ASSESSMENT OF GREENHOUSE CULTIVATION PROBLEMS IN KERALA

By

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(2019-18-004)

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2021

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Thesis

Submitted in partial fulfillment 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 Soil & Water Conservation Engineering

Kelappaji College of Agricultural Engineering and Technology

Tavanur-679 573, Malappuram.

2021

DECLARATION

I hereby declare that this thesis entitled **"Assessment of greenhouse cultivation problems in Kerala"** 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

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CERTIFICATE

Certified that this thesis entitled **"Assessment of Greenhouse cultivation problems in Kerala"** is a bonafide record of research work done independently by **Ms. Deepthi S Nair. (2019-18-004),** under my guidance and supervision and that it has not previously formed the basis for the award of any degree, diploma, fellowship or associateship to her.

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We, the undersigned, members of the Advisory Committee of **Ms. Deepthi S Nair,** a candidate for the degree of Master of Technology in Agricultural Engineering majoring Soil and Water Engineering agree that the thesis entitled **"Assessment of greenhouse cultivation problems in Kerala"** may be submitted by **Ms. Deepthi S Nair.,** in partial fulfillment of the requirement for the degree.

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ACKNOWLEDEMENT

First of all, I thankful to **God Almighty** for his invisible helping hand in this covid pandemic situation that guided me through the right way to pursue my journey to the completion of this project.

At the very outset I express my sincere regards, profound sense of gratitude and indebtedness to **Dr. Jinu A** Asst. Professor, Department of Soil and water Conservation Engineering, KCAET, Tavanur, my guide for his valuable suggestion, warm encouragement, thoughtful guidance, insightful decision, critical comments and correction of the thesis.

I also indebted to **Dr. Sathian K. K**, Dean, Kelappaji College of Agricultural Engineering and Technology, Tavanur, for providing me with the necessary support, permissions to carry out my research work with ease and correction of the thesis.

I would like to express my sincere gratitude to **Er. Priya G Nair**, Assistant professor, KVK Malappuram. **Dr. Prasanth K**, Assistant professor, KVK Malappuram, **Dr. Rema K P** Professor& Head, Department of Irrigation and Drainage Engineering, K.C.A.E. T, Tavanur and **Dr. Abdhul Hakkim, V M.** Professor, Department of Soil and Water Conservation Engineering, ARS Pattambi for their valuable suggestions and remarks during course of work.

I am extremely thankful to **PAO** and **Staffs** of **DHM** for providing me valuable information and data required for my survey. Along with them, I am immensely thankful to the **farmers** who shared their experiences, suggestions, and their valuable co-operation during survey.

It gives me immense pleasure to express my deep sense of gratitude to **Er. Arun** and **Er. Favazil Muhammed**, staff members of

Precision Framing Development Centre (PFDC), KCAET, Tavanur for their valuable suggestion and support throughout the project work.

I sincerely acknowledge the help and co-ordination rendered by all the labourers especially **Sri. Parameswaran** and **Smt. Mini.,** PFDC, KCAET, Tavanur.

My sincere thanks to all my M-Tech friends, seniors, and juniors especially **Er. Aiswarya L** and **Er. Adarsha G Bhat** for their support and encouragement during the course of study.

Words are not enough to express the deep sense of gratitude and love for my family for all the moral support and encouragement which instilled the motivation and confidence for the completion of my project.

Deepthi S Nair

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Date:

Dedication

This thesis is dedicated to my profession

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SYMBOLS AND ABBREVIATIONS

%	Percentage
°C	Degree Celsius
ACM	Air exchange per minute
cm	Centimeter
CRD	Completely Randomized Design
EBA	Ethylene Butyl Acrylate
EVA	Ethylene Vinyl Acetate
et al.	And others
etc.	et cetera
Fig.	Figure
GI	Galvanized Iron
GSR	Global Solar Radiation
Ha	Hectare
IR	Infra-Red
KAU	Kerala Agricultural University
KCAET	Kelappaji College of Agricultural Engineering and Technology
kg	Kilogram
LDPE	Low Density Polyethylene
m	Meter
m^2	Square meter
mm	Millimeter
N	North
Nm	Nanometer

PVC	Poly Vinyl Chloride
PAR	Photosynthetically Active Radiation
SHM	State Horticulture Mission
STPV	Semi Transparent Photovoltaic
t/ha	Tons per Hectare
UV	Ultra Violet
UVA	Ultra Violet A
UVO	Ultra Violet Opaque cover
UVT	Ultra Violet Transmitting cover
VPD	Vapour Pressure Deficit

CHAPTER 1

INTRODUCTION

Kerala is known as god's own country because it is having different diversities of land with a population density of 859 per sq.km. Although compared to other states agricultural production from our state is decreasing day by day. Agriculture is the backbone of our economic activity, so that production should be increased with the increasing population. But the percentage share of state income from agriculture is only 20% and this income is generated from marginal holdings of less than one hectare size with the average size being 0.18 ha (Gokul, 2015). So, increasing the agricultural production from these small landholdings becomes essential for the betterment of the state.

Kerala is blessed with fertile soil, a warm humid tropical climate, and receiving an average annual rainfall of around 3107mm. In rainy months like June and July receives most rainfall around 3223 mm while in summer months it will be less than 3000 (Guhathakurta *et al.*, 2020). The season-wise rainfall contribution over Kerala indicates that 68 % of annual rainfall is received during the monsoon followed by post-monsoon (16%). A complete analysis of vegetable production in the state depicts that majority of the vegetable production within the state is contributed by summer vegetables cultivated in rice fallows and river beds. During the rainy season, along with tuber crops only a few vegetables like, bitter gourd, brinjal, chilly, cowpea, and okra are grown in the State. But high humidity and high rainfall cause biotic stress on vegetable plants which drastically reduce the yield. Furthermore, untimely and erratic rainfall also lowers vegetable production as well as seed production (Pooja, 2017). As a result, Kerala depends on other neighboring states like Tamil Nadu, Karnataka, and Andhra Pradesh for its vegetable requirements during these periods. If Kerala has to come out as an economic power in the world, agricultural productivity should be increased. For improving the productivity, profitability, and sustainability of our major farming systems, unlike conventional methods hi-tech technology has to be adopted. One of such technology is greenhouse technology.

Greenhouses have existed for more than one and a half centuries in different parts of the world while in India this technology has started only in the 1980s and it was mainly used for research activities. Commercial utilization of greenhouses started in India since 1988 onwards with the introduction of the government’s liberalization policies and other development initiatives.

In Kerala, about 95 percent of food crops are grown in the open field. From the olden days itself, man has expert in growing plants under natural climatic conditions. The crop plants also evolved over time by the selection process carried out by the ancient human being through the process of domestication. But in some adverse climatic conditions, no crops can be grown and man has developed techniques for cultivating plants under this type of condition, in which suitable environmental conditions are provided to the plant. In addition to that, it ensures protection from adverse climatic conditions such as extreme temperature, precipitation, wind, cold, excessive radiation, insects, and diseases. It provides an ideal microclimate around the plants. It can be possible by erecting a greenhouse where environmental conditions are modified so that any plants can be grown irrespective of spacial and temporal differences by providing an ideal microclimate around the plant with minimum labor.

“Greenhouses are framed or inflated structures covered with transparent material large enough to grow crops under partial or fully controlled environmental conditions to get optimum growth and productivity” (https://agritech.tnau.ac.in). Greenhouse covered with UV stabilized polyethylene sheet is known as greenhouse. Generally, greenhouse reflects 43 percent of the incident solar radiation and is only allowed to transmit the photosynthetically active solar radiation in the range of 400-700 Nm wavelength. The sunlight entering the greenhouse is absorbed by crops, floors, and other objects in the greenhouse. These objects, in turn, emit long wave thermal radiation for which the covering materials have low transparency. As a result, temperature inside the greenhouse increases. This phenomenon is known as the greenhouse effect, it is the principle behind greenhouse cultivation. Vegetable crops like tomatoes, salad cucumber, capsicum, yard long bean and leafy vegetables are more suitable for greenhouse cultivation.

The benefits of greenhouse cultivations include, offseason production of vegetables and fruit crops are possible, high-quality products can be produced, income from small land holdings could be improved and water constraint of the crop is very limited and easy to manage.

A covering material should be selected based on the climate and location (Waaijenberg and Sonneveld, 2004). Good agricultural practices prove that polyethylene film should have maximum solar transmission and it is opaque to long wave radiation thereby reduce the heat loss at night conditions.

Greenhouse films are made up of polymers and additives. The most commonly used polymers in horticulture are LDPE (low-density polyethylene), EVA (ethylene vinyl acetate), and EBA (ethylene butyl acrylate). And commonly used additives are UV stabilizers and IR absorbing additives. In which polymers are the basic unit and additives providing different properties to the film like light diffusion and infrared absorption/reflection. UV stabilizers absorb UV radiation and protect polymer molecules degradation which enhances the longevity of cladding film. In the 1950s the life span of this film was only 9 months but now it increased to 45 months (Cepla, 2006). Greenhouse cladding film is usually having a thickness of around 200 μm and width up to 9 m is preferable.

In addition to that, this polyethylene film has some properties which are relevant in greenhouse agricultural production. One such property is diffuse film, which can increase the percentage of diffused radiation inside the greenhouse. In areas with clear skies and high solar radiation, direct radiation may cause leaf burning inside the greenhouse crops on warm days. Diffused radiations are radiations that deviate more than 2.5° from the direct incident radiation which reduces the harmful effect of direct radiation. Increased diffused radiation results in higher yield and light uniformity inside the greenhouse (Cabrera et al., 2009).

The next relevant property is anti-dust film. In polyethylene film, there is a chance of accumulation of static electricity when there is the friction caused by the wind. This results in the deposition of dust particles on the surface of the film. So, to reduce static electricity some additives are added on the surface of the film which shows anti-dust properties. (Montero et al., 2001) reported that dirt accumulation reduced light transmission of a new PE plastic film by approximately 6 percent after 1 year of exposure in coastal Spain. Furthermore, anti-drip is another necessary property of cladding material. Water vapor condenses on the cold inner cover surface forming droplets of water which reduces light transmission. (Castilla, 2005) reported that large size water droplets reduce light transmission less than small drops because of different contact angles of a drop with a plastic sheet. Along with condensation causes the fungal infection of crops. Anti-drip additives modify the surface tension of water and eliminate droplets and form a continuous thin layer of water.

Moreover, greenhouses are equipped with ventilation openings to provide a proper microclimate for plant growth. The vents should be completely covered with fine mesh screens to prevent pest attack.

Different types of greenhouses are available in Kerala such as naturally ventilated greenhouses, partially controlled greenhouses, fully controlled greenhouses, net houses, rain shelters and plastic low tunnels. In Kerala, naturally ventilated greenhouses are common everywhere. In which frame may be galvanized iron pipes, steel pipes, or wooden logs. The roof of the greenhouse is covered with UV stabilized polyethylene sheet as cladding material and sides are covered with 40 mesh insect-proof net. According to Kerala state planning board research report (2016-2017) 1200 greenhouses are located in Kerala, out of which 617 are registered in State Horticulture Mission (SHM).

Greenhouses have so many advantages along with some limitations. As the aging of greenhouses reduces the entry of visible spectrum of solar radiation into the greenhouse and as a result photosynthesis reduces which leads to reduction in yield from greenhouses and thereby farmers' efforts became meaningless. In addition to that inadequate marketing facility of greenhouse products, Lack of demand of greenhouse products, insect/fungal attack of greenhouse crops etc. are the main constraints faced by greenhouse farmers. Because of these many farmers are reluctant to take-up greenhouse cultivation citing crop failures after the initial phase. Under these circumstances, this study has been taken up to explore the reasons of failures of greenhouse cultivation under the hands of Kerala farmers. This study will be useful in the agricultural department to analyze the farmer’s works based on that they can take necessary actions to support farmers. While due to this covid pandemic situation, there are some limitations to collecting the farmer's responses directly.

The objectives of the present study are;

1. To conduct an explorative field survey on the performance of greenhouses maintained by the farmers of Kerala.
2. To study the variation of microclimate inside the greenhouse due to aging and discoloration of cladding material.
3. To propose remedial measures for overcoming the problems faced by greenhouse cultivators.

CHAPTER 2

REVIEW OF LITERATURE

This chapter deals with comprehensive review of the research work done by various researchers related to problems of greenhouse cultivation. Effect of age of greenhouse cladding material and resultant light transmission deficiency related studies also reviewed here. The literature pertaining to the performance of different crops under different microclimatic conditions are reviewed here.

2.1 MICROCLIMATE VARIABILITIES INSIDE THE GREENHOUSE

Ganesan (1999) conducted experiments in Ecohorticulture farm of M. S. Swaminathan Research Foundation at Tamil Nadu Livestock Research Station, Kattupakkam, Kancheepuram district, Tamil Nadu and reported that higher day temperature was recorded inside greenhouse compared to open field while relative humidity at 8 am was lesser inside the greenhouse. Likewise light intensity inside the greenhouse was lower than the open field. The yield performance inside the greenhouse was highest (2145 g tomatoes/plant) than open field.

Adams *et al.* (2001) conducted a study on the effect of temperature on growth and development of tomato fruits. They found that tomato fruits were ripened 95 days after flower opening at 14˚C inside the greenhouse. While fruits ripened within 42 days at 26 ˚C in outside condition and concluded that low temperature reduced absolute volume growth rates and delayed the time at which the absolute growth rate became maximal.

Kittas *et al.* (2001) investigated temperature and humidity gradient inside a commercial greenhouse producing cut flowers which was equipped with a cooling pad system and a half shaded plastic roof. The study revealed that cooling process reached 80% efficiency and maintained temperature 10 ˚C lower than that of outside. But in un shaded half of the greenhouse humidity remains constant while temperature increased from pads to the middle of the greenhouse. They reported that under dry climatic condition cooling pad system is efficient but in morning climate plant transpiration is lower than normal. Moreover, they concluded that in dry climates greenhouse roof shading should be avoided because of evaporative cooling itself can prevent overheating inside the greenhouse.

Kavitha *et al*. (2003) carried out a study in greenhouse provided with solar module aided spinning disc sprayer and solar energy aided exhaust fan. By attaining specific climatic conditions in the poly-house the crop response could be varied in such a way that tomato shoot length was increased by 96 percent and yield was increased by 27% and for brinjal 55% increase in shoot length and 85% increase in yield were observed.

Al-Helal (2007) conducted experiment on effect of ventilation rate on the environment of a shaded greenhouse equipped with fan and pad evaporative cooler. They reported that in 0.5 air exchange per minutes (ACM), average of day time air temperature is 33.6 ˚C and relative humidity is 33.5% inside the greenhouse while for 1 ACM average temperature and relative humidity were 30.2 ˚C and 37.5% respectively. At the same time outside temperature and relative humidity were 38.7 ˚C and 11% respectively. Furthermore, the study revealed that average electrical energy consumption from 700 to 2000 h with 0.5 ACM was 48.2 Wh/m^2 while 99.6 Wh/m^2 for 1 ACM.

Gazquez *et al*. (2008) conducted a study on effect of different cooling strategies viz., white washing, fogging and natural and forced ventilation and its impact on the microclimate, growth and yield of a crop under greenhouse. They reported that fogging was most efficient method in controlling temperature and vapour pressure deficit (VPD) values while least efficient in controlling canopy temperature. Based on economic evaluation whitening was the most profitable cooling treatment. And they concluded that a combination of whitening of plastic cover and natural ventilation is most efficient cooling system for Mediterranean climate.

Parvej *et al.* (2010) conducted experiment in greenhouse along with open field condition to compare phenological development and production potentials of two tomato varieties. They observed that air and soil temperature were higher inside the greenhouse compared to open field condition but photosynthetically active radiation inside the greenhouse was reduced by 40%. And they reported that due to this microclimatic variabilities flowering, fruit setting and fruit maturity of tomatoes in greenhouse plants were advanced by 3,4 and 5 days respectively compared to open field conditions. A higher yield of 81 t/ha was obtained from greenhouse as compared to 57 t/ha from open field.

Umesha *et al.* (2011) reported that growth and yield parameters of tomatoes under naturally ventilated greenhouse was greatly affected with changes in microclimate. And they found out that high temperature was reported at afternoon hours (39.88 ˚C) and high relative humidity at morning hours (91.06%). At the same time light intensity was higher at afternoon (58865 lux) while low intensity recorded at morning and evening hours.

Gogo *et al.* (2012) investigated the effects of eco-friendly agricultural nets on germination and performance of tomato seedlings. Tomato seeds were either raised in the open or under a permanent fine mesh net (0.4-mm pore diameter). They reported that eco-friendly net covers modified the microclimate resulting in significantly higher day temperatures and relative humidity, compared with the open treatment. They found that nets increased temperature and relative humidity by 14.8% and 10.4%, respectively. Moreover, they concluded that sowing seeds under a net advanced seedling emergence by 2 days and resulted in higher emergence percentage, thicker stem diameter, more leaves, and faster growth leading to early maturity of seedlings and readiness for transplanting.

Harel *et al*. (2014) conducted study in Mediterranean region and they reported that summer temperature has a detrimental effect on tomato fruit set process. Mean daily temperature of 25-26 ˚C are the upper limit of fruit set and fruit yield of tomatoes while pollen grain's viability can be improved with mean daily temperature of 24-24.5 ˚C together with increase of relative humidity from 50 to 70%.

Jamaludin *et al.* (2014) conducted experiment in a 300 m^2 tropical greenhouse with fan and pad cooling system to provide suitable microclimate inside the greenhouse. Horizontal and vertical profiles of temperature and relative humidity inside the greenhouse were studied. The results proved that temperature increase noticed along horizontal plane and vertical plane. But relative humidity decreased from lower level to upper level. It was found that a greenhouse with fan and pad cooling system is suitable for a tropical country like Malaysia.

Gokul (2015) analyzed the performance of cowpea and microclimatic factors under naturally ventilated greenhouse and rainshelter. He reported that the rise in air temperature inside the polyhouse compared to open field ranged from 2.7°C to 3.4°C. In rainshelter, the rise in air temperature compared to open field was 1.4°C to 2°C.

Prakash *et al.* (2015) conducted a comparative study of plant growth, fruit yield, fruit quality and biotic stress incidence in papaya under greenhouse and open filed conditions. The evaluation of papaya under greenhouse revealed that higher number of leafs at flowering (18.33), high flower initiation (64.67 days) and higher petiole length (84.32 cm) compared to open field cultivation. They also reported that papaya grown in greenhouse was almost free from papaya leaf curl virus, ring spot virus and stem rot virus.

Rajasekharan *et al.* (2015) reported from their experiment that low intercellular CO2 concentration and high stomatal resistance caused low carboxylation efficiency and photosynthetic rate at early stages of growth in greenhouse compared to open condition in a farmer's greenhouse at Thannyam in Thrissur district of Kerala during March to June. But at later stages of growth, the carboxylation efficiency and photosynthetic rate was maintained due to lower rate of stomatal limitations.

According to Roy *et al*. (2016) temperature and light intensity were lower inside the greenhouse while relative humidity was higher inside the greenhouse compared to open field condition. They also reported that product obtained from greenhouse having higher fruit length, higher yield and maximum number of fruits per plant compared to open field in case of chili.

Smitha *et al.* (2016) had done experiment in greenhouse, rain shelter and open field simultaneously and compare the performance of crop with six dates of planting. Higher plant height of cucumber (272.7 cm), leaf area index (2.77) and biomass at the time of last harvest (1.4 Mg ha-1) were recorded at the greenhouse compared to rain shelter and open field.

Shamshiri (2017) conducted a study on microclimatic parameters in protected cultivation of tomato under tropical climate condition. They reported that maximum temperature and relative humidity were recorded at mature fruiting stage of tomato and it was around 39.7 ˚ C and 98.9 % respectively. Maximum value of optimality degree temperature was 0.95 while minimum was 0.16. The maximum and minimum optimality degree of relative humidity were 1.0 and 0.31 respectively.

Jinu *et al.* (2018) conducted a comparative study on performance of automation system in controlling greenhouse microclimate. They analyzed that temperature inside the manually operated greenhouse was increased upto 43.1 ˚C whereas in automated greenhouse temperature was increased only upto 37.6 ˚C. This better temperature management inside the automated greenhouse resulted in higher yield (7.54 kg/plant) of salad cucumber compared to manually operated greenhouse.

Microclimate studies of greenhouse under tomato cultivation conducted by Job *et al.* (2018) in Ranchi revealed that air temperature inside the greenhouse was higher by 2^0 to 9 ˚ C than outside temperature during December to March and there after temperature at outside was higher. At the same time relative humidity was lower inside the greenhouse by 2-7 % during winter season, while during summer it was found higher by 4% than outside. Moreover, light intensity inside the greenhouse was lower by 30-50 % than open field.

Garde *et al*. (2019) compared the microclimate inside greenhouse and open field conditions. The mean highest temperature (33.27˚C) and relative humidity (91.28%) was recorded inside the greenhouse which was comparatively less than open field conditions. And highest mean light intensity (43781 lux) was recorded under open field growing conditions for the duration of the experimental period. And they reported that amaranthus having highest germination percentage compared to other leafy vegetables.

Nikolaou *et al. (*2019) reported from their study on impact of different cooling system and its effect on greenhouse microclimate. The use of a fan ventilation system increased the VPD values and there by enhance the crop transpiration rate by 60 % compared to transpiration rates of crops under fan pad system.

Suseela *et al.* (2020) analyzed the influence of different shapes of greenhouse on microclimate inside the greenhouse. They reported that temperature inside the gable shaped greenhouse was 2 ˚C less than the Quonset and Mansard greenhouse where as relative humidity inside the gable shaped greenhouse was more in peak hours of the day but lesser during night time. Finally, they concluded that optimal greenhouse design for Kerala climate is gable shaped structure oriented in north-south direction.

2.2 PROPERTIES OF DIFFERENT GREENHOUSE CLADDING MATERIAL

Pearson *et al. (*1995) had analyzed the radiative properties of different greenhouse cladding material. The highest PAR transmission (94.2%) was recorded on a polyethylene-based film fluorescent additive. Polycarbonate film scattered 7.2% of the incident radiation but diffuse polyethylene film scattered 86.6%. They concluded that there was large variation in degree of scattering with different films. And percentage of scattered radiation decreases with wavelength. They determined that drop wise condensation on cladding surface reduces the solar transmission by 13%.

Zhang *et al*. (1996) had conducted a study on extensive energy and microclimate assessment of different greenhouse cladding material. The difference in climate under single glass and three types of double polythene claddings were compared in terms of PAR transmission and humidity levels. They concluded that double polythene cladding with anti-log thermal layer for the inner layer and standard PE film for the outer layer was most energy efficient. The average vapour pressure deficit in the double PE houses was found to be 0.2 kPa lower than under single glass during the winter season.

Papadopoulos *et al.* (1997) reported that there was no significant difference between early marketable yield of tomato from greenhouses having double inflated polythene sheet and glasshouse. The early marketable yield of acrylic house is similar to that of glass house, but higher than the double inflated polythene film. Mid-season yield in the double inflated polythene film was lower than in the glass house. Final marketable yield in these three structures were similar.

Pieters *et al.* (1997) conducted experiment on four greenhouses covered with standard glass, low emissivity glass, polyethylene and thermal polyethylene in which tomato crop was planted. The results showed that values for the auxiliary heating requirements calculated from the model without condensation were underestimated by about 15% for a glasshouse and overestimated by about 20% for a polyethylene covered greenhouse. They reported that condensation flux has more effect on cladding material.

Pollet *et al.* (2000) investigated the effect of condensate on the transmittance of single glass, double glass, low emissivity glass, ordinary low-density polyethylene, anti-drop condensation polyethylene and anti-dust polyethylene. From the six cladding material studies they reported that presence of condensate reduced the transmittance by 0-23%. The effect of condensate on the transmittance of all glass plates was highest at high angle of incidence. But for non-anti-drop plastic film, at small incident angle highest transmittance reductions were found out.

Pieters *et al*. (2003) measured forward scattering properties of four cladding material in the dry state and in the condensed state at three different incident angles (0,15 and 30°). They found that in the dry state single glass act as quasi non diffusive material while three plastic film which scattered the radiation due to their surface roughness. Forward scattering of the material was broadened by the presence of condensate with the exception of anti-drop condensation polyethylene.

Ajwang *et al.* (2005) conducted a study on effect of insect proof screens on the microclimate of a greenhouse in humid tropical climates. They developed a dynamic energy and mass balance model of the greenhouse system to predict the microclimate of greenhouse from external weather data and properties of insect screen. The study revealed that the use of an anti-thrips net with a discharge coefficient of 0.22 increased the temperature around 5 °C relative to the ambient condition.

Cemek *et al. (*2005) determined condensation characteristics of experimental greenhouse covered with different plastic film covering materials like UV stabilized polyethylene, IR absorber polyethylene, Polyethylene with no additives and double layer polyethylene films. They reported that light transmission of double layer polyethylene film was found to be lowest but polyethylene with no additives was highest light transmission and average transmission loss due to dirt was 9 to 15%.

Al-helal *et al*. (2009) measured global solar radiation (GSR), photosynthetically active radiation (PAR), air temperature and relative humidity inside and outside of a two single covered polyethylene model structure. Their study revealed that exposure to the environment reduced the polyethylene film transmittance to photosynthetically active radiation and GSR. They recorded average daytime temperature inside the exposed structure was 45.7° C while inside the structure it was around 46.9 ° C. They concluded that relative losses of PAR transmittance were around 15% and GSR transmittance was 9%.

Geoola *et al*. (2009) investigated the overall heat transfer coefficient of different greenhouse polyethylene plastic film with or without thermal screen. They reported that overall heat transfer coefficient increases with increases in temperature difference. Moreover, they concluded that using a thermal screen would reduce the overall heat transfer coefficient by 30% and energy saving of about 30%.

Mashonjowa *et al.* (2010) conducted experiment on effects of whitening and dust accumulation on the microclimate and canopy behavior of rose plants cultivated in a greenhouse. They reported that whitening reduced the transmission coefficient of total solar radiation of the greenhouse cover from 0.74 to 0.55. In addition to that they found that dust and dirt accumulation within 6 months exposure to environment reduced transmittance of plastic layer by 15%.

Dehbi *et al.* (2011) had studied ageing effect on the properties of Tri layer PE film used as greenhouse roof. PE films are subjected to natural ageing and artificial ageing. In the artificial ageing the film was exposed to four different combined and simultaneous conditions of temperatures and UV-A radiations. These are 40 °C, 40 °C with UV-A radiation, 50 °C and 50 °C with UV-A radiations. In natural ageing film was exposed to climate. And they concluded that environmental factors have degraded effect on the PE film. The simultaneous effect of temperature and UVA radiation induced the most significant degradation on the film surface and consequently a reduction in the lifetime of the material.

Al-mahdouri *et al.* (2014) had conducted experimental study of solar thermal performance of different greenhouse cladding material. They established nongray rigorous radiative model for estimating the radiative heat transfer through greenhouse covering materials like silica glass, PVC and LDPE. And they observed that significant difference in inside air and ground temperatures between opaque silica glass, IR absorbing PVC and IR transparent LDPE. This increase in temperature was due to IR radiation trapping by absorption and reflectance of covering material.

Sangpradit (2014) conducted experiment on solar transmissivity of plastic cladding material before and after cleaning. The result found that average light transmittivity of new film is around 86%. They reported that before cleaning the film light transmissivity reduced from 50 % to 36% for a period of 6 months. While after cleaning the film light transmissivity reached to 85% and transmission loss is only 1% in 6 months.

Abdel-aal *et al.* (2018) evaluated new greenhouse covers with modified light regime to control cotton aphid and cucumber productivity. They reported that UV opaque cover (UVO) had the lowest air temperature compared to UVT (UV transmitting cover) while light intensity and relative humidly have no variation in both covers. In addition to that they found that total yield was increased to 21% for UVT covers and 25% for UVO covers and it has great influence on aphid infestation also.

Babaghayou *et al*. (2018) had studied anisotropic evaluation of low-density PE greenhouse covering films during their service life. The FTIR analysis of the weathered films proves that the sun exposition favors the oxidation of the LDPE films, as revealed by the increases of the carbonyl and vinyl indices. The study indicate that the photo ageing significantly increases the film crystallinity, the crystal thickness and the optical birefringence. These structural changes not only affect the mechanical properties of the film but also the mechanical anisotropy.

Bambara *et al*. (2018) reported from their experiment that semi-transparent photovoltaic (STPV) cladding could generated solar electricity, at the same time it caused internal shading and it affected supplemental lighting around 84 % which leads to reduction in heat energy up to 12%. Furthermore, they concluded that, in future this STPV roof could satisfy all needs of supplemental lighting under greenhouse.

Shahak *et al.* (2018) conducted a study on photo selective shade netting integrated with greenhouse technologies for improved performance of vegetable and ornamental crop. They concluded that photo selective, light dispersive shade nets and screens can be implemented with greenhouse technology which improve the crop profitability and pest control. Furthermore, they reported that this technology can be used by its own in net and screen houses.

2.3 PERFORMANCE OF LEAFY VEGETABLEBLES UNDER GREENHOUSE

Isaac *et al.* (2015) compared the performance evaluation of leafy vegetables like coriander, palak, green amaranthus, lettuce and red amaranthus in naturally ventilated greenhouse. They recorded that Green amaranthus, palak and coriander showed higher biomass production compared to red amaranthus and lettuce. Green Amaranthus recorded lower values for relative yields despite highest yield owing to the lower market price, but in lettuce, leaf yields were low. Due to the presence of white spots on the leaves of red amarantus reduced the marketable yield around 24.6 per cent than the actual harvested yield.

Chávez-Servín *et al.* (2017) cultivated amaranthus in greenhouse and open field and compare the basic chemical composition and growth parameters of amaranthus at two different growing conditions. Higher grain yield (26.5%), plant height (87.4%), stem diameter (24.3%) and biomass (61.2%) were recorded at greenhouse than field condition. Open field cultivation improved protein (9.0%), fat (17.6%), ash (43.1%) and grain size (22.5%) than that of greenhouse. Finally, they concluded that greenhouse cultivation of amaranthus provides higher yield but inferior chemical composition than open field cultivation system.

Chetri *et al.* (2019) conducted a study on comparative analysis of growth parameters of protected organic leafy vegetables. They reported that net assimilation rate and total dry weight were higher in the greenhouse compared to shade net. They found that crop maturity attained by the crop 10 days earlier in greenhouse compared to shade net. Moreover, their study revealed that growth parameters of all crops were better in the greenhouse than in the shade net.

Mishra *et al.* (2019) reported that nitrogen application increases the amaranthus plant height in greenhouse cultivation. Highest amaranthus yield was obtained at 140 kg Nitrogen/ha while lowest yield was reported at 0 kg Nitrogen/ha.

Kishore *et al. (*2020) conducted experiment on performance evaluation of drip system and profitability analysis of leafy vegetables under greenhouse cultivation. They evaluated profitability of five leafy vegetables that include palak, sorrel, methi, amaranthus and coriander. The study reveals that among the five leafy vegetables, methi has recorded highest benefit cost ratio and net returns while amaranthus has recorded lowest benefit cost ratio and net returns. They reported that the higher yield of green leafy vegetable in greenhouse during summer were mainly due to reduction of insect pests, reduced weed pressure and efficient use of soil nutrients.

Singh *et al*. (2020) conducted experiment using nutrient film technique system to quantify the effect of different concentrations of

CO_2on growth and nutritional quality of different leafy vegetables under greenhouse. For that purpose, they selected two identical greenhouses, one with CO_2 supplementation and other with control of ambient CO_2 concentration. The results revealed that supplemental CO_2 could increase the height and width of leafy vegetables under greenhouse. They found that supplemented CO_2 increased the fresh weight of leafy vegetables around 29-40 percent.

2.4 PEST INFECTION AND IT'S CONTROL INSIDE THE GREENHOUSE

Shipp *et al.* (2003) investigated the effect of different percentage humidity levels on percent infection of *Beauveria bassiana* on greenhouse insect and mite pest. They concluded that increasing relative humidity by 15% caused an increase of 17- 25% in percent of infection. In high humidity conditions spray greenhouse with *B. bassiana* which successfully suppressed populations of *Frankliniella occidentalis* (Pergande) and *Trialeurodes vaporariorum*.

Fargues *et al.* (2005) conducted research on effect of microclimate heterogeneity and ventilation system on entomopathogenic hyphomycete infection of *Trialeurode svaporariorum*in Mediterranean greenhouse tomato. They reported that entomopathogenic hyphomycete have a strong potential for microbial control of whitefly which infesting on tomato crop at ambient humidity.

Nagesh *et al.* (2005) conducted a study on the management of carnation and gerbera to control root knot nematode in greenhouses using dazomet (pre plant chemical) and carbofuran (post plant chemical) in comparison with various combination with bioagents. They reported that pre plant treatment of bed with dazomet followed by the application of neem cake reduced population of M. *incognita* and suppressed the nematode infection for 2 years. The study reveals that on a long-term basis, soil management with pre plant treatment of dazomet followed by the application of oil cakes along with antagonistic fungi, was more effective against *M. incognita* compared to post-plant treatment with carbofuran on carnation and gerbera grown in greenhouses.

Chandel *et al.* (2010) conducted qualitative and quantitative analysis of major plant parasitic nematodes in 214 greenhouses associated with main crops like cucumber, tomato and sweet pepper etc. The experimental study in Himachal Pradesh reveals that the presence of three plant parasitic nematode including *Meloidogyne incognita*,*Helicotylenchus dihystera* and *Pratylenchus* spp. in the main crops with their populations ranging from 8 to 5604 , 15 to 2560 and 5to 795 individuals/200 cc soil, respectively. They reported that *Meloidogyne incognita* was most alarming and threatening nematode which results in 11.31% yield losses.

Kaur *et al.* (2010) monitored major pest, insect and mites on cucumber, tomato and sweet pepper under greenhouse in Punjab. They observed that the red spider mite was the major pest of cucumber. Thrips and broad mites were predominant on sweet pepper. Aphid was the only insect found on tomato. And they reported that tobacco caterpillar damaged cucumber and tomato around 5% and 23.75% on sweet pepper.

Haneef *et al.* (2013) conducted a survey of predatory mites associated with economically important plants of North Kerala. The study revealed that occurrence of 15 species of predatory mites belonging to 6 genera like *Amblyseius*, *Euseius*, *Neoseiulus*, *Phytoseius*,*Typhlodromips*,and*Paraphytoseius*which comes under the sub order Mesostigmata.

Lenin *et al*. (2015) conducted a survey of mite pests and their natural enemies associated with vegetables cultivated under greenhouse in Kerala. They observed that cucumber and amaranthus were attacked by *Tetranychustruncates*while *T. macfarlanei*on French bean and cowpea. The tarsonemid mite, *Polyphagotarsonemus latus* was recorded on most of the greenhouse vegetables like cowpea, chilly, capsicum, amaranths and tomato. Moreover, they reported that *Stethoruspauperculus, Scolothrips*sp and *Oligota*sp.were natural enemies of mite pests.

Patil *et al.* (2017) conducted a survey of greenhouses in different districts of Haryana during 2015-2016 to determine the incidence of plant parasitic nematodes on vegetables crop family. They collected soil and root samples from each greenhouse and analyzed for the presence of plant parasitic nematodes. Finally, they concluded that root knot nematode (*Meloidogune incognita)* was found to be the major plant parasitic nematode under greenhouse cultivations.

Kumar *et al.* (2018) investigated the effect of soil fumigants on the population of root knot nematode and percentage of disease incidence on cucumber under greenhouse cultivation. Their study revealed that fumigants have great effect on reducing nematode along with reducing the percentage of disease incidence. Moreover they reported that all the fumigants were improved plant growth parameters, final nematode population, reduction factor and disease incidence as compared to untreated greenhouse.

Bhaskar *et al.* (2019) studied the efficacy of *Neoseiulus longispinosus*for the management of *Tetranychus urticae*on cucumber under greenhouse cultivation. They conducted experiment on laboratory as well as greenhouse to find out the optimum predator: prey ratio of *N. longispinosusto T. urticae* for effective control of spider mites. The study revealed that in the greenhouse, predator: prey ratios of 1:20 and 1:25 were significantly superior in reducing the population of *T. urticae* on cucumber.

Ghetiya *et al.* (2019) studied the efficacy of entomopathogenic fungi *Fusarium verticillioides* (Saccardo) Nirenberg against *Tetranychus urticae* Koch on okra in greenhouse. In their study six different concentrations of *F. verticillioides* ranging from 1×10^5cfu/ml to 1×10^{10}cfu/ml were evaluated against *T. urticae*on okra. and concluded that among the different treatment *F. verticillioides* at 1×10^{10}cfu/ml concentration was found out the significantly superior with highest (75.04%) mortality at 10 days after application.

Kadam *et al.* (2020) conducted a study to manage the fungal and bacterial pathogen in tomato and potato crop under greenhouse condition. For that purpose, they adopted traditional homa treatment as non-chemical treatment to control the pathogen inside the greenhouse. They reported that homa therapy effectively reduced the incidence of early blight disease of tomato and potato and reduced the pathogenic micro flora around 70% inside the greenhouse.

2.5 COST ECONOMICS OF GREENHOUSE

Biradar (1996) conducted a study on the evaluation of Gerbera cultivars under low-cost greenhouse. Their study revealed that initial investment for cultivation of Gerbera under greenhouse was very high while the profit obtained from Gerbera cultivation is 58000/100 m^2/year so it was profitable. Furthermore, they found that cultivation of roses was found to be more profitable than Gerbera.

Murthy *et al*. (2009) conducted a study on economic feasibility of vegetable production under greenhouse. They reported that cultivation of capsicum was found to be more profitable with high value of NPV, it was around 3,23145 per 500 m^2. And BCR was 1.8 while IRR was 53.7% with payback period of less than 2 years. They found that breakeven price for capsicum production in a greenhouse was less than average wholesale price. Furthermore, they reported that production of tomato in a greenhouse was not feasible as the breakeven price was more than average wholesale price.

Gnanasekaran *et al.* (2012)conducted a study on economic analysis of tomato cultivation in Dindigul district of Tamil Nadu. They identified the determinants of yield and factors causing yield gap with regard to small and large farmers in study area. And they found out the cost and return structure of tomato cultivation for small and large farmers and analyzed the nature of distribution of per acre and net income of farmers. They also reported problems of farmers like loan, climate, market prize and fertilizer cost in the market.

Yadav *et al.* (2014) reported that high value off season vegetables under low-cost greenhouse was found a viable and profitable technology for vegetable farmers. They reported that from low-cost greenhouse of 50 m^2 they earned around Rs.10000. Furthermore, they concluded that to enhance income and to ensure nutritional security of marginal farmers, vegetable cultivation along with off season nursery under low-cost greenhouse were found to be more profitable.

Duhan (2016) conducted a comparative study on cost benefit analysis of tomato production in greenhouse and open field. They reported that production cost and production were higher in greenhouse compared to open field. Production of tomato was more than three times in greenhouse than open field cultivation. In addition to that they concluded market price of tomato from greenhouse was higher than the tomato produced from open field. Finally, their study reveals that in long run greenhouse was more economic than open field while it would have significant limitations also.

Kumar *et al.* (2016) conducted a study on economic analysis of tomato cultivation under greenhouse and open field condition in Karnal district of Haryana. They reported that cost of cultivation of tomato under greenhouse was higher by Rs.206816 /acre as compared to open field cultivation while net return from greenhouse was higher by Rs.51097/acre. They concluded that production of tomato from greenhouse was higher by 53.71% as compared to open field production.

Kumar *et al.* (2017) reported from their experiment on cucumber that cost of cultivation of cucumber per acre under polyhouse was Rs.283684.40 where as in open field condition it was around Rs.98003.39. Here they found that 245.47 quintal was produced from greenhouse and net return was Rs. 97138.68. They concluded that yield and income of farmers can be increased by greenhouse technology in case of cucumber cultivation also.

Lakshmi *et al.* (2017) conducted a study on economic feasibility greenhouse vegetable cultivation in Kerala. And they reported that a sole crop of salad cucumber and crop sequence with cowpea were found economically feasible and profitable in Kerala climate. Moreover, their study reveals that selection of crop based on market demand and coinciding cultivation with higher market price should improve the profitability of greenhouse.

Nasrin *et al.* (2017) evaluated the knowledge of farmers on the cultivation practices of off-season vegetable crops under low-cost greenhouse technology in Assam. The study reveals that about 62.5% of population had knowledge regarding greenhouse technology. In addition to that they proved that low-cost greenhouse technology enable farmers to cultivate vegetables during off season and also fetch high prices to the farmers which can improve the economy of farmers.

Franco *et al.* (2018) conducted a study on economic feasibility of vegetable production under greenhouse in Palakkad district of Kerala. The study concluded that under the current scheme of subsidy on the establishment of greenhouses, the farmers' investment in poly-houses was found to be economically feasible as net present value NPV (131801), benefit cost ratio BC ratio (2.17) and internal rate of return IRR (37.51).

Meenakshi *et al.* (2019) conducted a study on economic analysis of cost and return of off-season vegetable production under greenhouse. They examined the cost and returns of various vegetables under greenhouse: assess the marketing cost, margins and price spread for different vegetables in various market and found out the problems faced by the greenhouse vegetable farmers.

Tiwari *et al*. (2019) conducted a study on economic analysis of cut flower production under greenhouse in Jabalpur district of Madhya Pradesh. They reported that total cost of cultivation of Gerbera was higher compared to rose cultivation. Along with they concluded that annual production of Gerbera flower was 409288 numbers while rose flower production was 342000 numbers. Furthermore, they reported that benefit cost ratio of gerbera and rose were 1.85 and 1.61 respectively.

Malik *et al.* (2020) conducted a study on economic viability of cucumber cultivation under greenhouses in Haryana. They evaluated benefit: cost ratio and analyzed the major constraints faced by greenhouse farmers. Their study reveals that benefit: cost ratio for cucumber cultivation by greenhouse farmers was 1.41. Moreover, they reported that higher initial investment (86.17%), less durability of cladding material (78.23%) and lack of skilled labour (81.95%) were the problems faced by the greenhouse farmers.

2.6 MARKETABILITY OF GREENHOUSE PRODUCTS

Yilmaz *et al*. (2005) analyzed the present status of Turkish Greenhouse industry and major problems faced by this industry. They reported that economic factors influenced the profitability of greenhouse production. So that domestic market dynamics plays a vital role in

Greenhouse development industry. They found that poor marketing of fresh produce in the domestic and export markets reduced the production and economic benefits of crop. Moreover, they concluded that major problems faced by Turkish Greenhouse farmers are declining crop prices, poor market system and sales uncertainty, price fluctuations based on over supply and lack of labours.

Bacharam (2012) studied the economic analysis of production and marketing of cut flowers like rose and gerbera under greenhouse cultivation in Satara district of Maharashtra. They reported that average cost of erection of rose greenhouse was Rs. 6.98 lakhs while for gerbera it was 6.50 lakhs. The share of frame work in the total cost of rose greenhouse erection was 46.56%, whereas for gerbera it was around 45.85%. Moreover, they analyzed marketing channels and their relative costs and different factors influencing prices of cut flowers.

Sridevi (2014) conducted a study on business analysis of Gerbera cultivation under greenhouse in Reddy district of Andhra Pradesh. They analyzed the financial feasibility of Gerbera cultivation under greenhouse conditions. Moreover, they identified the different marketing channels and price spread in Gerbera and identified the production and marketing constraints in greenhouse. They reported that due to international airport, product got good transport facility to the market area.

Ozen *et al.* (2018) conducted a survey on insurance claims and insurance intentions of greenhouse farmers and to determine the influencing factors affecting the insurance process. They analyzed that greenhouse farmers faced problems to continue their agricultural activities and suffer the damages due to natural conditions. So that insurance system is important to overcome the losses due to damages.

Furthermore, they concluded that insurance system provides market stability in the food sector.

Durmanov *et al.* (2019) developed a model for Greenhouse production optimization in Uzbekistan. The study was based on dynamics of average consumer prices of greenhouse vegetable products. The model was developed based on introduction of emerging technologies, and consideration of state regulations that influences market parameters and includes strategic directions for improving the effectiveness of greenhouse vegetable production. Finally, they constructed the model which can forecast the price of vegetable product for subsequent periods based on their seasonality factor.

Umarov *et al.* (2019) conducted a study on Greenhouse vegetable market development based on the supply chain strategy in the republic of Uzbekistan. They reported that lack of an effective vegetable marketing strategy and undiversified sales markets were major challenges of greenhouse farmers. Finally, they concluded that to overcome the current situation, increase the export volumes of vegetables and diversify them to the countries with high demand is the essential step in the development of greenhouse vegetable sales market in Uzbekistan.

2.7 PROBLEMS FACED BY GREENHOUSE FARMERS

Ergonen *et al*. (2005) conducted a study on pesticide use among greenhouse workers and their harmful effect on environment and human health of Turkey. They reported that 64.4% of greenhouse workers applied pesticide directly to the plant while 33.6% of them applied pesticides to both plant and soil. Out of this only 29.2% of greenhouse workers only used mask during pesticide application. Furthermore, they concluded that exposure of pesticide leads to serious health problems among greenhouse workers, and lack of adequate data regarding the usage of pesticides was the main problem of Turkey.

Jovita *et al*. (2011) conducted a study on pesticide use and related health problems among greenhouse workers in Batinah Coastal region of Oman. They reported that due to pesticide exposure farmers faced many health problems like skin irritation (70.3%), burning sensation (39.2%), headache (33.8%) and salivation (21.6%). They reported that majority of the farmers who never used personal protective equipment. It leads to health problems among farmers. Finally, they concluded that a provision be included in the Pesticide laws of Oman that make it compulsory for greenhouse farmers to provide with PPE.

Ribeiro *et al*. (2012) evaluated the occupational safety and health practices among greenhouse farmers in Brazil. They reported that greenhouse farmers were at high risk of pesticide exposure, along with some factors which intensify the exposure like lack of control on reentry intervals after pesticide application. Moreover, they concluded that special requirements are essential for greenhouse farmers for their protection such as establishment of ventilation criteria for restricted entry interval and clear reentry restrictions.

Hena *et al*. (2017) conducted a study on factors determined the adoption of greenhouse farming and problems faced by farmers. They reported that the important factor that determined the adoption of greenhouse farming was farmer's awareness about the greenhouse farming practices and economic benefit. Moreover, they also reported that the chances of declining yield due to insect attack and short life of cladding material.

Ghanghas *et al.* (2018) conducted a research study on problems and prospects of vegetable production under greenhouse technology in Haryana. They reported that advantages of greenhouse technology were increased production and productivity per unit of land, water, energy and labour , high quality and clean product and subsidy provision for high cost greenhouse. At the same time farmers faced many problems like attach of insect and white flies, frequent occurrence of windstorms, lack of cold storage facilities. Furthermore, they reported that good quality cladding material can control nematode infestations and proper marketing can overcome the problems of greenhouse farmers.

Kumar *et al.* (2018) conducted a study on status and constraint in vegetable cultivation under greenhouse in Haryana. They observed that maximum number of greenhouse technology was adopted in Karnal (220) while minimum number of greenhouses was found in Mahendergarh (10) of Haryana. The study revealed that major problems faced by greenhouse farmers were short life span of polyethylene sheet (92.5%), infestation of insect-pest (90%), high price fluctuation (87.5%) and lack of market information (75%).

CHAPTER 3

MATERIALS AND METHODS

There are different studies related to the advantages of greenhouse cultivation while it is having some limitations also. Because of this reason, greenhouse farmers are facing many challenging issues, especially in Kerala. So that many of the farmers are abandoning this cultivation technique after two or three years. The present study was mainly focused on identifying the reasons for failures of greenhouse cultivation under the hands of Kerala farmers.

3.1 STUDY AREA

A survey was conducted across fourteen districts of Kerala to analyze the problems of greenhouse farmers. From each district, 11 greenhouse farmers were selected randomly, thus the total sample size comprised of 154 farmers, and data were collected directly from greenhouse farmers by personal interview method. In addition to assess the effect of aging of cladding material on crop yield and its microclimate, an experiment was carried out in the instructional farm of KCAET, Tavanur, Kerala. The site is located on 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

3.2.1 SURVEY

The present study was conducted covering all 14 districts of Kerala. Greenhouse farmer's contact details were collected from State Horticultural Mission and District Horticultural Mission. Stratified random sampling was used for the selection of farmers from each district of Kerala and 11 farmers from each district were selected by random sampling using lots. A structured questionnaire regarding details of vegetable cultivation inside the greenhouse, profit obtained, problems faced by farmers during cultivation, etc. was prepared. Details from farmers were collected based on the personal interview method. The total sample size comprised of 154 farmers.

Table 3.1 Number of farmers from each district of Kerala

Sl. No	District	No. of Farmers
1.	Trivandrum	11
2.	Kollam	11
3.	Pathanamthitta	11
4.	Alappuzha	11
5.	Kottayam	11
6.	Idukki	11
7.	Ernakulam	11
8.	Thrissur	11
9.	Palakkad	11
10.	Malappuram	11
11.	Kozhikode	11
12.	Wayanad	11
13.	Kannur	11
14.	Kasaragod	11

Plate 3.1 Collecting details from greenhouse farmer

Plate 3.2 Greenhouse at CWRDM Kozhikode

3.2.1.1 Statistical Analysis of Survey

The data obtained from farmers were statistically analyzed using SPSS 16.0 software by cross tabulation, non parametric test and factor analysis.

3.2.2 FIELD EXPERIMENT

A field experiment was conducted at two greenhouses located at instructional farm of KCAET Tavanur. One greenhouse having cleaned cladding material and other is having aged one and compare the microclimate and crop performance under two greenhouses.

3.2.2.1 CLEANED NATURALLY VENTILATED GREENHOUSE

A naturally ventilated greenhouse (Fig.3.3) having an area of 292 m^2 is oriented in the East-West direction. Its frame is made up of galvanized steel pipe and covered with 200-micron UV stabilized polyethylene film. This cladding material was cleaned using water jet. It was done with the help of two labourers for 3 days. Two sides of the greenhouse were covered with 40 mesh insect-proof nets for preventing the entry of insect pests. In the present study, an area of 50 m^2 was selected inside the greenhouse to cultivate amaranthus. Specifications of the cleaned greenhouse are shown below.

Table 3.2 Specifications of naturally ventilated greenhouse

Sl No	Particulars	Specifications
1	Greenhouse 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 covering	UVA 205 N clear, Thermic anti drip, 5-layer, antivirus, 200-micron polythene
	Roof vent	0.75 m width covered with 40 mesh UV stabilized insect proof net
	Shade net screen inside	Black 50% UV stabilized movable

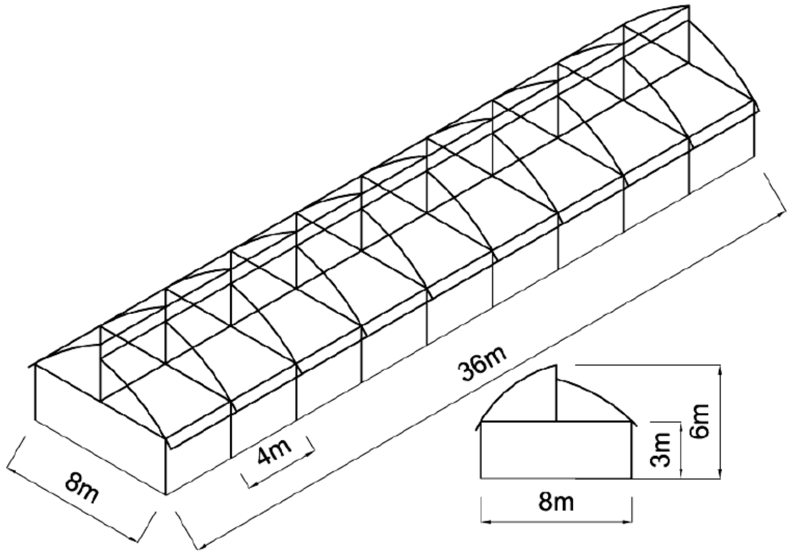


Fig 3.1 Schematic diagram of naturally ventilated greenhouse

Plate 3.3 Naturally ventilated greenhouse

Plate 3.4 Cleaning of Naturally ventilated greenhouse

3.2.2.2 NATURALLY VENTILATED GREENHOUSE WITHOUT CLEANING

This greenhouse is identical to that of a cleaned greenhouse and is located at the same place itself near to the cleaned greenhouse. And its cladding material has more than 4 years age.

Plate 3.5 Naturally ventilated greenhouse without cleaning

3.2.2.3 EXPERIMENTAL PROCEDURE

An area of 50 m^2 was selected inside both cleaned and uncleaned naturally ventilated greenhouses. Amaranthus variety CO-1 was cultivated inside both the greenhouses from April to June in 2021. All the cultural practices were done according to the Package of Practices Recommendations of KAU.

Along with a field experiment a survey was conducted from farmers of fourteen districts of Kerala based on personal interview method and stratified random sampling was used for surveying.

3.2.2.4 Land Preparation

Land inside both the greenhouses were ploughed using a mini tiller. The stubbles and stones were removed from the experimental plot and mixed the soil with cow dung. The field was kept idle for one week. The soil type inside both the greenhouses was sandy loam.

3.2.2.5 Bed Preparation

Four beds each having a size of 10 m length, 0.9 m width, and 0.3 m height were raised inside both greenhouses. In each bed spacing between the plants is 45cm and spacing between beds is also kept as 45 cm. Then drip lines and mulch sheets were installed on the bed.

Plate 3.6 Bed preparation inside the greenhouse

3.3. CROP VARIETY

Green amaranthus variety CO-1 was planted on 07-04-2021. Laterals with inline drippers were laid on each bed through which water was supplied to the plant. And fertilizers were applied manually once in three days from planting till the end of the crop. The fertilizers used according to package of practices of KAU.

3.3.1 CROP CULTIVATION

Crop	:	Amaranthus green variety CO-1(*Amaranthusdubius*). It belongs to the family Amaranthaceae.
Area	:	50 m^2
Growing structures/conditions	:	Naturally ventilated greenhouse with cleaned cladding material. Naturally ventilated greenhouse with uncleaned/aged cladding material.
Design	:	CRD
Replications	:	sixteen
Treatments	:	Two (T1, T2) T1- Crop cultivation inside the greenhouse with cleaned cladding material T2- Crop cultivation inside the greenhouse with uncleaned cladding material
Spacing	:	1.35 m x 0.45 m

3.3.2 LAYOUT OF FIELD EXPERIMENT

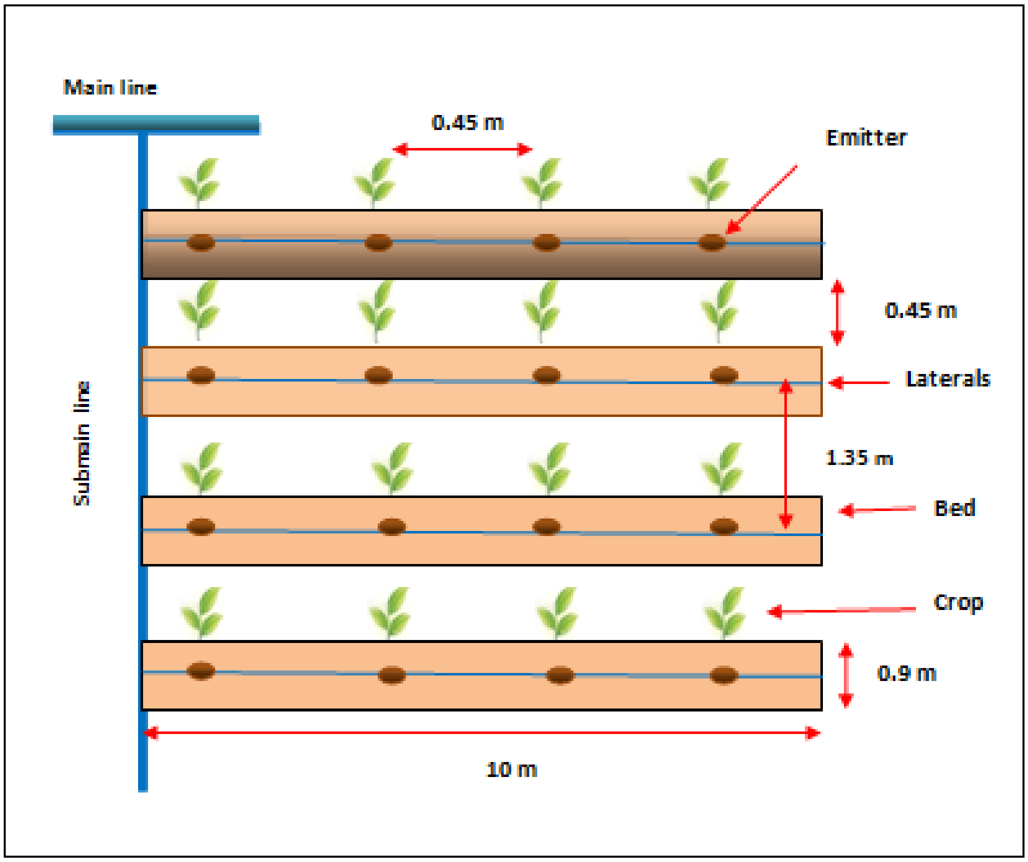


Fig 3.2 Layout of field experiment

It is the same layout followed in both greenhouses. Total 44 amaranthus plants were cultivated in each treatment through four beds at an area of 50 m^2 in both greenhouses. Each bed has the dimension of 10 m length, 0.9 m width, and 0.3 m height. Crops are cultivated with row to row spacing of 1.35 m and plant to plant spacing of 0.45 m. And spacing between the two beds was kept at 0.45m. Out of 44 plants, 16 plants were selected randomly (4 plants per bed) and tagged them, and observed the growth and yield parameters of 16 plants from each treatment.

3.4 INSTALLATION OF DRIP SYSTEM

Drip lines were installed at the center of every bed in both greenhouses. Inline drippers were spaced at a distance of 45 cm and have a discharge rate of 8 lph. Irrigation water was pumped using a 5 hp monoblock pump set and supplied through mains having a diameter of 63 mm PVC pipe from that water was conveyed to sub-main PVC pipe with a diameter of 50 mm. Later water was supplied to the laterals having a diameter of 16 mm. From drippers, water was provided to each plant root zone. Plants were irrigated daily at 4 PM for 10 minutes (Gokul *et al.*, 2020).

Plate 3.7 Control system of drip irrigation

3.5 OBSERVATIONS

3.5.1 Weather Parameters

Following weather parameters were recorded from both greenhouse from time of planting to harvesting.

3.5.1.1 *Temperature (◦ C)*

Maximum and minimum air temperature inside the both greenhouses and outside the greenhouses were recorded daily at 8 am, 12 pm and 4 pm using thermo hygrometer (specifications: Height 320mm, width 40 mm and length 80 mm) and expressed as mean monthly data.

Plate 3.8 Thermo hygrometer

3.5.1.2 Relative *Humidity (%)*

Relative humidity inside both the greenhouses and outside were computed from the readings of thermo hygrometer at 8 am, 12 pm and 4 pm and expressed as mean monthly data.

3.5.1.3 Light *Intensity*

Light intensity inside the both greenhouses and outside were recorded daily at 8 am, 12 pm and 4 pm using Lux meter and expressed as mean monthly data.

Plate 3.9 Lux meter

3.5.2 Vegetative Parameters

Vegetative parameters like plant height, number of branches, number of leaves and inter-nodal length of amaranthus were recorded at weekly intervals from both the greenhouses.

Plant height was recorded from sixteen randomly tagged plants from each treatment at weekly intervals from the time of planting to till the harvest. It was measured using a meter scale from the ground level to the growing tip. From that average value was calculated and denoted in centimeter. Similarly number of branches and number of leaves of tagged plants were counted at weekly intervals after planting. And inter nodal length was measured using a centimeter scale and it also recorded at weekly intervals after planting

3.5.3 Yield Parameters

Yield parameters like yield per plant and total yield were computed from both the greenhouses and compared. Yield per plant was calculated by recording total weight of leaves harvested from each plant till the final harvest. Likewise Total yield was calculated by recording the yield from net plot under each treatment and was expressed in Kilograms.

3.6 Stastical analysis of field data

The data related to growth and yield parameters of amaranthus were tabulated and analyzed using completely randomized design.

CHAPTER IV

RESULTS AND DISCUSSION

The results obtained from the present study "Assessment of greenhouse cultivation problems in Kerala" are discussed here, after analyzing the observations which were recorded during course of experiment.

4.1 STATISTICAL ANALYSIS OF SURVEY

Statistical analysis of survey data was done by SPSS 16.0 using non parametric Friedman test and factor analysis.

4.1.1 FARMER'S RESPONSE ON VARIATION OF CROP YIELD WITH CLEANING INTERVAL OF GREENHOUSE CLADDING MATERIAL

Table 4.1 Variation of crop yield and cleaning interval Cross tabulation

		Cleaning interval					
Variation of crop yield		6 months	1year	2-3 year	No cleaning	More than 3 year	Total
	No variation	0	3	0	0	0	3
	10-20% decrease	12	18	0	0	0	30
	20-30% decrease	0	3	9	1	1	14
	30-50% decrease	0	1	48	16	18	83
	More than 50% decrease	0	1	6	9	8	24
Total		12	26	63	26	27	154

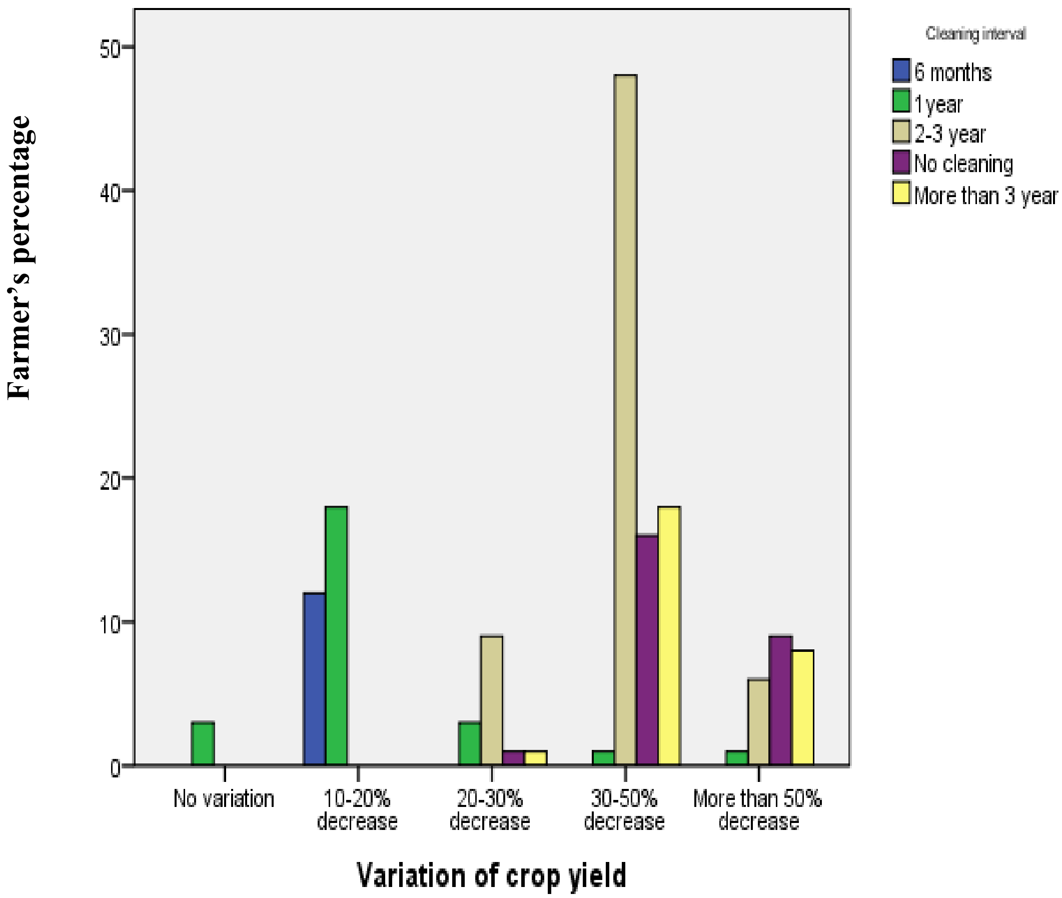


Fig 4.1 Variation of crop yield with cleaning interval of greenhouse cladding material

From the above Fig 4.1, it was clear that decrease in yield is more when the cleaning interval of greenhouse is more. 30-50% reduction in yield was reported around 50% farmers whose greenhouses were washed rarely (2–3 year cleaning interval, more than 3 year or no cleaning) whereas more than 50% decrease in yield was reported around 15% farmers whose greenhouses didn't washed yet. Moreover 11% farmers washed their greenhouse with one or two year interval, they got comparatively more yield around 10-20% decrease in yield only. The data were analyzed using non parametric Friedman test, then the p value is 0.0001 which should be less than 0.05. Hence there is significant difference between the yield and cleaning interval of greenhouse.

4.1.2 SATISFACTION LEVEL OF GREENHOUSE FARMERS

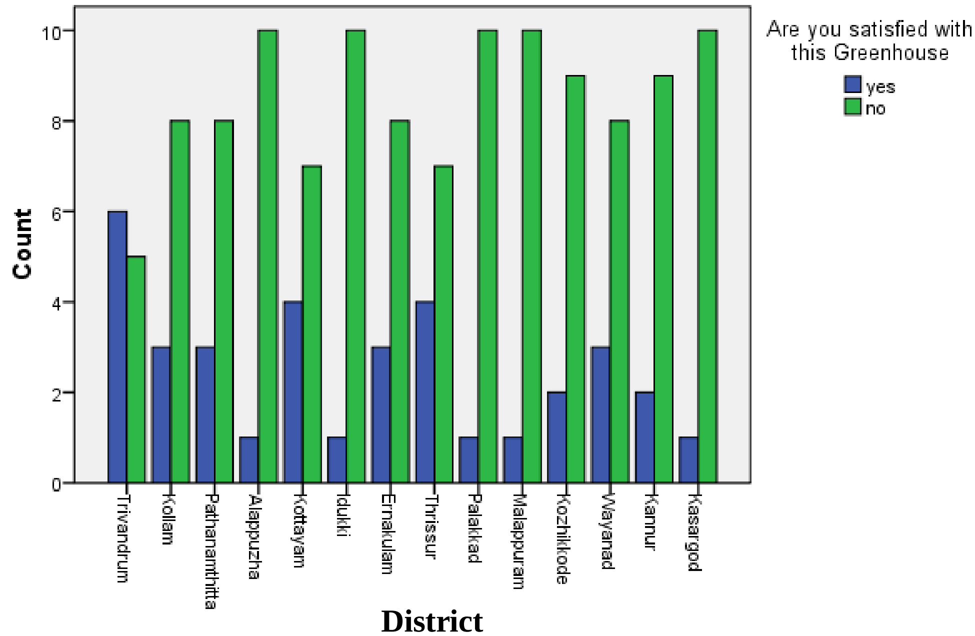


Fig 4.2 District wise satisfaction of greenhouse farmer

From the above Fig 4.2 it was clear that most of the farmers are dissatisfied with greenhouse in all districts of Kerala. In Alappuzha, Idukki, Palakkad, Malappuram and Kasargod districts around 90% farmers are not satisfied with greenhouse while in Kozhikkode and Kannur around 81% farmers are dissatisfied with greenhouse. And 72% farmers are not satisfied with greenhouse in Kollam, Pathanamthitta, Ernakulam and Wayanad districts. But in Kottayam and thrissur districts around 63% farmers are facing crop failure after the initial phase. Although 45% farmers only dissatisfied with greenhouse in Trivandrum district.

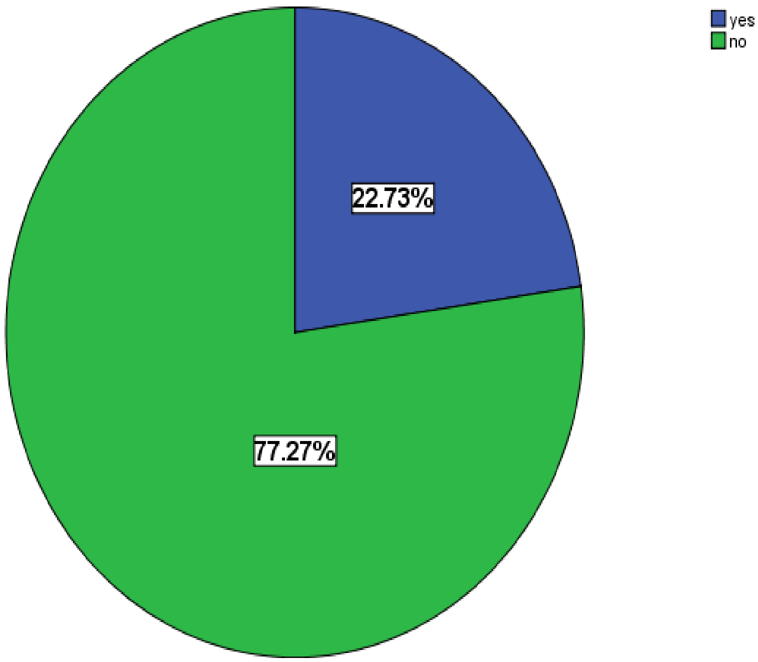


Fig 4.3 Satisfaction level of farmers shown in percentage

From the above pie diagram, it was clear that in Kerala around 77.27% of farmers are not satisfied with greenhouse cultivation because of the crop failure after the initial phase.

4.1.3 DISTRICTWISE ANALYSIS OF GREENHOUSE FARMER FOR REDUCTION IN YIELD

Table 4.2 District and reasons for decreasing yield cross tabulation

Count								
District	What is your conclusion for decreasing yield							Total
	Due to ageing of cladding material	Decrease of soil fertility	Others (Structural problems)	Both 1 and 2	Both 1 and 3	Both 1 and 4	Both 1 and 5	
Trivandrum	4	0	1	1	5	0	0	11
Kollam	6	0	0	1	0	3	1	11
Pathanamthitta	5	0	0	5	1	0	0	11
Alappuzha	7	0	0	1	2	1	0	11
Kottayam	5	0	1	2	0	2	1	11
Idukki	4	0	0	4	0	3	0	11
Ernakulam	5	0	0	2	1	2	1	11
Thrissur	6	0	0	3	0	2	0	11
Palakkad	4	0	0	7	0	0	0	11
Malappuram	5	1	0	4	0	1	0	11
Kozhikkode	4	0	0	5	1	1	0	11
Wayanad	6	0	0	1	2	2	0	11
Kannur	4	0	0	3	1	2	1	11
Kasargod	3	0	0	5	2	0	1	11
Total	68	1	2	44	15	19	5	154

Both 1 and 2 – Both aging of cladding material and decrease of soil fertility

Both 1 and 3- Both aging of cladding material and lack of maintenance and Inspection

Both 1 and 4 – Both aging of cladding material and fungal/insect attack

Both 1 and 5 – Both aging of cladding material and structural problems

From the table 4.2 it is clear that most of the farmers concluded that main reason of decreasing crop yield is due to aging of cladding material. Other reasons of crop failures include decrease of soil fertility, lack of maintenance and inspection, fungal/insect attack and other problems like structural problems etc. In Trivandrum district, 36% farmers were faced problems of aging of cladding material along with 9%farmer facing both the problems like decrease of soil fertility and aging of cladding material and 45% farmers were faced problems of aging of cladding material and lack of maintenance problems. In addition to that around 9% farmer is facing structural problems also.

In the case of Kollam district 54% farmers were faced problems of aging of cladding material while 27% farmers were faced the problems of both aging of cladding material and fungal infection due to high relative humidity inside the greenhouse. Furthermore around 10% farmer was facing the problems of decrease of soil fertility due to continuous use of soil and aging of cladding material. And 9% farmer was facing the problems of lack of proper design of greenhouse and aging of sheet.

Whereas in Pathanamthitta district, 45% farmers were faced crop failure due to aging of cladding material and 45% farmers were faced the problems of both decrease of soil fertility and ageing of cladding material. And remaining 9% farmer faced the problems of lack of maintenance and aging.

In Alappuzha district, 63% farmers were faced crop failure due to aging of cladding material and 18% farmers were faced the problems of both cladding material and lack of maintenance. And in kottayam, Ernakulam and

Malappuram districts 45% farmers were faced problems of cladding material while in Idukki, Palakkad, Kozhikkode and Kannur districts 36% farmers were faced crop failure due to this aging of sheet. In Wayanad and Thrissur districts, 54% farmers were faced the problems of cladding material whereas in Kasargod district 27% farmers were faced the same problem.

Along with aging of cladding material, farmers were faced the problems of decrease of soil fertility, in Kozhikkode and Pathanamthitta district 45% farmers were faced the problems of both aging of cladding material and soil fertility problems. From this analysis we observed that most of the farmers were faced crop failure due to aging of cladding material. Due to this issue, light transmission through the cladding material reduced and which adversely affect the microclimate inside the greenhouse and crop yield.

4.1.3.1 Selection of major reason for decreasing crop yield

Factor score is derived for selecting major reason for decreasing crop yield and it is done by factor analysis. Factor score is obtained by correlation between variable and the factor. It is the rank wise order of the variables within the factor in other words the important variable in each factor is given by factor score. The larger the value of variable, more important corresponding variable.

Table 4.3 Component Score Coefficient Matrix

	Component		
	1	2	3
No of farmers facing problems of aging of cladding material	.493	-.042	-.273
No of farmers facing problems of decrease of soil fertility problem	.047	-.136	-.372
Others (structural problem)	.013	.386	.154
Both aging of cladding material and soil fertility problem	-.440	-.225	-.064
Both aging of cladding material and lack of maintenance	.008	.496	-.094
Both aging of cladding material and fungal/insect attack	.290	-.254	.266
Both aging of cladding material and structural problems	-.085	-.078	.619

Extraction Method: Principal Component Analysis.

From the above table 4.3, it was clear that factors 1, 2, and 3 were major influencing factors for decreasing crop yield in greenhouse cultivation. Factor 1 represents the climatic factors, factor 2 indicates structural factors, and factor 3 represents both climatic and structural factors. Out of three factors, factor 1 is the most influential because it has high variance. Then considering factor 1, out of seven reasons for crop failure, aging of cladding material has a higher correlation coefficient of 0.493, which is the major reason for crop failure.

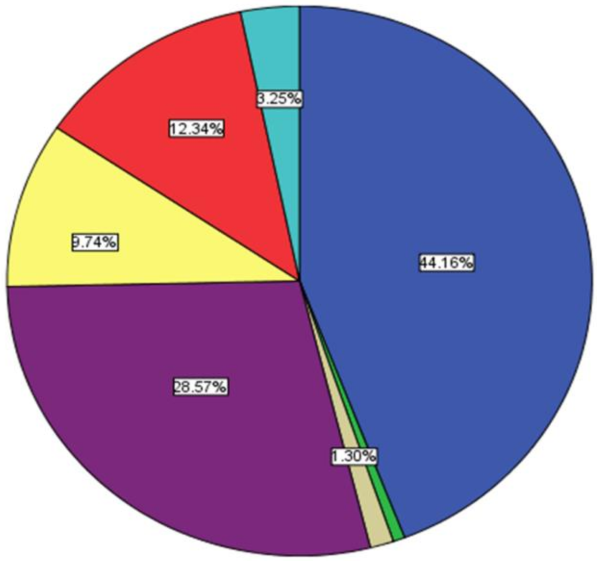
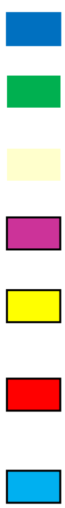


Fig 4.4 Reasons for decreasing crop yield shown in percentage



Due to aging of cladding material

Decrease of soil fertility

Others (Structural problems)

Both aging of cladding material and decrease of soil fertility

Both aging of cladding material and lack of maintenance and inspection

Both aging of cladding material and fungal/ insect attack

Both aging of cladding material and structural problems

The above figure depicts that the main reason for decreasing crop yield is due to the aging of cladding material, which is around 44.16%.

And 28.57% of farmers are facing both the problems of aging of cladding material and decrease in soil fertility. Moreover, 12.34% of farmers are facing the problems of both aging of cladding material and fungal/insect attack while 9.74% of farmers are facing the problems of aging of cladding material and maintenance problems. 3.25% of farmers are facing the problems of both aging of cladding material and design problems like shape, apron length, etc.

4.1.4 OTHER PROBLEMS OF GREENHOUSE FARMER

Table 4.4 District and Other problems faced by Greenhouse farmers Cross tabulation

Name of District	What are the problems faced by Greenhouse farmers				Total
	Marketing facility of agricultural product	No demand for the product	Decrease of yield due to insect or pest attach	Others	
Trivandrum	0	5	3	3	11
Kollam	0	0	8	3	11
Pathanamthitta	4	0	7	0	11
Alappuzha	1	1	8	1	11
Kottayam	1	1	7	2	11
Idukki	1	5	5	0	11
Ernakulam	4	0	7	0	11
Thrissur	3	0	8	0	11
Palakkad	5	1	5	0	11

Malappuram	2	1	8	0	11
Kozhikkode	1	1	9	0	11
Wayanad	1	3	7	0	11
Kannur	4	0	7	0	11
Kasargod	5	0	6	0	11

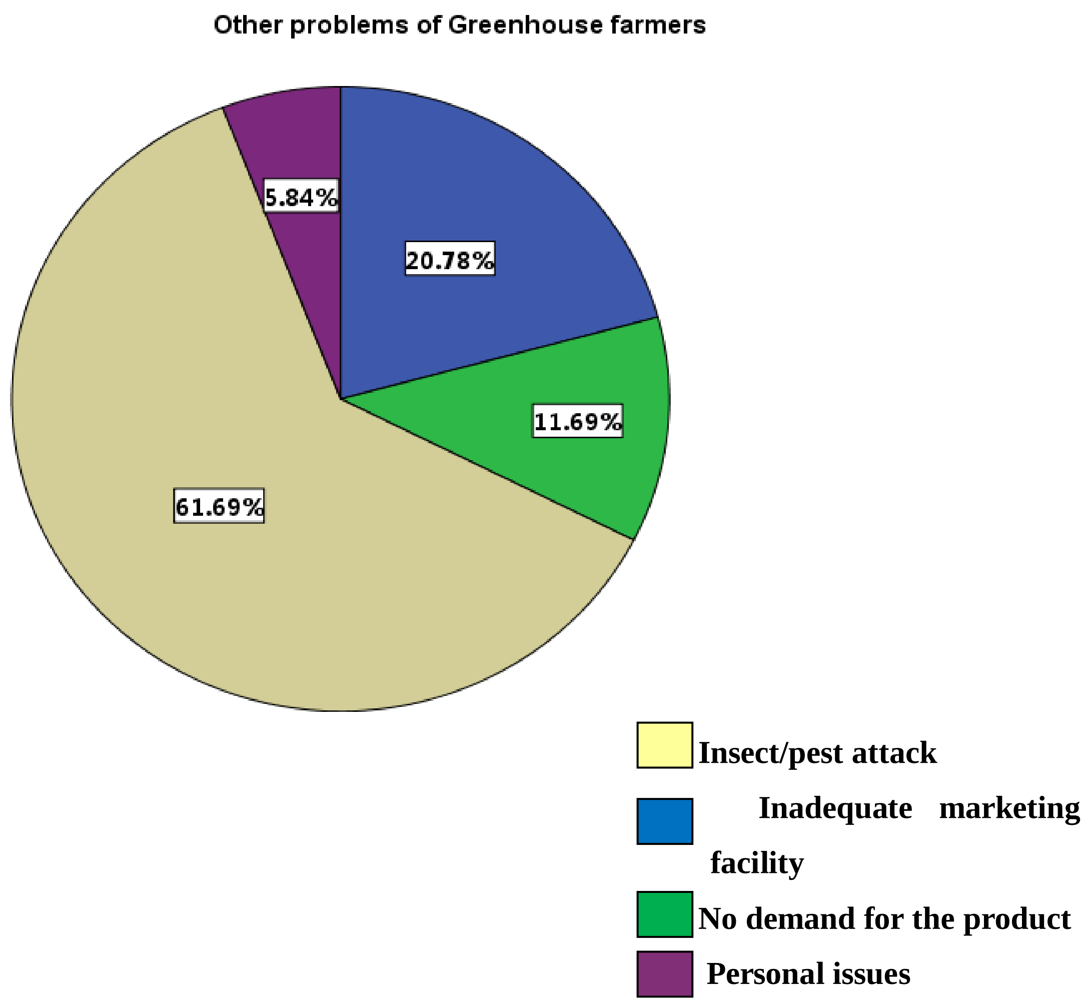


Fig 4.5 Other problems of greenhouse farmers shown in percentage

From the Fig 4.5 depicts the other problems faced by greenhouse farmers, it includes marketing facility of agricultural product, no demand for greenhouse product and decrease of yield due to insect/pest attack etc. From the above figure, it was clear that most of the farmers were faced the problems of insect/pest attack. Greenhouse is a protected structure even though crops were affected by fugal and insect/pest attack because of the high humidity inside the greenhouse. Moreover, other problems faced by farmers are no demand of greenhouse product, because of people in rural areas are not aware of the quality of product from greenhouses they are still depends on low rate imported vegetables, and its marketing facility of the product also one problem.

In Trivandrum district, 45% farmers were faced the problems of lack of proper demand of greenhouse products and 27.5% farmers were faced the problems of insect/pest attack, moreover 27.5% farmers were faced some personal issues like lack of interest in greenhouse cultivation so that which resulted into lack of proper maintenance. Most of the district farmers were facing one of the main issues is insect/pest attack. In Kozhikkode district around 80% farmers are facing the problems of insect/pest attack and remaining 20% farmers are facing both the problems of lack of demand of product and inadequate marketing facility. In Kollam, Alappuzha, Thrissur and Malappuram district around 72% farmers are facing insect/pest attack. In Pathanamthitta and Kottayam district around 63% farmers are troubled with insect attack

In addition to that one another problem faced by the farmers are structural problems of greenhouse. In Kerala most commonly used shape of the greenhouse is saw tooth type while according to successful farmers, most suitable shape of the greenhouse is Gable shaped one. It provides ventilation from two sides and which reduces the high temperature and high humidity inside a greenhouse .This result is in accordance to the results found by Suseela *et al*.

(2020). They compared the effect of shape of greenhouse in growth and yield of chilly and found that maximum yield was reported in gable shaped structure due to the optimum microclimatic condition inside the structure.

4.2 MICROCLIMATE ANALYSIS OF FIELD EXPERIMENT

Excellent understanding of microclimate parameters is essential for sustainable greenhouse production. Crop yield and quality of crop are influenced by the plant microclimate. That is temperature has considerable influence on crop yield and crop timing likewise, light intensity, relative humidity also have effect on crop yield (Pearson 1995). If a crop is raising successfully, which indicates the crop must be productive and economical to grow under that particular microclimate.

The observed plant microclimatic parameters viz. maximum and minimum temperature, relative humidity, light intensity during the course of experiment is presented and discussed here below.

4.2.1 MAXIMUM AND MINIMUM TEMPERATURE

The maximum and minimum temperature in the morning (8 AM), afternoon (12 PM) and evening (4 PM) inside the both greenhouses and outside are given in table 4.1, 4.2 and 4.3 respectively. The maximum temperature (43 °C) was recorded at12 PM under cleaned greenhouse in the month of May and minimum temperature at 8 AM under greenhouse without cleaning in the month of June (25 °C). Temperature inside the cleaned greenhouse was higher than the outside and greenhouse without cleaning. During afternoon around 6 °C was higher inside the cleaned naturally ventilated greenhouse compared to the old greenhouse, and it was higher by 4 °C compared to outside temperature. The high temperature inside the cleaned greenhouse is due to the good transmission of solar radiation through the cleaned cladding material while in old greenhouse transparency of cladding material was lost due to aging and which results in decrease in temperature inside the greenhouse.

Table 4.5 Mean maximum and minimum temperature at 8.00 AM

Temperature in the morning						
Month	**Cleaned greenhouse**		**Greenhouse without cleaning**		**Outside**	
	Max (° C)	**Min (° C)**	**Max (° C)**	**Min (° C)**	**Max (° C)**	**Min (° C)**
April	**32**	**26.5**	**30**	**25.5**	**29**	**26**
May	**33**	**28**	**31**	**26**	**30**	**26**
June	**31**	**26**	**29**	**26**	**28**	**25**

Table 4.6 Mean maximum and minimum temperature at 12.00 PM

Temperature in the afternoon						
Month	**Cleaned greenhouse**		**Greenhouse without cleaning**		**Outside**	
	Max (° C)	**Min (° C)**	**Max (° C)**	**Min (° C)**	**Max (° C)**	**Min (° C)**
April	**42.5**	**31**	**36**	**31**	**38**	**27**
May	**43**	**32**	**37**	**26.5**	**39.5**	**28.5**
June	**37**	**28**	**35**	**26**	**33**	**26**

Table 4.7 Mean maximum and minimum temperature at 4.00 PM

Temperature in the evening						
Month	**Cleaned greenhouse**		**Greenhouse without cleaning**		**Outside**	
	Max (˚ C)	**Min (˚ C)**	**Max (˚ C)**	**Min (˚ C)**	**Max (˚ C)**	**Min (˚ C)**
April	**37**	**33.5**	**32**	**27**	**35**	**31**
May	**38**	**34**	**34**	**28**	**36**	**27.5**
June	**33**	**27.5**	**30.5**	**27.5**	**31**	**27**

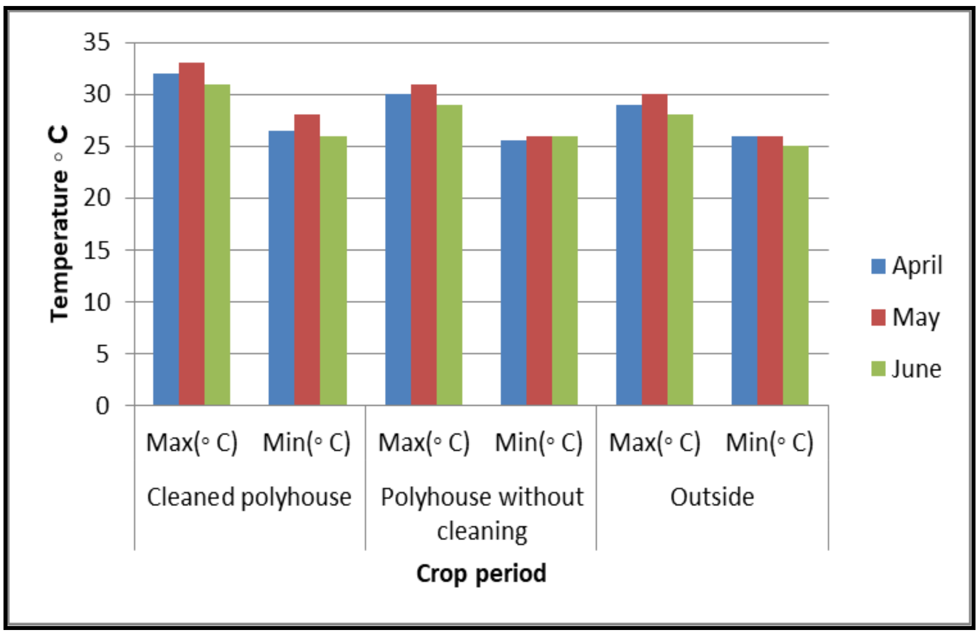


Fig 4.6 Maximum and minimum temperature variation inside and outside of both greenhouses at 8 AM

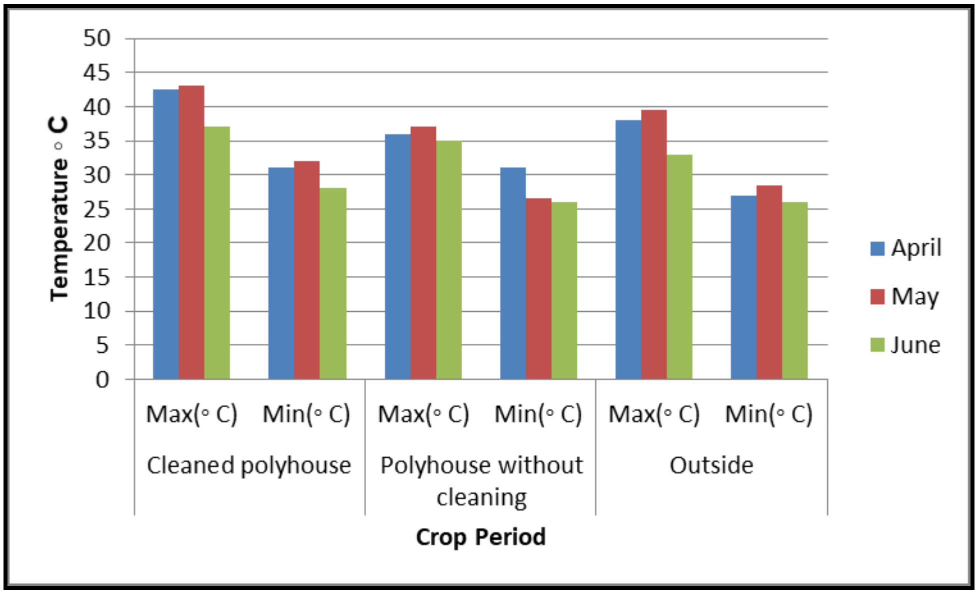


Fig 4.7 Maximum and minimum temperature variation inside and outside of both greenhouses at 12 PM

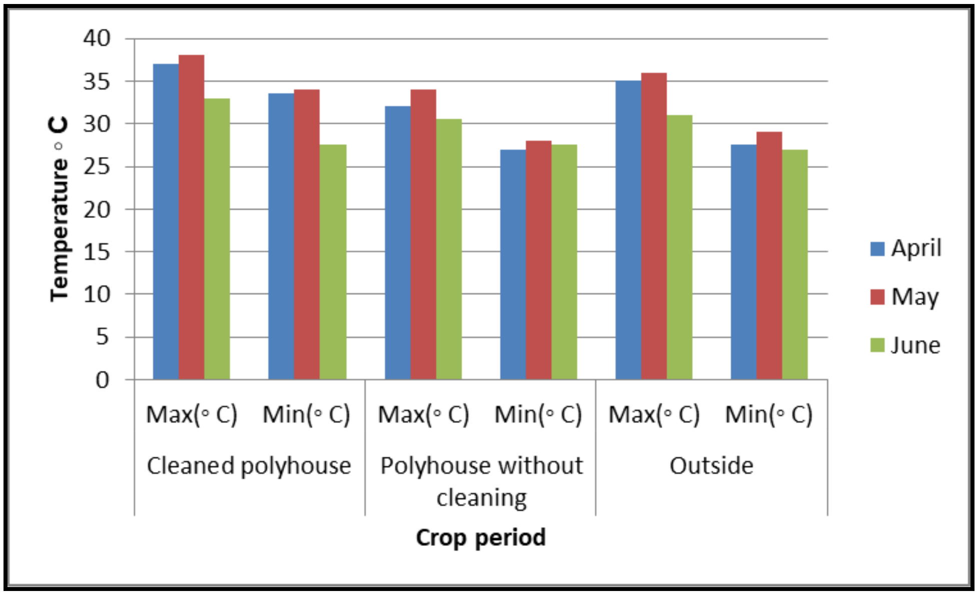


Fig 4.8 Maximum and minimum temperature variation inside and outside of both greenhouses at 4 PM

4.2.2 RELATIVE HUMIDITY

Along with temperature relative humidity also plays a vital role in crop growth and production. Growth and yield parameters of leafy vegetables and fruit crops under naturally ventilated greenhouse were greatly influenced by changes in relative humidity (Umesha *et al.*, 2011). Higher relative humidity has effect on energy balance of the crop. Long term disclosure of high or low humidity has negative effects on growth and production. The plant leaves control the transpiration which strongly influenced the relative humidity. This limitation has its influence on incidence of pest and diseases and has an important role in maintaining the quality of product (Bakker, 1990). Maximum relative humidity (95%) was reported at 8 am at the outside condition in the month of June while lowest humidity was reported in the month of May during afternoon inside the cleaned naturally ventilated greenhouse (43%). Around 15% variation between cleaned and uncleaned greenhouse. The variation of relative humidity in morning, afternoon and evening during crop period was shown in below.

Table 4.8 Mean maximum and minimum Relative humidity at 8 AM

Relative humidity in the morning						
Month	**Cleaned greenhouse**		**Greenhouse without cleaning**		**Outside**	
	Max(%)	**Min(%)**	**Max(%)**	**Min(%)**	**Max(%)**	**Min(%)**
April	**89.5**	**71**	**92.5**	**76**	**93**	**75**
May	**85**	**71**	**90**	**75**	**92**	**76**
June	**90**	**78**	**93**	**79**	**95**	**78**

Table 4.9 Mean maximum and minimum Relative humidity at 12 PM

Relative humidity in the afternoon						
Month	**Cleaned greenhouse**		**Greenhouse without cleaning**		**Outside**	
	Max(%)	**Min(%)**	**Max(%)**	**Min(%)**	**Max(%)**	**Min(%)**
April	**64**	**44**	**71.5**	**58.5**	**58**	**50.5**
May	**60**	**43**	**68**	**50**	**60**	**45**
June	**70**	**45**	**75**	**48**	**72**	**46**

Table 4.10 Mean maximum and minimum Relative humidity at 4 PM

Relative humidity in the evening						
Month	**Cleaned greenhouse**		**Greenhouse without cleaning**		**Outside**	
	Max(%)	**Min(%)**	**Max(%)**	**Min(%)**	**Max(%)**	**Min(%)**
April	**66**	**56**	**73.5**	**58.5**	**74.5**	**55.5**
May	**60**	**58**	**70**	**59**	**70**	**56**
June	**72**	**65**	**80**	**63**	**76**	**63**

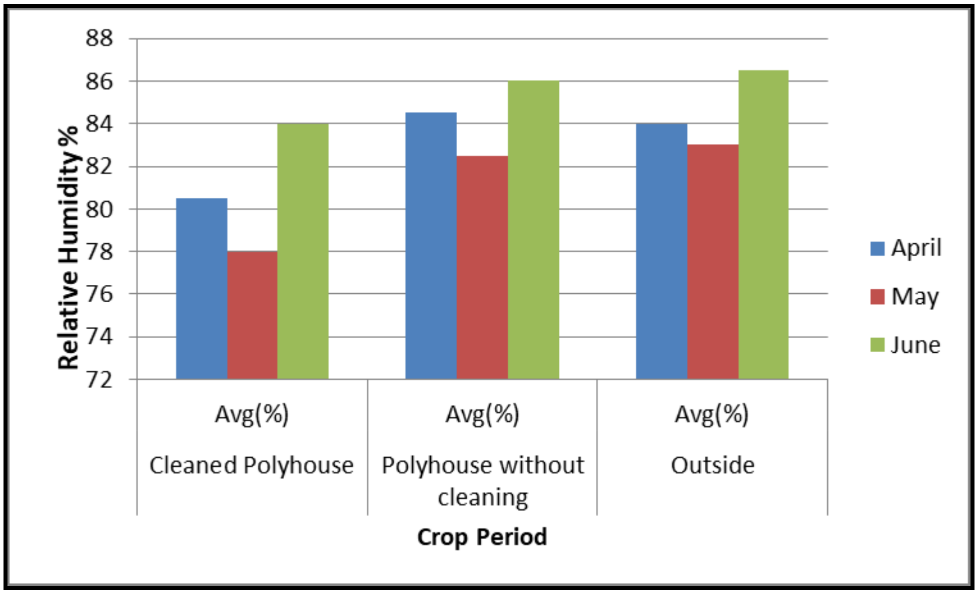


Fig 4.9 Variation of relative humidity at 8.00 AM

From the figure 4.9, it is clear that in higher humidity is recorded in morning hours in the month of June while lower humidity was recorded in May. Moreover, above figure depicts that relative humidity inside cleaned greenhouse in the morning is comparatively lower than outside and uncleaned greenhouse. It will be beneficial for the crop to protect from fungal infection and other diseases. Although relative humidity inside the old greenhouse is comparatively higher than the outside condition. This higher relative humidity inside the old greenhouse is due to aging of cladding material which results in changes in microclimate.

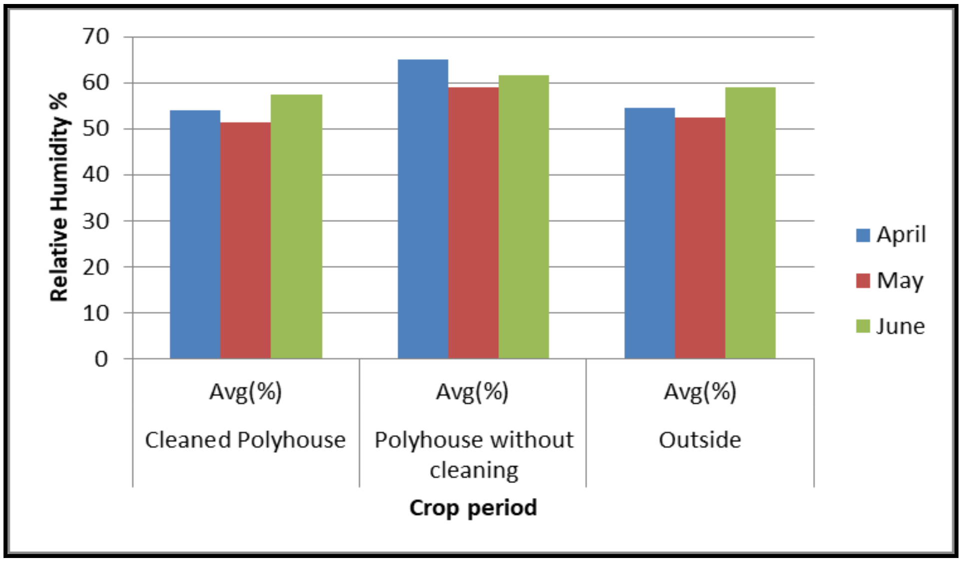


Fig 4.10 Variation of relative humidity at 12.00 PM

During afternoon comparatively very less humidity was recorded inside the cleaned greenhouse compared to outside and uncleaned greenhouse. It is because of higher transmission of sunlight through the cleaned cladding material and which is helpful for the plant to protect from fungal infection.

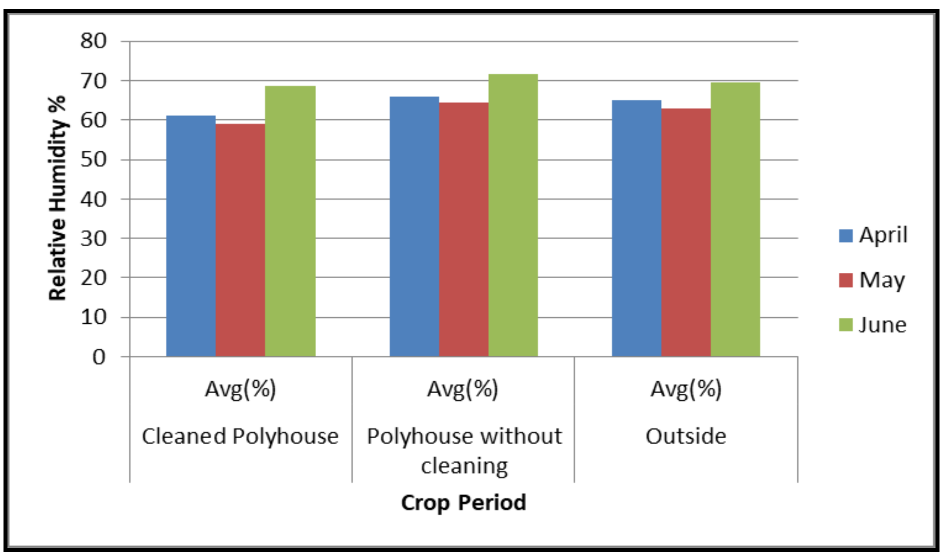


Fig 4.11 Variation of relative humidity at 4.00 PM

In the evening also the relative humidity was higher inside the old greenhouse followed by outside and cleaned greenhouse. In morning (8 am) variation of relative humidity between cleaned and uncleaned greenhouse is around 2-5% while at 12 pm and 4 pm it varies around 10-20% and 6-10% respectively.

4.2.3 LIGHT INTENSITY

Light intensity is a crucial element for plant growth because it controlled numerous events on plant development. Maximum light intensity was recorded outside the greenhouse condition (83500 lux) in the month of May during afternoon while in the month of June during morning, minimum light intensity (2000 lux) was recorded inside the greenhouse without cleaning. Similar results were observed by Garde *et al*. in 2019. From the Fig 4.7, 4.8 and 4.9 it was clear that minimum light intensity was recorded always under uncleaned greenhouse because of its aging property of cladding material. Light intensity improved the crop performance like plant height, number of leaves and number of branches of the plant. An increased proportion of diffused radiation through the cleaned cladding material improves the light use efficiency and photosynthesis at the canopy level which leads to increase in the crop yield (Sinclair and Muchow, 1999). Around 18,000 Lux variation was reported between cleaned and uncleaned greenhouse.

Table 4.11 Mean maximum and minimum Light intensity at 8 AM

Light intensity in the morning						
Month	**Cleaned greenhouse**		**Greenhouse without cleaning**		**Outside**	
	Max(Lux)	**Min(Lux)**	**Max(Lux)**	**Min(Lux)**	**Max(Lux)**	**Min(Lux)**
April	**17000**	**11000**	**7000**	**2600**	**24300**	**11300**

May	**19000**	**12000**	**9000**	**5200**	**27600**	**10500**
June	**10700**	**7800**	**6500**	**2000**	**21000**	**9000**

Table 4.12 Mean maximum and minimum Light intensity at 12 PM

Light intensity in the afternoon						
Month	**Cleaned greenhouse**		**Greenhouse without cleaning**		**Outside**	
	Max(Lux)	**Min(Lux)**	**Max(Lux)**	**Min(Lux)**	**Max(Lux)**	**Min(Lux)**
April	**46400**	**16600**	**27900**	**7900**	**72800**	**25700**
May	**47500**	**26500**	**28900**	**10500**	**83500**	**35500**
June	**36500**	**11200**	**23400**	**9800**	**68500**	**31000**

Table 4.13 Mean maximum and minimum Light intensity at 4 PM

Light intensity in the evening						
Month	**Cleaned greenhouse**		**Greenhouse without cleaning**		**Outside**	
	Max(Lux)	**Min(Lux)**	**Max(Lux)**	**Min(Lux)**	**Max(Lux)**	**Min(Lux)**
April	**24780**	**8500**	**11900**	**4200**	**41500**	**13900**
May	**25600**	**10000**	**12900**	**6300**	**51000**	**14300**
June	**21900**	**7600**	**10000**	**5200**	**39800**	**11200**

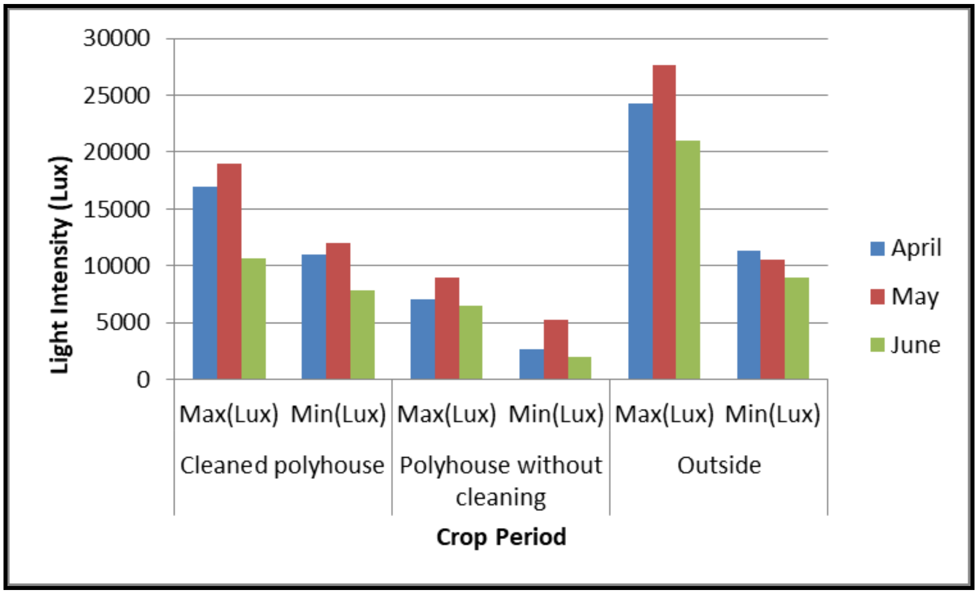


Fig 4.12 Variation of light intensity in the experimental plot at 8 am

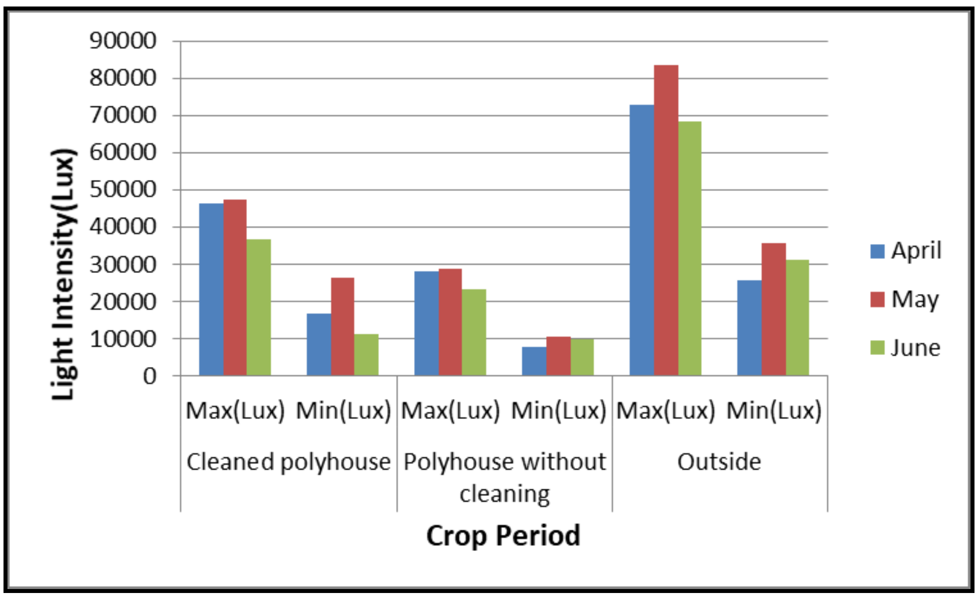


Fig 4.13 Variation of light intensity in the experimental plot at 12 pm

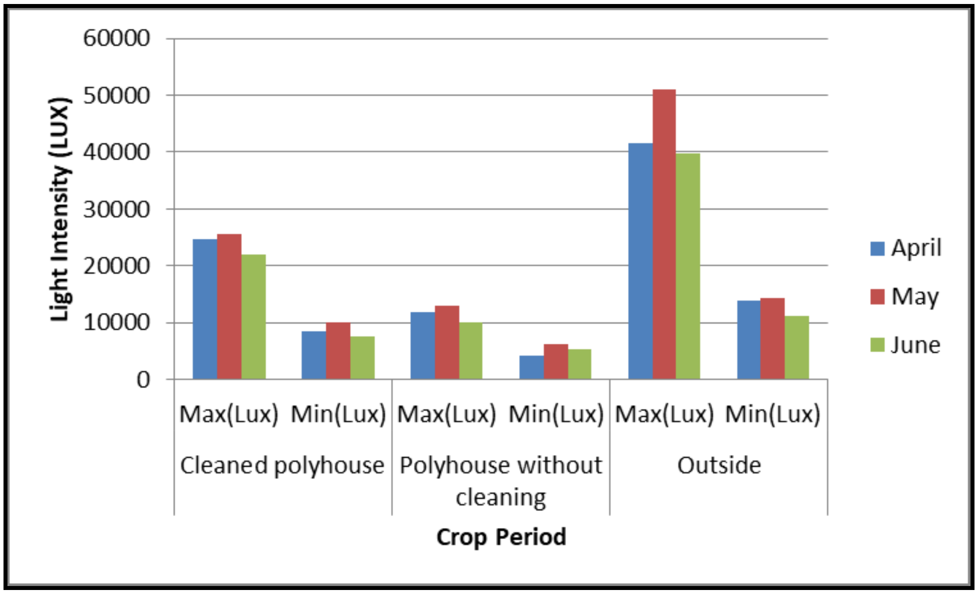


Fig 4.14 Variation of light intensity in the experimental plot at 4 PM

4.3 GROWTH PARAMETERS

4.3.1 Plant Height (cm)

The observations on plant height at different growth stages of amaranthus are shown in below Table 4.13. The plant height of crop differed due to various microclimatic condition viz., 1, 2,3,4,5 and 6 weeks after planting.

Table 4.14 Average plant height (cm) in cleaned greenhouse and greenhouse without cleaned cladding material at different stages of crop growth in amaranths

Treatment	Average Plant Height (cm)					
	1st Week	2nd Week	3rd Week	4th Week	5th Week	6th Week
T1- Cleaned Greenhouse	10	20	35	45	60	78
T2- Greenhouse	10	19	30	40	57	72

without cleaning						

Plant height is more in cleaned greenhouse than the other from second week onwards. This is because of more transmission of solar radiation in to the cleaned greenhouse compared to old one. It provides suitable microclimate for the plant which results in good crop quality. From the table itself it is clear that plant height was greatly influenced by growing environment. Graphical analysis of plant height at different growing environment is shown in below.

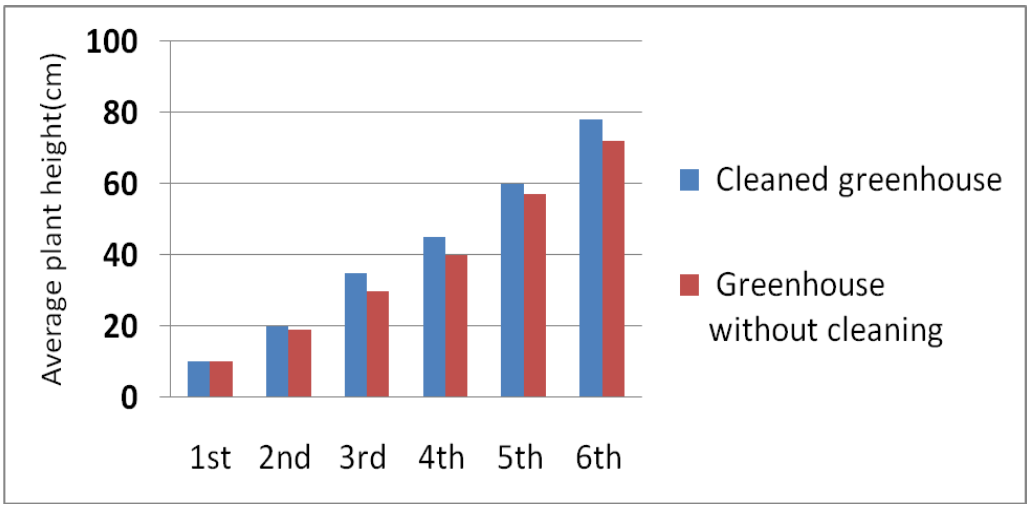


Fig 4.15 Variation of Plant Height(cm) in cleaned and uncleaned greenhouse before harvesting

Table 4.15 Statistical analysis of plant height in cleaned and uncleaned greenhouse

ANOVA						
Source of Variation	**SS**	**df**	**MS**	**F**	**P-value**	**F crit**
Between Groups	**997.63**	**1**	**997.63**	**51.18**	**8.73E-08**	**4.196**
Within Groups	**545.73**	**28**	**19.49**			
Total	**1543.367**	**29**				

From the statistical analysis, it is clear that p-value is less than 0.05 which implies that there was a significant difference in plant height and aging of cladding material. Maximum plant height was observed at cleaned greenhouse (78 cm) whereas plant height in old greenhouse after 6 weeks was around 72 cm only. This analysis reveals that growing environment has great influence on plant height.

4.3.2 Number of branches

The data on number of branches in cleaned and uncleaned greenhouses are shown in Table 4.16 and Fig. 4.16.

Table 4.16 Number of branches in cleaned and uncleaned greenhouses at different growth stages of amaranthus

Treatment	**Average Number of Branches per plant**					
	1st Week	**2nd Week**	**3rd Week**	**4th Week**	**5th Week**	**6th Week**
T1- Cleaned Greenhouse	**2**	**4**	**8**	**9**	**10**	**12**
T2- Greenhouse without cleaning	**2**	**3**	**4**	**5**	**6**	**8**

Above table depicts that maximum number of branches of Amaranthus was observed at cleaned greenhouse (12) after 6 weeks of plant growth while 8 number of branches of amaranthus was recorded in old greenhouse. It is because of the more transmission of solar radiation in to the cleaned cladding material than old one. As well as plant height, number of branches of crop also influenced by aging of cladding material.

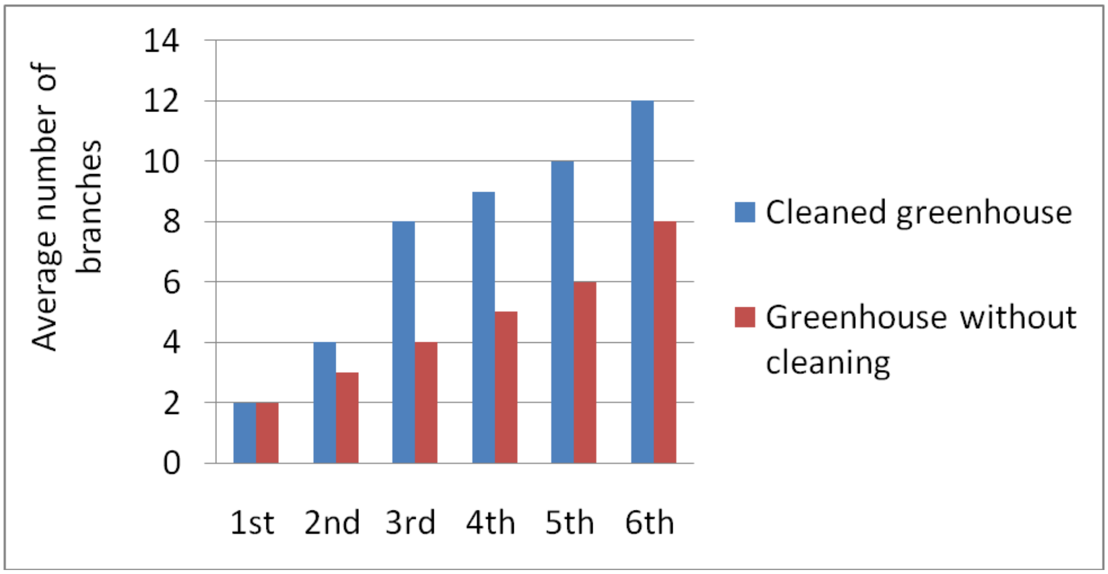


Fig 4.16 Variation of Number of branches in cleaned and uncleaned greenhouse

Table 4.17 Statistical analysis of no. of branches in amaranthus for cleaned and uncleaned greenhouse

ANOVA						
Source of Variation	***SS***	***df***	***MS***	***F***	***P-value***	***F crit***
Between Groups	**67.5**	**1**	**67.5**	**127.7**	**6.06E-12**	**4.196**
Within Groups	**14.8**	**28**	**0.528571**			
Total	**82.3**	**29**				

From the analysis, it was clear that $F_{Table} > F_{Crit}$ so that there is a significant difference between number of branches of amaranths and aging of cladding material.

4.3.3 Number of leaves

The data on number of leaves of amaranthus at different growing stages in cleaned and uncleaned greenhouse are shown in below.

Table 4.18 Number of leaves at different growth stages of amaranths in cleaned and uncleaned greenhouse

Treatment	Average Number of Leaves per plant					
	1st Week	2nd Week	3rd Week	4th Week	5th Week	6th Week
T1- Cleaned Greenhouse	10	18	26	37	45	53
T2- Greenhouse without cleaning	10	14	18	21	25	28

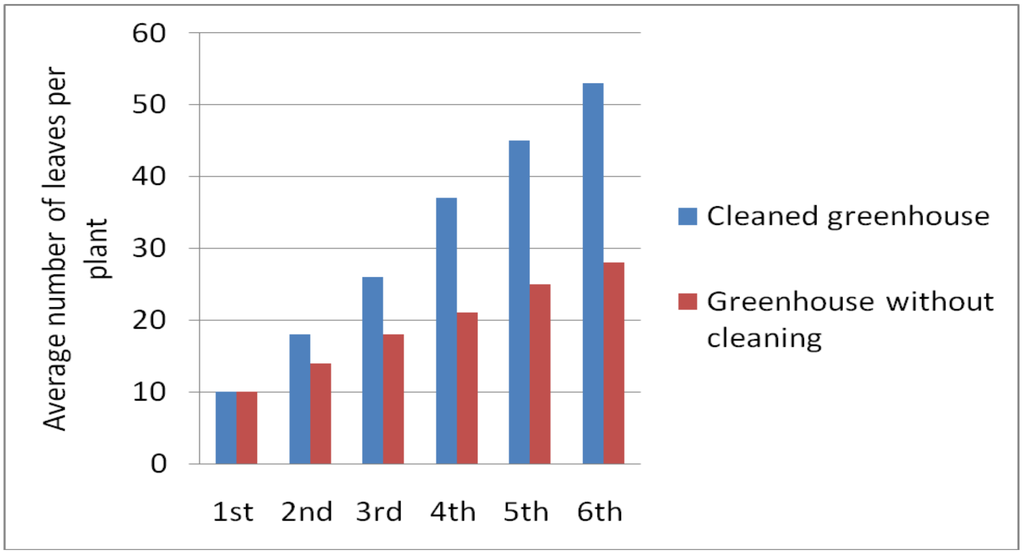


Fig 4.17 Variation of Number of leaves in cleaned and uncleaned greenhouse

Maximum number of leaves was recorded in cleaned greenhouse, it was around 53 leaves after 6 weeks before the time of harvesting while around 28 leaves were observed in old greenhouse. So, this analysis reveals that number of leaves has great influence on light transmission of cladding material.

Table 4.19 Statistical analysis of no. of leaves in amaranthus in cleaned and uncleaned greenhouse

ANOVA						
Source of Variation	***SS***	***df***	***MS***	***F***	***P-value***	***F crit***
Between Groups	**5044.033**	**1**	**5044.033**	**1736.47**	**9.67E-27**	**4.196**
Within Groups	**81.33**	**28**	**2.9**			
Total	**5125.367**	**29**				

From the table 4.19, it is clear that p- value is very less than 0.05, So there is a significant difference between number of leaves and aging of cladding material.

4.3.4 Inter nodal length(cm)

The data on inter nodal length at different growth stages of amaranthus as influenced by light transmission through cladding material are shown in below.

Table 4.20 Inter nodal length (cm) at different growth stages of amaranthus in cleaned and uncleaned greenhouse

Treatment	Average Inter nodal length(cm) per plant					
	1st Week	2nd Week	3rd Week	4th Week	5th Week	6th Week
T1- Cleaned Greenhouse	2.5	3.5	4.5	6.5	7.5	8
T2- Greenhouse without cleaning	2.5	5.2	6.2	7	8	9

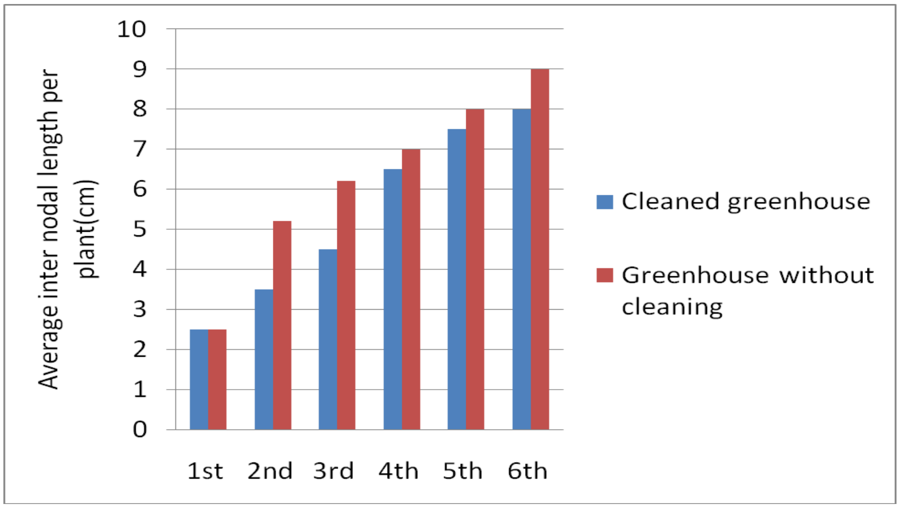


Fig 4.18 Inter nodal length(cm) of amaranthus in cleaned and uncleaned greenhouse

Maximum inter nodal length of amaranths was observed in greenhouse without cleaning compared to cleaned greenhouse. This variation in intermodal length is due to less availability of sunlight inside the old greenhouse. This is because of the ageing of cladding material which reduces the light transmission into the greenhouse due to the deposition of dust particles and fungal growth over the cladding material. Due to the effect of positive phototropism, inter nodal length is more in old greenhouse.

Table 4.21 Statistical analysis of Inter nodal length of amaranthus in cleaned and uncleaned greenhouse

ANOVA						
Source of Variation	***SS***	***df***	***MS***	***F***	***P-value***	***F crit***
Between Groups	**5.04**	**1**	**5.04**	**20.31**	**9.34E-05**	**4.17**
Within Groups	**7.44**	**30**	**0.25**			
Total	**12.48**	**31**				

From the above analysis, it was clear that $F_{Table}>F_{Critical}$ so that there is a significant difference between inter nodal length and its growing environment.

Plate 4.1 Crop stand in cleaned greenhouse

Plate 4.2 Crop stand in greenhouse without cleaning

4.4 YIELD PARAMETERS

4.4.1 Yield per plant(Kg)

The data on yield per plant at different stages of crop growth in cleaned and uncleaned greenhouse are shown in below.

Table 4.22 Variation of yield per plant at different growth stages of amaranthus in cleaned and uncleaned greenhouse

Treatment	Yield per plant(Kg)				
	7thWeek	8th Week	9thWeek	10thWeek	11thWeek
T1- Cleaned Greenhouse	0.218	0.223	0.325	0.255	0.2

T2- Greenhouse without cleaning	**0.076**	**0.066**	**0.086**	**0.124**	**0.083**

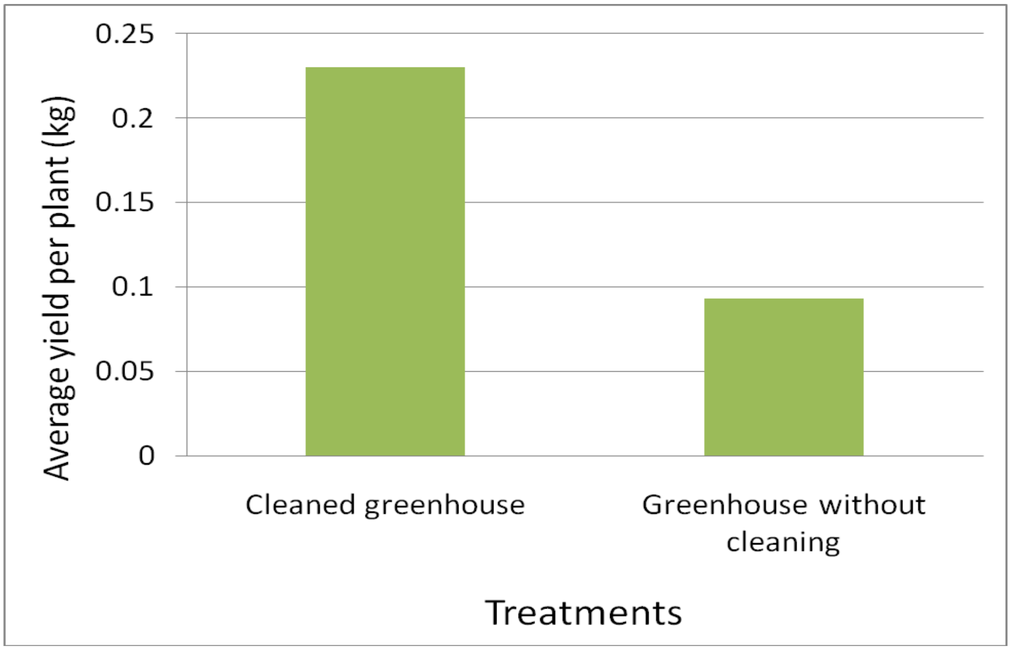


Fig 4.19 Variation of yield per plant (Kg) in cleaned and uncleaned greenhouse

The total yield obtained from the cleaned greenhouse is 53.72 kg/50 m2, so as to 10744 kg/ha while from uncleaned greenhouse 3828 kg/ha. So that it was clear that the yield obtained from the cleaned greenhouse is 2.8 times more than the old one. This implies that microclimatic factors have great effect on crop performance.

Plate 4.3 Harvested amaranthus from cleaned greenhouse

Plate 4.4 Harvested amaranths from greenhouse without cleaning

Table 4.23 Statistical analysis of yield per plant in cleaned and uncleaned greenhouse

ANOVA						
Source of Variation	***SS***	***df***	***MS***	***F***	***P-value***	***F crit***
Between Groups	**0.15**	**1**	**0.15**	**113.622**	**1.01E-11**	**4.17**
Within Groups	**0.04**	**30**	**0.0013**			
Total	**0.19**	**31**				

From the statistical analysis, it was clear that there is a significant difference between yield and aging of cladding material. Higher yield was recorded in cleaned greenhouse because of the more transmission of solar radiation through the cleaned cladding material.

From this experiment, it is clear that the aging of cladding material has wide influences on microclimate inside the greenhouse and crop performance. Higher temperature and higher light intensity were recorded inside the cleaned greenhouse than the old one while relative humidity was higher inside the old greenhouse. Higher temperature and higher light intensity improved the crop performances and comparatively lower relative humidity inside the cleaned greenhouse protected the crop from fungal infection. Optimum values of microclimatic variables like temperature, relative humidity and light intensity for amaranthus inside the greenhouse were 25-30 °C, 60-80 % and 45000-55000 Lux respectively. From the field experiment it was clear that very less light intensity and higher relative humidity were observed inside the uncleaned greenhouse and it greatly influenced the crop performance. Hence aging of cladding material has direct influences on crop performances under greenhouse. Around 6 °C reduction in temperature was reported in uncleaned greenhouse than cleaned greenhouse and 15% variation in relative humidity. Moreover, light intensity was reduced around 18,000 Lux inside uncleaned greenhouse. This variation in microclimate leads to 2.8 times reduction in yield inside the uncleaned greenhouse.

CHAPTER V
SUMMARY AND CONCLUSION

A study was conducted to explore the reasons for the failures of greenhouse farmers in Kerala. For that, a survey was conducted across 14 districts of Kerala. An analysis of the survey details was done by SPSS 16.0 using a non-parametric test. In addition to that one field experiment was conducted at the instructional farm of KCAET, Tavanur, Kerala during the period from April to June 2021 to study the effect of aging of cladding material on microclimate inside the greenhouse and crop yield. The treatment consists of two growing environments viz., naturally ventilated greenhouse with cleaned cladding material and old greenhouse with uncleaned polyethylene sheet. The experiment was laid out in CRD with eight replications. The summary of the study is discussed in this chapter.

From the statistical analysis of the survey, it was clear that most of the greenhouse farmers in Kerala are not satisfied with the greenhouse. Because they are facing crop failure after two or three years, the main reason for crop failure is due to the aging of cladding material because of that dust particles and fungal growth deposited on the polyethylene sheet due to the high humidity inside the greenhouse which reduces the light transmission and it leads to the negative effect on crop growth. In addition to that, another problem faced by farmers is a decrease in soil fertility. Due to the continuous crop cultivation soil fertility inside the greenhouse decreases which results in a reduction in yield. According to some of the successful farmers, they changed the soil after two or three cultivation and maintain the soil fertility which can overcome the crop failure up to a limit. But the problem is it's not a cost-effective process. And one another problem faced by the farmer was the structural problems like shape of the greenhouse, length of apron, construction criteria.

From the results of field experiment, the variation of weather parameters like temperature, relative humidity, and light intensity was analyzed for both greenhouses and outside condition. Maximum temperature (43 °C) was recorded inside the cleaned greenhouse in May during the afternoon hours while minimum temperature (25 °C) was reported inside the old greenhouse in June during the morning hours. The rise in temperature in the cleaned greenhouse is due to the increased transparency of cladding material which results in better transmission of solar radiation into the greenhouse. Likewise, maximum relative humidity (95%) was observed in the outside condition in June during the morning, it is because of the heavy rain during the morning whereas minimum humidity (43%) was recorded inside the cleaned greenhouse in May during the afternoon. Furthermore, Maximum light intensity (83500 lux) was recorded outside conditions during the afternoon in May although minimum light intensity (2000 lux) was observed under an old greenhouse during the morning.

Crop growth parameters like plant height, number of branches, number of leaves, internodal length were noted during different crop growth stages of two treatments.

All the growth parameters except internodal length were significantly higher inside the cleaned greenhouse because of the maximum entry of solar radiation through the cleaned cladding material while significantly higher inter nodal length in the old greenhouse is due to the positive phototropism of crops in the shaded region. Moreover, yield parameters are also significantly higher inside the cleaned greenhouse. Hence it can be concluded that growing crops under the cleaned greenhouse is more profitable than an uncleaned greenhouse.

From the analysis of survey, the most suitable shape of the greenhouse is the Gable shape which is having ventilation on both long sides and it provides maximum ventilation which can reduce the humidity inside the greenhouse up to a limit. Furthermore, some design characteristics of the greenhouse also depend on microclimate inside the greenhouse and thereby crop yield also.

Major conclusions of the present study are:

1. From the explorative field survey of greenhouse farmers, it was clear that major problems faced by farmers are climate problems, soil problems and structural problems. Microclimate inside the greenhouse is varied due to aging of cladding material which adversely affect the crop yield. Another relevant problem is decrease of soil fertility due to continuous crop cultivation inside the greenhouse. In addition to those structural problems like shape of the greenhouse, and other design elements make them unfavorable effect.
2. From the field experiment it was proved that aging of cladding material has negative effect on crop yield.
3. Remedial measures to overcome the problems faced by farmers are intermittent cleaning of cladding material to reduce aging thereby it removes the dust particles and fungal deposits over the sheet which improves the transparency of cladding material, and maintain the soil fertility by changing the soil in greenhouse to avoid soil problems. For rectifying the structural problems, design elements have to be modified such as select gable shaped greenhouse instead of saw tooth.

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Appendix I

QUESTIONNAIRE FOR FARMERS

District:

Place:

Date of survey:

Questionnaire No:

- Farmer's name:
- Address :

1. Area of Greenhouse cultivated:
   - ☐ 100-500 m^2
   - ☐ 500-1000 m^2
   - ☐ 1000-2000 m^2
   - ☐ Above 2000 m^2

2. Year of Establishment of Greenhouse:
   - ☐ Below 1990
   - ☐ 1990-2010
   - ☐ 2010-2021

3. Total expenditure for Greenhouse establishment (initial cost):
   - ☐ 1 lakh - 10 lakh
   - ☐ 10 lakh - 20 lakh
   - ☐ 20 lakh - 50 lakh
   - ☐ Above 50 lakhs

4. Which are the crops cultivated in Greenhouse:
   - ☐ Vegetable/Fruit crops
   - ☐ Flower crops
   - ☐ Nursery

5. Maximum how many crops per year:

   ☐ 1-3 ☐ 3-5 ☐ More than 5

6. Variation of Yield:
   - ☐ No variation
   - ☐ 10-20% decrease
   - ☐ 20-30% decrease
   - ☐ 30-50% decrease
   - ☐ > 50% decrease

7. What is your conclusion for decreasing yield:
   - ☐ Due to ageing of cladding material (Formation of mosses)
   - ☐ Decrease of soil fertility

- ☐ Lack of maintenance and Inspection
- ☐ Fungal/insect attack
- ☐ Others

8. When mosses start to grow in greenhouse cladding material:
   - ☐ Within 1 month
   - ☐ 1-6 months
   - ☐ 6 months – 2 years
   - ☐ 2- 5 years
   - ☐ More than 5 years
9. How often Greenhouse cleaning is required (cleaning interval):
   - ☐ 6 months
   - ☐ 1 year
   - ☐ 2-3 years
   - ☐ No cleaning
   - ☐ More than 3 years
10. Cost required for Greenhouse cleaning:
    - ☐ Below 5000
    - ☐ 5000 – 10000
    - ☐ More than 10000
    - ☐ No charge
11. Are you satisfied with this Greenhouse:
    ☐ Yes ☐ No
12. What are the other problems faced by Greenhouse farmers:
    - ☐ Marketing facility of agricultural products
    - ☐ No demand for the product
    - ☐ Decrease of yield due to insect/pest attach
    - ☐ Others

ASSESSMENT OF GREENHOUSE CULTIVATION PROBLEMS IN KERALA

By

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(2019-18-004)

Abstract

Submitted in partial fulfillment 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

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2021

ABSTRACT

Greenhouses are framed or inflated structure covered with transparent or translucent material large enough to grow crops under partial or fully controlled environmental conditions to get optimum growth and productivity. Greenhouse have many advantages and some limitations also. Due to this farmer are abandoning this cultivation method citing crop failures after the initial phase. Thus, a survey was conducted to explore the reasons of failures of greenhouse farmers in Kerala covering all fourteen districts. Major problem faced by farmers was crop failure due to ageing of cladding material. So that fungal growth and dust deposit over the cladding material reduce the light transmission to the greenhouse which affect its microclimate and growth and yield parameters. To prove this, a field experiment was conducted during the period from April to June 2021 in the instructional farm of KCAET, Tavanur, Kerala.

CO-1(Amaranthus green variety) was planted inside both cleaned greenhouse and uncleaned greenhouse (greenhouse without cleaned cladding material) and compared the microclimate and performance of Amaranthus in both conditions. Mean monthly values of light intensity and temperature were higher inside the cleaned greenhouse than the uncleaned one while relative humidity was higher inside the old greenhouse. Thus, crop growth parameters like plant height, number of leaves, number of branches and average yield per plant were higher inside the cleaned greenhouse than the old one whereas the inter nodal length of the plant was higher inside the old greenhouse. From this experiment, it was clear that the aging of cladding material has much influence on crop performance under the greenhouse.

Other major problems faced by farmers were a decrease in soil fertility, Fungal/Insect attack inside the greenhouse, high maintenance cost

and structural problems of greenhouse, no demand and marketing facility of greenhouse products, etc. From the statistical analysis of survey details, it was clear that farmers are not satisfied with the greenhouse.