximum shoot length and number of branches per plant were recorded for the treatment with 75 per cent of pan evaporation with fertigation of 75 per cent of Nitrogen and Potassium (Vijayakumar *et al.*, 2007).

Ahmed *et al.* (2009) had conducted the field experiment during winter season 2007-2008 at farm of the Faculty of Agriculture, Tanta University, Egypt. The study was to investigate the effect of irrigation frequency and potassium source (K SO_4or KCl_2) on water application, water use efficiency of garlic. The results obtained that irrigation once every 15 days followed by irrigation every 20 days were superior to other treatments and increased water application and water use efficiency. Application of K SO_4 fertilizer was more effective compare to KCl_2 to improve the vegetative growth characters and also yield qualities and storability.

Feleafel and Mirdad (2013) had conducted an experiment during winter season 2011-2012 at Agricultural Experiment Station, King Abdulaziz University to evaluate the NPK fertigation rates on the growth, yield, quality and nutrient uptake of eggplant crop. The experiment has twelve treatments, were the combinations of fertigation rates of three NPK fertilizer were 60 per cent, 80 per cent and 100 per cent of recommendation 250, 90, 250 kg of N, K_2O per ha and four fertigation frequencies one dose biweekly (six doses per season), one dose weekly (12 doses per season), two doses weekly (24 doses per season) and three doses weekly (36 doses per season). The result indicated that increase in the total fruit yield/ ha and number of fruits were 278 per cent and 146 per cent of three doses weekly over with one dose biweekly.

2.6 COST ECONOMICS

Hoon and Vander (1979) had studied the cost economics of cultivation for cut flowers in greenhouse and reported that returns remained the same continuously for three consecutive years during 1976-1978, while cost had risen considerably. A similar experiment revealed that greenhouse cultivation of roses for three years cost of cultivation increased with time, but profitability declined greatly (Rijssel and Oprel, 1979).

Grangesand Leger(1989)had reported that by increasing the number of plants from three to six per square meter increase the total yield by 80 and gross returns by 50 under the greenhouse condition.

The greenhouse cultivation resulted in higher returns by producing higher yields produce, its initial investments and maintenance costs were much higher than natural or traditional cultivation methods. Therefore growers should be provided with the same technology and structures at lower costs to suit the Indian conditions as it results in better feasibility and profitability (Khan, 1995).

A studies conducted that capsicum under greenhouse has highest net profit was Rs. 7,698 for 100 m^2 compare to the open field system was Rs.282 for 100 m^2 per crop with a cost benefit ratio of 1.46 as compared to open field condition was 0.24 (Megharaja, 2000).

Nagendraprasad (2001) had reported economic analysis for capsicum with three plant spacing, medium spacing of 45 cm × 30 cm found the highest net returns of

Rs. 21,018 100per m^2 per year and higher cost benefit ratio of 2.60 because of excellent quality fruits fetching relatively good price (Rs.20 kg^{-1}) as compared to those from open field conditions was Rs.2560 100 per m^2 per year with least cost benefit ratio of 1.65 (Rs.16/kg).

Sengar and Kothari (2008) had conducted a study on economic evaluation of rose nursery inside the greenhouse at College of Agricultural Engineering and Technology, Ratnagiri. Rose nursery raising is very difficult in winter season because of low temperature. Rose plants were selected for experiment based on the temperature requirement for nursery raising for proper growth in winter. The total constructional cost of arch shaped greenhouse of size 80 m^2 was Rs.100000/-. In 80 m^2 floor area, 55 m^2 area was used for plant seedling and 25 m^2 area was left for movement in the greenhouse carrying out agricultural operations. In 55 m^2 area of greenhouse, 9700 seedling could be raised with 0.075 x 0.075 m spacing in 20 pits. The results obtained that the internal rate of return, the cost benefit ratio, when rose nursery grown inside the greenhouse were Rs.453221 /-, 53 per cent, 4.5 respectively.

Wachira *et al.* (2014) conducted a study on the profit comparison of small scale greenhouse and open-field tomato production systems at Nakuru-North District, Kenya. The study states that greenhouse tomato production is less susceptible to diseases and weather conditions. The tomato growing technology inside the greenhouse has been wanting, with the cost of greenhouse installation and maintenance being quoted as the key impediment. Using survey data from 216 tomato farmers in area the results obtained that Gross margin and Net Profit for both greenhouse and open-field tomato production systems were determined. The results obtained that the mean net profit per m^2 from greenhouse tomato was more than 10 times higher than open-field tomato production system.

Gokul (2015) had conducted an experiment on comparative evaluation under polyhouse, rainshelter and open field under the performance of cowpea. The results observed that all the vegetative parameter was found higher under polyhouse compare to all structures. And also Gross margin and Net Profit for all the structures were determined. Cost Benefit (B: C) ratio found maximum 1.73 was noted in open field cultivation. Cost Benefit ratio for naturally ventilated polyhouse and rainshelter were 1.06 and 1.34 respectively.

Materials and Methods

CHAPTER 3

MATERIALS AND METHODS

There are different arguments regarding the adaptability and advantages of polyhouse and rainshelter for protected cultivation in Kerala. The present investigation was carried out to study the performance of tomato under naturally ventilated polyhouse and rainshelter. Materials used and methodology adopted for this study was briefly discussed in this chapter.

3.1 GEOGRAPHICAL LOCATION OF EXPERIMENTAL SITE

The experiment was carried out in the instructional farm of KCAET, Tavanur, Kerala. The study was conducted using tomatocrop during the period from December 2016 to April, 2017 under naturally ventilated polyhouse and rainshelter of PFDC, KCAET, Tavanur, Kerala. The site is situated on the cross point of 10° 51'18" N Latitude and 75°59' 11" E Longitude at an altitude of 8.54 m above mean sea level.

3.2 EXPERIMENTAL DETAILS

Table 3.1 Experimental details

Location	Kelappaji College of Agricultural Engineering and Technology, Tavanur.
Crop	Tomato (*Solanum lycopersicum*) crop belongs to the family Solanaceae.
Variety	Akshaya
Spacing	60 cm between the plants
Area	100 m^2 each
Protected structure/ condition	Naturally ventilated polyhouse Rainshelter
Design	CRD

Replications	Ten
Treatments	Two

3.3 PROTECTED STRUCTURES

3.3.1Naturally ventilated polyhouse

An experiment was carried out in the naturally ventilated polyhouse of area 292 m^2 (36 m length and 8 m width) is oriented in East-West direction situated in the instructional farm of KCAET, Tavanur. Frame of the structure is made up of galvanized steel pipe and covered with 200 micron UV stabilized polyethylene film. The sides of the polyhouse are covered by insect proof net of 40 mesh for natural ventilation and protection against entry of insect and pests. For the present trial an area of 100 m^2 of length 20 m and breadth 5 m was selected inside the polyhouse for cultivating tomato. Specifications and schematic diagram of the naturally ventilated polyhouse is given in Table 3.2 and Fig 3.1.

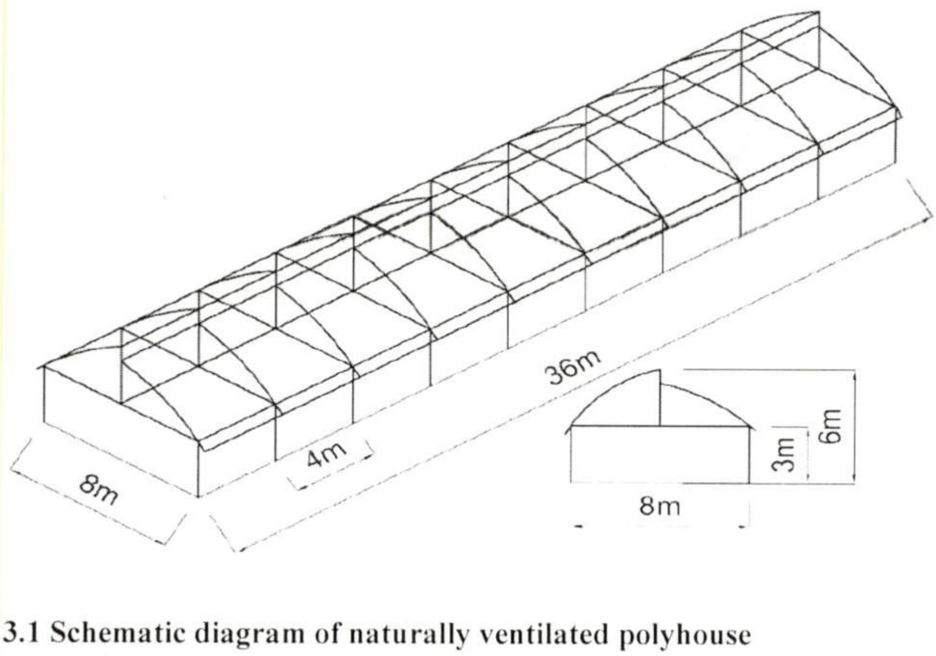

Fig 3.1 Schematic diagram of naturally ventilated polyhouse

Table 3.2 Specifications of naturally ventilated polyhouse

Sl No.	Particulars	Specification
1	Green House type	Naturally ventilated, tropical with corridor, fixed roof vent, (saw tooth type)
2	Column height	3 m
3	Centre height	6 m
4	Inside area	292 m^2
5	Structure	
	External column pipe	2" diameter, 2 mm thick galvanized steel B class
	Internal column pipe	1.5" diameter, 2 mm thick galvanized steel B class
	Arch	1.5" diameter, 2 mm thick galvanized steel B class
	Gutter	2 mm galvanized
	Entrance	Double door sliding with sealing brushes
6	Ventilation	
	Side walls	Covered with 40 mesh UV stabilized net
	Roof vent	At least 0.75 m width covered with 40 mesh UV stabilized insect proof net
	Shade net screen inside	Black 50 per cent UV stabilized movable

48

Plate 3.1 Naturally ventilated polyhouse

Plate 3.2 Rainshelter

3.3.2 Rainshelter

The rainshelter situated beside the polyhouse was selected for the study. Rainshelter having an area of 100 m^2 with 20 m length, 5 m width and 3 m height is oriented in East-West direction as in the case of polyhouse. The frame is made up of galvanized iron pipe and covered with 200 micron UV stabilized polyethylene film. Specifications of rainshelter are given in Table 3.3 and Fig 3.2 shows the schematic diagram of structure.

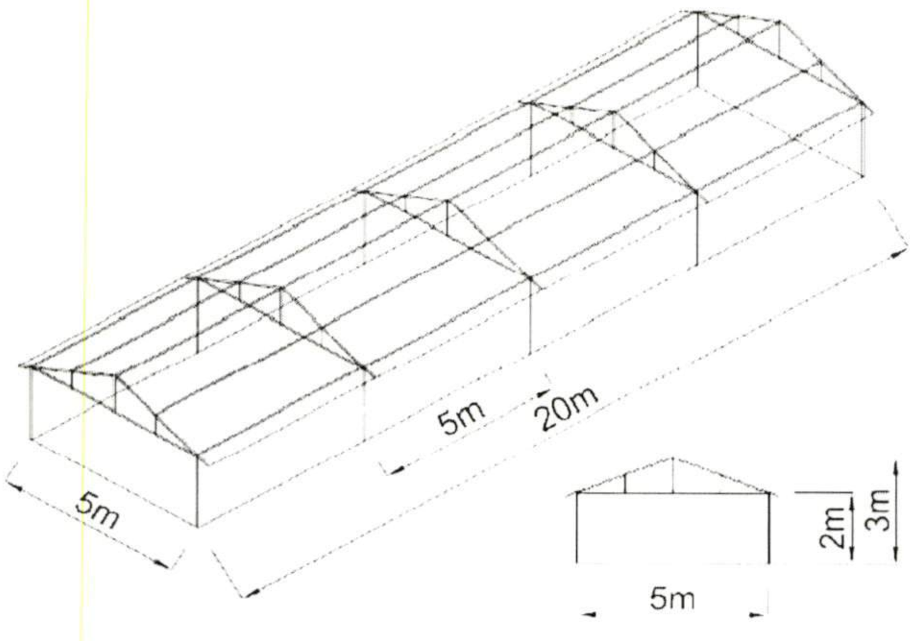

Fig 3.2 Schematic diagram of rainshelter

Table 3.3 Specifications of rainshelter

Sl. No.	Particulars	Specification
1	Rain shelter type	Gable shaped
2	Column height	2 m
3	Centre height	3 m
4	Inside area	100 m^2
5	Structure	
	Column pipe	1.5" diameter, 2 mm thick galvanized iron
6	Ventilation	
	Side walls	Covered with 50 mesh net on all four sides at a height of 1 m from ground
	Roof covering	200 micron polythene with 85 per cent light transmission

3.4 EXPERIMENTAL PROCEDURE

The experiment was conducted in an area of 100 m^2 (20×5 m^2) inside the existing polyhouse of 292 m^2 and a rainshelter of size 100 m^2 (20×5 m^2) near the polyhouse. The crop tomato (Akshaya) was raised in the polyhouse and rainshelter during the period from December 2016 to April 2017. All the cultural practices were done according to the Package of Practices recommendations of KAU.

3.5 FIELD EXPERIMENT

3.5.1 Nursery preparation

Tomato seedlings were prepared by using portrays having 98 cells of size 4 cm in diameter and 4.5 cm depth which were filled with vermin compost, soil and coco peat in equal proportion. Sowing was done by placing each seeds in a hole at a depth 0.5cm and covered by thin layer of growing medium. The trays were watered lightly and placed in a sheltered place. Seeds were treated with *Trichoderma* to avoid soil borne diseases. Seeds germinated in 4-6 days and the seedlings were ready for transplanting 21 days after sowing (Plate 3.3).

Plate 3.3 Nursery preparation

3.5.2Land preparation

The type of the soil in experimental plot was sandy loam. The land inside the polyhouse and rainshelter were ploughed thoroughly using mini tiller. All the weeds, stubbles, stones *etc.* were completely removed. The experimental plot was incorporated with well decomposed farmyard manure and lime and left idle for one week after application. The other manures used were 25 kg neem cake, *Trichoderma* @ 500 g per 50 litres was used as soil drench and 400 kg cow dung.

3.5.3 Bed preparation

Land was irrigated three to four times, ploughed again and brought to a fine tilth. The beds having a size 20 m length, 1 m width and 0.4 m height were raised inside the polyhouse and rainshelter. Each bed contains 30 plants with spacing of 60 cm and with a walking space of 50 cm between beds. The plots after the bed preparation are shown in Plates 3.4 and 3.5.

Plate 3.4 Polyhouse after bed preparation

Plate 3.5 Rainshelter after bed preparation

3.5.4 Drip irrigation

At the centre of the bed, inline drip laterals were laid for providing water and fertilizer effectively to the root zone depth. Inline drippers are spaced at 60 cm apart with a discharge rate of 2 lit/hr. The plants were irrigated daily through drip irrigation system. Irrigation water was pumped using 5 hp monoblock pump set and conveyed through the main line of 63 mm diameter PVC pipes after filtering through the disc filter. From the main pipe, sub main of PVC pipes (50 mm) were installed. From the sub mains water is conveyed to laterals of diameter 16 mm. Venturi injector was installed for fertigation along with irrigation unit (Plate 3.6).

Plate 3.6 Control system of drip irrigation

3.5.5 Spacing

The row system of planting was followed for planting to have more aeration space between the plants. A distance of 50 cm between the beds and 60 cm spacing between the plants were followed for the planting.

3.5.6 Crop variety

Tomato variety Akshaya released by KAU, was used for the trial. Sowing was done on 09-10-2016. The seeds were sown at a depth of 0.5 cm in portrays and transplanting was done on 1-12-2016. The seeds were treated in *Trichoderma* for 24 hours.

3.5.7 Transplanting

Beds were watered to before transplanting. The holes were made on each mark by using PVC pipe. Seedlings of 21 days old and uniform size were selected for planting and transplanted under polyhouse and rainshelter with spacing of 60 cm between the plants. Transplanting was done in morning. Seedlings from portrays were removed by giving slight pressure from the bottom of individual cells. Seedlings were transplanted at recommended spacing at a shallow depth of 2.5 – 3.0 cm from the ground level.

3.5.8Fertigation

Duration of the crop is 150 days and fertigation was scheduled as 50 splits once in three days from planting till the end of crop. Fertilizers were applied through drip irrigation system using venturi assembly. The fertigation schedule was followed based on PFDC recommendation as shown in Table 3.4.

Table 3.4Fertigation schedule for tomato

Crop	Tomato
Total NPK	215:112:215 kg ha^{-1}
Basal P	65:00 kg ha^{-1}
Establishment stage (split into 10 doses)	21.50:11.2:21.50 kg ha^{-1}
Vegetative stage (split into 15 doses)	**32.25:16.8:32.25 kg ha^{-1}**
Fruiting stage (split into 25 doses)	53.25:28.0:53.25 kg ha^{-1}

3.5.9 Training of tomato plants

Training of plants was done by using the plastic twine. Separate plastic twine was provided for each plant and to each branch so that branches do not break up. Tying of plants to the plastic twine started from fourth week after transplanting and tying was done at weekly intervals along with pruning operation (Plate 3.7 and 3.8).

Plate 3.7 Crop stand in polyhouse after training of plants

Plate 3.8 Crop stand in rainshelter after training of plants

3.5.10 Inter cultural operation and weeding

Manual weeding was done in a periodic manner. Drip irrigation could control the growth of weeds as it gives only sufficient amount of water directly to each plant.

3.5.11 Plant protection measures

Plant protection measures using recommended dose of chemicals were adopted to prevent the incidence of pest and disease attacks. Various pesticides used are *Trichoderma* for seed treatment (10 g/kg) and Indofil-M-45 (3 g/l) for the management of various fungal diseases.

3.5.12 Harvesting

Harvesting of tomato fruits started at 70-80 days after transplanting and continued until 140-150 days after transplanting. The fruit were harvested on colour basis and was done daily.

3.6SOIL PROPERTIES

3.6.1 Particle size distribution

The grain size distribution of soils was done by sieve analysis. Dry sieve analysis was carried out using different sieves sizes. Sieving was done using sieve shaker and weight of soil retained in each sieves were noted.

3.6.2 Soil pH

Soil collected from the experimental sites were analyzed for the pH.

3.6.3 Soil moisture constants

Laboratory analysis for determination of field capacity and permanent wilting point was carried out using pressure plate apparatus. The pressure plate apparatus consists of ceramic pressure plate of high air entry values contained in airtight metallic chambers strong enough to withstand high pressure (15 bars or more).

For the analysis of soil moisture constraints both the porous plates and the soil samples were saturated and the saturated soil samples were placed on the plates and transferred to the metallic chambers. The compressed air was filled inside the pressure plate apparatus chamber and valves were adjusted to apply varied pressures from the compressor. The chamber was closed tightly for ceiling it. The pressure was applied for duration of 48 hours until the water in sample was drained completely and no water dripped from the sample to the outlet. The moisture retained in media after application of varied pressures *viz,* 1/3, and 15 bars was determined by gravimetric methods. The apparatus as shown in the plate 3.9.

Plate 3.9 Pressure plate apparatus

3.7 OBSERVATIONS RECORDED

Observations on growth, yield and fruit quality parameters were recorded at various stages of crop growth and harvest from randomly 5 selected and labeled plants inside both polyhouse and rainshelter.

3.7.1Weather parameters

Following weather parameters were recorded from the time of transplanting to that of last harvest of fruits in both polyhouse and rainshelter.

3.7.1.1 Temperature (°C)

Thermo hygrometer was used to record the daily air temperature inside the polyhouse and rainshelter and expressed as mean monthly data.

3.7.1.2 Relative humidity (%)

Thermo hygrometer was used to record the daily relative humidity inside the polyhouse and rainshelter and expressed as mean monthly data.

3.7.1.3 Soil temperature (°C)

Soil temperature inside the polyhouse and the rainshelter at a depth of 10 cm were recorded by using thermocouple thermometer at daily interval.

3.7.2Growth parameters

3.7.2.1 Plant height (cm)

The plant height was recorded from the five randomly tagged plants selected from each treatment at 30, 45, 60, 70, 90 and 105 days after transplanting (DAT). The height of plants was recorded by using meter scale from the base to its growing tip of the main stem and the mean value was expressed in centimetres.

3.7.2.2 Number of primary branches

Numbers of branches from the tagged plant were counted at 30, 45, 60, 75, 90 and 105 days after transplanting (DAT) and recorded. Number of branches before final harvesting was also recorded.

3.7.2.3 Inter-nodal length (cm)

Inter-nodal length of the tagged plants from the each treatment was recorded at 30, 45, 60 75 90 and 105 days after transplanting (DAT).

3.7.2.4 Stem girth (cm)

Stem girth of the tagged plants from each treatment was recorded at base, middle and top portion of the stem at the end of the cropping period using vernier caliper and average girth was calculated.

3.7.2.5 Number of leaves per plant

Total number of leaves on primary and secondary branches of five tagged plants was counted before final harvesting and average was calculated.

3.7.3Reproductive parameters

3.7.3.1 Time taken for flower initiation

The number of days taken from date of transplanting to fifty per cent flowering was recorded in polyhouse and rainshelter.

3.7.3.2 Days taken from flowering to harvest

The number of days taken from flowering to harvest was recorded from the five tagged plants under each treatment and expressed as days taken for first harvest of fruit.

3.7.4 Yield parameters

3.7.4.1 Number of fruits per plant

The total number of fruit harvested was recorded from five randomly tagged plants from each treatment at weekly intervals was recorded till the end of the cropping period.

3.7.4.2 Average fruit weight (g)

Average weight of 10 fruits was recorded under each treatment at every harvest using digital electronic balance and mean was expressed in grams.

3.7.4.3 Average fruit diameter (cm)

The fruit diameter was recorded from each treatment by randomly selecting10 fruits and measuring diameter of individual fruits using vernier calipers.

3.7.4.4 Yield per plant (kg)

The weight of fruits per plant in each harvest was recorded till the final harvest and total yield of fruits per plant was recorded in kilograms.

3.7.4.5 Total yield (kg)

Total yield was calculated by recording the yield from the net plot under each treatment and was expressed in kilograms.

3.7.5 Quality parameter

3.7.5.1Total soluble solid (TSS)

The fruits were randomly selected from each treatment was cut and extract juice which was placed on hand refractometer and expressed in degree Brix.

3.8 DETERMINATION OF WATER USE EFFICIENCY

Water use efficiency was calculated for each treatment. It is the ratio of yield of crop in kg/ha and total water applied in mm.

$$WUE = \frac{Y}{WA}$$

Where,

WUE = Water Use Efficiency (kg/ha mm) of water used

Y = Yield of the crop (kg/ha)

WA = Total water applied (mm)

3.9 COST ECONOMICS

Cost Economics of tomato production under polyhouse and rainshelter was workedout by considering the present price of inputs and produce.

$$\text{Cost-Benefit Ratio} = \frac{\text{Net returns}}{\text{Cost of cultivation}}$$

3.10 STATISTICAL ANALYSIS

The data of growth and yield parameters were tabulated based on treatment and replication wise. IBM SPSS 20.0 statistical software was used to analyze the data. The data were expresses as Mean. One way Analysis of variance (ANOVA) with POST-HOC(TURKEY) analysis was used to compare the significant differences among mean of the treatments at 0.05 level of probability.

Results and Discussion

CHAPTER 4
RESULTS AND DISCUSSION

The results obtained from the present study "Comparative Evaluation of Naturally Ventilated Polyhouse and Rainshelter on the Performance of Tomato" are furnished based on observation taken during research detailed discussion are carried out in this chapter.

4.1 SOIL PROPERTIES

Soil properties like pH, soil physical properties and soil moisture constants were noted inside the polyhouse and rainshelter.

4.1.1 Particle size distribution

Soil samples from the polyhouse and rainshelter were analyzed for particle size distribution using sieve analysis and the results are given in Appendix I and Appendix II respectively. Soil texture of all the samples was sandy loam.

4.1.2 Soil pH

The value of soil pH inside polyhouse and rainshelter were found 7.0 and 6.7 respectively. The soil inside the polyhouse is neutral and the soils inside the rainshelter are slightly acidic in nature.

4.1.3 Soil moisture constants

Field Capacity (FC) and Permanent Wilting Point (PWP) were determined by using pressure plate apparatus. The field capacity inside the polyhouse and rainshelter were found as 12.6 per cent and 11.7 per cent respectively. Permanent Wilting Point inside the polyhouse and the rainshelter were found as 8.7 per cent and 7.4 per cent respectively.

4.2 WEATHER PARAMETERS

Growth, development, production and quality of the produce of any crop largely depend on the interaction between the plant genetics and the growing environmental conditions. Environment is the aggregate of all external conditions influencing the growth and development of crop, which play an important role in the crop production. Reddy *et al.* (1999) reported that every crop has its own set of environmental conditions under which it grows best and crops are not profitable unless they are adapted to the region in which they are produced. Raising a crop successfully means the crop must be productive and economical to grow under prevailing conditions.

Micro climatic parameters were varied between polyhouse and rainshelter. The observed weather parameters viz. maximum and minimum temperature, relative humidity, soil temperature for the months of December, January, February, March and April are presented and discussed here under.

4.2.1 Maximum and minimum temperature

Temperature is the major regulator of the development process for the crops which influences on the flower and fruit development. The effect of temperature on net photosynthesis is important for crop production. The higher temperature has more adverse influence on net photosynthesis of the crop than lower temperature leading to decreased production of photosynthetic activity above a certain temperature (Bhatt and Rao, 1989). The temperature can be controlled and regulated under protected structure, for the healthy and better growth of plants. Maximum and minimum temperatures in the morning, afternoon and evening inside polyhouse and rainshelter are given in Tables 4.1, 4.2 and 4.3 respectively. The maximum temperature (36.4 ^{0}C) was observed inside the polyhouse during the month of April in the afternoon and minimum temperature (22.3 ^{0}C) was recorded inside the rainshelter during the month of January. The temperature was found higher inside the polyhouse than the rainshelter throughout crop period. The higher temperature inside polyhouse may be due to the green house effect in which all the radiation entering into the greenhouse will contribute to the potential increase of the greenhouse temperature above that of the external air (Day and Bailey, 1999). Variation of maximum and minimum temperature inside the polyhouse and rainshelter in the morning, afternoon and evening are plotted and shown in Fig 4.1, 4.2 and 4.3 respectively. The monthly average maximum and minimum temperature in the afternoon was higher compare to morning and evening inside both the structures. The rise in air temperature inside the polyhouse compared to rainshelter ranges from 2.5 °C to 3.6 °C. The similar results were obtained by Parvej *et al.* (2010).

Table 4.1 Mean maximum and minimum temperature at 8.30 AM

Temperature in the morning				
Month	**Polyhouse**		**Rainshelter**	
	Max(^{0}C)	**Min(^{0}C)**	**Max(^{0}C)**	**Min(^{0}C)**
December	32.2	26.1	30.5	24.3
January	31.3	26	29.4	24.1
February	31.6	25.7	29.1	23
March	32.7	28	31.6	24.5
April	33.4	26.3	31.8	24.6

Table 4.2 Mean maximum and minimum temperature at 12.30 PM

Temperature in the afternoon				
Month	**Polyhouse**		**Rainshelter**	
	Max(^{0}C)	**Min(^{0}C)**	**Max(^{0}C)**	**Min(^{0}C)**
December	35.8	25.8	32.8	24.8
January	33.1	24.2	30.5	22.3
February	34.8	25.1	26.1	22.8
March	35.2	26.3	32.4	23.4
April	36.4	25.8	33.2	24.5

Table 4.3 Mean maximum and minimum temperature at 4.00 PM

Temperature in the evening				
Month	**Polyhouse**		**Rainshelter**	
	Max(^{0}C)	**Min(^{0}C)**	**Max(^{0}C)**	**Min(^{0}C)**
December	34.2	26.1	32.1	24.1
January	33.8	25	31.8	22.8
Febuary	34.5	27.4	31.9	23.4
March	33.2	24.6	31.5	23.6
April	34.1	26.5	32.6	24.3

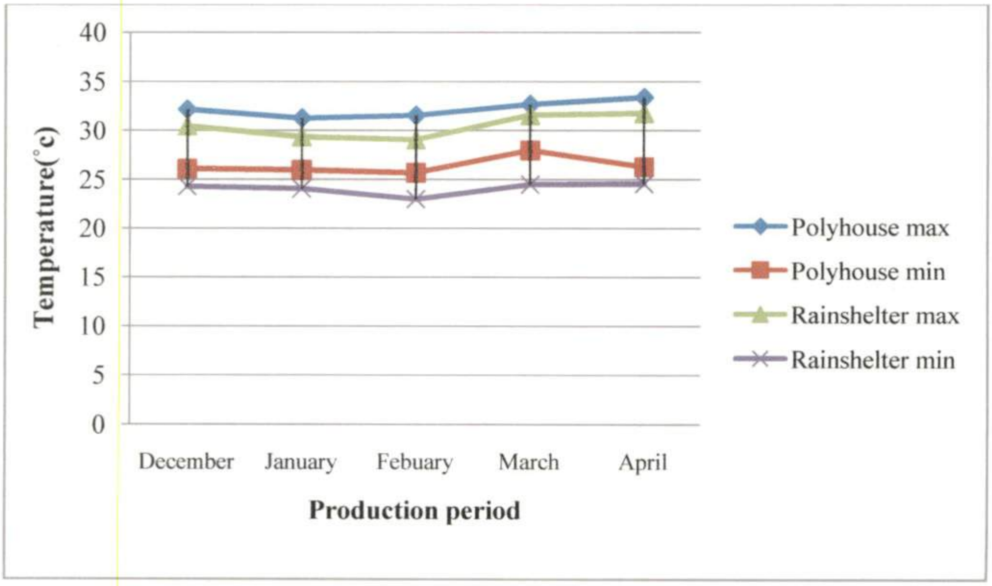

Fig 4.1 Maximum and minimum temperature variation inside polyhouse and rainshelter at 8.30 AM

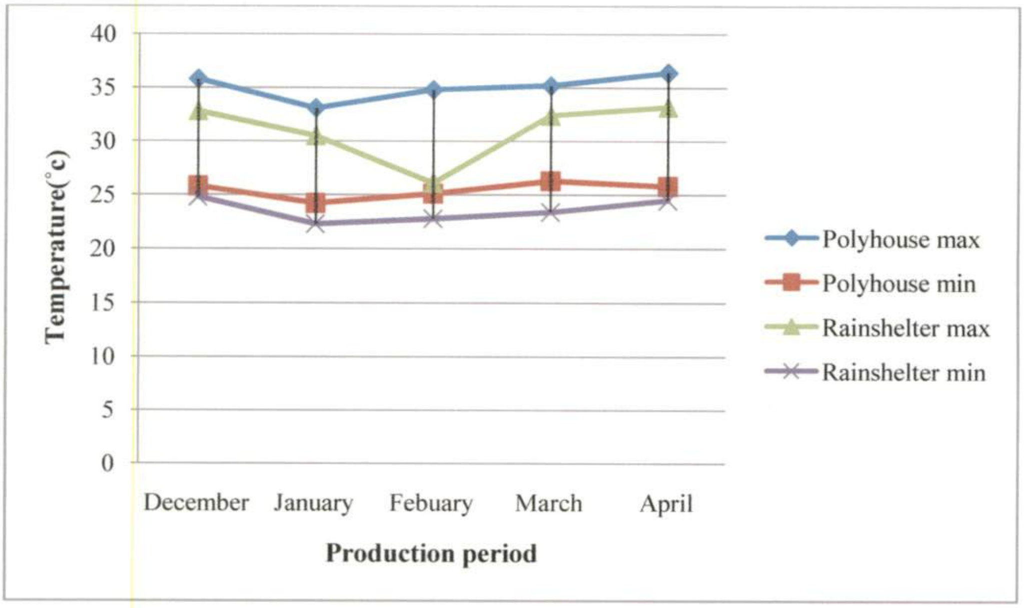

Fig 4.2 Maximum and minimum temperature variation inside polyhouse and rainshelter at 12.30 PM

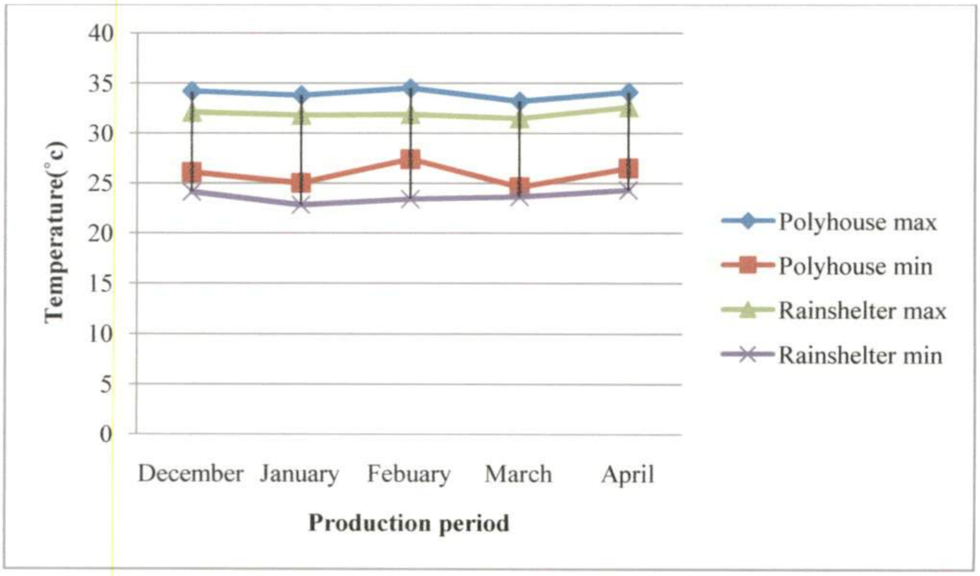

Fig 4.3 Maximum and minimum temperature variation inside polyhouse and rainshelter at 4 PM

4.2.2 Relative humidity

Relative humidity is a key component of environmental control and plays an important role in plant growth and development. The photosynthetic activity increased with an increase in relative humidity because with the increased relative humidity lowers water stress in the leaf which results in the increase of stomatal conductance and the CO_2 concentration in the leaf are maintained at higher levels. Bakker (1991) reported that the photosynthetic rate was improved by high humidity with increasing stomatal conductance. The yield of crop is to be increased by higher relative humidity (Leonardi *et al.*, 2000). The maximum relative humidity (83.82 per cent) was recorded during the month of December in the polyhouse and the minimum relative humidity (70.2 per cent) was recorded during the month of April in the rainshelter. Variation of relative humidity inside the polyhouse and rainshelter in the morning, afternoon and evening are plotted and are shown in Fig 4.4, 4.5 and 4.6 respectively.

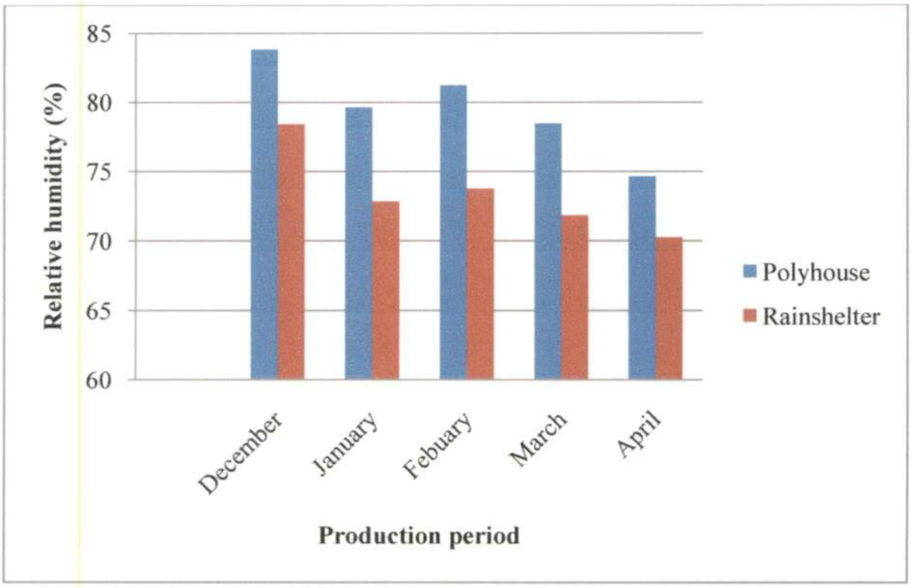

Fig 4.4 Variation of relative humidity at 8.30 AM

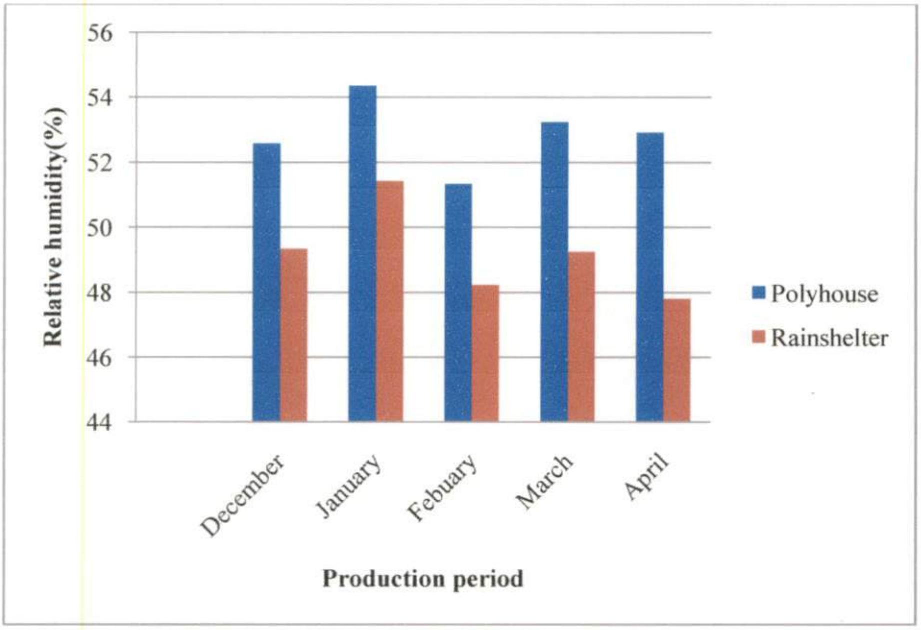

Fig 4.5 Variation of relative humidity at 12.30 PM

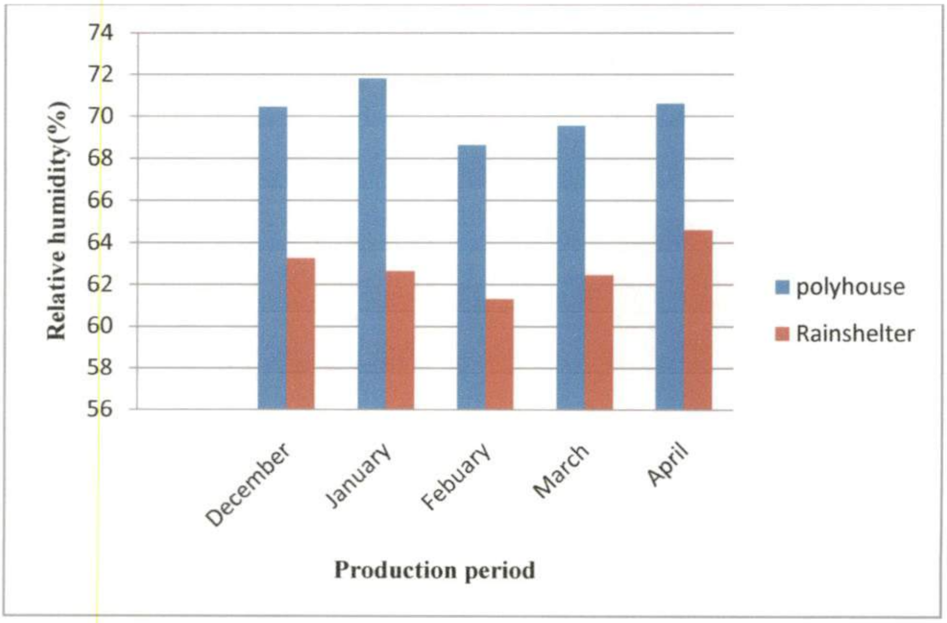

Fig 4.6 Variation of relative humidity at 4 PM

From Fig 4.4 it was noted that the relative humidity inside polyhouse is higher than that in the rainshelter in the morning throughout the crop period. Similar results reported that the relative humidity was found higher inside the polyhouse than in the open field which influenced tomato growth and yield (Nimje and Shyam, 1993). From Fig 4.4, 4.5 and 4.6, it is evident that relative humidity was found higher inside the polyhouse than the rainshelter both in the afternoon and evening.

4.2.3 Soil temperature

Variation of soil temperature inside the polyhouse and rainshelter in the morning, afternoon and evening are shown in Fig 4.7. Soil temperature was observed higher in polyhouse than the rainshelter throughout the crop period. Soil temperature inside the polyhouse was always found 3 to 5 °C higher as compared to rainshelter throughout the growth period of the crop. The maximum soil temperature (37.8 ^{0}C) was observed inside the polyhouse during the month of March in the morning and minimum soil temperature (25 ^{0}C) was observed inside the rainshelter during the month of February in the afternoon. The higher temperature inside the polyhouse is due to the green house effect. Similar results were reported by Sam and Regeena (2016) that soil temperature in the polyhouse was 2- 3 °C higher than at the outside soil during all the growing stages of crops.

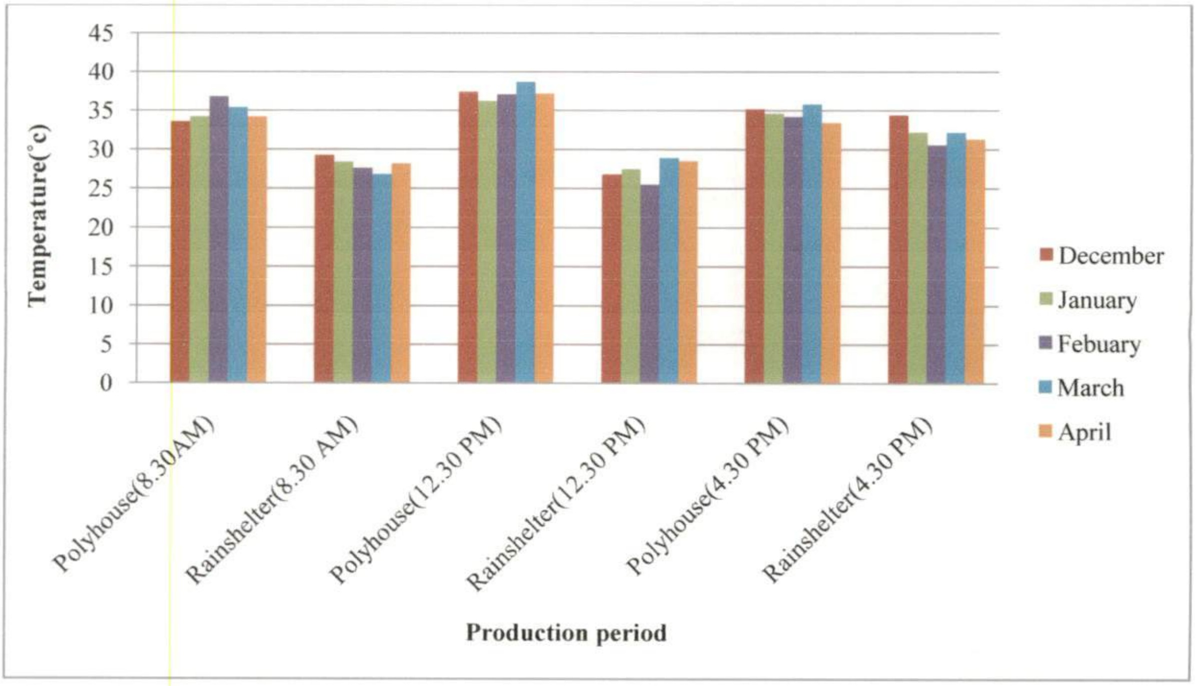

Fig 4.7 Variation of soil temperature in the experimental plots at 8.30 AM 12.30PM and 4.00 PM

4.3 GROWTH PARAMETERS

4.3.1 Plant height (cm)

The data on plant height at different stages of tomato as influenced by growing environment are shown in Table 4.4 and Fig 4.8. The plant height of tomato differed significantly due to growing environment in all stages of crop growth *viz.,* 30, 45, 60, 75, 90 and 105 days after transplanting (DAT).

Table 4.4 Plant height as influenced by growing environment at different stages of crop growth of tomato

	Plant height(cm)					
Treatment	**30DAT**	**45DAT**	**60DAT**	**75DAT**	**90DAT**	**105DAT**
T1-Polyhouse	30[a]	49.8 [a]	78.2 [a]	100 [a]	136.4 [a]	155 [a]
T2-Rainshelter	26.8[b]	44[b]	65.2[b]	79.6[b]	93.2[b]	111.4[b]

DAT- days after transplanting

The plant height increased as the plant got aged and there were statistically significant differences among the treatments. At 30 DAT, plant height was 30 cm in the polyhouse, which was found significantly superior over the rainshelter. Lower plant height (26.8 cm) was recorded inside the rainshelter. Lesser plant height (44 cm and 65.2 cm) was recorded inside the rainshelter at 45 DAT and 60DAT compared to polyhouse (49.8 cm and 78.2 cm). Similar trend was noted at 75 DAT and 90DAT and was found that plant height was more inside the polyhouse than the rainshelter. At 105 DAT, plant height was 155 cm inside the polyhouse, which was significantly superior over the rainshelter (111.4 cm). This may be attributed to the enhanced plant metabolic activities like photosynthesis and respiration due to favourable micro-climatic conditions that prevailed in the polyhouse as compared to the rainshelter. Similar results of higher growth rates in the polyhouse were reported by More *et al.* (1990) in cucumber and Ganesan (1999) in tomato plants.

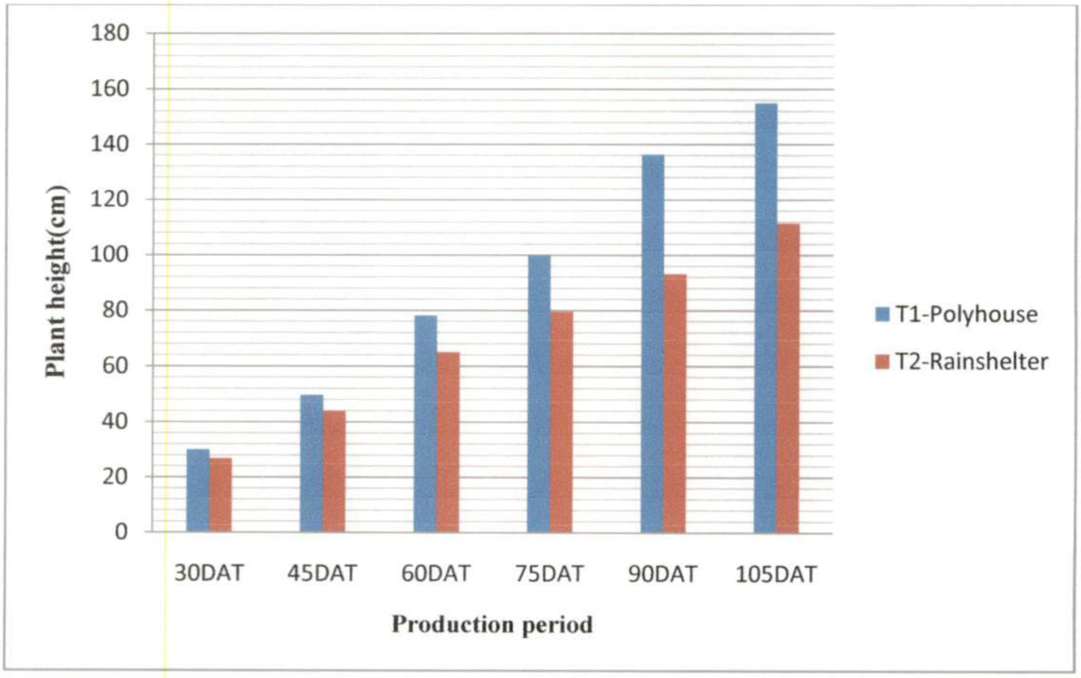

Fig 4.8 Plant height (cm) as influenced by growing environment at different stages of crop growth of tomato

4.3.2 Number of branches

The number of branches at different stages of tomato growth as influenced by the growing environment is shown in Table 4.5 and Fig 4.9. From the data it is evident that the number of branches is more inside the rainshelter than the polyhouse at all stages of crop growth. The number of branches was found as 27.8 inside the rainshelter and 23.2 inside the polyhouse at 105 DAT. More number of branches inside rainshelter as compared to polyhouse was reported by Gokul (2015) for cowpea. The result indicates that the crop might require more light intensity for better growth and development of the plant (Marcelis and Hofman-Eijer, 1993).

Table 4.5Number of branches as influenced by growing environment at different stages of crop growth of tomato

	No. of branches					
Treatment	**30DAT**	**45DAT**	**60DAT**	**75DAT**	**90DAT**	**105DAT**
T1-Polyhouse	6.2[b]	9.6[b]	13.6[b]	19.4[b]	22.8[b]	23.4[b]
T2-Rainshelter	8[a]	13.8[a]	14.2[a]	22.6[a]	27.8[a]	27.8[a]

DAT - Days after transplanting

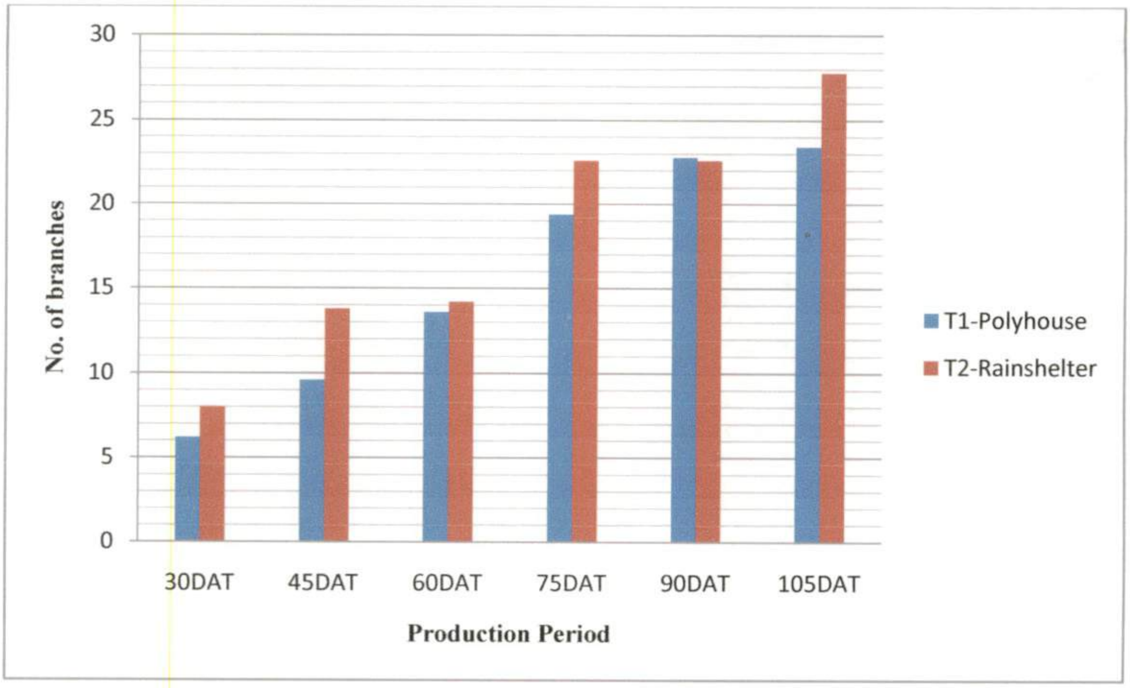

Fig 4.9 Number of branches as influenced by growing environment at different stages of crop growth of tomato

4.3.3 Inter-nodal length (cm)

The data on inter-nodal length at different stages of crop growth as influenced by growing environment are shown in Table 4.6 and Fig 4.10. During the different stages of crop growth *viz.*, 30, 45, 60, 75, 90 and 105 DAT, the inter-nodal length of tomato increased and it was 39.6 cm at 105 DAT inside the naturally ventilated polyhouse.

Table 4.6 Inter-nodal length as influenced by growing environment at different stages of crop growth of tomato

	Inter-nodal length(cm)					
Treatment	**30DAT**	**45DAT**	**60DAT**	**75DAT**	**90DAT**	**105DAT**
T1-Polyhouse	13.2 [a]	21.2 [a]	25.8 [a]	30.6 [a]	36.2 [a]	39.6 [a]
T2-Rainshelter	12.4 [b]	18.4 [b]	22.4 [b]	26 [b]	28.8 [b]	33.2 [b]

DAT - Days after transplanting

The inter-nodal length of tomato differed significantly due to growing environment at all stages of growth. The inter-nodal length was significantly higher inside the polyhouse compared to the rainshelter. The increase in inter-nodal length inside polyhouse may be due to enhanced plant metabolic activities like photosynthesis and respiration due to favourable micro-climatic conditions that prevailed inside the polyhouse as compared to rainshelter. Similar results were reported by Ramesh and Arumugam (2010) for vegetables grown inside the polyhouse.

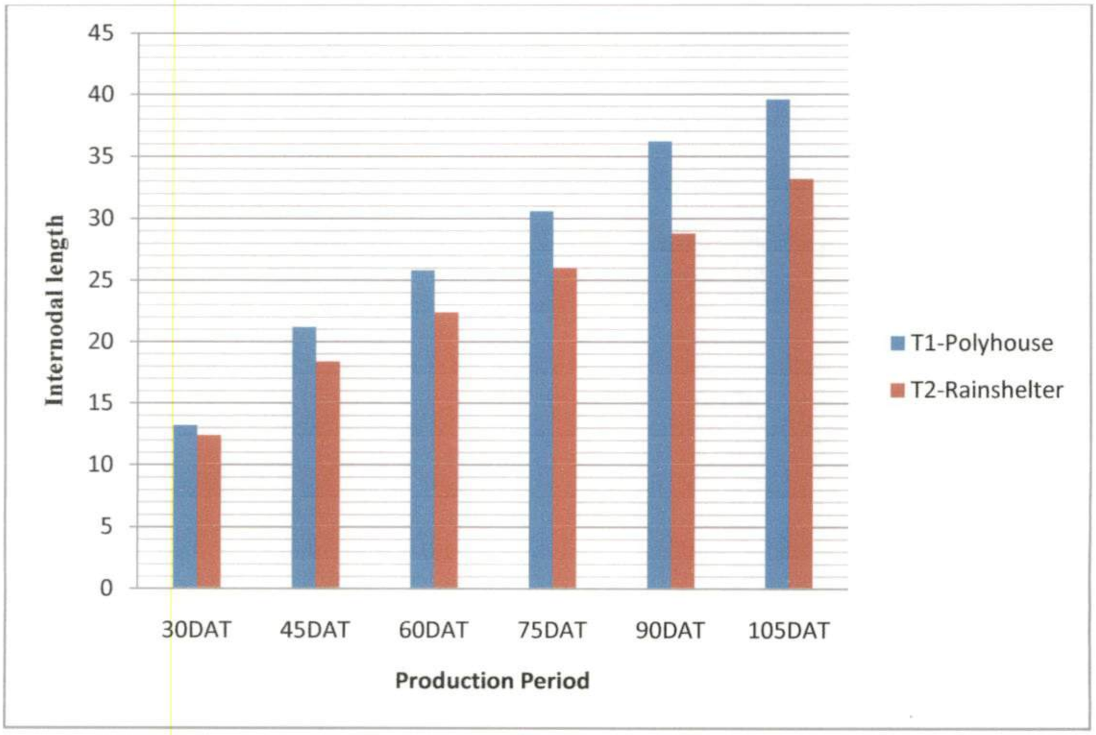

Fig4.10 Inter-nodal length (cm) as influenced by growing environment at different stages of crop growth of tomato

4.3.4 Stem girth

The data on stem girth of the plant at different stages of growth as influenced by growing environment are shown in Table 4.7 and Fig 4.11. During the different stages of crop growth *viz.*, 30, 45, 60, 75, 90 and 105 DAT, the stem girth of tomato was found increasing and it was 2.7 cm at 105 DAT inside the rainshelter, which is higher as compared to 2.3 cm inside the naturally ventilated polyhouse. From the Table 4.7 it is clear that stem girth of plant is higher inside the rainshelter compared to naturally ventilated polyhouse at all stages of the plant growth.

Table 4.7 Stem girth as influenced by growing environment at different stages of crop growth of tomato

	Stem girth(cm)					
Treatment	**30DAT**	**45DAT**	**60DAT**	**75DAT**	**90DAT**	**105DAT**
T1-Polyhouse	0.64 [a]	0.95 [b]	1.42 [b]	1.86 [b]	2.3 [b]	2.3 [b]
T2-Rainshelter	0.68 [a]	1.08 [a]	1.54 [a]	2.24 [a]	2.5 [a]	2.7 [a]

DAT- days after transplanting

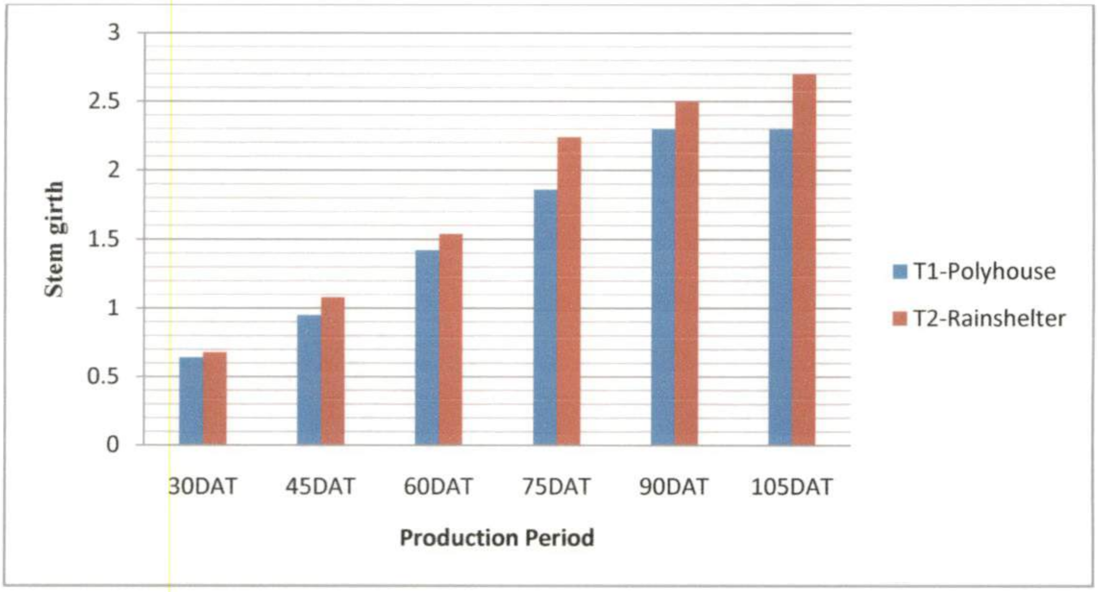

Fig 4.11 Stem girth as influenced by growing environment at different stages of crop growth of tomato

4.3.5 Number of leaves

The data on number of leaves at different growth stages of tomato as influenced by the environment are shown in Table 4.8 and Fig 4.12. From the data it is evident that the number of leaves was more inside the rainshelter compared to the polyhouse at all stages of crop growth and number of leaves were 24.6 and 15.2 at 30 DAT. At the final stage the number of leaves was 105.4 and 101inside the rainshelter and the polyhouse respectively. This indicates that the crop might require more light intensity for better growth and development of the plant (Marcelis and Hofman-Eijer, 1993).

Table 4.8 Number of leaves as influenced by growing environment at different stages of crop growth of tomato

	No. of leaves					
Treatment	**30DAT**	**45DAT**	**60DAT**	**75DAT**	**90DAT**	**105DAT**
T1-Polyhouse	15.2 [b]	27.8 [b]	39.2 [b]	61.4 [b]	78.2 [b]	101 [b]
T2-Rainshelter	24.6 [a]	37.8 [a]	63.2 [a]	80.2 [a]	91.6 [a]	105.4 [a]

DAT- days after transplanting

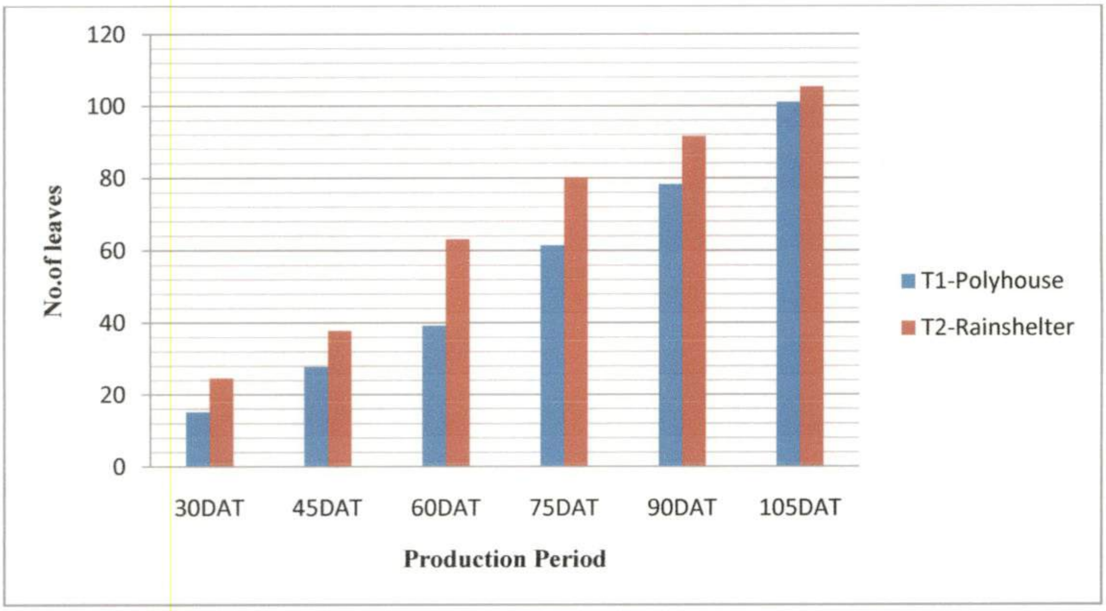

Fig 4.12 Number of leaves as influenced by growing environment at different stages of crop growth of tomato

4.4 REPRODUCTIVE PARAMETERS

4.4.1 Time taken for flower initiation

The data on time taken for flower initiation of tomato as influenced by growing environment are shown in Table 4.9. Compared to the rainshelter early flower initiation was noted inside the polyhouse. The time taken to the first harvest was less in case of polyhouse compared to the rainshelter. Similar result was obtained by Kang and Sidhu (2005) and it was reported that polyhouse climate influenced the crops to open flower and mature of fruits earlier.

4.4.2 Time taken for 50 per cent flowering

The time taken for 50 per cent flower initiation as influenced by growing environment for tomato is shown in Table 4.9.The growing environment significantly influenced the average number of days required for 50 per cent flowering. Plants grown in naturally ventilated polyhouse reached 50 per cent flowering earlier (53 days) as compared to rainshelter (58 days). This may be due to maximum photosynthesis activity inside the polyhouse and faster growth, which might have influenced the early initiation of flowers and 50 per cent flowering. Similar results were reported by Zende (2008) that early flower initiation found in greenhouse compared to shallow house.

4.4.3 Time taken to first harvest

The data on time taken to first harvest as influenced by growing environment for tomato are presented in Table 4.9. Early harvesting (72 days) was possible inside the polyhouse compared to the rainshelter (74 days). This is in agreement with the finding of Zende(2008).

80

Table 4.9 Time taken for different growth attributes as influenced by growing structures of tomato

Treatment	Time taken for flower initiation (days)	Time taken for 50 per cent flower initiation (days)	Time taken for first harvest (days)
T1-Polyhouse	45	53	72
T2-Rainshelter	49	58	74

4.5 YIELD PARAMETERS

4.5.1 Number of fruits

The data on number of fruits per tomato plant at different stages of crop growth as influenced by growing environment are presented in Table 4.10 and Fig 4.13. At 110-120 DAT number of fruits per plant was maximum (16.8) under rainshelter, which was significantly higher when compared to the polyhouse. This might be due to the increased number of flowers and maximum fruit set inside the rainshelter.

Table 4.10 Number of fruits per plant at different stages of crop growth oftomato

Treatment	0-70 DAT	70-80 DAT	80-90 DAT	90-100 DAT	100-110 DAT	110-120 DAT	120-130 DAT	130-140 DAT	140-150 DAT
T1-Polyhouse	2.4^{b}	5^{b}	3.6^{b}	3^{b}	5^{b}	4^{b}	4^{b}	3.6^{b}	3.6^{a}
T2-Rainshelter	4.4^{a}	8.4^{a}	14.8^{a}	13^{a}	11.4^{a}	16.8^{a}	13.6^{a}	11.8^{a}	0

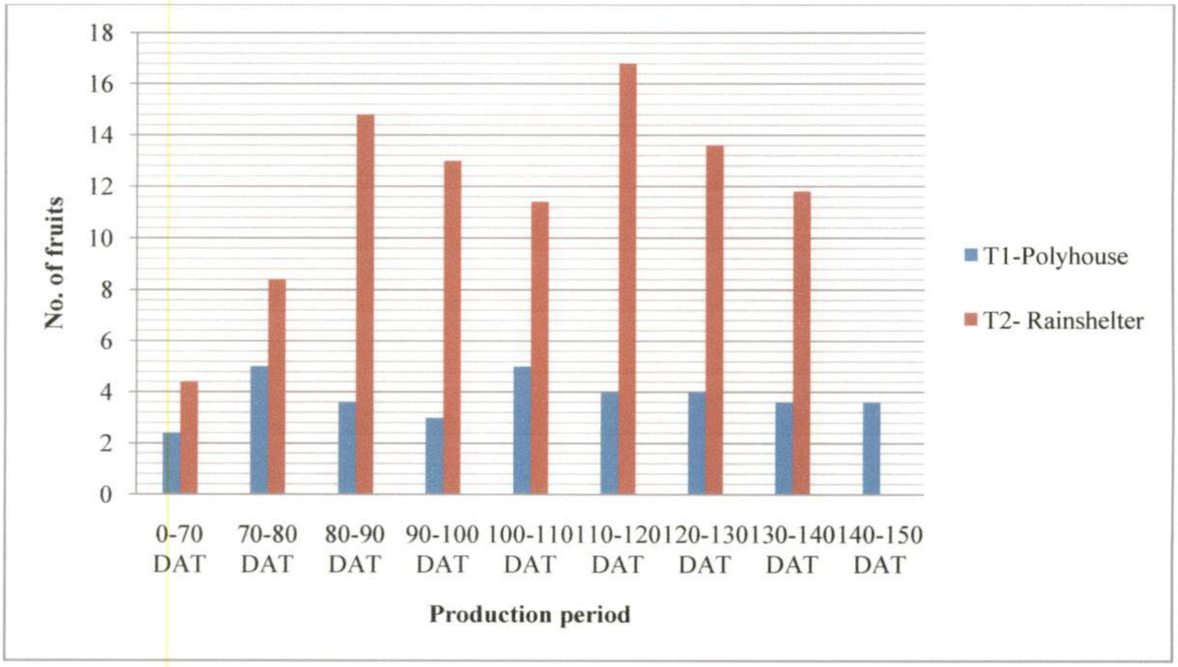

Fig 4.13 Number of fruits at different stages of crop growth of tomato

4.5.2Fruit diameter (cm)

The average diameter of the fruits inside the polyhouse and rainshelter are shown in Table 4.11. Average fruit diameter of 7.42 cm was obtained inside the polyhouse, whereas it was 6.52 cm inside the rainshelter. Similar results were reported by Yellavva (2008) under polyhouse.

Table 4.11 Average diameterand weight of the tomato fruits under polyhouse and rainshelter

Treatment	Average diameter of fruits(cm)	Average weight of the fruits(g)
T1- Polyhouse	7.42	75
T2- Rainshelter	6.52	64

4.5.3 Fruit weight (g)

The data on the average diameter of the fruits under polyhouse and rainshelter recorded are shown in Table 4.11. Among the different structures, the average weight per fruit 75 g was recorded under the polyhouse. The less weight per fruit was found under rainshelter 64 g.This was may be due to the increased length and breadth of fruit. Similar results were obtained by Yellavva (2008) under polyhouse.

4.5.4 Yield per plant

The data on yield per plant at different stages of tomato as influenced by growing environment are shown in Table 4.12 and Fig 4.14.

Table 4.12 Yield per plant at different stages of crop growth of tomato

Yield per plant (kg)									
Treatment	**0-70 DAT**	**70-80 DAT**	**80-90 DAT**	**90-100 DAT**	**100-110 DAT**	**110-120 DAT**	**120-130 DAT**	**130-140 DAT**	**140-150 DAT**
T1-Polyhouse	0.07 [b]	0.1 [b]	0.13 [b]	0.24 [b]	0.19 [b]	0.19 [b]	0.19 [b]	0.18 [b]	0.15 [a]
T2-Rainshelter	0.16 [a]	0.19 [a]	0.45 [a]	0.47 [a]	0.32 [a]	0.7 [a]	0.68 [a]	0.56 [a]	0

DAT– Days after transplanting

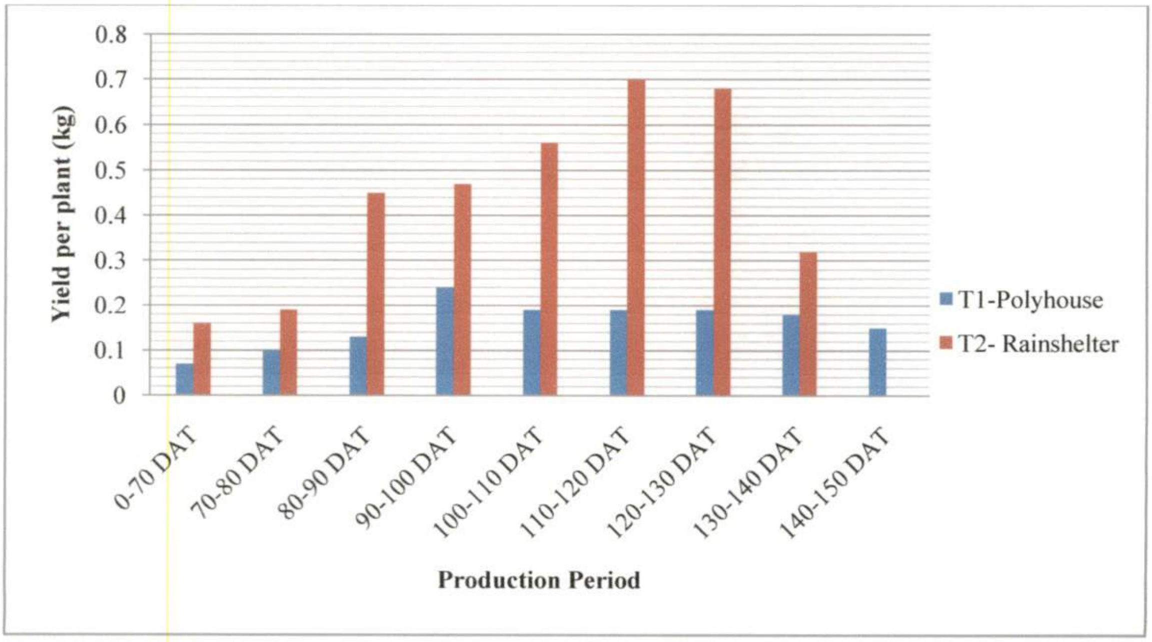

Fig 4.14 Yield per plant at different stages of crop growth of tomato

4.5.6 Total yield

The total yields of the tomato at different stages of crop growth are given in the Table 4.13 and Fig 4.15. The total yield was higher from the rainshelter and was 415.85 kg, which was significantly higher than the yield obtained from the polyhouse. The total yield obtained from the polyhouse was only 131.35 kg.

Table 4.13 Total yield (kg) at different stages of crop growth of tomato

Treatments	0-70 DAT	70-80 DAT	80-90 DAT	90-100 DAT	100-110 DAT	110-120 DAT	120-130 DAT	130-140 DAT	140-150 DAT
T1-Polyhouse	3.00 [b]	6.00 [b]	8.30 [b]	16.20 [b]	18.00[b]	23.5 [b]	27.50 [b]	22.25 [b]	7 [b]
T2-Rainshelter	6.40 [a]	23.50 [a]	42.50 [a]	68.25 [a]	90.75 [a]	83.20 [a]	66.5 [a]	34.25 [a]	0

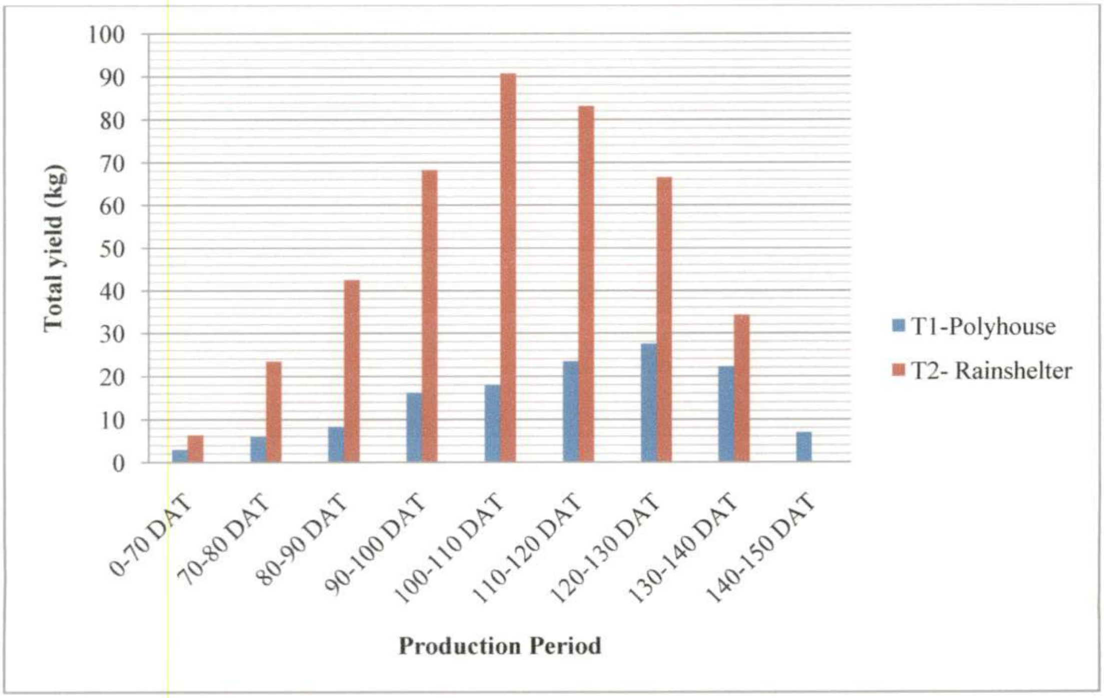

Fig 4.15 Total yield at different stages of crop growth of tomato

Plate 4.1 Harvested fruits

At 100 to 110 DAT, yield per plant from the rainshelter was significantly higher than that from the polyhouse. In case of all the harvests there was significant difference in yield of tomato grown inside polyhouse and rainshelter and the rainshleter gave higher yield compared to the polyhouse always. This may be attributed to the favourable climatic conditions for tomato prevailed under the rainshelter leading to higher number of fruits, contributing to maximum fruit weight.

Tomato plants under rainshelter gave significantly higher yield per plant (3.4 kg) and yield per square meter (4.15 kg). This higher yield per plant and yield per square meter may be due to higher number of leaves which in turn increased the photosynthetic activity and ultimately resulted in higher yield per plant. Similar results were reported by Kengar (2008).

4.6 QUALITY PARAMETERS

4.6.1 TSS (^{0}B)

The data on total soluble solids as influenced by the tomato under polyhouse and rainshelter was found by using refractrometer. The results indicated that TSS content of tomato under the polyhouse system was found to be 4.56 ^{0}B and in rainshelter it was 4.0 ^{0}B. Similar results were obtained by Hazarika and Phookan (2005) in tomato in polyhouse condition.

4.7 WATER USE EFFICIENCY

Table 4.14 shows the water use efficiency values obtained under polyhouse and rainshelter treatments. Water use efficiency is greatly improved by scheduling irrigation when plants can utilize the water more efficiently. In the same area under polyhouse and rainshelter with daily irrigation, WUE was found high under rainshelter than under polyhouse.

Table 4.14 Variation of irrigation water use efficiency under polyhouse and rainshelter

Treatments	Yield (kg/ha)	Water used (mm)	Water use efficiency (kg/ha.mm)
T1- polyhouse	13135	252	52.123
T2- rainshelter	41685	252	165.416

4.8 ECONOMICS

4.8.1 Cost economics of polyhouse

The cost economic analysis of a naturally ventilated polyhouse was done by making the following assumptions and is tabulated below. It is assumed that 2 crops are cultivated in a year.

Assumptions

1. Expected life of the system is 15 years
2. Annual growth rate of costs and benefits is 5%
3. Salvage value is nil
4. The costs and benefits are discounted at 12%
5. Size of polyhouse: 20 m ×5 m
6. Cost of construction of polyhouse: Rs 1100/ m^2
7. Capital cost (cost of construction+installation cost of irrigation system):Rs 1200/ m^2
8. Cost of cultivation of tomato: Rs 30/ m^2
9. Yield of tomato: 1.31 kg/ m^2
10. Price of tomato: Rs 30/ kg

Table 4.15 Economic analysis of tomato cultivation in polyhouse

Year	Capital Cost (Rs)	O&M Cost (Rs)	Production Cost (Rs)	Total Cost(Rs)	Benefits (Rs)	Discount Factor (Rs)	Present worth of Costs (Rs)	Present worth of Benefits(Rs)	Cash Flow(Rs)	Net Present Worth (NPW) (Rs)
1	120000	0	6000	126000	7860	1	126000	7860	-118140	-118140
2			3150	3150	8253	0.893	2813	7369	5103	4556
3			3308	3308	8665.6	0.797	2637	6908	5358	4271
4		6000	3473	9473	9098.9	0.712	6743	6476	-374	-266
5			3647	3647	9553.8	0.636	2317	6072	5907	3754
6			3829	3829	10031.5	0.567	2173	5692	6203	3520
7		6946	4020	10966	10533.1	0.507	5556	5336	-433	-219
8			4221	4221	11059.8	0.452	1910	5003	6839	3093
9			4432	4432	11612.8	0.404	1790	4690	7180	2900
10		8041	4654	12695	12193.4	0.361	4578	4397	-501	-181
11			4887	4887	12803.1	0.322	1573	4122	7916	2549
12			5131	5131	13443.2	0.287	1475	3865	8312	2390
13		9308	5388	14696	14115.4	0.257	3772	3623	-580	-149
14			5657	11314	14821.2	0.229	2593	3033	3507	804
15			5940	11880	15562.2	0.205	2431	3184	3682	753
Total		**20986**	**67736**	**206433**	**169608**		**168359**	**77631**	**-60020**	**-90364**

Discount Rate (%) :12
Benefit-Cost Ratio :0.46

4.8.2 Cost economics of rainshelter

The economic analysis of a simple rainshelter was done by making the following assumptions and is tabulated below. It is assumed that2 crops are cultivated in a year.

Assumptions

1. Expected life of the system is 15 years
2. Annual growth rate of costs and benefits is 5%

3. Salvage value is nil

4. The costs and benefits are discounted at 12%

5. Size of rainshelter: 20 m ×5 m

6. Cost of construction of rainshelter: Rs 650/ m^2

7. Capital cost (cost of construction + installation cost of irrigation system):Rs 750/ m^2

8. Cost of cultivation of tomato: Rs 30/ m^2

9. Yield of tomato: 4.15 kg/ m^2

10. Price of tomato: Rs 30/ kg

Table 4.16 Economic analysis of tomato cultivation in rainshelter

Year	Capital Cost (Rs)	O&M Cost (Rs)	Production Cost (Rs)	Total cost (Rs)	Benefits (Rs)	Discount Factor (Rs)	Present worth of Costs(Rs)	Present worth of Benefits(Rs)	Cash Flow(Rs)	Net Present Worth (NPW) (Rs)
1	75000	0	6000	81000	24900	1	81000	24900	-56100	-56100
2			3150	3150	26145	0.893	2813	23344	22995	20531
3			3308	3308	27452.25	0.797	2637	21885	24145	19248
4		6000	3473	9473	28824.86	0.712	6743	20517	19352	13774
5			3647	3647	30266.11	0.636	2317	19235	26620	16917
6			3829	3829	31779.41	0.567	2173	18032	27951	15860
7		6946	4020	10966	33368.38	0.507	5556	16905	22402	11350
8			4221	4221	35036.8	0.452	1910	15849	30815	13939
9			4432	4432	36788.64	0.404	1790	14858	32356	13068
10		8041	4654	12695	38628.07	0.361	4578	13930	25934	9352
11			4887	4887	40559.48	0.322	1573	13059	35673	11486
12			5131	5131	42587.45	0.287	1475	12243	37456	10768
13		9308	5388	14696	44716.82	0.257	3772	11478	30021	7706
14			5657	11125	46952.66	0.229	2550	10760	35828	8211
15			5940	11682	49300.3	0.205	2390	10088	37618	7697
Total		**30294**	**67736**	**184240**	**537306**		**123275**	**247083**	**353066**	**123807**

Discount Rate (%) :12
Benefit-Cost Ratio :2.00

Summary and Conclusions

CHAPTER 5

SUMMARY AND CONCLUSIONS

A study was conducted at the instructional farm of KCAET, Tavanur, Kerala, during the period from December 2016 to April 2017 to compare the performance of tomato grown under different protected structures. The treatments comprised of two growing environments *viz.*, naturally ventilated polyhouse and rainshelter. The experiment was laid out in CRD with ten replications with five in each treatment. The salient findings of the study are summarized below.

The variation of weather parameters such as maximum and minimum temperature, relative humidity and soil temperature during the crop period was studied. The maximum temperature (36.4 ^{0}C) was recorded inside the naturally ventilated polyhouse during the month April and minimum temperature (22.3 ^{0}C) was recorded in the rainshelter during month of January. The rise in air temperature inside the polyhouse compared to rainshelter ranged from 2.5 °C to 3.6 °C. The maximum relative humidity (83.82 per cent) was recorded in the month of December in the polyhouse and the minimum relative humidity (70.2 per cent) was recorded in the month of April in the rainshelter in the morning. The maximum soil temperature (37.8 ^{0}C) was observed under the polyhouse in the month of March at the morning and minimum soil temperature (25 ^{0}C) was recorded in the rainshelter in the month of February at the afternoon. Soil temperature in the polyhouse was found that always 3 to 5 °C higher temperature as compared to the soil in the rainshelter throughout growing periods of the crop. There was no rainfall recorded during December 2016 to April 2017.

Crop growth parameters such as plant height, inter-nodal length, stem girth, number of leaves, number of branches and time taken for flower initiation were recorded during various crop growth stages for all the treatments.

In case of vegetative characters, the maximum plant height was recorded under naturally ventilated polyhouse compare to rainshelter in all growth stages of the plant. Among the structures, plants under polyhouse exhibited significantly higher plant height at 105 DAT. The number of branches was more under rainshelter than the polyhouse at all the stages of plant growth. Also observed that there is no significant difference between the number of branches inside polyhouse and rainshelterat 75 and 90 days after transplanting. The inter-nodal length was significantly higher inside the polyhouse compared to the rainshelter. Stem girth of the plant was higher under rainshelter than the polyhouse. The higher numbers of leaves per plant were observed under rainshelter structure than polyhouse. Among the different treatments, early flower initiation (45 days) was recorded in the polyhouse followed by rainshelter (49 days).

Yield parameters such as number of fruits per plant, yield per plant and total yield for each treatment were observed during different stages of crop growth.

In case of individual fruit weight, fruit diameter higher values were observed under naturally ventilated polyhouse than rainshelter structure. Number of fruits per plant was maximum under rainshelter than naturally ventilated polyhouse at all the growing stages of the plant growth. Yield per plant was found significantly higher under rainshelter at all the stages of plant growth than the naturally ventilated polyhouse. In polyhouse the duration of plant was higher than the rainshelter. There was significant difference in total yield of tomato harvested from polyhouse and rainshelter. The total yield of tomato recorded from polyhouse and rainshelter were 1.31 kg/m^2 and 4.15 kg/m^2 respectively.

Quality parameter of tomato like total soluble contents of fruits for each treatment was observed. TSS content of tomato under the polyhouse system was found 4.56 ^0B and rainshelter was found 4.0 ^0B.

Water use efficiency is greatly improved by scheduling irrigation when plants can utilize the water more efficiently. In the same area under polyhouse and rainshelter with daily irrigation, WUE was found high under rainshelter than under polyhouse. It was observed that incidence of pests and diseases were comparatively higher under the naturally ventilated polyhouse than the rainshelter.

Cost Benefit (B: C) ratio for each treatment was calculated. The maximum benefit cost ratio of 2.00 was noted in rainshelter than the 0.46 under polyhouse cultivation.

From the study it is evident that there was significant difference in total yield of tomato harvested from the polyhouse and rainshelter during the entire growing season.The lesser cost in case of rainshelter resulted in a higher benefit cost ratio as compared to naturally ventilated polyhouse. So cultivation of tomato (Akshaya) in second season is not recommended for polyhouse but recommended for rainshelter and also Incidence of pests and diseases were comparatively low inside the rainshelter and higher incidence of pests and diseases were noticed polyhouse. Hence it can be concluded from the study that growing tomato inside the rainshelter will be more profitable than growing it inside naturally ventilated polyhouse for Kerala condition.

References

94

REFERENCES

Ahmed, M.E., El-Kader, N., and Derbala, A.E. 2009. Effect of Irrigation Frequency and Potassium Source on the Productivity, Quality and Storability of Garlic. *Australian J. Basic and Applied Sci.* 3(4): 4490-4497.

Anitha, S. and Geethakumari, V.L. 2006. Nutrient management in Chilli based cropping system. *Indian J. Crop Sci.* 1(2): 209-210.

Bachav, S.M. 1995. Fertigation in India. *International Symposium on Fertigation.* Israel Institute of Technology, Israel, pp. 11-24.

Baghel, B.S., Gupta, M., and Tiwari, R. 2003. Potential and prospects of protectivecultivation of horticultural crops In; *Proceedings of All India Seminar .on Potential and Prospects for Protective Cultivation*, organized by the Institute of engineers, Ahmednagar, Gujarat, December 12-13 pp: (2).

Bakker, J.C. 1991. Effects of humidity on stomatal density and its relation to leaf conductance. *Sci. Hortic.* 48: 205–212.

Baliyan.and Pal, S. 2014.Improving sustainable vegetable production and income through net shading: a case study of botswana. *J. Agric. Sustainability.* 5: 70-103.

Berry, S. Z. and Uddin, M. R. 2003. Effect of high temperature on fruit set in tomato cultivars and selected germplasm. *Hort. Sci.***25:** 606-608

Bhatnagar, R.R., Vedprakash, R.C., and Srivastav, R.C. 1990. Production of vegetables in polythene greenhouse during winters in mid hills of Uttar Pradesh.Progress. *Hortic.* 22: 97-100.

Bhatt, R.M. and Rao, N.K.S. 1993. Response of bell pepper to photosynthesis, growth flower and fruit setting to night temperature. *Photosynth.* 28:127132.

Bibi, B., Sajid, M., Rab, A., Tanveershah, S., Ali, N., Ibadullah, J., Ihsanul, H., Wahid, F., Haleema, B., and Ali, I. 2012. Effect of partial shade on growth and yield of tomato cultivars. *Global J. biology, agric. health sci. 1(1):22-26*

Chen, J., Kang, S., Taisheng, D., Qiu, R., Ping Guo, P., and Chen, R. 2013. Quantitative response of greenhouse tomato yield and quality towater deficit at different growth stages.*Agric. Water Manag.* 129: 152– 162.

Chen, R., Kang, S., Hao, X., Fusheng, L., Taisheng, D., Qiu, R., and Chen, J. 2015.Variations in tomato yield and quality in relation to soil propertiesand evapotranspiration under greenhouse condition. *Scienti. Hortic.* 197: 318-328.

Clemmens, A.J. 1990. Feedback Control for Surface Irrigation Management. In: *Visions of the Future*. ASAE Publication 04-90. *American Soc. Agric. Engineers, St. Joseph, Michigan,* pp. 255-260.

Day, W. and Bailey, B.J. 1999. Physical principles of microclimate modification Ecosystems of the world. Elsevier, Amsterdam, 42 p.

Debnath, M. and Patel, N. 2015. Performance of a developed low cost microcontroller based automated drip irrigation system in kinnow crop[abstract]. Innovative energy technology systems and environmental concerns: a sustainable approach. pp. 118.

Deepa, C.N., Josena, J., Sreemol, S., and Varun, E.A. 2010. Standardization of irrigation requirement of salad cucumber in polyhouse. BTech (Ag. Engg.) Project Report, Kerala Agricultural University, Tavanur, 30 p.

Deli, J. and Tiessen, H. 1969. Interaction of temperature and light intensity of flowering in capsicum fruit California Wonder. *J. Afr. Soc. Hortic. Sci.* 94: 349-351.

Feleafel, M.N. and Mirdad, Z.M. 2013.Optimizing the Nitrogen, Phosphorus and Potash Fertigation Rates and Frequency for Eggplant in Arid Regions. *Int. J. Agric. Bio*. 12: 737–742.

Ganesan, M. 1999. Effect of poly-greenhouse models on plant growth and yield of tomato. *Indian J. Agric. Sci.* 10: 586-588.

Gokul, A. 2015. Comparative evolution of naturally ventilated polyhouse and rainshelter on the performance of cowpea. M.Tech (Ag. Engg.) thesis, Kerala Agricultural University, Tavanur.

Granges, A. and Leger, A. 1989. How to improve the yield of sweet pepper grown on short term crops under glass. *Sci. Hortic.* 21(5): 313-316.

Gubbuk, H. and Pekmezci, M. 2004. Comparison of open-field and protected cultivation of banana *(Musa spp. AAA)* in the coastal area of Turkey. *N. Z. J. Crop Hortic. Sci.*32: 375-378.

Hagin. andLowengart, A. 1996. Fertigation for minimizing environmental pollution by fertilizers. *Fertil. Res.* 43(3): 5-7.

Hartmann, J.F. 1986. Style, scope and rigor in comparative Tai research. In: Bickner, R.J. (ed.), *A Conference on Thai Studies In Honor of William J. Gedney*, Ann Arbor, Michigan, pp. 171-184.

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

Hebbar, S.S., Ramachandrappa, B.K., Nanjappa, H.V., and Prabhakar.M. 2004. Studies on NPK drip fertigation in field grown tomato (*Lycopersicon esculentum* Mill.). *Europ. J. Agron.* 21: 117–127.

Hicklenton, P.R. and Jollifee, P.A. 1979. Effects of greenhouse co_2 enrichment on the yield and photosynthetic physiology of tomato plants. *J. plant Sci.*58: 801-817.

Hoon, W.M. and Vander. 1979.Fressia growers will have to become more efficient all the time. *Vakblad Voorde Bloemisterij*. 34(32): 46-47.

Idris, A.Y. 1999. Economic comparison of tomatoes production under green houses versus open fields in Khartoum state. M.Sc (Agric-Econ) University of Khartoum – Faculty of Agriculture Department of Agricultural Economics.

Jain, V.K., Shukla, K.N., and Singh, P.K. 2001. Response of potato under drip irrigation and plastic mulching [abstract]. In: *Abstr. 6th International Micro-irrigation Congress,* 22-27 October, 2000. Cape Town, South Africa, pp. 1-6.

Kaviani, I., Basirat, M., and Malakouti, M.J. 2004. A Comparison between the Effects of Fertigation and Soil Application of Potassium Chloride and Soluble SOP on the Yield and Quality of Tomato in Borazjan Region of Boushehr. *IPI regional workshop on Potassium and Fertigation development in West Asia and North Africa; Rabat, Morocco, 24-28 November.*

Kang, B.S. and Sidhu, B.S. 2005. Studies on growing off-season tomato nursery under polyhouse. *Ann. Agri Bio Res. 10 (1): 53-56.*

Kengar, I. 2008. Performance of tomato (*Solanum lycopersicum L.*) Hybrids under shade house condition. M.Sc. (Ag) Thesis, Univ. Agric. Sci., Dharwad. 62 p.

KAU (Kerala Agricultural University) 2016. *An Analytical Study on Agriculture in Kerala*. Kerala Agricultural University, Thrissur. 1p.

Khan, M.M. 1995. Relevance of greenhouse*: A Report from Training on Construction and Management of Low Cost Greenhouse,* 8-10 May, 1985, 8p.

Leonardi, C., Guichard, S., and Bertin, N., 2000. High vapour pressure deficit influences growth, transpiration and quality of tomato fruits. *Sci. Hortic.* 84: 285–296.

Locascio, S.J. and Smajstat, A.G. 1996. Water application scheduling by pan evaporation for drip irrigated tomato. *J. Amer. Soci. Hortic. Sci.* 121(1): 63-68.

Mahajan , G. and Singh, K.G. 2006. Response of Greenhouse tomato to irrigation and fertigation. *Agric. Water Manag.* 84: 202-206.

Majid, R. and Fereydoun, K. 2011. Effect of different irrigation methods on crop yield and yield components of cantaloupe in the arid lands of Iran. *World Appl. Sci. J.* 15 (6): 873-876.

Malshe, K.V., Palshetkar, M.G., and Desai, B.G. 2016. Comparative study of different capsicum varieties under open and protected conditions. *Plant Archives* 16: 931-933.

Mane, T.A., Pampattiwar, P.S., Patil, B.R., and Khadil, K.K. 1987. Comparative studies on drip and furrow methods of irrigation for bhendi crop *[abstr]. In: national seminar on drip and sprinkler irrigation methods.* Adoption, 8 p.

Manohar. R.K. and Igathinathane. C. 2012. *Greenhouse Technology and Management.* BS Publication, Hyderabad. 4p.

Mantur, S.M., Biradar, M.S., Patil, A.A., and Mannikeri, I.M. 2014. Effect of spacing on cherry tomato varieties grown under shade house. *Karnataka J. Agric. Sci.* 27 (2): 199-201.

Mantur, S.M. and Patil, S.R. 2008. Influence of spacing and pruning on yield of tomato grown under shade house. *Karnataka J. Agric. Sci.* 21 (1): 97-98.

Marcelis, L.F.M. and Hofman-Eijer, B.L.R. 1993. Effect of temperature on growth of individual cucumber fruits. *Physiol. Plantarum*87: 321-328.

Max, F.J., Horst, W.J., Mutwiwa, U.N., and Tantau, H. 2009. Effects of greenhouse cooling method on growth, fruit yield and quality of tomato (solanumlycopersicum l.) In a tropical climate. *Scientia. Hortic.* 122: 179–186.

Megharaja, K.M. 2000. Studies on the effect of growing conditions and growth regulators on growth and productivity of hybrid capsicum cv. Indira. *M. Sc. (Agri.) Thesis*, Univ. Agric. Sci. Bangalore, Karnataka, India.

Mikkelsen, R.L. 1989. Phosphorous fertilization through drip irrigation. *J. Prod. Agric.* 2(3): 279-286.

More, T.A., Chandra, P., Majumdar, G., and Singh, J.K. 1990. Some observations on growing cucumber under plastic greenhouse In: *Proceedings of X1 International Congress on the use of Plastics in Agriculture,* pp.49-55.

Nagendraprasad, H.N. 2001. Effect of plant density on growth and yield of capsicum grown under greenhouse and open conditions. *M.Sc. (Ag) Thesis,*Univ. Agric. Sci.,Bangalore. 165 p.

Nair, J.K. and George, E.(eds.). 2014. *Greenhouse Management and Operation.* Department of Agriculture. Kerala,189p.

Neelam, S., Sureshkumar, N.N., and Angiras, S.S. 1998. Response of onion to phosphorus and sulphur application. *Himachal J. Agric. Res.* 13 (2):151-153.

Nimje, P.M. and Shyam, M. 1993. Effect of plastic Greenhouse on plant microclimate and vegetable production. *Farm Syst.* 9:13-19.

Ohigbu, A.A. and Harris, G.P. 1989. Effect of film plastic cover on the growth and yield of tomato grown in a bed system. *J. Hortic. Sci.* 64(1): 61-68.

Pack, M. and Mehta, K. 2012. Design of Affordable Greenhouse. *IEEE Global Humanitarian Technology Conference.*

Parvej, M.R., Khan, M.A., and Awal, M.A. 2010. Phenological development and production potentials of tomato under polyhouse climate. *J. Agri. Sci.* 5: 19-31.

Prabhakar,M. and Hebbar, S.S. 1996. Micro irrigation and fertigation in capsicum and tomato. *National Seminar on problems and prospects of micro irrigation-A critical appraisal,* held at Bangalore during 19-20 November 1999, pp.60-68.

Rajasekar, M., Arumugam, T., and Ramesh, K.S. 2013. Influence of weather and growing environment on vegetable growth and yield. *J. Hortic. For.* 5(10): 160-167.

Ramesh, K.S. and Arumugam, T. 2010. Performance of vegetables under naturally ventilated polyhouse condition. *Mysore J. Agric. Sci.* 44(4):770-776.

Rai, D.S., Yadav, K.K., and Patel, R.K. 1995. Studies on shelf life of capsicum grown under protected and open conditions. *J. Agri. Sci.* 34(3): 343-351.

Rajendra, B.N., Patil, S.R., Swamy, K.M., and Anasubai, G.H. 2013. Impact of different spacing on growth and yield of indeterminate tomato grown under shade house. *The asian J. Hortic.* 8:377-378.

Rijssel, E.V. and Oprel, L. 1979. Causes of differences in productivity on rose nurseries.*Vakblad Voorde Bloemisterij,* 34 (39): 26-27.

Rao, K.V., Vijay, A., Lavesh, C., Ravish, K., and Patel, G.P. 2013. Performance evaluation of capsicum crop in open field and under covered cultivation. *Int. J. agric. Sci.* 9(2): 602-604.

Reddy, M.T., Ismail, S., and Reddy, Y.N. 1999. Shade and allelopathic effects on growth, productivity and quality of radish (*Raphanus sativus* L.) under pot culture. *South Indian Hortic.* 47:77-80.

Salokhe, V. and Sharma, A.K. 2012. *Greenhouse Technology and Application*. Greta Somani Agrotech Publishing Academy. Udaipur. 53p.

Sam, B. and Regeena, S. 2014. Production potentials of tomato and capsicum under poly house condition in Kerala. *Int. J. Scientific Eng. Res.* 4: 24-27.

Sengar, S. H. and Kothari, S. 2008. Economic evaluation of greenhouse for cultivation of rose nursery. *Afr. J. Agric. Res.* 3 (6): 435-439.

Sefer, B. and Gulsum, S.M. 2009. The effects of drip line depths and irrigation levels on yield, quality and water use characteristics of lettuce. *Afr. J. biotech.* 10(7): 3370-3379.

Shao, G.C., Deng, S., Liu, N., Wang, M.H., and She, D. L. 2015. Fruit quality and yield of tomato as influenced by rain shelters and deficit irrigation. *J. Agric. Sci. Tech.* 17: 691-704.

Shindhe, S.H., Bhoi, P.G., Raskhar, B.S., Pawar, D.D., and Bangar, A.R. 1997. Effect of water soluble fertilizers applied through drip on growth and yield of chilli. *Proceedings of the Third International Conference on Precision Agriculture*: June 23-26, 1997, Minneapolis, Minnesota. pp. 182-194.

Singandhupe, R.B., Rao, S.N., Patil, N.G., and Brahmanand, P.B. 2003. Fertigation studies and irrigation scheduling in drip irrigation system in tomato crop. *Europ. J. Agron.* 1(3): 1-17.

Singh, H.P., Ashwani, K., Jose, C., and Samuel. (eds.). 2000. Micro irrigation for horticultural crops. *Indian Hortic.* 45(1).

Singh, H.P., Kaushish, S.P., Ashwani, K., Murthy, T.S., Jose, C., and Samuel. (eds.). 2001. *Micro Irrigation.* Central Board of Irrigation and Power, New Delhi, pp. 495-99.

Sivanappan, R.K., Raj Gopal, A., and Palaniswan, D. 1977. Response of vegetables to the drip irrigation. *Madras Agric. J.* 65 (9): 576-79.

Srinivas, K., Shikhamany, S.D.,and Reddy, N.N. 1999. Yield and water-use of grape (*Vitis vinifera*) vines under drip and basin irrigation. *Can. J. Agric. Sci.* 69(1): 21-23.

Suzuki, M., Umeda, H., Matsuo, S., Kawasaki, Y., Ahn, D., Hamamoto, H.,and Iwasaki, Y. 2015. Effects of relative humidity and nutrient supply on growth and nutrient uptake in greenhouse tomato production. *Scientia Hortic.* 187: 44–49.

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

Thompson, E. and Strik, C. 2009. High Tunnels Verses Open Field: Management of Primocame-Fruiting Blackberry Using Pruning and Tipping to Increase Yield and Extend the Fruiting Season. *Hortic. Sci.* 44(6):1581-1587.

Varughese, A., Balan, M.T., Sajna, A., and Swetha K.P. 2014. Cowpea inside Polyhouse with Varying Irrigation and Fertigation Levels. *Int. J. Eng. Res. Dev.* 10: 18-21.

Veeranna, H.K., Khalak, A., and Sujith, G.M. 2001. Effect of fertigation methods on yield, water and fertilizer use efficiencies in chilli. *S. Indian Hortic.* 49: 101-104.

Vijayakumar, G., Tamilmani, D., and Selvaraj, P.K. 2007. Irrigaion and fertigation scheduling under drip irrigation in brinjal crop. *Int. J. Biodivers. Sci. Manag.* 1(2): 72-76.

Wachira, J.M., Mshenga, P.M., and Saidi, M. 2014.Comparison of the Profitability of Small-scale Greenhouse and Open-field Tomato Production Systems in Nakuru-North District, Kenya. *Asian J. Agric.Sci.* 6(2): 54-61.

Wani, K. P.; Singh, P. K.; Amin, A.; Mushtaq, F. and Dar, Z. A. 2011. Protected cultivation of tomato, capsicum and cucumber under Kasmir valley conditions. *Asian J. Sci. Tech.*, **1**(4): 56-61.

Willits, D.H. 2003. Cooling fan-ventilated greenhouses: a modelling study. *Biosyst. Eng.* 84(3): 315-329.

Yang, L., Zhao, F., Chang, Q., Tianlai, L., and Fusheng, L. 2015. Effects of vermicomposts on tomato yield and quality and soil fertility in greenhouse under different soil water regimes. *Agril. Water Manag.* 160: 98–105.

Yellavva, K. and Patil, A.A. 2008. Evaluation of capsicum hybrids under different protected structures. M.Sc.(Horti.) thesis. University of Agricultural Science. Dharwad, 63p.

Yohannes, F. and Tadesse, T. 1988. Effect of drip and furrow irrigation and plant spacing on yield of tomato at Dire Dawa, Ethiopia. *Agric. Water Manag.* 35: 201–207.

Yuan, B.Z., Jie, S., Yaohu, K., and Soichi, N. 2006. Response of cucumber to drip irrigation water under a rainshelter. *Agric. Water Manag.* 81: 145–158.

Zende, U.M. and Mathad, J.C. 2008. Investigation on production techniques in capsicum under protected Cultivation. M.Sc.(Horti.) thesis. University of Agricultural Science. Dharwad, 83p.

Appendices

Appendix I

Particle size distribution of soil inside polyhouse

Mass of dry soil sample = 1490 g

IS Sieve	Particle size(mm)	Mass retained(g)	% retained	cumulative % retained	cumulative % finer
4.75mm	4.75	318.412	21.370	21.370	78.630
2mm	2	345.321	23.176	44.546	55.454
1mm	1	228.645	15.345	59.891	40.109
600	0.6	164.565	11.045	70.936	29.064
425	0.425	61.234	4.110	75.045	24.955
300	0.3	66.314	4.451	79.496	20.504
212	0.212	207.102	13.899	93.396	6.604
150	0.15	20.152	1.352	94.748	5.252
75	0.075	31.255	2.098	96.846	3.154
Tray		46.321			

Appendix II

Particle size distribution of soil inside rainshelter

Mass of dry soil sample = 1590 g

IS Sieve	Particle size(mm)	Mass retained(g)	% retained	cumulative % retained	cumulative % finer
4.75mm	4.75	320.362	20.149	20.149	79.851
2mm	2	366.125	23.027	43.175	56.825
1mm	1	234.251	14.733	57.908	42.092
600	0.6	170.254	10.708	68.616	31.384
425	0.425	65.758	4.136	72.752	27.248
300	0.3	70.157	4.412	77.164	22.836
212	0.212	214.125	13.467	90.631	9.369
150	0.15	22.014	1.385	92.015	7.985
75	0.075	34.142	2.147	94.163	5.837
Tray		40.914			

Abstract

COMPARATIVE EVALUATION OF NATURALLY VENTILATED POLYHOUSE AND RAINSHELTER ON THE PERFORMANCE OF TOMATO

By

POOJA B G

(2015-18-006)

Abstract of the Thesis

Submitted in partial fulfilment of the

requirement for the award of degree of

Master of Technology

in

Agricultural Engineering

(Soil and Water Engineering)

Faculty of Agricultural Engineering and Technology

Kerala Agricultural University

Department of Land & Water Resources and Conservation Engineering

Kelappaji College of Agricultural Engineering and Technology

Tavanur - 679 573, Malappuram.

Kerala

2017

ABSTRACT

A study was conducted in the Instructional Farm of KCAET, Tavanur, Kerala, during the period from December 2016 to April 2017 to compare the performance of tomato grown under polyhouse and rainshelter cultivation. Tomato variety Akshaya, released by KAU, was used for the study. Drip irrigation system using venturi assembly was used for fertilizer application. The variation of weather parameters such as maximum and minimum temperature, relative humidity and soil temperature during the crop growth period was studied. Mean monthly values of temperature, relative humidity and soil temperature inside the polyhouse was higher than that in rainshelter throughout the growth period. The maximum temperature (36.4 ^{0}C) was recorded inside the naturally ventilated polyhouse during the month April and minimum temperature (22.3 ^{0}C) was observed in the rainshelter during month of January. The maximum relative humidity (83.82 per cent) was observed in the month of December in the polyhouse and the minimum relative humidity (70.2 per cent) was observed in the month of April in the rainshelter in the morning. The maximum soil temperature (37.8 ^{0}C) was observed under the polyhouse in the month of March at the morning and minimum soil temperature (25 ^{0}C) was observed inside the rainshelter in the month of February. Crop growth parameters such as plant height, inter-nodal length, number of branches, stem girth, number of leaves and time taken for flower initiation were noted during various crop growth stages for all the treatments. During all growth stages, the plant height and inter-nodal length were significantly higher inside the polyhouse than rainshelter. Stem girth of the plant was higher under rainshelter than the rainshelter. The higher numbers of leaves per plant were observed under rainshelter structure than polyhouse. Among the different treatments, early flower initiation (45 days) was observed in the polyhouse and late flower initiation (49 days) in rainshelter. Yield parameters such as number of fruits per plant and total yield per plant for each treatment were noted during various crop growth stages. Number of fruits per plant was maximum under rainshelter than naturally ventilated polyhouse at all the growing

stages of the plant growth. The fruit diameters, average weight per fruit are significantly higher in polyhouse compare to rainshelter. The total yield of tomato observed from polyhouse and rainshelter were 1.31 kg/m^2 and 4.15 kg/m^2 respectively. Quality parameter of tomato like TSS content of tomato under the polyhouse system was found 4.56 ^{0}B and rainshelter was found 4.0 ^{0}B. Water use efficiency was observed higher under rainshelter (165.41 kg/ha.mm) than the polyhouse (52.12 kg/ha.mm). Cost Benefit (B:C) ratio for each treatment was calculated. The maximum benefit cost ratio of 2.00 was observed in rainshelter than the 0.46 under polyhouse cultivation. From the results of the study it was evident that growing of tomato inside the rainshelter is more profitable than growing it inside naturally ventilated polyhouse.