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"Effect of growing environment and climate change on growth and yield of cucumber [*Cucumis sativus* (L.)]under organic management"

by

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(2012-20-114)

THESIS

Submitted in partial fulfilment of the requirement

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DECLARATION

I hereby declare that the thesis entitled **"Effect of growing environment and climate change on growth and yield of cucumber [*Cucumis sativus* (L.)] under organic management"** is a bonafide record of research work done by me during the course of research and the thesis has not been previously formed for the award to me any degree, diploma, fellowship or other similar title, of any other University or Society.

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Dedicated to my beloved guide & my family

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Abishna P.V.

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LIST OF ABBREVIATIONS

%	-	Percent
@	-	At the rate of
˚C	-	Degree celsius
B: C	-	Benefit cost ratio
Cfu	-	Colony forming unit
DAS	-	Days after sowing
dSm^{-1}	-	Deci siemen per meter
EC	-	Electrical conductivity
FYM	-	Farm Yard Manure
et al	-	And others
i.e	-	That is
IPCC	-	Inter-governmental Panel on Climate Change
K	-	Potassium
kg	-	Kilogram
kg ha^{-1}	-	Kilogram per hectare
N	-	Nitrogen
NS	-	Not significant
P	-	Phosphorus
PAR	-	Photosynthetically active radiation
SOC	-	Soil Organic Carbon
SOM	-	Soil Organic Matter
WAS	-	Weeks After Sowing
WMO	-	World Meteorological Organization

LIST OF PLATES

Introduction

1. INTRODUCTION

The threat of global climate change has caused concern for agricultural production in certain regions of the world, especially as key climate variables for crops (Slingo et al., 2005).Because of the increasing concentrations of radiative or greenhouse gases, there is much concern about future changes in our climate and direct or indirect effect on agriculture.

Organic agriculture is one of the adaptation strategies to climate change .It will help to reduce the CO_2 emission significantly, which in turn will sequester carbon in soils and biomass. Open field organic cultivation is generally perceived as an eco-friendly activity with less input requirement. Organic agriculture helps to increase resilience of farming systems through better management of soil and water, promoting biodiversity and strengthening community knowledge systems. It provides better results in many aspects of environmental issues compared to conventional agriculture (Food and Agriculture Organization, 2008).

In Kerala, the production of vegetables is low during the monsoon period due to heavy rainfall and unfavourable conditions. This could also solve the problem of low productivity during extreme weather conditions and could be used to improve yield and quality (Singh *et al.*, 1999; Ganesan, 2004). The productivity and quality of cucumber grown under open field conditions is generally low. Small and marginal farmers can adopt rain shelter for successful cultivation of vegetables in rainy season.

Protected cultivation of vegetable crops suitable for domestic and export purposes could be a more efficient alternative for land use and other resources (Sanwal *et al.,* 2004). Cucumber is one of the most preferred vegetables grown under protected conditions in the developed world compared to open field. Higher yield of cucumber has been reported under naturally ventilated poly house condition (Srivastava and Singh, 1997).

Vegetable growers can substantially increase their income by protected cultivation of vegetables in off-season, as the vegetables produced in normal season do not fetch good returns due to the increased availability of these vegetables in the market. Moreover, during the rainy season, vegetable crop suffer from yield losses due to heavy rains. Simple rain shelters prevent water logging and the damage on developing fruits with consequent increase in yield.

Hence, the study on "Effect of growing environment and climate change on growth and yield of cucumber [*Cucumis sativus* (L.)] under organic management" was under taken to evaluate the performance of cucumber in rain shelter and poly house condition and to find out the optimum planting time under organic management.

Review of literature

2. REVIEW OF LITREATURE

The review of literature pertaining to the study on "Effect of growing environment and climate change on growth and yield of cucumber [*Cucumis sativus* (L.)] under organic management" is presented below.

2.1 EFFECT OF GROWING ENVIRONMENT ON CROP GROWTH AND YIELD

The use of green house in arid region decreased the crop water requirement by reducing evapotranspiration to the tune 65 to 80% compared to outside (Fernades *et al.,* 2003). Protected cultivation of vegetable crops suitable for domestic and export purposes could be a more efficient alternative for land use and other resources (Sanwal *et al.,* 2004).

In rain shelter, efficient air flow was possible due to effective ventilation system and it maintained natural balance which promoted the crop growth (Sharif *et al.*, 2008). The study conducted by Arin and Ankara (2001) indicated that low tunnels are useful for promoting early harvesting and high total yield when compared with uncovered crop.

Chaugale *et al.* (1990) reported that the relative humidity was lower under open field than polyhouse and relative humidity fluctuation affected the growth and development of cucumber. The growth of musk melon inside green house was much higher as compared to open field (Sethi *et al.*2003). It was observed that the average growth rate of plants in green house was 4mm per day whereas it was 2mm per day in open field.

According to Vezhavendan (2003), capsicum under rain shelter took lesser number of days to harvest than open field in both Rabi and Kharif season in Kerala.

According to Rahman and Al-Wahaibi (2004), the irrigation water use efficiency was higher in the greenhouse than that of the open field because of the lower water requirement and higher yield of cucumber.

Interaction between the time of transplanting and environment showed a significant increase in number of fruits (12.6), fruit length (18.5cm) and yield (5.38kg/plant) when transplanting was done early under poly house (Sharma *et al.*, 2006).

Under rain shelter, day time temperatures raised above ambient and this was suitable for growing warm season crops like tomato at cooler (Kratky, 2006).

According to Parvej *et al.* (2010) better growth, development and yield of tomato were achieved under polyhouse due to the higher temperature and lower relative humidity during the winter months (December to February) which positively influenced the morpho-phenological and physiological events of tomato plants.

Cucumber varieties grown under green house exposed to low light and temperature of spring and winter seasons resulted higher yield (Narayanankutty *et al.*,2013). A study conducted at Vellanikkara showed that both summer and rainy season cucumber had maximum vine length and number of branches under rain shelter compared to open field (Sadanendan, 2013).

The mean weekly temperature was higher under open field condition compared to shade net house during summer and winter seasons. The lower temperature inside the shade net house increased the plant height, number of branches, inter nodal length, average fruit weight and yield per plant than that in the open field (Rajasekar *et al.*, 2013).

During summer season, the cost : benefit ratio of cucumber inside the rain shelter and open field was 1:5.15 and 1:4.8 respectively while the values were 1:1.4 and 1:6 respectively in rainy season (Sadanendan, 2013).

Girish (2014) concluded that the germination percentage, seedling length and dry weight, length of vine, number of leaves, fruit weight, fruit length and fruit width of cucumber were significantly higher under poly house condition compared to open field. Mean air temperature of 40.3°Cto 24.6°C, mean relative humidity of 91.80 to 30.53%, mean sunshine hours 8.04 to 11.04 hours, wind speed 1.72 to 6.55 km/hr were found to be optimum for higher yield of cucumber under shade net (Patel and Bhagat, 2014).

The temperature recorded showed variation between shade net and open field during both summer and winter season. Maximum mean temperature of 34.20°C and 32.8°C and minimum temperature of 32.0°C and 30.10°C were recorded in open field condition during winter and summer seasons. Under different growing environments, light intensity showed significant difference where under open field condition the highest light intensity (34044.45 and 25867.01μ mol / m^2respectively) was observed during summer and winter seasons. In shade net house, the minimum light intensity of 25867.01 and 18333.74 μ mol / m^2) was observed during summer and winter season (Rajasekar *et al.*, 2014).

Yield character of cucumber was significantly influenced by prevailing weather and more fruit per plant could be obtained under shade net house during summer and winter season. During both summer and winter seasons, the fruits inside the shade net house were longer compared to open field condition and shade net grown cucumber had heavier fruit than field cultivation in both seasons. The highest fruit weight was recorded under shade net (Rajasekar *et al.*, 2014).

The study conducted at Vellanikkara to study the growth of cucumber under open field and poly house revealed that the number of harvest in poly house was 21.52% more than open field (Gayathri and Nandini, 2015).

2.2 EFFECT OF WEATHER PARAMETERS ON BIOMERIC AND PHENOLOGICAL CHARACTERS

Arin and Ankara (2001) reported that tomato plants grown under low tunnel results 643.7 per cent increase in height compared to that grown without tunnel (602.8%). According to Anbarasan (2002), plant height of tomato was found to be higher under poly house compared to open field in both summer and kharif seasons.

Rajasekar *et al.* (2013) found that plant height was the highest under shade net house compared to open field in both winter and summer seasons due to favourable microclimatic conditions viz. temperature, relative humidity, light intensitywhich enhanced photosynthesis and respiration in the shade net house.

Inthichack *et al.* (2014) studied the plant growth and mineral composition in cucumber, melon and water melon grown under four constant day and night temperatures of 25/15°C,22.5/17.5°C,17.5/22.5°C and 15/25°C and they concluded that decreased day temperature resulted in decreased plant height and relative chlorophyll content of the cucumber.

Kharif tomato took 60.7 days and summer tomato took 55 days for fifty per cent flowering in open field whereas it was 58.6 days and 59.4 days respectively for poly house crop (Anbarasan, 2002). Vezhavendan (2003) observed early flowering of capsicum in rain shelter compared to open field condition.

In a glass house trials using cucumber (cv. corona) planted on 15^{th} July, 24^{th} July,12^{th} August and 25^{th} August, early planting increased the yield (17.6 kg/m^2) while delayed planting resulted in yield loss to the tune of $1.7kg/m^2$ (Bruyn *et al.* 1988)

The cucumber sown on 14^{th} March recorded higher cumulative yields and average fruit weight. Early planting contributed more average fruit (Tanis, 1990).

Campiothi *et al.* (1991) found that the mean fruit weight and the number of fruits per plant in cucumber were lower in the autumn than in the spring season. Cucumber sown in December and January produced more number of fruits per plant and higher yield (Lyutova and Kamontseva, 1992).

Grimstad and Frimanslund (1993) reported that an average daily temperature of 15.0 to 25.0°C reduced the time for first harvest in cucumber under greenhouse by two days. Grimstad (1995) observed that low temperature resulted in a delayed harvesting of tomato in greenhouse.

Marcelis and Baan Hofman (1993) working with cucumber observed that the biomass allocation to the fruits increased with extended treatment period (62 days). Isshiki (1994) observed a double yield of tomato in rain shelter than open field.

Kim *et al.* (1994) conducted an experiment on the influence of temperature on growth of parthenocarpic cucumber. He observed that a low temperature of 15°C resulted in the highest rate of fruit set and growth rate of 78 % and it was below 50 per cent at 20°C, 25°C and 30°C.

Cucumber under polyhouse recorded 239g while all the plants in open field gave poor yield (Kanthaswamy *et al.,* 2000). Fruits obtained from polyhouse had higher weight of 26.5g compared to open field (25.2g) during summer. During kharif season it was 27.7g and 22.2g respectively (Anbarasan, 2002).

Development of cucumber fruits by suppressing the growth of third and fourth lateral branches were noticed at 30°Ctemperature and 60% relative humidity whereas the development of lateral branches by suppressing fruit growth was recorded at 25 °C air temperature and 40% relative humidity (Nobuo *etal.*,2011).

Nobuo *et al.* (2011) studied the effect of air temperature on fruiting in cucumber. Air temperature at 25°C and relative humidity at 40% resulted higher number of fruits. During low temperature seasons, percentage of marketable fruit was decreased so that the number of fruits developed to maturity in cucumber was significantly lower in kharif season as compared to summer.

A study conducted by ICAR (2004) revealed that the average fruit weight of tomato was 23g during Rabi and 39.1g during kharif inside rain shelter whereas it was 17.5g and 43.1g respectively in open field. Number of fruits, weight, length, diameter and yield of cucumber fruits significantly depends on time of transplanting (Sonia and Sharma, 2006).

Girish *et al.,* (2014) found that the mature number of fruits in cucumber was significantly more in kharif season than summer. A study conducted at Vellanikkara to find out the suitable growing environment for cucumber revealed that the fruit weight was 13.3% more in poly house than in open field (Gayathri, 2015).

2.3 EFFECT OF WEATHER PARAMETERS ON YIELD OF CUCUMBER

2.3.1 Air temperature

Among the meteorological elements, air temperature is considered as the most important element determining the rate of plant growth and development (Ahmed *et al.,* 2004, Chmielewski *et al.*, 2005). Increase in the air temperature changed the growth stages of cucumber (Kalbarczyk, 2009)

Temperature had significant effect on cucumber growth and development and there was a decrease in leaf and stem dry weight of cucumber under low day and night temperature (Inthichack *et al.*, 2014).

Markovsakaya (1994) observed that the optimum day and night temperature range for cucumber seedlings (cv. Alma- Atinskii) was from 28 to 32°C.Widders and Kwantes(1995) found that under high night temperature (24 or 29°C)under full sunlight and regular irrigation, expansion growth rates of cucumber fruits as measured by changes in fruit diameters were rapid.

Reduction in plant height and leaf petiole length without a decrease in plant dry weight was noticed at optimal temperature drop (Sysoeva *et al.*, 1997). Under control regime of air temperature, shoot growth can be modified and the sinusoidal regimes of temperature control can increase the cucumber growth (Yoshida *et al.*, 1998).

In Poland, reduction in the total yield occurred with a frequency from 40% to above 80% and reduction in the marketable yield occurred with a frequency from 50% to above 70% due to high air temperature (Kabarczyk, 2010). Air temperature at 25.0°C showed a suppressed fruit growth and increased leaf development in cucumber (Nobuo, 2011). An increase of 1°C of average temperature shortened the stages of cucumber from -0.6 to -4.5 days/10years (Kalbarczyk and Kalbarczyk 2012).

Both summer and winter season mean weekly temperature was higher under open field condition compared to shade net house and the lower temperature increased the plant height, number of branches, internodal length, average fruit weight and yield per plant in the shade net house than in the open field (Rajasekar *et al.,* 2013).

2.3.2 Soil temperature

Krug and Liebig (1990) found that soil temperature at 24°C resulted increased the stem growth of cucumber and showed a wilting when the soil temperature was below 16°Cand showed a long term retardation of stem and leaf growth. Wilcox and Pfeiffer (1990) studied the effect of soil temperature on growth of vegetables and found that the growth of bean, cucumber, eggplant, sweet paper and watermelon was limited when the soil temperature was maintained in the range 16.7–18.9°C or lower.

Low soil temperature will inhibit the growth of cucumber (Krug and Liebig, 1990). Kalbarczyk (2009) studied the effect of soil temperature on cucumber yield and found that from sowing to harvesting a reduction in soil temperature to a tune of 6°C lead to 5% has led to a reduction in the yield.

2.3.3 Relative humidity

Bakker (1990) observed the effect of humidity on growth and propagation of glasshouse tomatoes, cucumber and sweet pepper. Humidity levels were observed to be 20 to 25 per cent higher as compared to outside conditions. Growth of plants was increased by 30 % in glass house and the fruits matured earlier. Combination of high temperature and humidity allowed higher rate of carbon dioxide injection and promoted the maximum growth of cucumber (Olympios and Hanan, 1992).

Sanden *et al.* (1992), from an experiment on cucumber seedlings (cv.corona) grown at air RH of 55, 75 or 95 percent, concluded that the relative growth rate increased with increase in humidity. This was attributed to increase in net assimilation rate and stomatal conductance as air humidity increased from 55 to 75 per cent.

Adams and Hand (1993) studied the effect of humidity on dry matter and found that humidity decreased the leaf dry weight in cucumber. Relative humidity in the shade net house was always higher than that in the open field (Rajasekar *et al.*, 2013).

Significant variation in weather parameters was observed among the growth situations and growing seasons. Under shade net house, the highest relative humidity of 59.50 and 67.10% was recorded during summer and winter seasons respectively whereas the lowest relative humidity of 52.6% and 56.62% was recorded during summer and winter season under open field condition (Rajasekar *et al.,* 2014).

2.3.4 Photo synthetically Active Radiation (PAR)

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Haque *et al.* (2009)reported a drastic decrease in number of leaves per plant and yield when the PAR was at 50%. Cucumber growth and development was influenced by PAR. There was a reduction of 48.2% of PAR inside the poly house when compared to that in open field (Gayathri, 2015).

Materials & Methods

3.MATERIALS AND METHODS

The present study on the "Effect of growing environment and climate change on growth and yield of cucumber [*Cucumis sativus*(L.)] under organic management" was carried out at the Academy of Climate Change Education and Research, Kerala Agricultural University, Vellanikkara, Thrissur during 2016-2017. The materials used and the methodology adopted for the study are described in this chapter.

3.1 DETAILS OF FEILD EXPERIMENT

3.1.1 Location

The field experiment was conducted at Water Management Research Unit located at Vellanikkara, Thrissur district, Kerala. The site was located at 10° 31' N 76° 13' E longitude and at an altitude of 22.25 m above MSL.

3.1.2 Time of experiment

The experiment was conducted from 1st June to 30th September 2017.

3.1.3 Climate and weather conditions

The area experiences a typical warm humid climate and receives average annual rainfall of 2663 mm. The mean weekly averages of important meteorological parameters were observed during the experimental period.

3.2 METHODS

3.2.1 Variety

Subhra variety of cucmber was used for the experiment. Plants are long and well branched. Fruits are green and tender having normal weight. Thorns are present during the initial stages of fruit development.

3.2.2 Technical Programme

3.2.2.1 Design – Split plot

3.2.2.2 Treatments

Main plots- Growing environment

M_1-Poly house (Naturally ventilated)

M_{2}- Rain shelter

Sub plots- Dates of sowing

S_1 - Sowing on1st June ,2017

S_2 - Sowing on 11th June, 2017

S_3 - Sowing on21st June, 2017

S_4 - Sowing on 2nd July, 2017

Replications –3

Plot size – 36 m^2

Variety – Subra

Spacing: 2 m x 1.5 m

Location – Water Management Research Unit,Vellanikkara

3.3 CULTURAL OPERATIONS

The land in polyhouse and rain shelter was prepared by digging and pits were taken as per the Package of Practices Recommendations(*Ad hoc*) for organic farming :Crops (KAU,2009). Seeds were soaked in a solution containing *Pseudomonas* sp.(1%) and cowdung (10%) for 6 hours. Dibbling of seeds was done with pre- soaked cucumber seeds @ 3 per pit.

All the management practices were done as per the Package of Practices Recommendations (*Ad hoc*) for organic farming :Crops (KAU,2009). Manures were applied uniformily to all the pits (FYM @ 12 t/ha and vermi compost @4 t/ha as basal and cow dung slurry @ 50 kg/ha at fortnightly intervals). Liquid organic manures were sprayed at fortnightly intervals as per the technical programme (Jeevamrutham – 7 DAS, Panchagavyam – 14 DAS, Fish amino acid – 21 DAS, Green leaf extract – 28 DAS).

The plant protection measures were adopted as and when required as per the Package of practices recommendations (Adhoc) for organic farming : Crops(KAU,2009).

Plate 1. Field view

Plate 2. Plants inside different growing envoironments

Plants inside poly house

Plants inside the rain shelter

Plate .3 Fruits inside different growing environments

Fruit inside the polyhouse

Fruit inside the rain shelter

3.4 OBSERVATIONS

Three plants from each replication from poly house and rain shelter conditions were selected for recording observations.

3.4.1 Soil characters

Soil characters before and after the experiment were estimated using appropriate methods (Table1). Observations on pH, electrical conductivity, organic carbon and content of major nutrients (N, P and K) in soil were taken from the poly house and rain shelter.

Total microbial population (bacteria, fungi, and actinomycetes) were estimated before and after the experiment (Table 2).

Table 1: chemical properties of soil

Particulars	Method used
1.pH	1:2.5 soil water ratio Beckman glass electrode (Jackson,1973)
2. EC (dS/m)	Conductometric method (Jackson,1973)
3. Organic Carbon (%)	Walkley and Black method (Jackson, 1973)
4. Available N (kg/ha)	Alkaline permanganate method (Subbiah and Asijah, 1956)
5. Available P (kg/ha)	Ascorbic acid reduced molybdophosphoric blue colour method (Watnabe and Olsen, 1965)
6. Available K (kg/ha)	Neutral normal ammonium acetate extractant flame photometry (Jackson, 1973)

Table 2:Media used for enumeration of micro organisms in soil

SI No.	Microbes	Medium	Reference
1	Bacteria	Nutrient agar	Agarwal and Hasija, 1986
2	Fungi	Martin's Rose Bengal Agar	
3	Actinomycetes	Kenknight's Agar	

3.4.2. Biometric and physiological observations

3.4.2.1 Lenth of vine

Length of vine (cm) was measured from the base of the plant to the tip of the growing point at fortnightly intervals.

3.4.2.2 Number of leaves

Number of fully opened leaves was counted at fortnightly intervals from the first vine appeared to the final harvest.

3.4.2.3 Number of flowers

Number of fully opened flowers were recorded at fortnightly intervals.

3.4.2.4 Days to first flowering

The number of days taken to first flowering from the date of sowing was noted.

3.4.2.5 Days to first harvest

The number of days to first harvest of green fruits from the date of sowing was recorded.

3.4.2.6 Duration of the crop

The number of days taken from sowing of cucumber seeds to the last harvest of the crop was recorded.

3.4.2.7 Number of harvest

The number of harvest made from each growing environment was recorded.

3.4.2.8 Average fruit weight

Average fruit weight (g) was worked out from the fruit yield per plant and number of fruits per plant.

$$\text{Average fruit weight} = \frac{\text{Fruit yield per plant}}{\text{Number of fruits per plplant}}$$

3.4.2.9 Fruit weight per plant and total yield

Fruit weight per plant was calculated for all the selected plants by adding the weight of individual fruits (g).

3.4.2.10 Yield per hactare

The per hectare yield was calculated and was expressed in tonnes per hectare.

3.4.3 Weather observations

The weather parameters were recorded using meteorological instruments installed inside each growing environment (Table 3).

Table 3: Weather parameters

Sl.no	Weather parameter	Unit
1	Maximum temperature	°C
2	Minimum temperature	°C
3	Rain fall	mm
4	Relative humidity	%
5	Photosynthetically Active Radiation	$\mu mols^{-2}m^{-2}$
6	Soil moisture	%
7	Soil temperature	°C

3.5 STATISTICAL ANALYSIS

The data recorderd was analysed statistically using 'Analysis of variance' technique in OPSTAT. Correlation analysis was done between the plant characteristics and weather parameters.

Results

4. RESULTS

The results of the experiment entitled "Effect of growing environment and climate change on growth and yield of cucumber [*Cucumis sativus* (L.)] under organic management" are presented in this chapter

4.1. SOIL CHARACTERS

4.1.1 pH

The pH of soil before and after the experiment is furnished in Table 4. The initial pH of the soil was 6.53 and 7.05 in poly house and rain shelter respectively. After the experiment, pH in poly house increased to 7.8 whereas rain shelter that had a slight change of 7.3.

4.1.2 EC

The EC of the soil before and after the experiment presented in Table 4. The initial EC of the soil was 0.47 dS/m and 0.71dS/m in poly house and rain shelter respectively. After the experiment, EC in poly house decreased (0.25 dS/m) whereas that in rain shelter increased (0.93 dS/m).

4.1.3 Available N, P and K

The data pertaining to the effects of growing environment on available status of major nutrients in soil is given in Table 5. The available nitrogen content of the soil before and after the experiment revealed that the treatments had significant difference on soil available nitrogen. The initial value of nitrogen content was 56.5 kg/ha and 52 kg/ha in poly house and rain shelter respectively. After the experiment, the value of available nitrogen increased both in poly house (158.6 kg/ha) and rain shelter (170 kg/ha).

The data given in (Table 5) clearly shows that the significant influence growing environment on available phosphorus content in soil. The initial value of P content in soil was 23.76 kg/ha and 29.28 kg/ha in poly house and rain shelter respectively. After the experiment, the value of available phosphorus increased in both poly house (82.36 kg/ha) and rain shelter (116.5 kg/ha)

The growing environments significantly influenced the available potassium content of the soil after the experiment. Initial K content of the soil was 68.4 and 70.5 kg/ha in poly house and rain shelter respectively. After the experiment, the value of available K in poly house increased to 371.5 kg/ha and in rain shelter to 520 kg/ha.

4.1.4 Organic carbon

The organic carbon content of soil before and after the experiment is presented in Table 5. It shows that there was a significant difference in the soil organic carbon content. The initial organic carbon content of the soil was 1.8% and 1.84% in poly house and rain shelter respectively. After the experiment, percentage of organic carbon in poly house increased to 2.54 % and in rain shelter, it increased as 3.12%.

4.1.5 Total microbial population in soil

The data on microbial population in soil (Table 6) showed that there was significant difference in the microbial population among the growing environments before and after the experiment. The initial population of bacteria in the soil was 16.15×10^6 cfu g^{-1} and 20.61×10^6 g^{-1} in poly house and rain shelter respectively. After the experiment, the population of bacteria increased in poly house to 33.7×10^6 cfu g^{-1}-whereas in rain shelter it was increased to 45.95×10^6 cfu g^{-1}.

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The initial population of fungi in soil was 40.2×10^{6} cfu g^{-1} and 45.95×10^{6} cfu g^{-1} in poly house and rain shelter respectively. After the experiment, population of fungi was in rain shelter increased to 79.35×10^{6} cfu g^{-1} and in poly house to 76×10^{6} cfu g^{-1}. However, the presence of actinomycetes could not be detected either in poly house or in rain shelter

Table 4: Effect of the growing environment on pH and EC of the soil

	Poly house		Rain shelter	
	Initial	Final	Initial	Final
pH	6.53	7.8	7.0	7.3
EC (dS/m)	0.47	0.25	0.71	0.93

Table 5: Effect of the growing environment on, nitrogen, phosphorus potassium and organic carbon content in the soil

	Poly house		Rain shelter	
	Initial	Final	Initial	Final
Available Nitrogen (kg/ha)	56.5	158.6	52	170
Available phosphorus (kg/ha)	23.76	82.36	29.28	116.5
Available potassium (kg/ha)	68.4	371.5	70.5	520
Organic carbon (%)	1.8	2.54	1.84	3.12

Table 6: Effect of growing environment on total microbial population in the soil

	Poly house		Rain shelter	
	Initial	Final	Initial	Final
Bacterial population(cfu/g)	16.15×10^6	33.7×10^6	20.61×10^6	45.95×10^6
Fungal population(cfu/g)	40.2×10^6	76×10^6	45.95×10^6	79.35×10^6

4.2 BIOMERIC OBSERVATIONS

4.2.1 Length of vine

The highest length of vine recorded under different growing environments and dates of sowing are given in Table 7.The length vine was the highest under poly house condition with the date of sowing 11th June (565 cm) closely followed by sowing on 21st June (564.4 cm).Under rain shelter the highest value was in the plants sown on 21st June (502.1 cm). At all sowing dates the length of vine was significantly higher in polyhouse than rain shelter

4.2.2 Number of leaves per plant

The number of leaves per plant under different growing environments and dates of sowing are presented in Table 7. The number of leaves per plant was significantly higher plants grown in poly house than in rain shelter at all dates of sowing. The highest number of leaves of 83 was recorded for the crop sown inside the poly house on 1stJune whereas the crop under the rain shelter condition sown on 2nd July produced the highest number of 69 leaves per plant.

4.2.3 Number of flowers per plant

Table 7 reveals that growing environment and the date of sowing had a significant effect on the number of flowers. Irrespective of the date of sowing, the crop grown inside the poly house produced significantly higher number of flowers. The highest number of flowers was noticed with date of sowing of 2ndJuly (60.9) in poly house and with the date of sowing of 11thJune (34.2) in rain shelter.

Table 7: Effect of growing environment and date of sowing on length of vine, number of leaves and number of flowers 46

Date of sowing	Growing Environment	Length of vine(cm)	Number of leaves	Number of flowers
1st June 2017	Poly house	537.0 (23.1)	83.0 (9.16)	56.6 (7.52)
	Rain Shelter	491.2 (22.1)	65.6 (8.16)	34.9 (5.90)
11th June 2017	Poly house	565.0 (23.7)	75.0 (8.71)	47.3 (6.87)
	Rain Shelter	495.6 (22.2)	68.0 (8.30)	34.2 (5.84)
21st June 2017	Poly house	564.4 (23.7)	42.3 (6.58)	58.1 (7.62)
	Rain Shelter	502.1 (22.4)	39.3 (6.34)	41.6 (6.44)
2nd July 2017	Poly house	542.1 (23.2)	78.3 (8.90)	60.9 (7.80)
	Rain Shelter	494.6 (22.2)	69.0 (8.63)	40.3 (6.34)
CD (Growing environment)		7.612 (0.165)	1.392 (0.064)	1.769 (0.228)
CD(Date of sowing)		1.528 (0.035)	3.753 (0.229)	1.289 (0.151)

4.3. PHENOLOGICAL OBSERVATIONS

4.3.1. Days to first flowering

The data pertaining to the days to first flowering are furnished in Table 8.The growing environment and date of sowing had a significant effect on appearance of the first flower. Crop sown on 1st June took 36 days for flowering under poly house condition and that in rain shelter flowering was delayed by 1-2 days.

4.3.2. Days to first harvest

The date of sowing and growing environment had a significant effect on the days to first harvest (Table 8). The in the poly house took significantly more days to first harvest than the crop in the rain shelter. The crop sown under poly house conditions on 1st June and11th June took 67.3 and 67.0 days respectively for the first harvest. The crop inside the rain shelter took 51-52 days on an average for the first harvest.

4.3.3. Duration

The date of sowing and the growing environment had no significant effect on the number of days taken for final harvest (Table 8). The duration of the crop sown inside the poly house varied from 85-86 days and in the rain shelter 82-85 days.

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Table 8: Effect of growing environment and dates of sowing on first flowering, first harvest and last harvest

Date of sowing	Growing Environment	First flowering	First harvest	Final harvest
1st June 2017	Poly house	36.0 (6.08)	67.33 (8.26)	86.6 (9.36)
	Rain Shelter	37.3 (6.19)	52.0 (7.20)	85.0 (9.27)
11th June 2017	Poly house	37.0 (6.16)	67.0 (8.24)	86.3 (9.34)
	Rain Shelter	37.6 (6.21)	51.3 (7.23)	85.0 (9.27)
21st June 2017	Poly house	38.3 (6.27)	64.0 (8.06)	86.6 (9.36)
	Rain Shelter	38.3 (6.27)	51.0 (7.21)	82.0 (9.11)
2nd July 2017	Poly house	37.0 (6.16)	60.6 (7.85)	85.0 (9.27)
	Rain Shelter	40.3 (6.42)	52.0 (7.28)	85.0 (9.27)
CD(Growing environment)		1.021 (0.082)	1.683 (0.110)	NS
CD(Date of sowing)		1.070 (0.087)	1.208 (0.080)	NS

4.4. YIELD AND YIELD ATTRIBUTES

4.4.1 Number of fruits per plant

The data pertaining to the number of fruits per plant are furnished in Table 9. Regardless of date of sowing, number of fruits per plant was significantly higher under rain shelter. Under poly house, highest number of fruits per plant was observed with the date of sowing 1st June (31.8) and in rain shelter also the crop sown on 1st June.

4.4.2 Fruit weight per plant

Table 9 showed that the growing environments and dates of sowing had a significant effect on fruit weight per plant. The highest fruit weight per plant was recorded inside the rain shelter (9.53) with the date of sowing of 1stJune. The highest value (4.69) was also found with 1st June sown under the poly house condition. Irrespective of date of sowing, the higher fruit weight per plant was obtained under rain shelter condition.

4.4.3 Average fruit weight

The average fruit weight values are given in Table 9. In general fruit weight was significantly higher in rain shelter. Crop sown on 1st June inside the rain shelter showed the highest average fruit weight (177 g) whereas the highest average fruit weight recorded under poly house was 151.7 g sown on 11th June.

4.4.4 Number of harvest

From the Table 10, it is clear that the number of harvests was found to be higher for the crop sown under the rain shelter than the crop sown in poly house. In poly house, crop sown on 1st June took the highest number of harvest (8) and the crop raised in rain shelter also took the highest number of harvest of (12) sown on 1st June.

4.4.5 Yield per hectare

The yield per hectare was found to be significantly influenced by the growing environment and the date of sowing (Table 10). Yield per hectare was significantly higher under rain shelter growing than poly house farming. Sowing the crop on 1st June recorded significantly higher fruit yield both under rain shelter and poly house farming. The highest fruit yield of 31.6 t/ ha was recorded under rain shelter farming sown on 1st June. Similarly the highest yield of 15.6 t/ha was recorded under poly house sown on 1st June.

Table 9: Effect of growing environment and date of sowing on number of fruits per plant, average fruit weight fruit and fruit weight per plant

Date of sowing	Growing Environment	Number of fruits per plant	Average fruit weight (g)	Fruit weight per plant (kg)
1st June 2017	Poly house	31.8 (5.73)	149.16 (12.2)	4.69 (2.38)
	Rain Shelter	54.0 (7.41)	177.45 (13.3)	9.53 (3.24)
11th June 2017	Poly house	26.3 (5.22)	151.73 (12.3)	3.87 (2.20)
	Rain Shelter	43.6 (6.68)	161.13 (12.73)	6.89 (2.80)
21st June 2017	Poly house	28.0 (5.38)	138.15 (11.79)	3.82 (2.19)
	Rain Shelter	41.0 (6.48)	158.40 (12.6)	6.44 (2.72)
2nd July 2017	Poly house	27.3 (5.31)	143.50 (12.0)	3.88 (2.20)
	Rain Shelter	40.5 (6.44)	140.83 (11.9)	5.63 (2.57)
CD (Growing environment)		4.815 (0.406)	2.746 (0.115)	14.842 (N/S)
CD (Date of sowing)		3.031 (0.262)	2.073 (0.086)	9.426 (0.382)

Table 10: Effect of growing environment and date of sowing on number of harvests and yield of cucumber

Date of sowing	Growing environment	Number of harvests	Yield(t/ha)
1st June 2017	Poly house	8.00 (2.99)	15.6 (4.08)
	Rain Shelter	12.00 (3.59)	31.6 (5.71)
11th June 2017	Poly house	7.00 (2.85)	13.0 (3.75)
	Rain Shelter	9.00 (3.16)	23.0 (4.90)
21st June 2017	Poly house	6.00 (2.64)	12.6 (3.69)
	Rain Shelter	8.00 (2.99)	21.2 (4.70)
2nd July 2017	Poly house	7.00 (2.82)	12.8 (3.71)
	Rain Shelter	9.00 (3.16)	18.7 (4.44)
CD (Growing environment)		2.006 (0.313)	3.042 (0.416)
CD (Date of sowing)		1.621 (0.258)	1.677 (0.186)

4.5. WEATHER DURING THE CROP PERIOD

4.5.1 Maximum Temperature

The weekly maximum temperature for the entire crop season observed inside the poly house and rain shelter is presented in Table 11.The highest temperature of 39.9°C was observed inside the poly house in 9^{th} week whereas in rain shelter it was 34.1°C in 4^{th} week. The lowest value in poly house was 9^{th} week 37.8°C in 13^{th} week and in rain shelter it was recorded in 13^{th} week of 31.4 °C.

4.5.2 Minimum temperature

Table 12, clearly shows that the highest value of minimum temperature (27.5°C) was observed inside poly house in the 13^{th} week whereas in rain shelter the highest value (25.9°C) was observed in the 1^{st} week. The lowest value recorded inside the poly house was 26°C in 16^{th} week and in rain shelter it was 24.4°C in 12^{th} week.

4.5.3 Soil temperature

4.5.3.1 Soil temperature at surface

The data on weekly variation in soil temperature at surface is presented in Table13. The highest value of soil temperature was observed inside the poly house (31.6°C) in the 15^{th} week and that in rain shelter was 30.5°C in the 15^{th}week. The lowest value was recorded inside the poly house (27.8°C) in 7^{th}week whereas in rain shelter it was 26.4°C in 13^{th} week.

4.5.3.2 Soil temperature at 15 cm depth

The weekly variation of soil temperature at 15 cm depth is presented in Table 14. The highest value recorded under polyhouse was 35.6°C in 15^{th} week and that in rain shelter was 34.6°C in 15th week. The lowest value was observed on 7th week in both poly house and rain shelter with values of 31. 3°C and 31.5 °C respectively.

4.5.3.3 Soil temperature at 30 cm depth

The soil temperature at 30 cm depth at weekly interval is presented in Table 15. The highest value of soil temperature was observed in the poly house 36.6°C in 15th week whereas in rain shelter it was 35.6°C in the 14th week. The lowest value was observed inside the poly house (32.8°C) in 7th week whereas in rain shelter it was 32.0°C in 1st week.

4.5.4 Soil Moisture

4.5.4.1 Soil Moisture at surface

The weekly variation of soil moisture at surface is furnished in Table 16. The highest moisture content was recorded under poly house (24.5 %)on 12th week whereas in rain shelter it was 28.3% also on the 12th week .The lowest moisture content was observed inside the polyhouse (13.2%) in 1st week and in rain shelter was 17.4%.in 1st week.

4.5.4.2 Soil moisture content at 15cm depth

The weekly variation of soil moisture content at 15 cm depth is furnished in Table 17. The highest soil moisture content recorded in poly house was 25.9% in 12th week and in rain shelter, it was 29.8% in the 11th week. The lowest moisture content was recorded in the poly house (14.7%) in 1st week whereas in rain shelter it was 19 % in 8th week.

4.5.4.3Soil moisture content at 30cm depth

The data pertaining to weekly soil moisture at 30 cm depth are presented in Table 18. The highest moisture content was recorded inside poly house (31.8 %) in 11th week and in rain shelter, it was 32.3% in the 12th week. The lowest moisture content of 16.7% was recorded inside poly house in 1st week while in rain shelter it was 20.3 % in 7th week.

4.5.3 Relative humidity

The weekly variation of relative humidity is presented in the Table 19.The highest value of relative humidity was recorded inside the poly house (93.5%) in 4thweek whereas in the rain shelter it was (92.5%) also in the 4th week. The lowest value was recorded inside poly house (84.8%) in 1st week. In rain shelter, it was 84% in 3rdweek.

4.5.4 Photo synthetically Active Radiation (PAR)

The fortnightly PAR observed during the entire crop-growing period is furnished in Table 20.The highest value of PAR recorded inside the poly house was 4756 $\mu mols^{-2}m^{-2}$ in the 12th week and in rain shelter, it was 4797 $\mu mols^{-2}m^{-2}$ recorded in the 14th week. The lowest value recorded inside the poly house was 4332 $\mu mols^{-2}m^{-2}$and in rains shelter it was 4423 $\mu mols^{-2}m^{-2}$ both in 16th week.

Table 11: Weekly maximum temperature during the crop period

Maximum temperature (°C)								
	Week1	Week2	Week3	Week4	Week5	Week6	Week7	Week8
Poly house	39.2	38.4	39.7	38.2	38.6	38.4	38.7	38.9
Rain shelter	33.2	32.0	33.7	31.5	32.6	31.7	32.9	33.0
	Week 9	Week 10	Week 11	Week 12	Week 13	Week 14	Week 15	Week 16
Poly house	39.9	38.5	39.2	38.7	37.8	39.4	39.5	38.5
Rain shelter	34.1	32.5	32.8	32.5	31.4	33.4	33.5	32.5

Table 12: Weekly minimum temperature during the crop period

Minimum temperature (°C)								
	Week 1	Week 2	Week 3	Week 4	Week 5	Week 6	Week 7	Week 8
Poly house	27.1	26.6	27.6	26.7	26.4	26.5	26.5	26.3
Rain shelter	25.9	25.0	26 .0	24.8	24.8	25.1	24.6	24.3
	Week 9	Week 10	Week 11	Week 12	Week 13	Week 14	Week 15	Week 16
Poly house	26.9	27.0	26.7	26.5	27.5	26.5	26.1	26.0
Rain shelter	25.1	25.3	25.6	24.4	24.7	25.6	25.3	23.9

Table 13: Weekly soil temperature at surface during the crop period

Surface soil temperature(°C)								
	Week 1	Week 2	Week 3	Week 4	Week 5	Week 6	Week 7	Week 8
Poly house	28.6	29.3	28.6	30.2	30.5	29.6	27.8	30.3
Rain shelter	27.5	28.5	28.8	29.0	29.6	28	26.8	29.5
	Week 9	Week 10	Week 11	Week 12	Week 13	Week 14	Week 15	Week 16
Poly house	29.8	30.2	29.5	28.8	27.9	30.5	31.6	29.5
Rain shelter	27.5	30.1	29.2	28.6	26.4	28.5	30.5	28.5

Table 14: Weekly soil temperature at 15 cm depthduring the crop period

Soil temperature at 15 cm depth								
	Week 1	Week 2	Week 3	Week 4	Week 5	Week 6	Week 7	Week 8
Poly house	32.1	32.8	32.1	33.7	34	33.1	31.3	33.8
Rain shelter	30.6	31.7	32.6	32.8	33	32	31.5	33
	Week 9	Week 10	Week 11	Week 12	Week 13	Week 14	Week 15	Week 16
Poly house	35.3	33.7	33	32.3	31.4	34	35.6	33
Rain shelter	32.4	33	32.3	31.8	32.5	33	34.6	34.3

Table 15: Weekly soil temperature at 30 cm depth during the crop period

Soil temperature at 30 cm depth								
	Week 1	Week 2	Week 3	Week 4	Week 5	Week 6	Week 7	Week 8
Poly house	33.6	34.3	33.2	35.2	32.5	34.6	32.8	35.3
Rain shelter	32.0	34	33	33.6	34.5	34	33.5	34.5
	Week 9	Week 10	Week 11	Week 12	Week 13	Week 14	Week 15	Week 16
Poly house	34.8	35.2	34.5	33.8	32.9	35.5	36.6	35.6
Rain shelter	34.2	34	34.5	34.5	32.5	35.6	33	34.5

Table 16: Weekly soil moisture content at surface during the crop period

Surface soil moisture (%)								
	Week 1	Week 2	Week 3	Week 4	Week 5	Week 6	Week 7	Week 8
Poly house	13.2	14.5	14.8	15.9	18.4	15.6	20.1	13.3
Rain shelter	17.4	18.6	18.5	20.2	21.8	19.8	26.3	17.5
	Week 9	Week 10	Week 11	Week 12	Week 13	Week 14	Week 15	Week 16
Poly house	14.03	15.6	14.3	24.5	19.5	14	15.6	16.4
Rain shelter	18.2	19.2	19.8	28.3	23.5	18.5	19.2	22

Table 17: Weekly soil moisture variation at 15 cm depth during the crop period

Soil moisture content at 15 cm depth (%)								
	Week 1	Week 2	Week 3	Week 4	Week 5	Week 6	Week 7	Week 8
Poly house	14.7	16.0	16.3	17.4	19.9	17.1	21.6	14.9
Rain shelter	20.1	20.3	20.0	21.7	23.3	21.3	27.8	19
	Week 9	Week 10	Week 11	Week 12	Week 13	Week 14	Week 15	Week 16
Poly house	19.7	20.7	21.3	25.9	25	20.2	20.7	23.5
Rain shelter	20.7	21.3	29.8	29.6	22	20.7	23.5	26.8

Table 18: Weekly soil moisture content at 30 cm depth during the crop period

Soil moisture content at 30 cm depth (%)								
	Week 1	Week 2	Week 3	Week 4	Week 5	Week 6	Week 7	Week 8
Poly house	16.7	18	18.3	19.4	21.9	23.6	16.7	21.7
Rain shelter	21.4	22.6	25.5	24.2	25.8	23.8	20.3	21.5
	Week 9	Week 10	Week 11	Week 12	Week 13	Week 14	Week 15	Week 16
Poly house	22.8	23.3	31.8	27	22	22.8	23	25.5
Rain shelter	22.2	23.5	23.8	32.3	27.5	22.5	23.5	28.6

Table 19: Weekly relative humidity during the crop period during the crop period

Relative humidity (%)								
	Week 1	Week 2	Week 3	Week 4	Week 5	Week 6	Week 7	Week 8
Poly house	84.8	91.3	85.4	93.5	89	90	88	87
Rain shelter	85.1	88.9	84.0	92.5	86.9	87.9	87.1	85.9
	Week 9	Week 10	Week 11	Week 12	Week 13	Week 14	Week 15	Week 16
Poly house	85	90.2	88.5	91.5	91.8	88.0	87.8	91.5
Rain shelter	84.2	89.9	87.5	89.8	91.1	86.7	86	90.1

Table 20: Biweekly PAR during the crop period

PAR($\mu mols^{-2}m^{-2}$)								
	Week 2	Week 4	Week 6	Week 8	Week 10	Week 12	Week 14	Week 16
Poly house	4752	4629	4590	4535	4525	4756	4689	4332
Rain shelter	4783	4698	4610	4556	4589	4769	4797	4423

4.6 CROP WEATHER RELATIONSHIPS

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4.6.1 Maximum temperature and different plant growth parameters

The data pertaining to the correlation between maximum temperature and different plant growth characters are presented in Table 21.The crop sown on 1st June in the rain shelter showed significant negative correlation with length of vine, number of leaves and it exhibited negative correlation with number flowers in poly house. The maximum temperature showed positive correlation with number of leaves and negative correlation with number of flowers inside rain shelter with the date of sowing of 11th June.

Crop sown on 21st June showed significant positive correlation with number of flowers in poly house. The maximum temperature showed significant positive correlation with length of vine and number of leaves both in rain shelter and poly house where it showed significant negative correlation with number of flowers in rain shelter with the date of sowing 2nd July.

4.6.2 Minimum temperature and different plant growth parameters

The correlation between minimum temperature and plant growth parameters are given in Table 22. The minimum temperature showed significant negative correlation with length of vine and number of leaves in both growing environments with the date of sowing 1st June. The crop sown on 11th June, the minimum temperature exhibited significant negative correlation with numbers of flowers in rain shelter.

The minimum temperature showed significant positive correlation with length of vine in both growing environments and it also showed a positive correlation with length of vine and number of leaves in poly house while negative correlation with number of flowers in rain shelter with the date of sowing 21stJune. The crop sown on

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2nd July showed significant negative correlation with number of leaves in poly house and positive correlation with that in rain shelter.

Table 21: Correlation between maximum temperature and different growth parameters

	Length of vine		Number of leaves		Number of flowers	
Date of sowing	**Poly house**	**Rain shelter**	**Poly house**	**Rain shelter**	**Poly house**	**Rain shelter**
June 1st	NS	-0.380	NS	-0.375	-0.323	0.457
June 11th	NS	NS	NS	0.479	NS	-0.563
June 21st	NS	NS	NS	NS	0.425	NS
July 2nd	0.549	0.351	0.405	0.326	NS	-0.484

Table 22: Correlation between minimum temperature and different plant growth parameters

	Length of vine		Number of leaves		Number of flowers	
Date of sowing	**Poly house**	**Rain shelter**	**Poly house**	**Rain shelter**	**Poly house**	**Rain shelter**
June 1st	-0.374	-0.362	-0.431	-0.367	NS	NS
June 11th	NS	NS	NS	NS	NS	-0.557
June 21st	0.368	0.368	0.466	NS	NS	-0.417
July 2nd	NS	NS	-0.324	0.325	NS	NS

4.6.3 Soil temperature and different growth parameters

4.6.3.1 Soil temperature at surface and plant growth parameters

The correlation between soil temperature at surface and biometric characters of plants are provided in Table 23. The crop sown on June 1st showed significant positive correlation with length of vine and negative correlation with number of flowers in poly house. The number of leaves had a significant positive correlation with soil temperature at surface in poly house with the date of sowing of 11th June.

Number of leaves and flowers exhibited a significant negative correlation with surface soil temperature in poly house with the date of sowing 21st June whereas it showed a positive correlation with number of leaves in rain shelter with the date of sowing of 2nd July.

4.6.3.2 Soil temperature at 15 cm depth and plant growth parameters

The correlation between soil temperature at 15 cm depth and different biometric characters of plants are presented in Table 24.Soil temperature at 15 cm depth showed a positive correlation with length of vine in poly house and number of leaves and flowers in rain shelter. It showed a significant negative correlation with number of flowers inside the poly house with the date of sowing of 1st June.

The crop sown on 2nd July showed a significant positive correlation with length of vine both in poly house and rain shelter.

4.6.3.3 Soil temperature at 30 cm depth and plant growth parameters

The correlation between soil temperature at 30 cm depth and biometric characters of plant are furnished in Table 25. The soil temperature at 30 cm depth showed a significant positive correlation with number of leaves in poly house and number of flowers in rain shelter with the date of sowing 1st June.

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4.6.4 Soil moisture and plant growth parameters

4.6.4.1 Soil moisture at surface and plant growth parameters

The correlation between soil moisture at surface and different biometric characters of plant are presented in Table 26. The surface soil moisture showed a significant positive correlation with length of vine both in poly house and rain shelter with all dates of sowing except 2nd July. The crop sown on 2nd July showed negative correlation with length of vine in poly house and rain shelter.

The surface soil moisture showed a significant positive correlation with number of leaves inside the poly house with all dates of sowing except 2nd July. The crop sown on July 2nd showed negative correlation with number of leaves in poly house and positive correlation with that in rain shelter. Surface soil moisture exhibited a negative correlation with number of flowers in poly house with the date of sowing 1stJune and in rain shelter with the date of sowing 2nd July. It showed a positive correlation with number of flowers in rain shelter with the date of sowing 21st June.

4.6.4.2 Soil moisture at 15 cm depth and plant growth parameters

The correlation between soil moisture at 15cm depth and plant parameters are presented in Table 27. The crop sown on June 1st showed a significant positive correlation with length of vine both in poly house and rain shelter and also number of leaves in poly house and it exhibited a significant negative correlation with number of flowers in poly house.

Soil moisture at 15 cm depth showed significant positive correlation with length of vine and number of leaves both in poly house and rain shelter with the date of sowing 11th June. The crop sown on June 21st exhibited a significant positive correlation with length of vine and number of leaves in poly house and length of vine and number flowers in rain shelter. The length of vine and number of flowers showed negative correlation while the number of leaves showed positive correlation in rain shelter with the date of sowing of 2nd July. poly house length of vine had a negative correlation.

4.6.4.3 Soil moisture at 30 cm depth and plant growth parameters

The correlation between soil moisture at 30 cm depth and growth parameters are presented in Table 28. The crop sown on 1st June showed significant positive correlation with number of flowers in poly house. The crop sown on 11th June, exhibited a significant positive correlation with length of vine and number of leaves in rain shelter and number of leaves in poly house.

Soil moisture at 30cm depth showed a significant positive correlation with number of flowers in rain shelter with the date of sowing of 21st June. The crop sown on 2ndJuly showed a significant negative correlation with length of vine and number of flowers in rain shelter.

Table 23: Correlation between soil temperature at surface and plant growth parameters

	Length of vine		Number of leaves		Number of flowers	
Date of sowing	**Poly house**	**Rain shelter**	**Poly house**	**Rain shelter**	**Poly house**	**Rain shelter**
June 1st	0.425	NS	NS	NS	-0.526	NS
June 11th	NS	NS	0.325	NS	NS	NS
June 21st	NS	NS	-0.425	NS	-0.480	NS
July 2nd	NS	NS	NS	0.485	NS	NS

Table 24: Correlation between soil temperature at 15 cm depth and plant growth parameters

	Length of vine		Number of leaves		Number of flowers	
Date of sowing	**Poly house**	**Rain shelter**	**Poly house**	**Rain shelter**	**Poly house**	**Rain shelter**
June 1st	0.496	NS	NS	0.423	-0.569	0.456
June 11th	NS	NS	NS	NS	NS	NS
June 21st	NS	NS	NS	NS	NS	NS
July 2nd	0.369	0.429	NS	NS	NS	NS

Table 25: Correlation between soil temperature at 30 cm depth and plant growth parameters

	Length of vine		Number of leaves		Number of flowers	
Date of sowing	**Poly house**	**Rain shelter**	**Poly house**	**Rain shelter**	**Poly house**	**Rain shelter**
June 1st	NS	NS	0.526	NS	NS	0.426
June 11th	NS	NS	NS	NS	NS	NS
June 21st	NS	NS	NS	NS	NS	NS
July 2nd	NS	NS	NS	NS	NS	NS

Table 26: Correlation between soil moisture content at surface and plant growth parameters

	Length of vine		Number of leaves		Number of flowers	
Date of sowing	**Poly house**	**Rain shelter**	**Poly house**	**Rain shelter**	**Poly house**	**Rain shelter**
June 1st	0.453	0.490	0.541	NS	-0.578	NS
June 11th	0.552	0.552	0.399	NS	NS	NS
June 21st	0.548	0.548	0.378	NS	NS	0.344
July 2nd	-0.423	-0.437	-0.368	0.485	NS	-0.448

Table 27: Correlation between soil moisture content at 15 cm depth and plant growth parameters

	Length of vine		Number of leaves		Number of flowers	
Date of sowing	**Poly house**	**Rain shelter**	**Poly house**	**Rain shelter**	**Poly house**	**Rain shelter**
June 1st	0.326	0.369	0.569	NS	-0.456	NS
June 11th	0.394	0.526	0.405	0.428	NS	NS
June 21st	0.429	0.536	0.396	NS	NS	0.356
July 2nd	-0.501	-0.495	NS	0.485	NS	-0.496

Table 28: Correlation between soil moisture content at 30 cm depth and plant growth parameters

	Length of vine		Number of leaves		Number of flowers	
Date of sowing	**Poly house**	**Rain shelter**	**Poly house**	**Rain shelter**	**Poly house**	**Rain shelter**
June 1st	NS	NS	NS	NS	0.456	NS
June 11th	NS	0.429	0.425	0.428	NS	NS
June 21st	NS	NS	NS	NS	NS	0.526
July 2nd	NS	-0.326	NS	NS	NS	-0.499

4.6.5 Relative humidity and plant growth parameters

The correlation between relative humidity and different plant parameters are presented in Table 29. In the case of the crop sown on 1st June, the relative humidity showed a significant negative correlation with number of flowers in poly house and length of vine and number of leaves in rain shelter. The relative humidity exhibited a significant negative correlation with the number of leaves in poly house with the date of sowing of 11th June. The crop sown on 2nd July showed a significant negative correlation with length of vine in poly house and number of leaves in both poly house and rain shelter.

4.6.6 Rain fall and plant growth parameters

The correlation between rainfall and different growth parameters are given in Table 30. The crop sown on June11th showed a significant negative correlation with length of vine in both poly house and rain shelter and number of leaves in rain shelter. It exhibited negative correlation with length of vine, number of leaves and number of flowers in poly house in the crop sown on 21st June. In rain shelter it showed a significant negative correlation with length of vine with the date of sowing of June 21st.

The crop sown on July 2nd showed a significant positive correlation with number of flowers in poly house and number of leaves in rain shelter. The rain fall exhibited a significant negative correlation with length of vine and number of leaves in poly house.

4.6.7 PAR and different growth parameters

The correlation between PAR and plant growth parameters is furnished in Table 31. It showed a significant negative correlation with length of vine in poly house with the date of sowings of 1st June and 2nd July.

Table 29: Correlation between plant relative humidity and plant growth parameters 71

	Length of vine		Number of leaves		Number of flowers	
Date of sowing	**Poly house**	**Rain shelter**	**Poly house**	**Rain shelter**	**Poly house**	**Rain shelter**
June 1st	NS	-0.458	NS	-0.550	-0.450	NS
June 11th	NS	NS	-0.500	NS	NS	NS
June 21st	NS	NS	NS	NS	NS	NS
July 2nd	-0.461	NS	-0.424	-0.386	NS	NS

Table 30: Correlation between rainfall and different plant growth parameters

	Length of vine		Number of leaves		Number of flowers	
Date of sowing	**Poly house**	**Rain shelter**	**Poly house**	**Rain shelter**	**Poly house**	**Rain shelter**
June 1st	NS	NS	NS	NS	NS	NS
June 11th	-0.366	-0.513	NS	-0.449	NS	NS
June 21st	-0.355	-0.355	-0.335	NS	-0.326	NS
July 2nd	-0.594	NS	-0.594	0.325	0.480	NS

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Table 31: Correlation between PAR and different plant growth parameters

	Length of vine		Number of leaves		Number of flowers	
Date of sowing	**Poly house**	**Rain shelter**	**Poly house**	**Rain shelter**	**Poly house**	**Rain shelter**
June 1st	-0.399	NS	NS	NS	NS	NS
June 11th	NS	NS	NS	NS	NS	NS
June 21st	NS	NS	NS	NS	NS	NS
July 2nd	-0.402	NS	NS	NS	NS	NS

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4.6.8 Correlation between days to first flowering and different weather parameters

The correlation between days to first flowering and different weather parameters are presented in Table 32. From the table, it is clear that the days to first flowering in poly house showed significant positive correlation with maximum temperature and relative humidity and negative correlation with rain fall. In the case of rain shelter, days to flowering showed significant positive correlation with minimum temperature but remaining weather parameters had no effect on days to first flowering.

4.6.8 Correlation between days to first harvest and weather parameters

The correlation between days to first harvest and weather parameters are furnished in Table 33.The days to first harvest showed a positive correlation with relative humidity, rain fall and soil temperature in poly house whereas the other weather parameters did not showed any significant effect on the days to first harvest.

For the crops sown under rain shelter, the days to first harvest had significant positive correlation with minimum temperature and soil moisture and negative correlation with soil temperature and PAR.

4.6.7 Correlation between crop duration and weather parameters

The correlation between crop duration and weather parameters are given in Table 34.The duration of the crop showed a significant positive correlation with minimum temperature, rainfall and PAR under poly house. The duration of the crop exhibited a significant positive correlation with the relative humidity, rain fall and soil moisture while had a negative correlation with soil temperature and PAR under rain shelter.

Table 32: Correlation between weather parameters and days to first flowering

Days to first flowering		
Weather parameters	**Rain shelter**	**Poly house**
Tmax	NS	0.4378
Tmin	0.4708	NS
RH	NS	0.4729
RF	NS	-0.4088
SM	NS	NS
ST	NS	NS
PAR	NS	NS

Table 33: Correlation between weather parameters and days to first harvest

Days to first harvest		
Weather parameters	**Rain shelter**	**Poly house**
Tmax	NS	NS
Tmin	0.6012	NS
RH	NS	0.5081
RF	NS	0.5743
SM	0.4343	NS
ST	-0.6215	0.4106
PAR	-0.4665	NS

Table 34: Correlation between weather parameters and crop duration

Crop duration		
Weather parameters	**Rain shelter**	**Poly house**
Tmax	NS	NS
Tmin	NS	0.571
RH	0.496	NS
RF	0.495	0.518
SM	0.457	NS
ST	-0.529	NS
PAR	-0.495	0.655

Discussion

5. DISCUSSION

The experiment entitled "Effect of growing environment and climate change on growth and yield of cucumber [*Cucumis sativus* (L.)] under organic management" was conducted during 2016-2017 in Academy of Climate Change Education and Research, Vellanikkara. The results pertaining to the study are discussed below.

5.1 SOIL CHARACTERS

The soil characters like pH, EC, N, P, K, OC and microbial population showed significant difference between the growing environments. After the experiment EC, N, P, K and OC increased inside the rain shelter while there was a slight increase in pH under poly house. The higher population of bacteria and fungi found in rain shelter might be due to the low soil temperature and high soil moisture, which favoured the growth of soil microbes

5.2 BIOMETRIC CHARACTERS

The growing environment and dates of sowing had a significant influence on biometric characters of cucumber plants. The highest length of vine was recorded inside the poly house (565 cm) whereas the lowest was found (491 cm) inside the rain shelter. The highest number of leaves was recorded inside the poly house (83) while the lowest of 39.3 was observed under the rain shelter condition. Irrespective of date of sowing, the highest length of vine and number of leaves were observed inside the poly house. The lower light intensity within the poly house might have retarded the destruction of auxin (IAA) and thereby promoted the cell division and cell expansion in the apical portion and that might be the reason for increase in vine length. These results agree with the findings of by El-Aidy *et al.* (1988), Abou-Habid *et al.* (1994), and Dongsheng, and Pingping (2013).

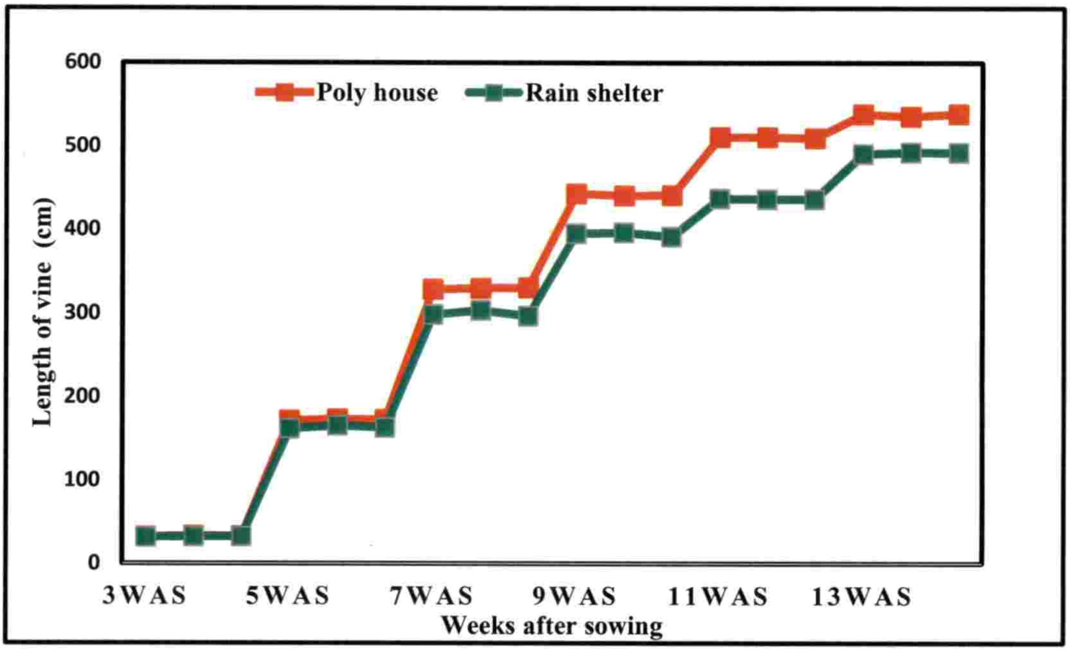

Figure 1: Fortnightly variation in length of vine (Date of sowing 1st June)

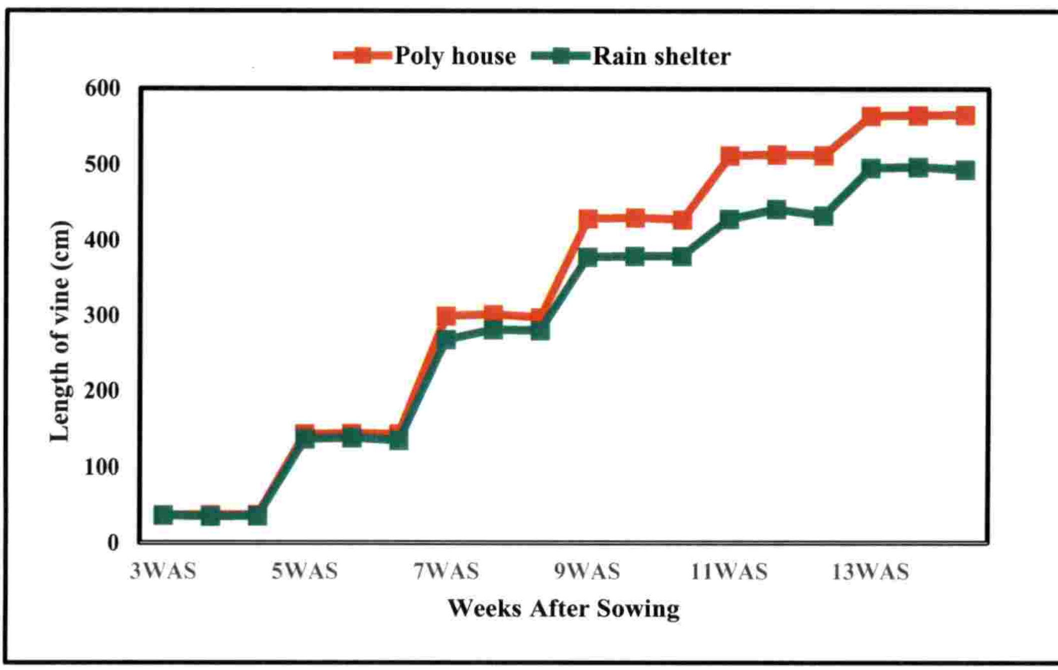

Figure 2: Fortnightly variation in length of vine (Date of sowing 11th June)

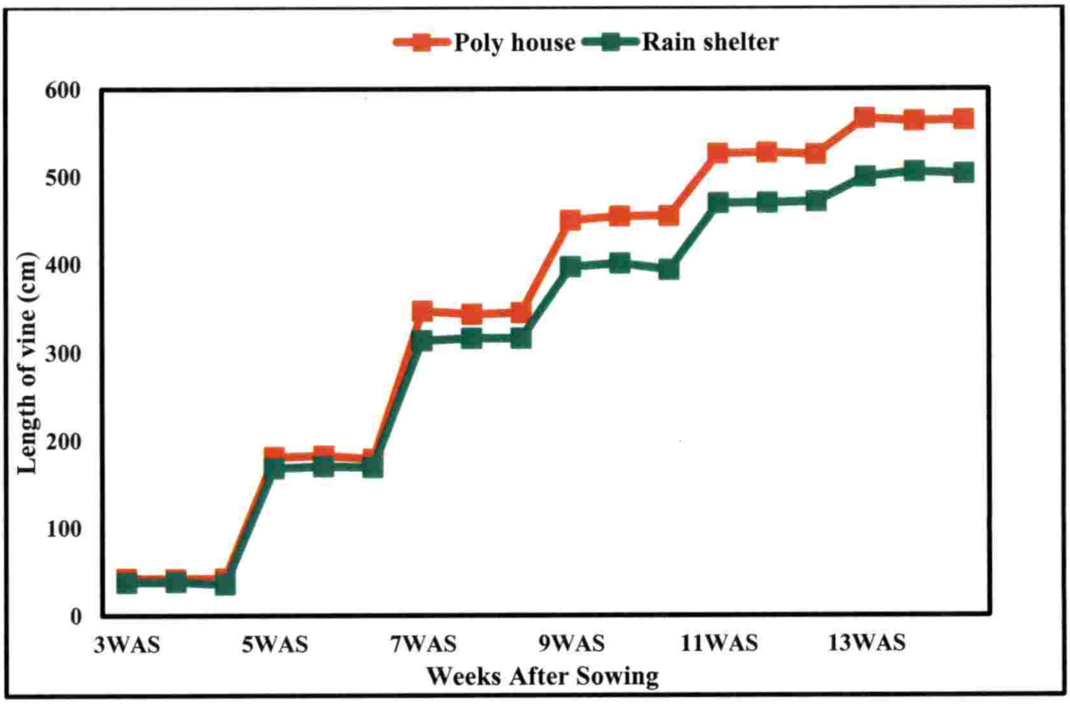

Figure 3: Fortnightly variation in length of vine (Date of sowing 21st June)

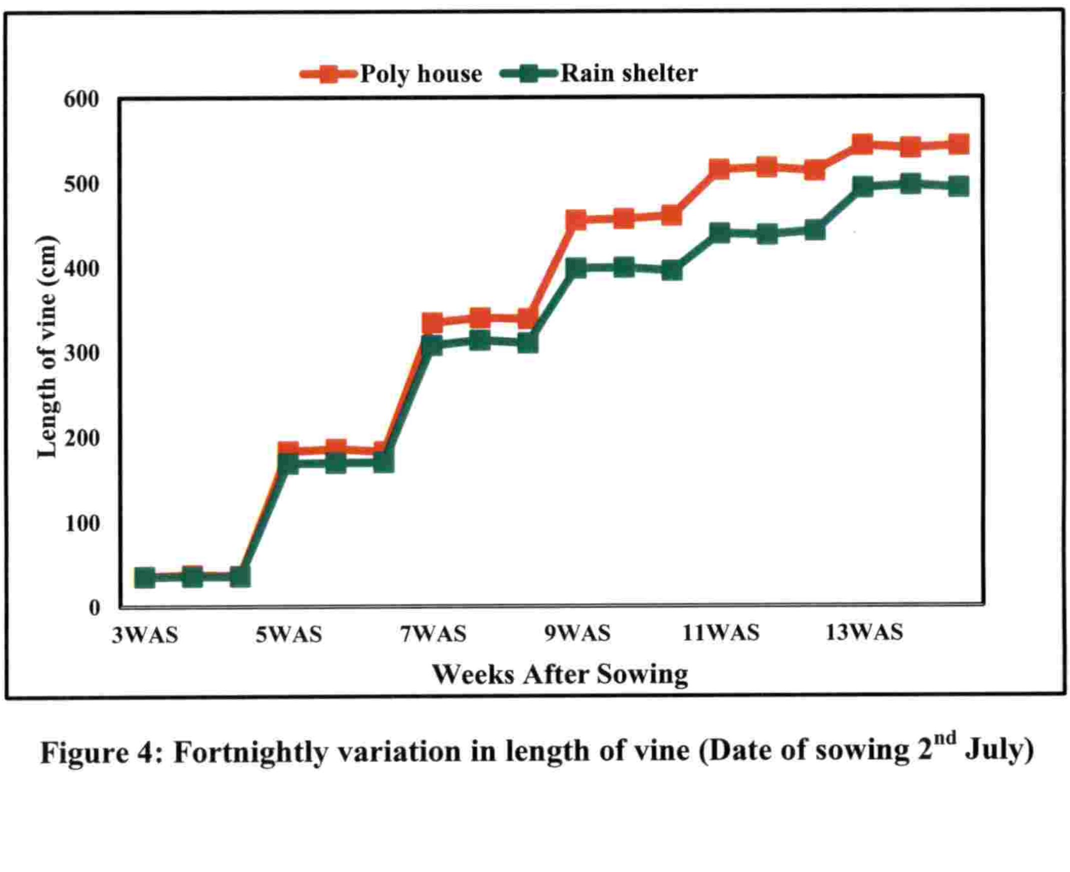

Figure 4: Fortnightly variation in length of vine (Date of sowing 2nd July)

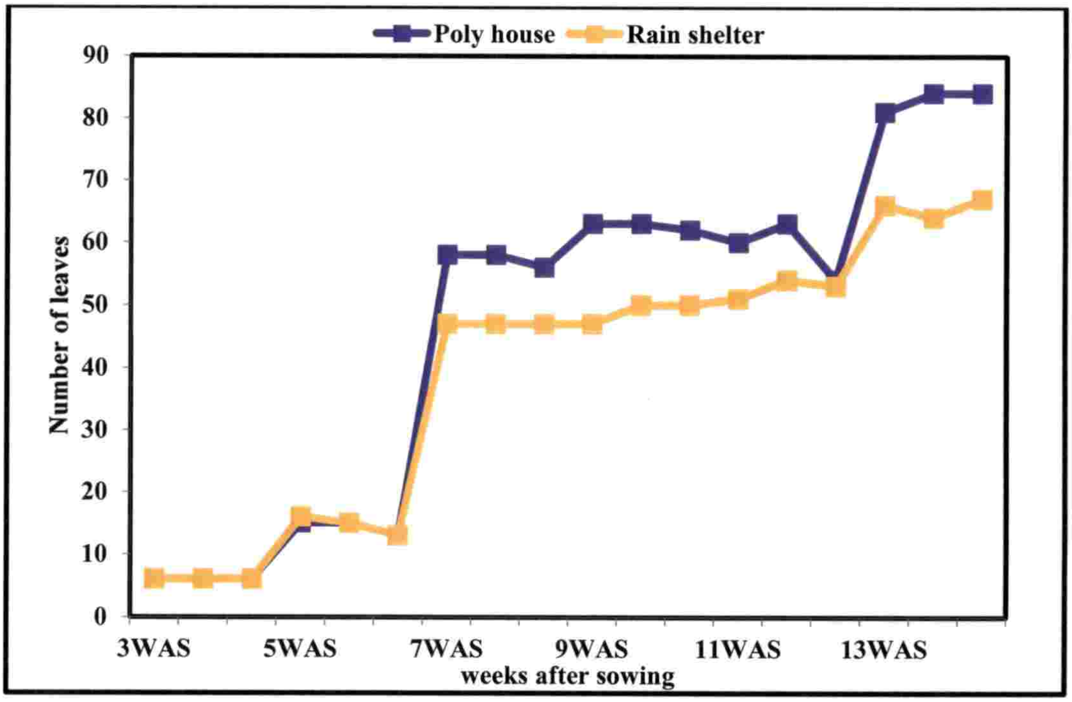

Figure 5: Fortnightly variation in number of leaves (Date of sowing 1st June)

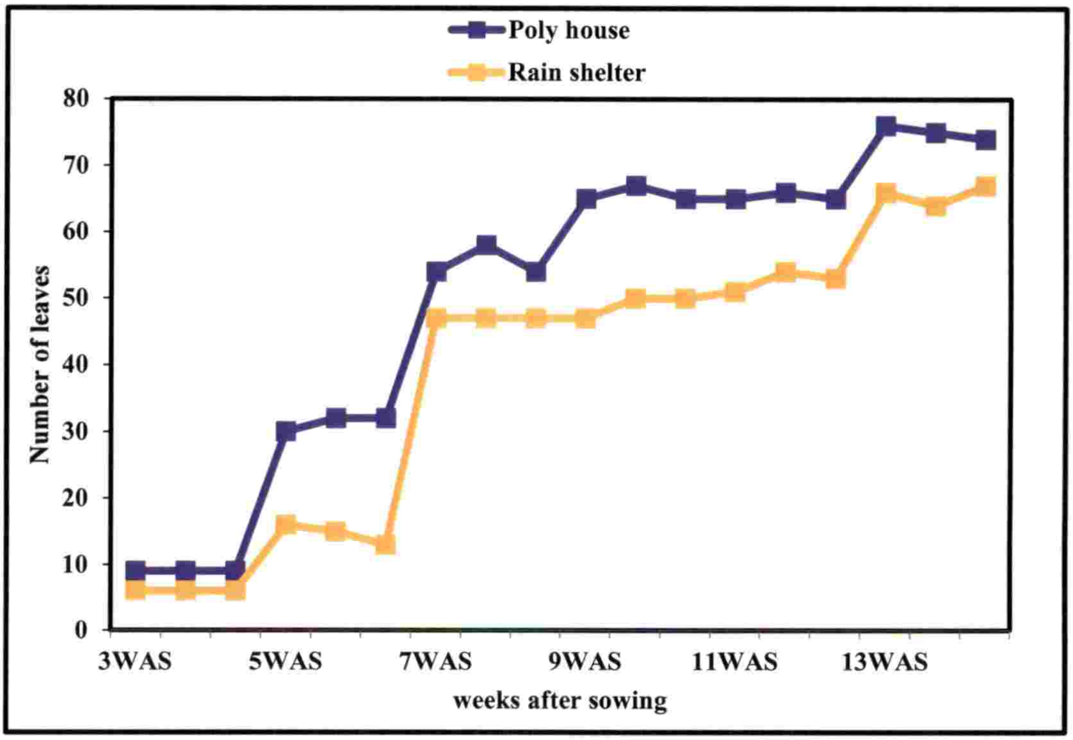

Figure 6: Fortnightly variation in number of leaves (Date of sowing 11th June)

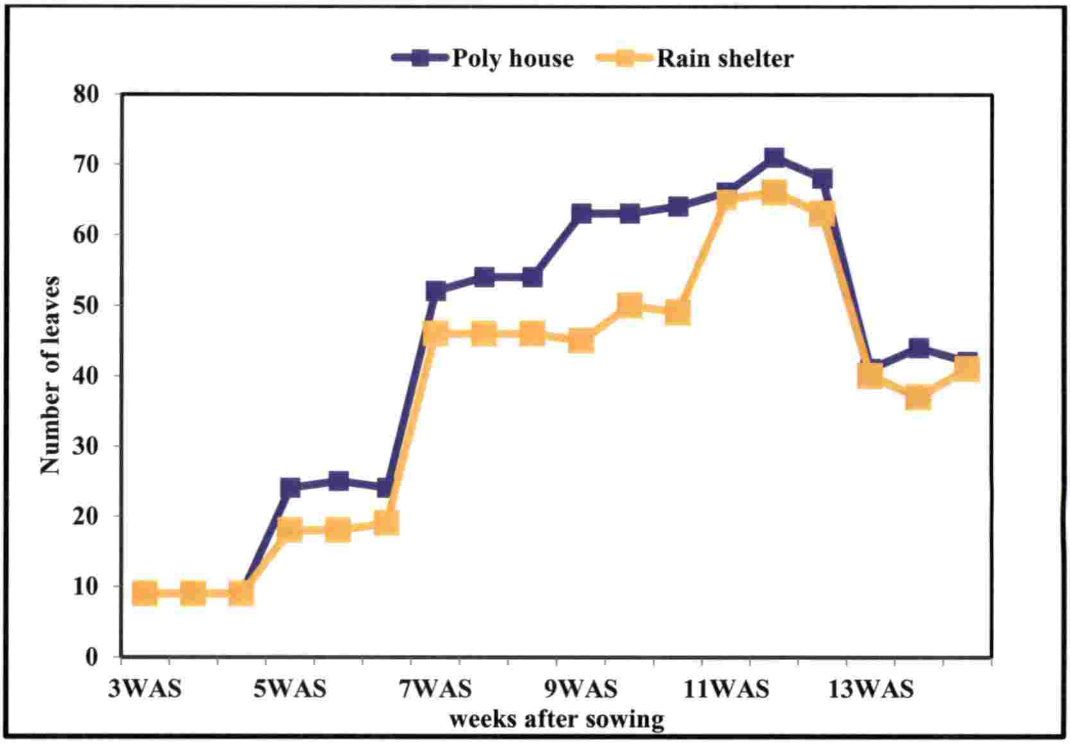

Figure 7: Fortnightly variation in number of leaves (Date of sowing 21st June)

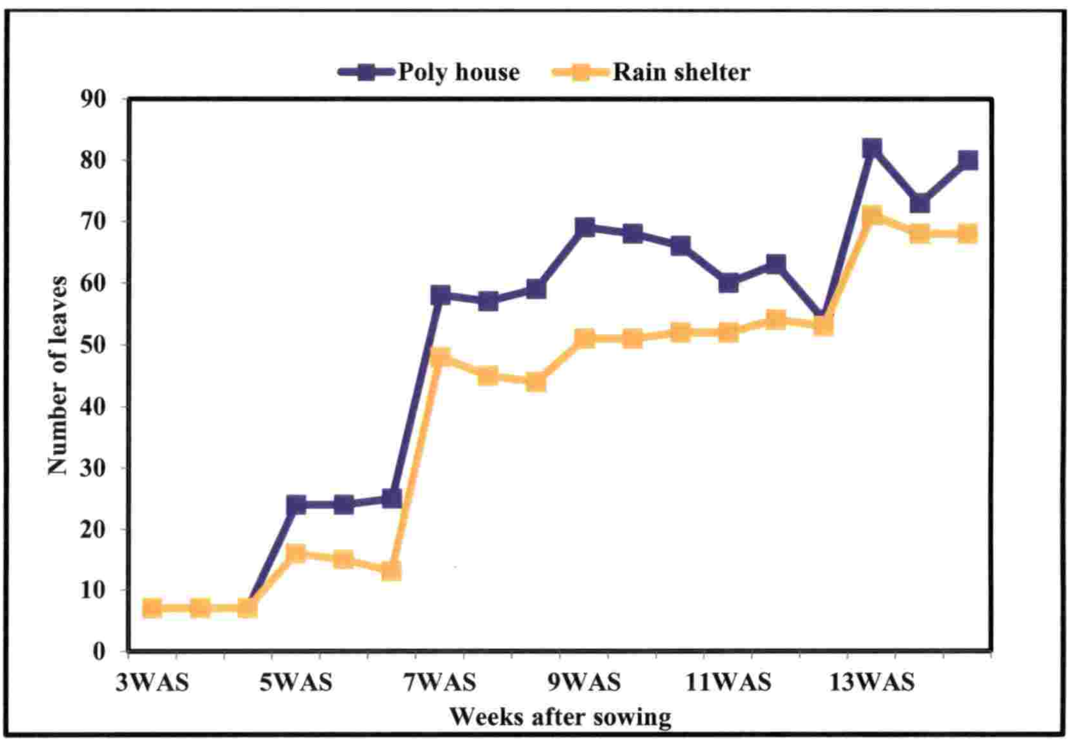

Figure 8: Fortnightly variation in number of leaves (Date of sowing 2nd July)

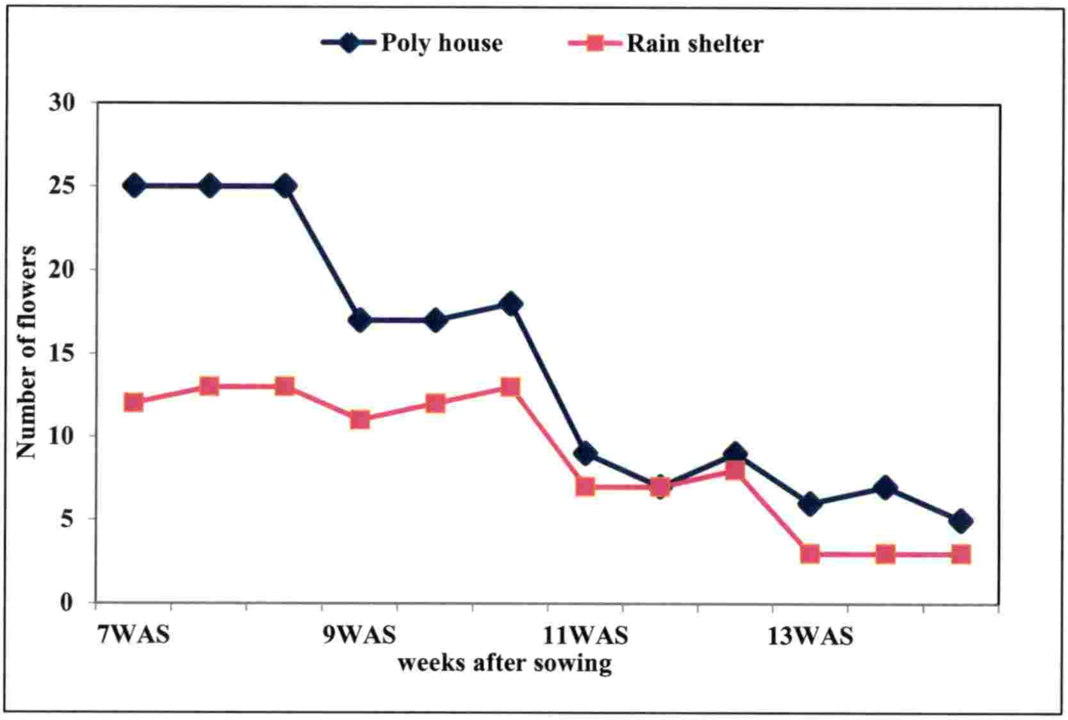

Figure 9: Fortnightly variation in number of flowers, Date of sowing 1st June

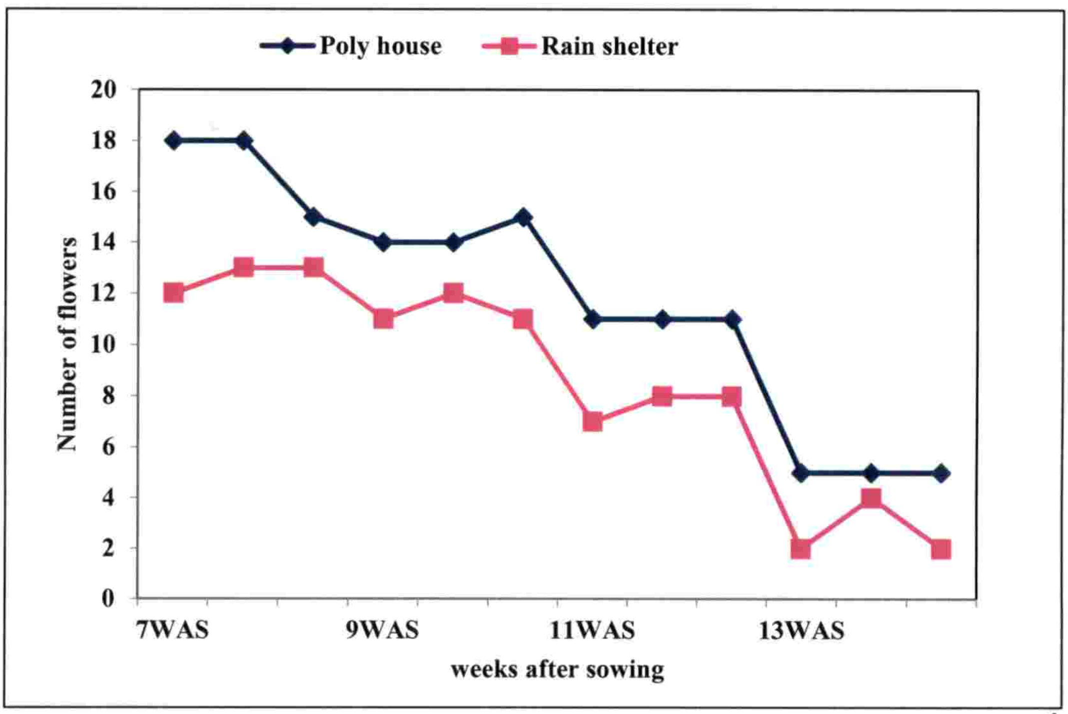

Figure 10: Fortnightly variation in number of flowers (Date of sowing 11th June)

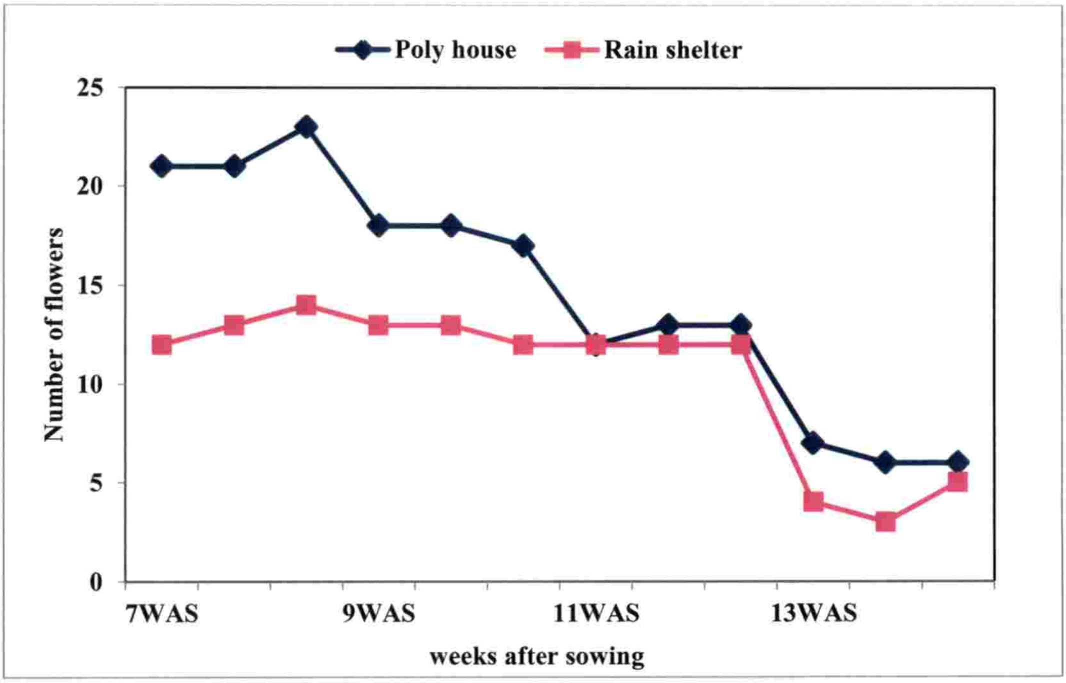

Figure 11: Fortnightly variation in number of flowers (Date of sowing 21st June)

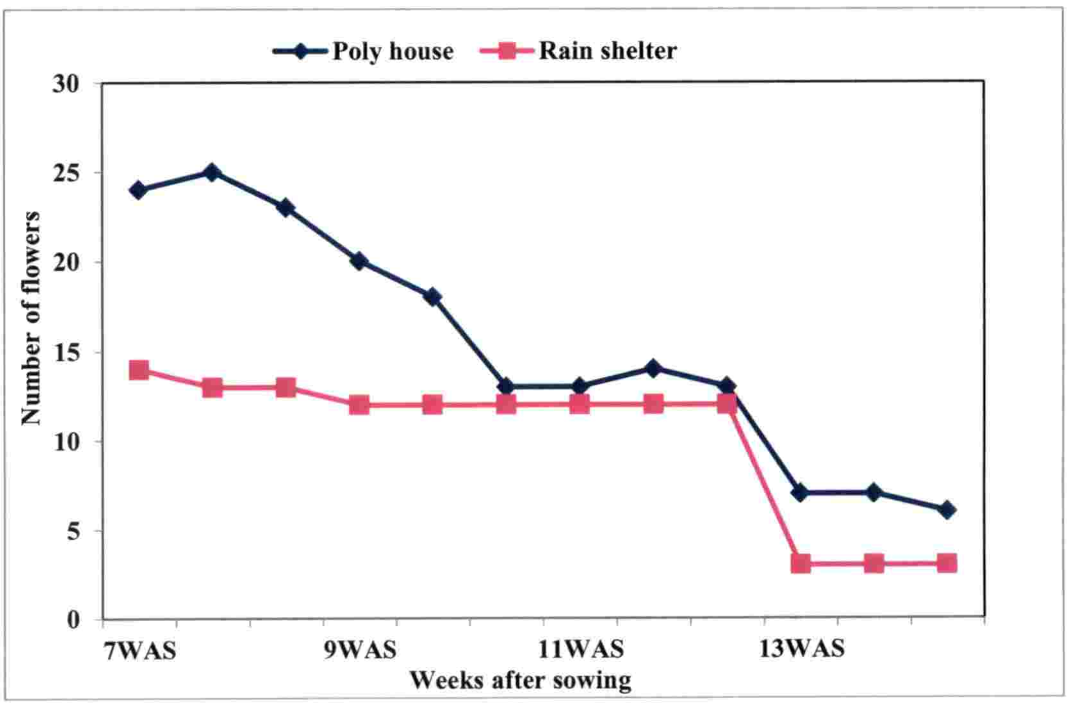

Figure 12: Fortnightly variation in number of flowers (Date of sowing 2nd July

5.3 PHENOLOGICAL CHARACTERS

The growing environment and date of sowing had a significant effect on the number of days taken for the appearance of first flower (Figure13). The plants in poly house showed a tendency for early flowering. The appearance of first flower in poly house was earlier by 1-3 days than that in rain shelter. The results agree with the findings of Grimstad (1995) where the low temperature delayed flowering. The highest number of flowers was also noticed (60.9) in poly house compared to rain shelter.

The growing environment and dates of sowing had a significant effect on the days to first harvest (Figure14). The crop sown inside the poly house took more days for the first harvest (67.3 days) than in rain shelter (51 days). The first harvest inside the poly house was delayed by 8-15 days compared to that of rain shelter. The reason might be the high temperature and relative humidity inside the poly house.

The date of sowing and the growing environment had a significant effect on crop duration (Figure15). The highest crop duration was observed inside the poly house (86.6 days) while the lowest was observed in rain shelter (82 days). This agree with the findings of Rajasekher and Nandini (2014) where the crop duration was found to be related to low light intensity and PAR.

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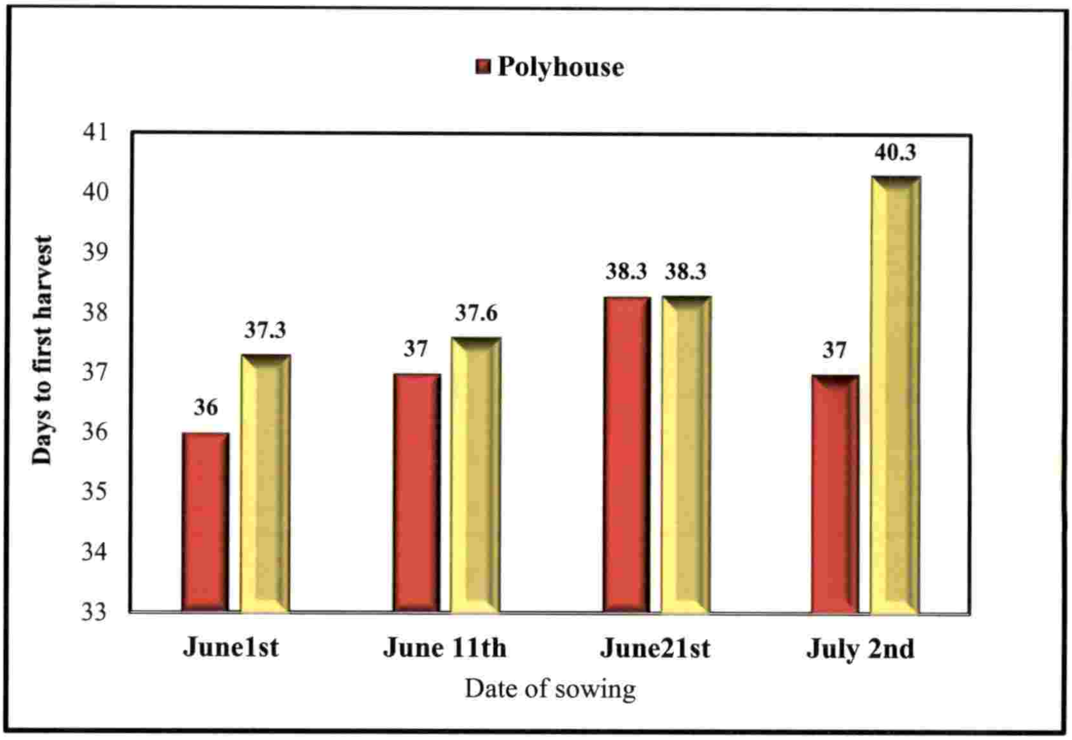

Figure 13: Days to first flowering

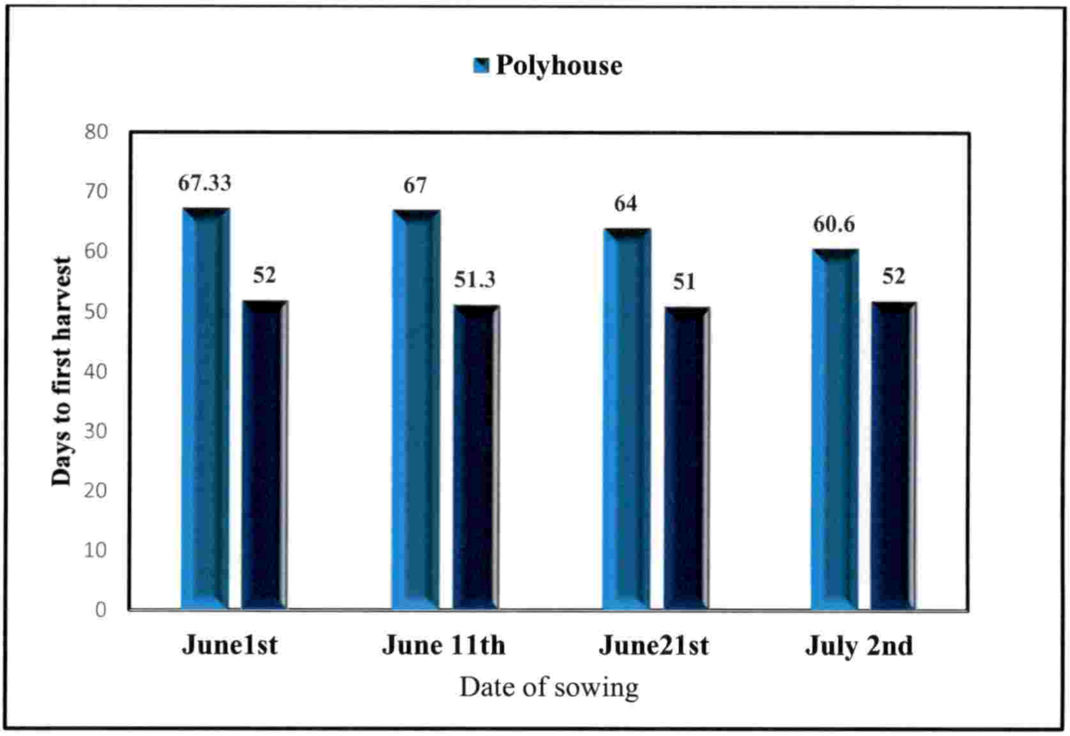

Figure 14: Days to first harvest

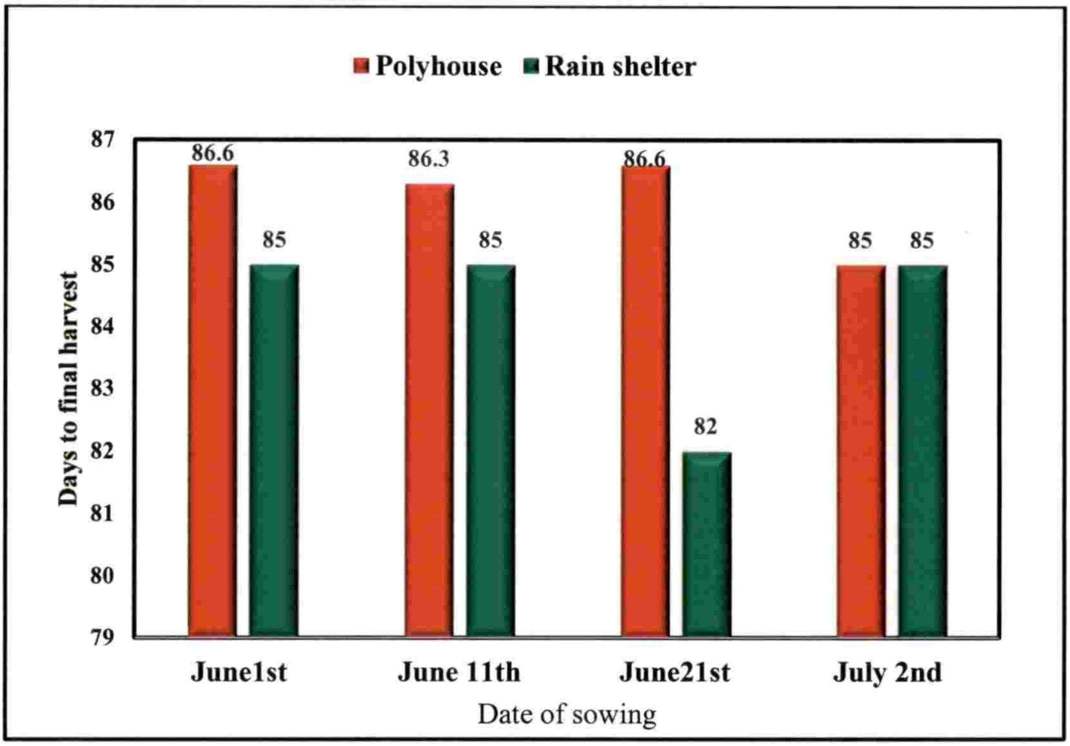

Figure 15: Days to final harvest

5.4 YIELD AND YIELD ATTRIBUTES

The fruit weight per plant, number of harvest and yield per hectare was found to be significantly influenced by the date of sowing and growing environment. The highest fruit weight per plant, number of fruits per plant and yield per hectare were obtained from rain shelter than that of poly house. More number of fruits and fruit weight per plant ultimately contributed to more fruit yield per hectare in cucumber. Similar findings were also reported by Anjanappa *et al.* (2012), Pant *et al.* (2001), and Mohomedin *et al.* (1991).

In spite of early flowering, higher number of flowers and increased crop duration, the fruit set in the poly house might have been affected by the increase in temperature and humidity resulting in yield reduction

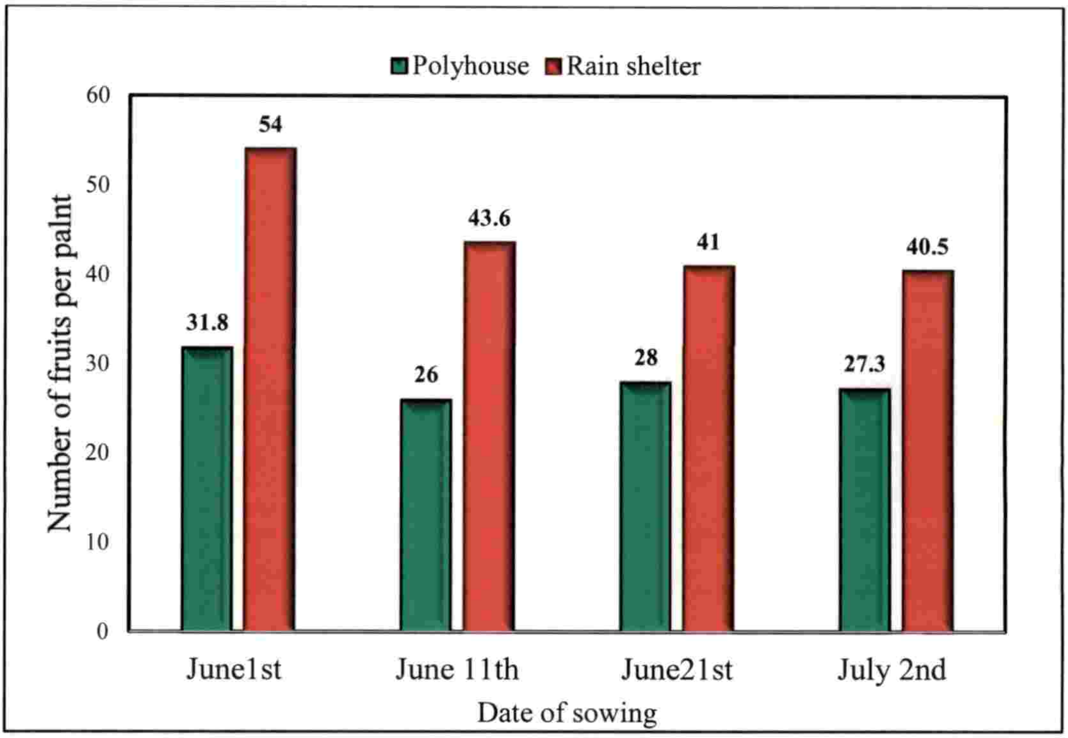

Figure 16: Number of fruits per plant

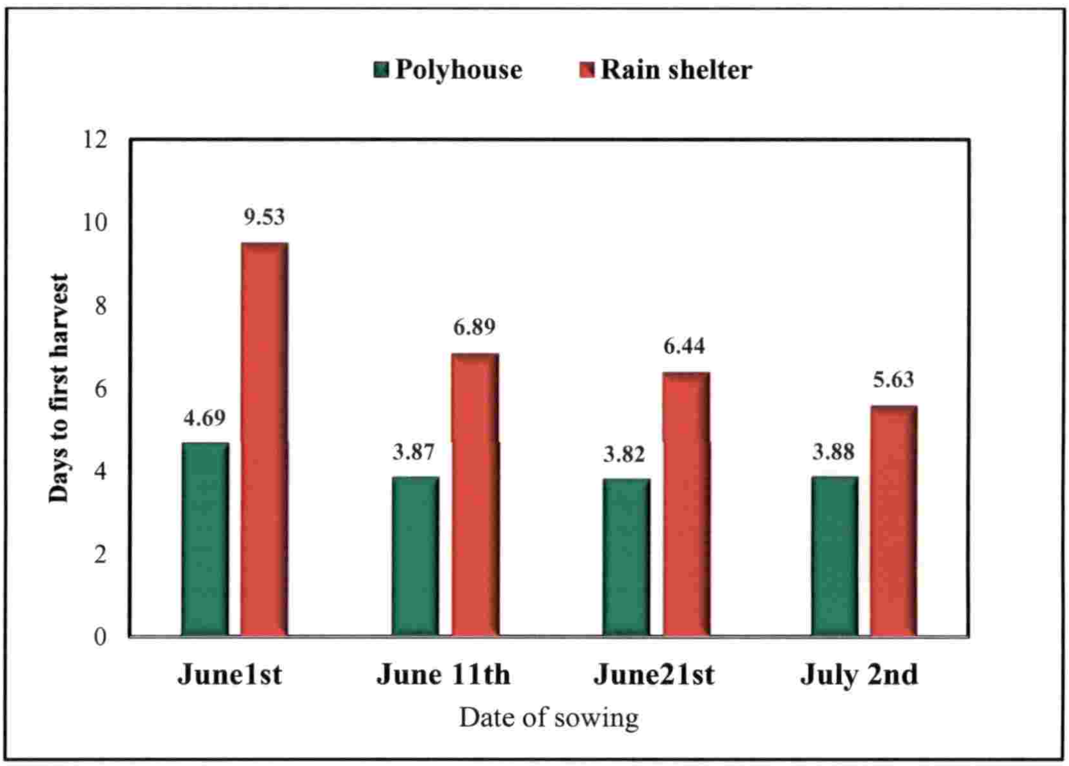

Figure 17: Fruit weight per plant

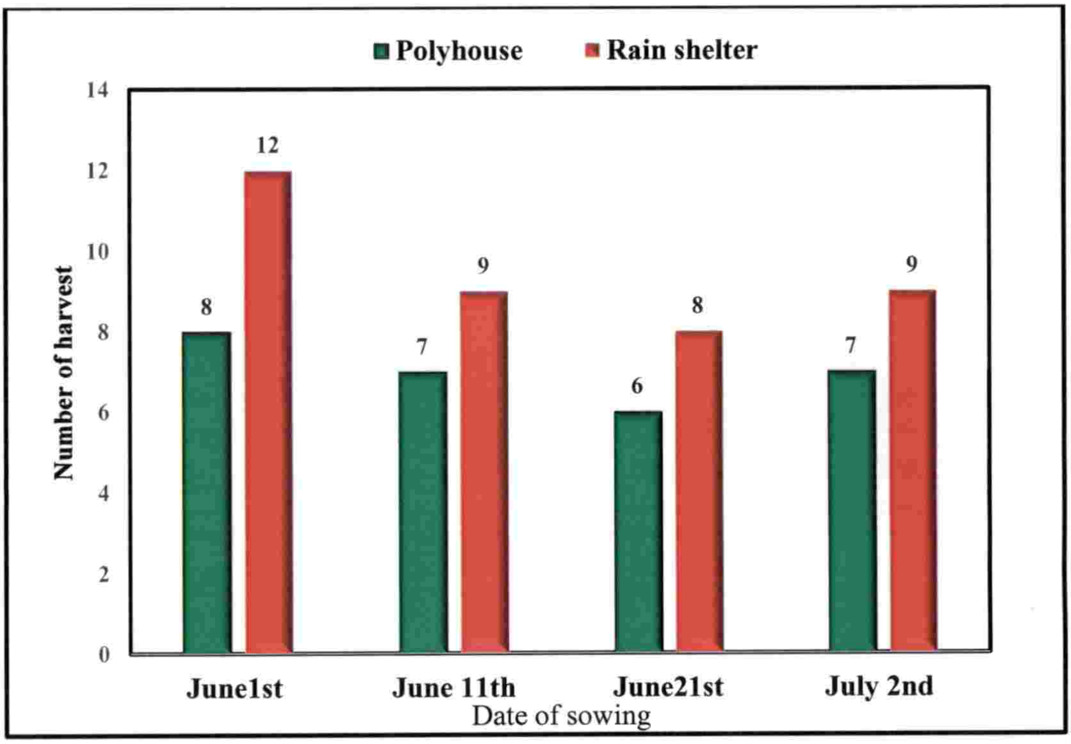

Figure 18: Number of harvest

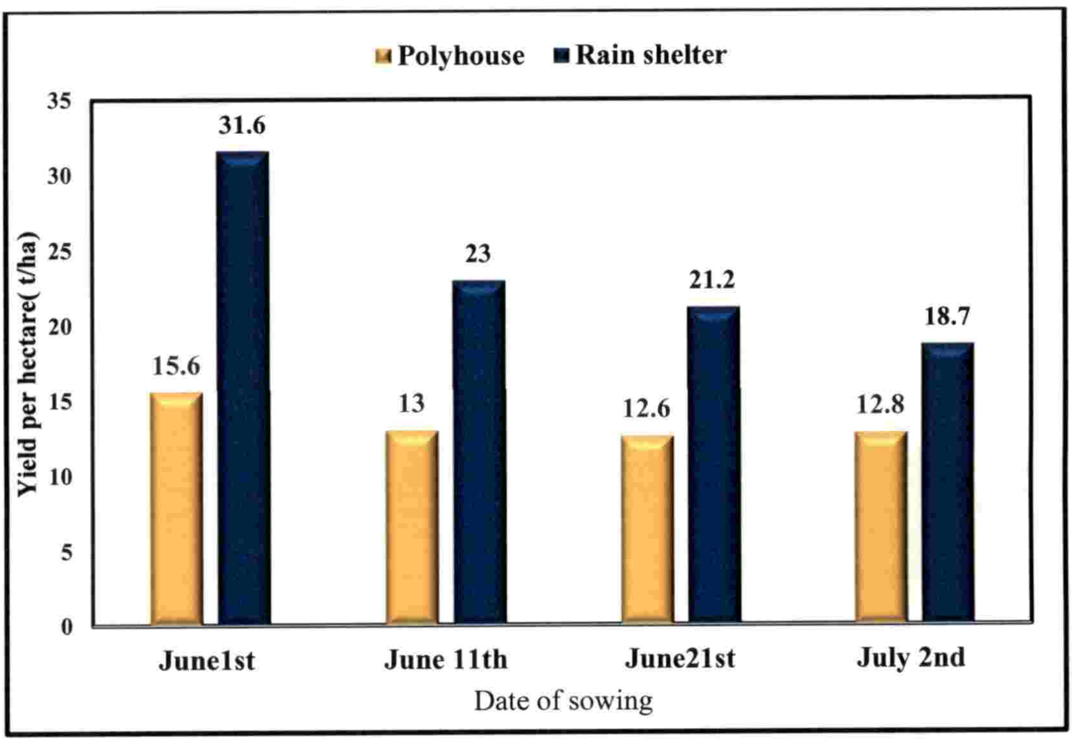

Figure 19: Yield per hectare

5.5 WETHER PARAMETERS

Regardless of date of sowing, the highest weekly maximum and minimum temperatures were recorded inside the poly house compared to rain shelter. High temperature inside the poly house might be due to the long wave radiation trapped by the covering material of the poly house. The temperature in the protected structure was considerably higher compared to ambient temperature and this might have resulted in better morphological growth (Hirama *et a.,* 2003 and Dhandare *et al.* (2008).

The temperature inside the rain shelter was higher than in the open but less than the poly house. The higher yield obtained from rain shelter may be because of the optimum weather conditions prevailed inside the rain shelter compared to that in poly house. In the case of poly house, high temperature and humidity may be the reason for better morphological and higher flower production growth but it has led to reduction in yield due to lesser number of fruits per plant and less average fruit weight.

The soil temperature also varied with the growing environments (Figure 22 to 27). The soil moisture showed a positive correlation with length of vine, number leaves, days to first flowering, first harvest and final harvest. This agree with the findings of supported by Igbal *et al.* (2009) in hot pepper, Singh and Kamal (2012) in tomato. The extended retention of soil moisture also might have led to higher uptake of nutrients, proper growth and development and resulted in higher plant growth.

Relative humidity was found to be negatively correlated with length of vine, number of leaves, and number of flowers and positively significant with final harvest. The highest relative humidity was recorded inside the poly house while the lowest was in rain shelter (Figure 28).This may be due to restricted air exchange inside the poly house than in the rain shelter. The same result was obtained by Bakker (1984) and Hand (1988).

The highest value of PAR recorded inside the rain shelter compared to poly house (Figure 29) which was found to be optimum for better growth and yield. In open field the higher rate of PAR may create a stressful environment which may affect the crop growth and yield. The same results were observed by Rajasekharan (2014).

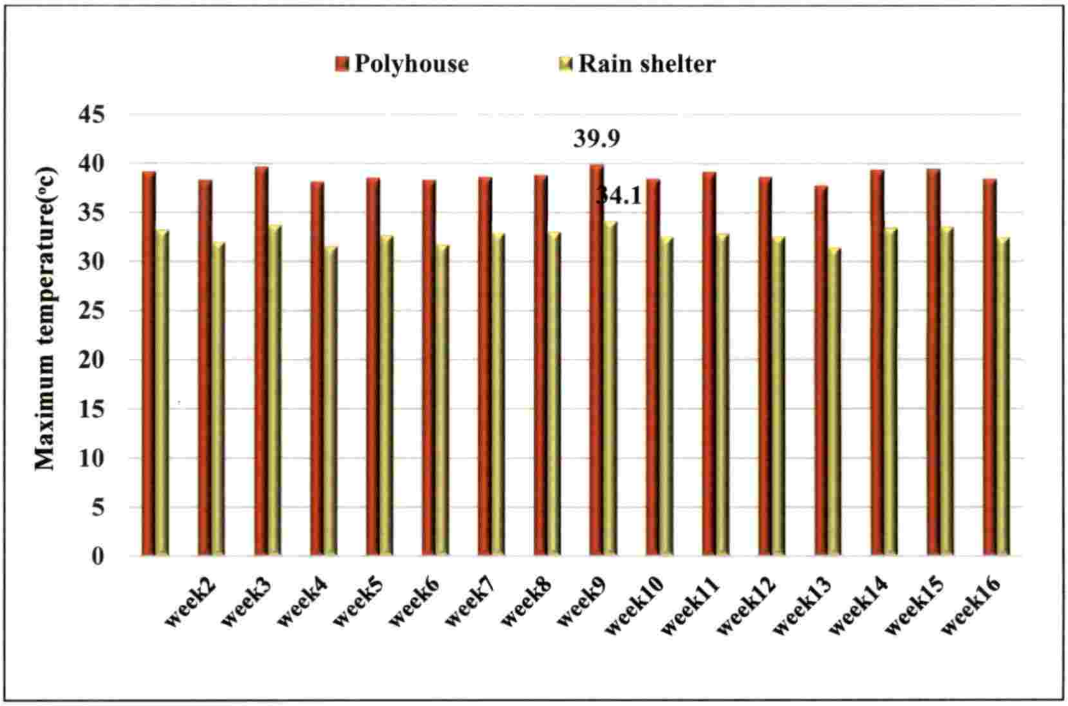

Figure 20: Weekly variation of maximum temperature

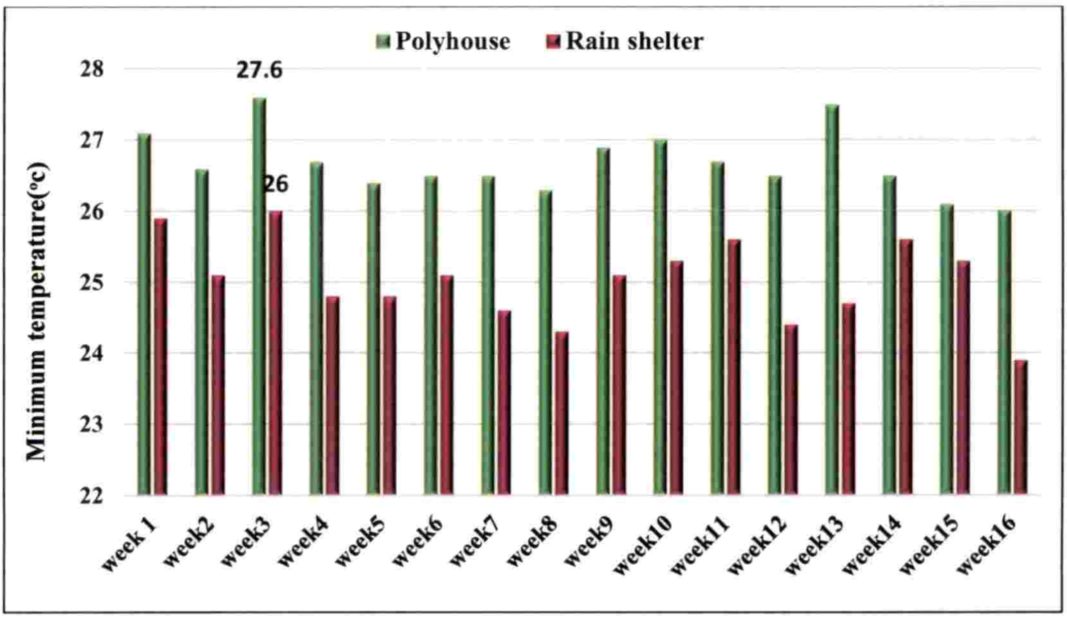

Figure 21: Weekly variation of minimum temperature

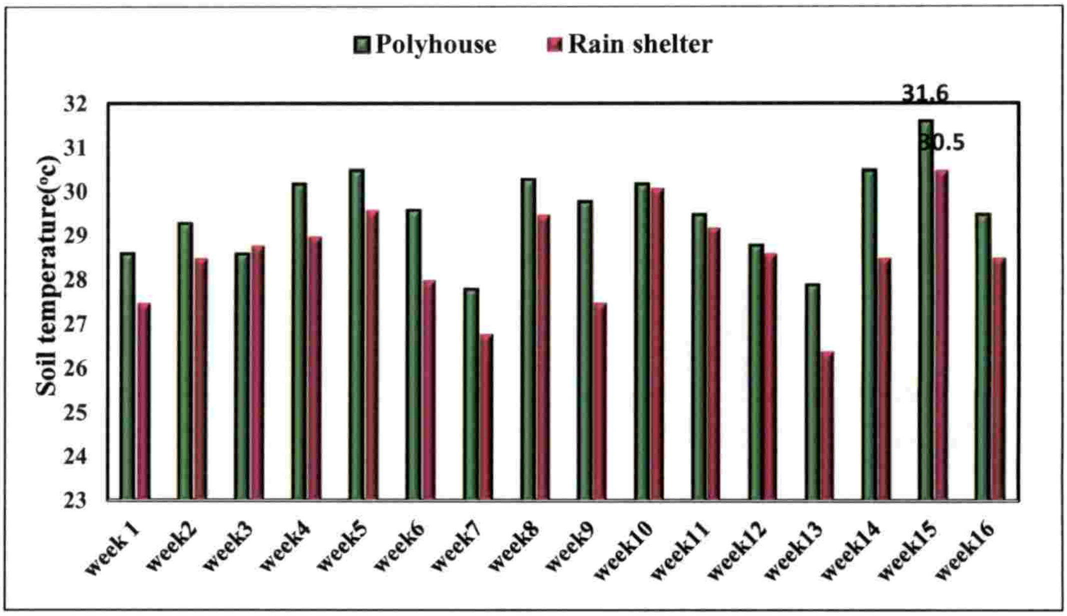

Figure 22: Weekly variation of soil temperature at surface

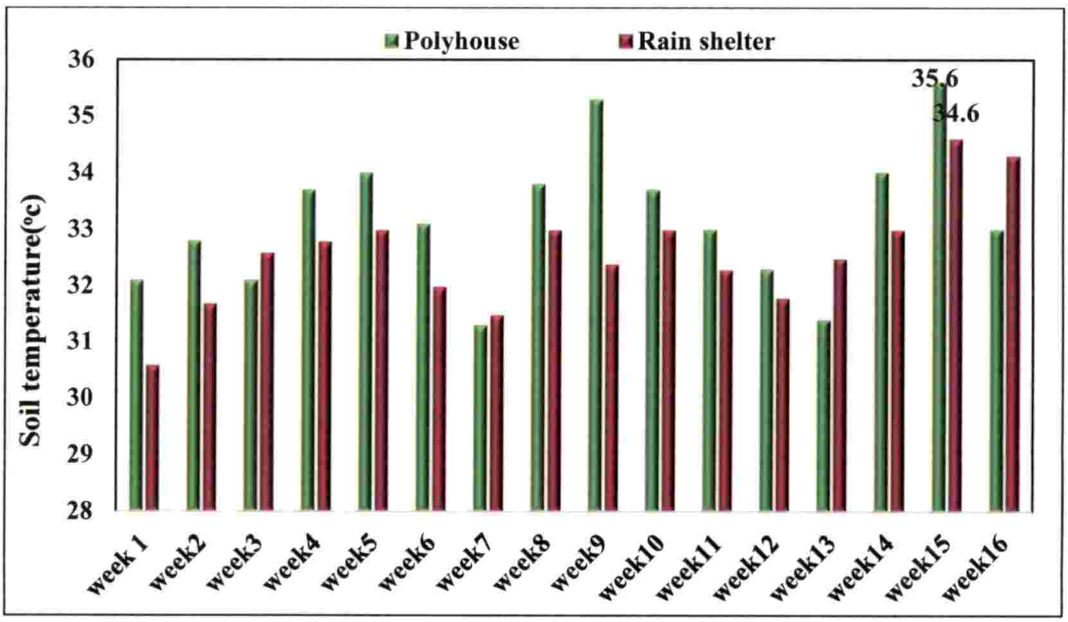

Figure 23: Weekly variation of soil temperature at 15 cm depth

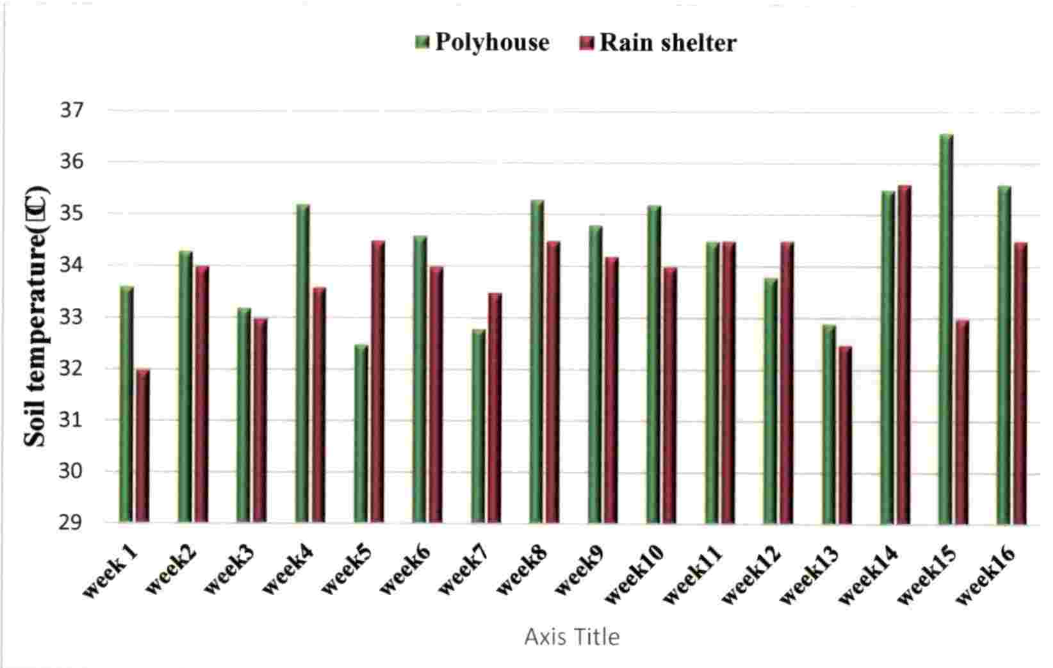

Figure 24: Weekly variation of soil temperature at 30 cm depth

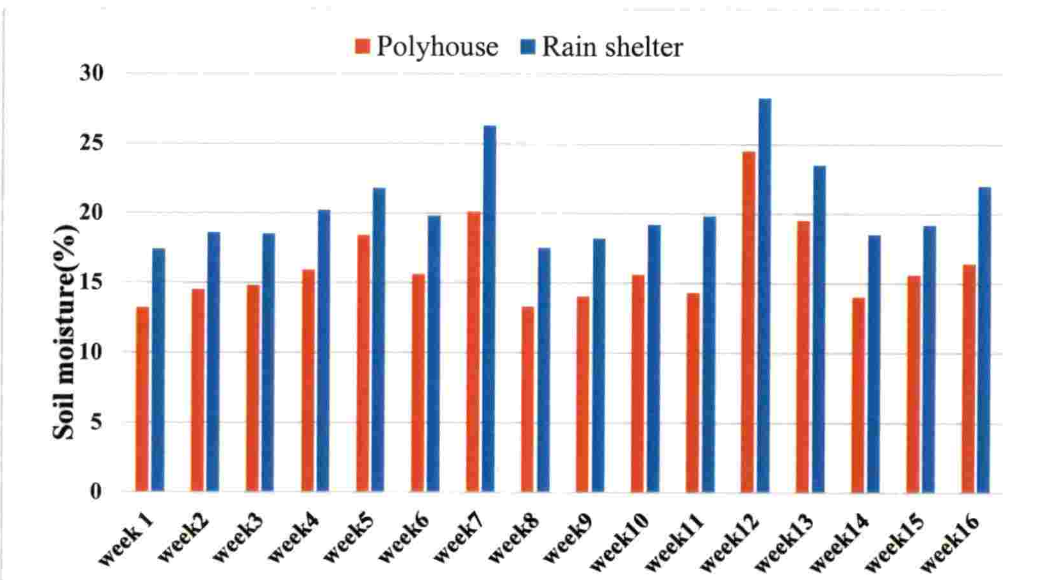

Figure 25: Weekly variation of soil moisture at surface

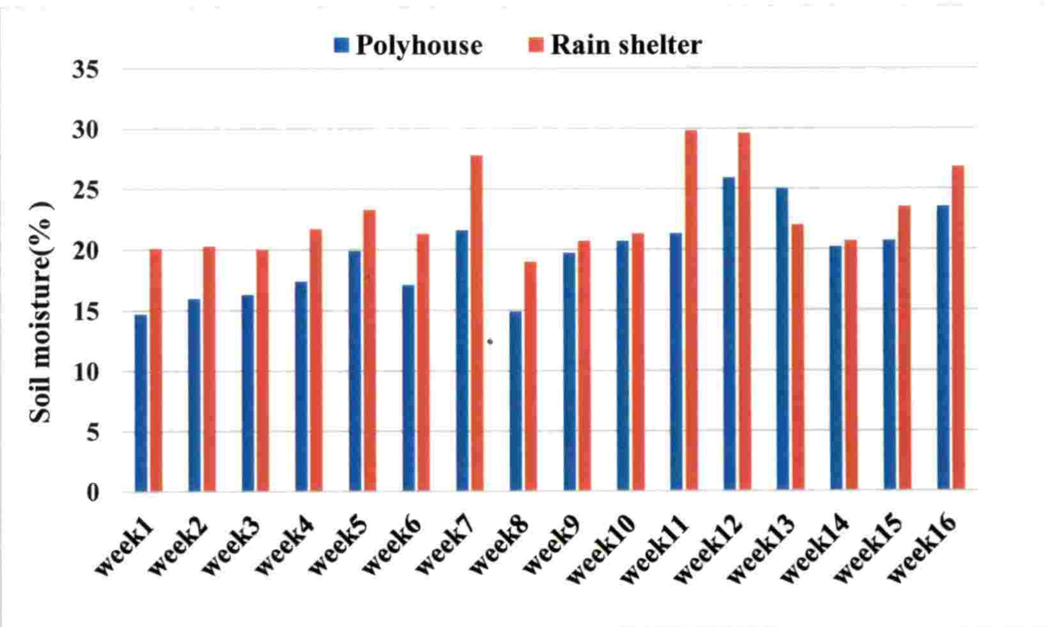

Figure 26: Weekly variation of soil moisture at 15 cm depth

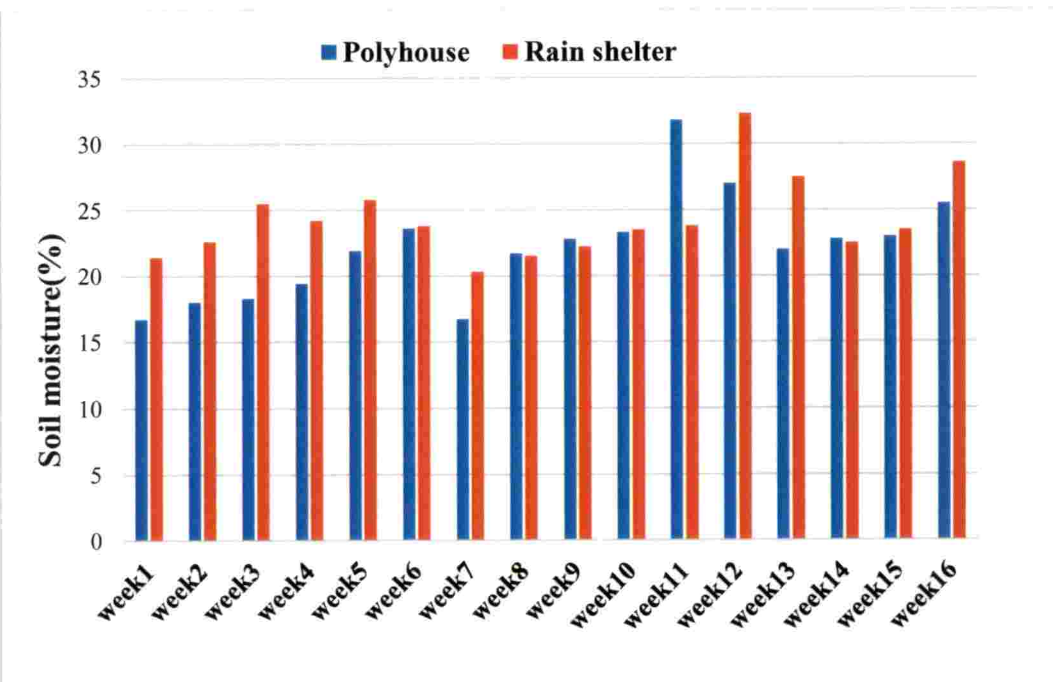

Figure 27: Weekly variation of soil moisture at 30 cm depth

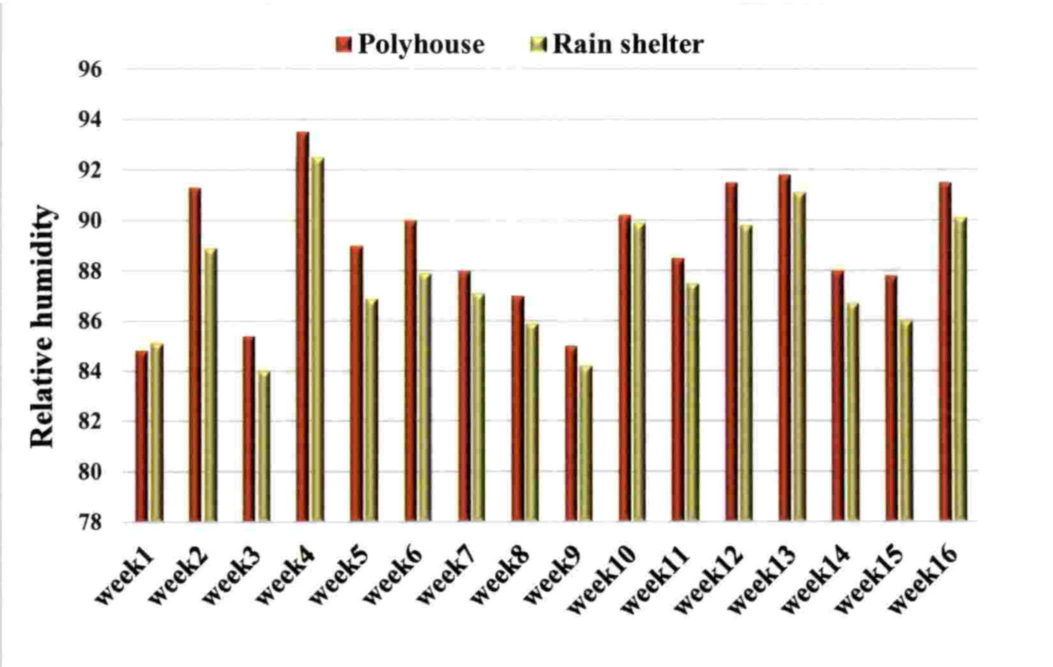

Figure 28: Weekly variation of Relative humidity

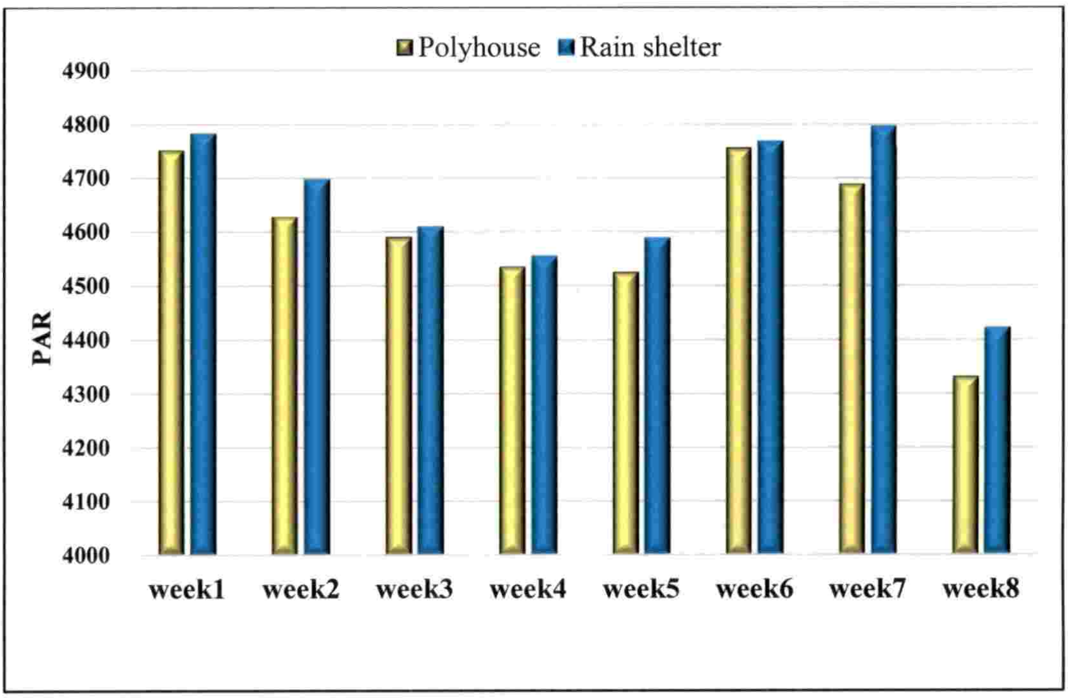

Figure 29: Weekly variation of PAR

CONCLUSION

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The study on "Effect of growing environment and climate change on growth and yield of cucumber {*Cucumis sativus*(L.)} under organic management" revealed that the growing environment and date of sowing had a significant influence on growth and yield of cucumber. Rain shelter was found to be a suitable method to obtain better yield than poly house. The optimum micro climate was maintained inside the rain shelter which in turn has improved the soil and crop productivity. The optimum date of sowing for higher yield of cucumber was found to be 1st June, 2017 both in poly house and rain shelter.

Summary

6.SUMMARY

The present study on "**Effect of growing environment and climate change on growth and yield of cucumber [*Cucumis sativus* (L.)] under organic management**" was carried out in Academy of Climate Change Education and Research, Kerala Agricultural University, Vellanikkara, Thrissur during 2016-2017. The trial was laid out in split plot design with three replications. The treatments included two growing environments and four dates of sowing. The summary of salient findings is presented below.

- The contents of nitrogen, phosphorus, potassium and organic carbon increased tremendously inside the rain shelter and poly house while after the trial. The pH was slightly increased in poly house (7.8) after the experiment.

- The highest bacterial (45.95×10^6cfu g^{-1}) and fungal (76×10^6cfu g^{-1}) population was observed inside the rain shelter. However, the presence of actinomycetes could not be detected either in poly house or rain shelter.

- The crop sown inside the poly house recorded the highest length of vine (565 cm), number of leaves (83) and number of flowers (60). Early flowering (36 days) and more duration (86.6 days) was also observed under poly house.

- The crop sown inside the rain shelter had the highest number of fruits (54), fruit weight per plant (9.53 kg), average fruit weight (177 g), early harvest (60 days), number of harvest (12) and fruit yield (31.6 t/ha).

- The crop sown on 1st June showed early flowering, the highest number of fruits per plant, fruit weight per plant, number of harvest and yield in both rain shelter and poly house.

- The crop sown on 11th June recorded the highest length of vine inside poly house and rain shelter.
- The crop sown on 21st June had the highest number of flowers inside the rain shelter and could be harvested earlier whereas the duration of the crop was extended in poly house.
- The crop sown on 2nd July number of leaves in rain shelter whereas the number flowers and early harvest was observed in poly house.
- The highest maximum temperature, minimum temperature, soil temperature and relative humidity were observed inside the poly house throughout the crop season.
- The highest soil moisture and PAR were observed inside the rain shelter throughout the crop season.
- In poly house, days to first flowering showed significant positive correlation with maximum temperature and relative humidity and negative correlation with rainfall. In the case of rain shelter, it showed significant positive correlation with minimum temperature.
- The days to first harvest showed a positive correlation with relative humidity, rainfall and soil temperature in poly house and the crops sown under rain shelter had significant positive correlation with minimum temperature and soil moisture and negative correlation with soil temperature and PAR.
- The duration of the crop showed a significant positive correlation with minimum temperature, rainfall and PAR under poly house whereas it exhibited positive correlation with the relative humidity, rainfall and soil moisture and a negative correlation with soil temperature and PAR under rain shelter.

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7.REFERENCES

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"Effect of growing environment and climate change on growth and yield of cucumber [*Cucumis sativus* (L.)] under organic management"

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ABSTRACT OF THE THESIS

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ABSTRACT

The study entitled "Effect of growing environment and climate change on growth and yield of cucumber [*Cucumis sativus* (L.)] under organic management" was carried out at the Academy of Climate Change Education and Research, Kerala Agricultural University, Vellanikkara, Thrissur during 2016-2017. The experiment consisted of two growing environments (poly hose and rain shelter) and four dates of sowing (1^{st}, 11^{th}, 21^{st} June and 2^{nd} July).

The biometric, phenological and yield parameters were significantly influenced by the growing environments and date of sowing. The crop sown inside the poly house recorded the highest length of vine (565 cm), number of leaves (83) and number of flowers (60). Early flowering (36 days) and more duration (86.6 days) was also observed under poly house. The crop sown inside the rain shelter had the highest number of fruits (54), fruit weight per plant(9.53 kg), average fruit weight (177 g), early harvest(60 days), number of harvest (12) and yield (31.6 t/ha).

The crop sown on 1^{st} June showed early flowering, more number of fruits per plant, weight per plant, number of harvest and yield both in rain shelter as well as poly house. The crop sown on 11^{th} June recorded the highest length of vine inside the poly house. The crop sown on 21^{st} June had the highest number of flowers and early harvest inside the rain shelter whereas the duration was extended in poly house. The crop sown on 2^{nd} July number of leaves in rain shelter whereas the number flowers and early harvest was observed in poly house.

The highest N, P and K (170 kg/ha, 116.5 kg/ha and 520 kg/ha) and organic carbon (3.12%) were also found the soil under rain shelter after the experiment. The highest bacterial (45.95×10^{6}cut ml^{-1}) and fungal (76×10^{6}cfu ml^{-1}) population was observed inside the rain shelter. Actinomycetes could not be detected either in poly house or in rain shelter.

With respect to the micro climate, the highest maximum temperature, minimum temperature, soil temperature and relative humidity were observed inside the polyhouse throughout the crop season. The highest soil moisture content and PAR was observed inside the rain shelter.

The results of the present study revealed that growing environment and date of sowing has significant influence on growth and yield of cucumber. Rain shelter is a potential method to maintain the micro climate in favor of cucumber growth and yield. Rain shelter growing and sowing on 1st June had a significant impact on realizing the highest yield parameters and yield in cucumber compared to poly house growing and other dates of sowing.