MICROCLIMATIC CHARACTERISTICS OF DIFFERENT TYPES OF PROTECTED STRUCTURES

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PROJECT REPORT

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KELAPPAJI COLLEGE OF AGRICULTURAL ENGINEERING AND TECHNOLOGY, TAVANUR-679573, MALAPPURAM, KERALA, INDIA

2024

DECLARATION

We, hereby declare that this project report entitled "**MICROCLIMATIC CHARACTERISTICS OF DIFFERENT TYPES OF PROTECTED STRUCTURES**" is a bonafide record of research work done by us during the course of research and the thesis has not previously formed the basis for the award to us of any degree, diploma, associateship, fellowship or other similar title, of any other University or Society**.**

Tavanur
18/06/2024

Fathima Jasleena K P (2020-02-013)

Vivek U S (2020-02-024)

CERTIFICATE

Certified that this project report entitled "**MICROCLIMATIC CHARACTERISTICS OF DIFFERENT TYPES OF PROTECTED STRUCTURES**" is a record of research work done by Ms. Fathima Jasleena K P (2020-02-013) and Mr. Vivek U S (2020-02-024) 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 them.

Tavanur

18/06/2024

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DEDICATED TO OUR

AGRICULTURAL ENGINEERING

PROFESSION

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SYMBOLS AND ABBREVIATIONS

%	Percentage
°C	Degree Celsius
ACM	Air exchange per minute
cm	Centimeter
DBT	Dry bulb temperature
EBA	Ethylene Butyl Acrylate
et al.	And others
EVA	Ethylene Vinyl Acetate
Fig.	Figure
FTIR	Fourier Transform Infrared Spectroscopy
gsm	Grams per square metre
ha	Hectare
HDPE	High density polyethylene
KAU	Kerala Agricultural University
KCAET	Kelappaji College of Agricultural Engineering and Technology
LDPE	Low Density Polyethylene
m	Meter
m^2	Square meter
mm	Millimeter
PAR	Photosynthetically Active Radiation
PC	Polycarbonate
PFDC	Precision Farming Development Centre
PPFD	Photosynthetic Photon Flux Density
STPV	Semi- transparent photovoltaic
UV	Ultra Violet
UV A	Ultra Violet A

UVO	Ultra Violet Opaque cover
UVT	Ultra Violet Transmitting cover
VPD	Vapour Pressure Deficit
WBT	Wet bulb temperature

INTRODUCTION

CHAPTER I

INTRODUCTION

Kerala is referred as the "God's own country" due to its diverse landscape, greenery and back waters. It has a population density of 859 people per square kilometer. Even still, our state's agricultural output is declining day by day when compared to other states. Since agriculture is the foundation of our economy, productivity should rise in tandem with population growth. However, just 20% of the state's total revenue comes from agriculture, and the majority of this revenue comes from marginal holdings with an average size of 0.18 ha (Gokul, 2015). So, increasing the agricultural production from these small landholdings has become essential for the betterment of the state.

Kerala is endowed with rich soil, a warm, humid tropical climate, with about 3107 mm of annual precipitation. The majority of rainfall occurs in the rainy months of June to September, very less rainfall is received in summer (Guhathakurta and Kumar, 2020). According to Kerala's season-specific rainfall contribution, the monsoon season accounts for 68% of yearly rainfall, with the post-monsoon season accounting for 16% of total rainfall. Due to the irregular and untimely rainfall of Kerala the yield of seeds of vegetables are reduced (Pooja, 2017). Kerala therefore, relies on its surrounding states, such as Tamil Nadu, Karnataka, and Andhra Pradesh, to meet its vegetable needs during these times. Increasing agricultural production is necessary if Kerala is to emerge as a global economic force. Unlike conventional approaches, high-tech technology needs to be employed in order to improve the productivity, profitability, and sustainability of our main farming systems. Greenhouse technology is one example of such technology.

In certain parts of the world, greenhouses have been around for more than 150 years; however, in India, this technology was mostly employed for research purposes when it was first introduced in the 1980s. India began using greenhouses for commercial purposes in 1988 when the government implemented liberalization policies and other development programs.

According to https://agritech.tnau.ac.in, "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."A greenhouse is defined as a structure covered in UV-stabilized polyethylene sheeting. In general, greenhouses only allow the transmission of solar energy that is photosynthetically active between 400 and 700 nm in wavelength, reflecting 43 percent of incident solar radiation. Crops, greenhouse flooring, and other greenhouse items absorb solar radiation that enters the space. The covering materials are not transparent to the longwave thermal radiation that these things release. As a result, the greenhouse's inside temperature rises. The idea for greenhouse cultivation is this phenomena, which is referred to as the "greenhouse effect."

The benefits of greenhouse cultivations include the ability to produce high-quality products, increase income from small land holdings, produce vegetables and fruit crops during the off-season and manage crop water constraints with ease.

The location and climate should be taken into consideration when choosing a covering material (Waaijenberg and Sonneveld, 2004). Good farming practices demonstrate that polyethylene film should have the highest possible solar transmission and be opaque to long wave radiation in order to minimize heat loss at night.

Additives and polymers come together to form greenhouse films. EVA (ethylene vinyl acetate), EBA (ethylene butylacrylate), and LDPE (low-density polyethylene) are the polymers most frequently used in horticulture. In addition, UV stabilizers and IR absorbers are often utilized additives. whereby polymers serve as the fundamental building block and additives provide the film unique qualities like light diffusion and infrared absorption/reflection. The durability of cladding layer is increased by UV stabilizers, which absorb UV light and prevent the destruction of polymer molecules. This film's lifespan has extended from nine months in the 1950s to forty-five months currently (Cepla, 2006). It is ideal for greenhouse cladding film to have a width of up to 9 meters and a thickness of around 200 micrometers.

Furthermore, the qualities of this polyethylene film are pertinent to greenhouse agricultural production. Diffuse film is one such feature that can raise the proportion of dispersed radiation within the greenhouse. On warm days, direct sunlight in regions with clear skies and high solar radiation may burn leaves inside greenhouse crops. Radiations that diverge more than 2.5 degrees from the direct incoming radiation are referred to as diffused radiations because they lessen the negative effects of direct radiation. Higher yield and more homogeneous light inside the greenhouse are the outcomes of increased diffused radiation (Cabrera *et al*., 2009).

The anti-dust film is the next important feature. When there is friction from the wind, there is a potential that static electricity will build up in polyethylene film. As a result, dust particles accumulate on the film's surface. Thus, certain chemicals with anti-dust qualities are applied to the film's surface to lessen static electricity. After a year of exposure in coastal Spain, dirt deposition decreased the light transmission of a fresh PE plastic film by around 6%, according to (Montero *et al*., 2001). Another essential feature of cladding material is anti-drip. Light transmission is decreased when water vapor condenses on the chilly inner cover surface to create water droplets. Because a drop's contact angle with a plastic sheet varies, larger water droplets impede light transmission less than smaller drops (Castilla, 2005). Fungal infection of crops is caused in conjunction with condensation. Anti-drip additives change the water's surface tension, get rid of droplets, and create a thin, continuous layer of water.

Kerala show cases a variety of greenhouse options, including net houses, rain shelters, plastic low tunnels, naturally ventilated greenhouses, and greenhouses with partial or complete controls. Naturally ventilated greenhouses are ubiquitous in Kerala. The frame contains wooden logs, steel pipes or galvanized iron pipes. The greenhouse's sides are covered with an insect-proof net with a mesh size of 40 and the roof is coated with UV-stabilized polyethylene sheeting for cladding.

Although they have many benefits, greenhouses also have several drawbacks. As greenhouses age, less visible spectrum light enters the structure, which in turn causes reduced photosynthesis and a decline in greenhouse yield, rendering farmers' labour ineffective. The main challenges faced by greenhouse farmers are insect and fungal attacks on greenhouse crops, inadequate facilities for marketing greenhouse products, a lack of demand for greenhouse products, etc. Due to these, a lot of farmers are hesitant to start growing crops in greenhouses, alleging crop failures following the first stage. In the light of these informations, this study aims to investigate the crop failures after the initial phase in greenhouse farming with the following specific objectives:

1. To compare the microclimatic parameters of different protected structures
2. To study the effect on discoloration of cladding material on the microclimatic parameters.
3. To study the relationship between important microclimatic parameters.

REVIEW OF LITERATURE

CHAPTER II

REVIEW OF LITERATURE

This chapter covers a thorough analysis of the study on greenhouse cultivation issues conducted by different researchers. Studies pertaining to light transmission deficiencies and the impact of aging of greenhouse cladding material are also reviewed here. Here is an overview of the literature on how various crops perform under various microclimatic conditions.

2.1 MICROCLIMATIC CONDITION UNDER PROTECTED CULTIVATION

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.

Kitta *et al*. (2012) conducted a study on shading intensity for optimal greenhouse microclimate which should not exceed 35% to 40%. Natural ventilation alone may not be sufficient for cooling during sunny summer days, necessitating additional cooling methods like shading screens. The decision on shading intensity and timing is crucial for managing greenhouse heat load effectively. Greenhouse cooling methods are essential in Mediterranean regions to counter high temperatures and vapor pressure deficit levels that can negatively impact crop growth and quality.

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 rain shelter. 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 rain shelter, 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 field 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 and Nandini (2015) reported from their experiment that low intercellular CO_2 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.

Roy and Sajitharani (2016) studied on temperature and light intensity which is 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 chilli.

Smitha and Sunil (2016) had done experiment in greenhouse, rainshelter 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 optimal degree temperature was 0.95°C while minimum was 0.16°C. The maximum and minimum optimal relative humidity was 100% and 31% respectively.

Job (2018) conducted microclimate studies of greenhouse under tomato cultivation in Ranchi and revealed that air temperature inside the greenhouse was higher by 2 to 9℃ 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.

Jinu and Hakkim (2019) 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℃ whereas in automated greenhouse temperature was increased only upto 37.6℃. This better temperature management inside the automated greenhouse resulted in higher yield (7.54 kg/plant) of salad cucumber compared to manually operated greenhouse.

Garde *et al*. (2019) compared the microclimate inside greenhouse and open field conditions. The mean highest temperature (33.27℃) 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 (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℃ 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.

da Silva *et al*. (2021) done a comprehensive study to evaluate the impact of different protected environments on micrometeorological variables like global solar radiation, air temperature, and relative air humidity throughout the four seasons and twelve months of the year. These variables are interconnected and crucial for expressing the best plant potential, highlighting the need for a holistic approach in plant cultivation. Factors like film thickness, color, and the use of screens under the film significantly influence radiation availability within protected environments, impacting the types of crops that can be grown. The relative humidity inside protected environments with shading screens was notably higher than the external environment, emphasizing the role of these structures in creating suitable growing conditions for plants. Air temperatures in protected environments with less shading were higher than in more shaded environments, with differences observed between different types of shading screens used in the study.

2.2 PROPERTIES OF DIFFERENT POLYHOUSE CLADDING MATERIAL

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%.

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.

Li (2015) conducted study on greenhouses which offer optimal growth conditions for crops, enhancing production and quality. Light is crucial for plant photosynthesis, often limiting growth in greenhouse horticulture. Diffuse glass improves light distribution in canopies, enhancing crop photosynthesis and leaf area index. Diffuse glass reduces leaf temperature and photo-inhibition, positively impacting crop photosynthesis under high radiation. Diffuse glass cover increases crop RUE in shade-tolerant pot-plants, leading to higher biomass production. Cultivar-specific responses to diffuse light are linked to stomatal conductance variations and instantaneous leaf photosynthesis. Source-sink balance is crucial for assimilate production and utilization in plants, affecting overall growth and productivity. Tomato plants exhibit sink limitation during early growth stages and source limitation during fruiting stages, impacting potential fruit size. The research provides insights into improving radiation use efficiency in greenhouse production systems through better understanding of crop physiology.

Babaghayou *et al*., (2018) had studied anisotropic evaluation of low-density polyethylene 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 and Athienitis (2018) reported from their experiment that semi-transparent photovoltaic (STPV) cladding could generate 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.

Kim *et al*. (2022) had done an experimental study to compare the microclimate and thermal environment in greenhouses covered with plastic film, polycarbonate (PC), and glass. PC-covered greenhouse was most effective for night time heating during the cold season. Glass-covered greenhouse was best for cooling during the hot season. Plastic-covered greenhouse was inexpensive but had difficulty controlling indoor environment. PC-covered greenhouse had the lowest thermal load leveling values, showing superior environmental control and energy savings. The research also focused on air temperature, humidity, surface temperature, thermal load leveling and heat flux of different greenhouse covering materials. Polycarbonate was identified as the most suitable material for saving heat at night in the cold season. Glass was found to be the most suitable for saving cooling energy during the hot season.

Muñoz-Liesa *et al*. (2022) compared the effects of different covering materials like polycarbonates, horticultural glass, and Ethylene tetrafluoroethylene films on tomato crop yields and environmental impacts. Results showed that using alternative materials with higher solar transmissivity, such as 4 mm-antireflective glass and Ethylene tetrafluoroethylene film, led to significant improvements in tomato yields and environmental performance. The lifetime crop yields increased by up to 46.6% when using 4 mm-antireflective glass, producing 19.9 ± 2.2 kg/m^2 of tomatoes, while Ethylene tetrafluoroethylene film resulted in 19.2 ± 2.3 kg/m^2 of tomatoes with improved environmental performance up to 41.7%.

2.3 LIGHT INTENSITY AND PLANT GROWTH RELATION

Mortensen and Strømme (1987) investigated the effects of different light qualities such as blue, green, yellow, and red light had varying effects on plant growth. Blue light inhibited stem elongation, while green and yellow light promoted elongation due to differences in the red to far-red and blue to red ratios.

Fan *et al*. (2013) had done a study focused on the effects of different light intensities on young tomato plants using red and blue LEDs. Results showed superior growth parameters at 300, 450, and 550 mol m^{-2} s^{-1}. Specific leaf area decreased with increasing PPFD, with optimal net photosynthesis rate at 300 mol m^{-2} s^{-1}. The higher

PPFD led to decreased leaf thickness and specific leaf area. Stomatal frequency and area per unit leaf area increased with light intensity, affecting photosynthesis rates. High light intensity may decrease stomatal frequency as a protective mechanism against excessive light.

Pérez-Saiz et al. (2015) conducted a study to focus on the spectral distribution of light in various regions: UV, B, R, FR, PAR, NIR, and Global, assessing how different structures and cover materials influence radiation transmission. Structural typologies in greenhouses alter global radiation uniformly across the spectrum, except for UV where the "Parral" greenhouse shows lower transmission. Aluminised screens reduce radiation, especially in UV and B bands. Ratios like PAR/NIR, B/R, B/FR, and R/FR are higher without aluminised screens, indicating differences in light quality. Anti-pest mesh leads to a significant reduction in radiation received by crops, particularly in UV and B bands.

Neugart and Schreiner (2018) conducted study on UV radiation effects on plants. UV radiation (UV) in sunlight, specifically UVB (280-315 nm) and UVA (315-400 nm), has beneficial effects on plant growth, photosynthesis, and secondary metabolites in horticultural and agricultural crops. UVB exposure leads to the production of flavonoids, which have health benefits and serve various functions in plants, such as UV shielding and antioxidant properties. The effects of UVB and UVA on plants are genotype-dependent and vary based on the plant's developmental stage, UV intensity, and duration of exposure.

Serrano and Moreno (2020) conducted study to focus on analyzing the spectral transmission of solar radiation by plastic and glass material. Measurements were taken on clear days in July 2018 and January 2019 to calculate transmittances in different spectral ranges. Materials like methacrylate and smoked glass showed high transmittance values in the UVB, UVA, VIS, and NIR ranges. The study highlights that erythemal damage could occur after prolonged exposure to solar radiation through these materials.

Khapte *et al.* (2021) have done a study to reveal that the naturally ventilated polyhouse (NVP) significantly modified the microenvironment by reducing photosynthetically active radiation (PAR) by 70%, net radiation by 48%, and air temperature by 1.2°C, while increasing relative humidity by 17% compared to other structures in the hot arid ecosystem. Among the different low-tech protected structures studied, the NVP provided the most favorable microclimate for cucumber cultivation, enhancing growth, development, and physiological functioning of the plants. The average PAR levels in the three structures ranged from 154-842 μmol m^{-2} s^{-1} during the cucumber growing period, with the least variation noted in NVP, potentially aiding in better maintenance of physiological functioning compared to other structures. The high levels of PAR in the insect proof net house (INH) structure, especially during mid-day hours, may have adversely affected plant metabolisms, indicating that excessive PAR can be detrimental for optimum growth of cucumber plants.

Lycoskoufis et al. (2022) have carried out an experiment on effects of UV Radiation on Red Lettuce. The UV radiation intensity impacts red lettuce yield and quality. Two experiments were conducted to study the effects of UV transparency on plant growth and antioxidant concentration in red lettuce. Red lettuce grown in a UV-block greenhouse had higher head weight but lower antioxidant content compared to UV-open greenhouse. Supplemental UV lighting before harvest improved red lettuce quality without affecting yield negatively.

Park and Runkle (2023) conducted experiment which focuses on the utility of spectral-conversion films in greenhouses, specifically examining the conversion of green (G) photons to red (R) photons and the exclusion of far-red (FR) light for plant growth. It discusses the importance of green and far-red light in plant growth regulation, despite their perceived lower efficiency in photosynthesis compared to red and blue light. The study evaluates the effects of substituting G with R light and excluding FR light on the growth of lettuce and tomato plants indoors using LED lighting scenarios. Results showed that substituting G with R light had minimal effect on tomato growth but increased fresh and dry mass of lettuce when FR light was present. Excluding FR light inhibited plant growth in both lettuce and tomato, affecting parameters like plant height, leaf area, and dry mass. So by converting G-to-R photons can enhance plant growth in certain crop species like lettuce, while excluding FR light decreases crop growth and yield.

MATERIALS AND METHODS

CHAPTER III

MATERIALS AND METHODS

This chapter elaborates on location, materials used for the research work and methodologies adopted for the characterisation of cladding material in polyhouse and rainshelter and the microclimate in them.

3.1 DETAILS OF STUDY AREA

3.1.1 Experimental location

To assess the effect of deposition of algae and dust on cladding material and its microclimate, an experiment was carried out in the Precision Farming Development Centre (PFDC) of KCAET, Tavanur, Kerala. The site is located on 10º 51'8'' N Latitude and 75º 59'12'' E Longitude at an altitude of 22 m above mean sea level.

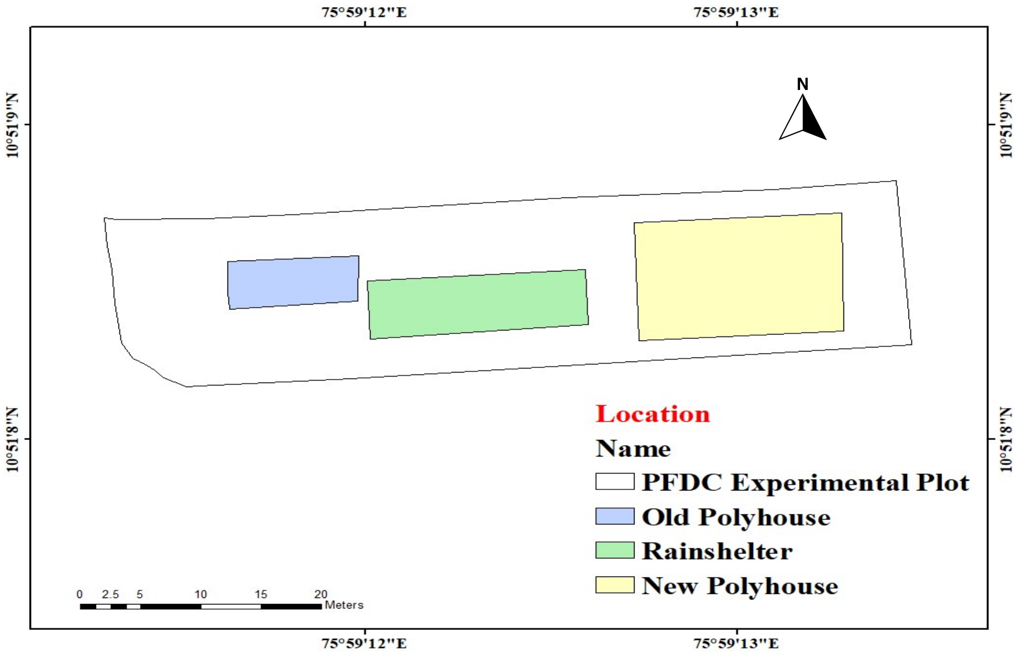

Fig. 3.1 Location of PFDC experimental plot

3.1.2 Study Area set up

A field experiment was conducted on two polyhouses and one rainshelter located at PFDC of KCAET Tavanur. One of the polyhouses has new cladding material and other is having 3 years old one and a comparison of their microclimate have been done. In the case of rainshelter, it's cladding material is also 3 years old half of this rainshelter was cleaned and other left as it is and a comparisonal study were conducted on cleaned and uncleaned cladding material.

3.1.2.1 Old Polyhouse

A fully closed polyhouse (Plate 3.1) of area 28.8 m^2 which is oriented in the east-west direction has been used in the study. 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 1 day. Two sides of the greenhouse were covered with 40 mesh insect-proof nets for preventing the entry of insect pests. Specifications of the cleaned greenhouse are shown below.

Table 3.1 Specification of old polyhouse

Sl. No.	Item	Specification
1	Size	8m x 3.6m
2	Side height	3.5m
3	Centre height	6m
4	Cladding material	205 N UV stabilized sheet, 5 layer, 88% light transmission, 60% light diffusion, anti-dust polyethylene
5	Insect net	40 mesh, 105 gsm

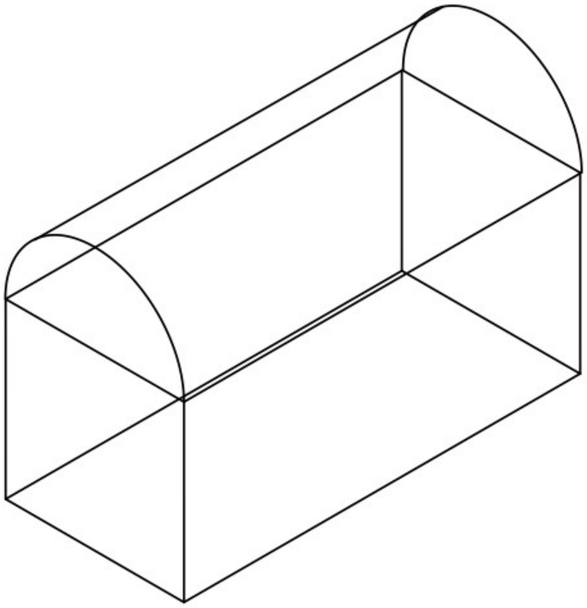

Fig. 3.2 Schematic diagram of old polyhouse

Plate 3.1 Old Polyhouse

3.1.2.2 Rainshelter

A rainshelter (Plate 3.2) used in the study has got an area of 90 m^2 and is oriented in east-west direction. Its frame is made up of galvanized steel pipe and covered with 200-micron UV stabilized polyethylene film. The half portion of cladding material was cleaned using water jet and other half was left uncleaned. The specification of rainshelter is given below.

Table 3.2 Specification of rainshelter

Sl. No.	Item	Specification
1	Size	5 m x 18 m
2	Side height	2 m
3	Centre height	3 m
4	Cladding material	U V stabilized polyethylene sheet

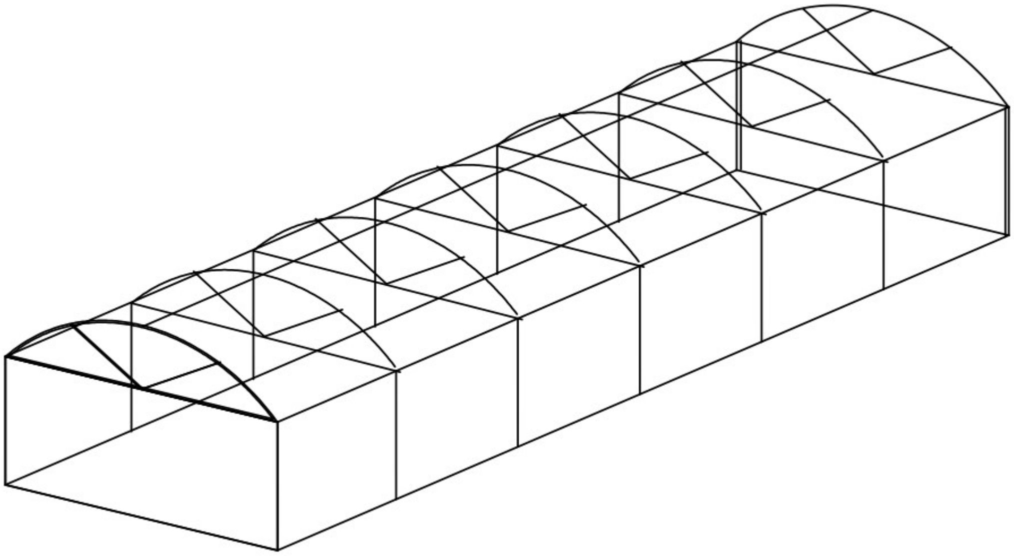

Fig. 3.3 Schematic diagram of rainshelter

Plate 3.2 Cleaned and uncleaned rainshelter

3.1.2.3 New Polyhouse

The new polyhouse was a two span type with double door entry having arch shape with umbrella vent polyhouse (Plate 3.3) having an area of 192 m^2 is oriented in the East-West direction. Its frame is made up of galvanized steel pipe and covered with 200-micron, 5 layered UV stabilized polyethylene film. The sides of the polyhouse were covered with 1400 micron HDPE sheet. Specification of new polyhouse is shown below.

Table 3.3 Specification of new polyhouse

Sl. No.	Item	Specification
1	Size	12 x 16 m, two span with double door entry, arch shape with umbrella vent
	Center height	7.5m
	Total width	16 m (2 x 8 m span)
	Gutter height	4.5 m
	Span width	8 m

	Bay length	3 m
	Door	2.5 m x 2 m
2	UV sheet	200 micron, 5 layer, UV stabilized 86% light transmission, light diffusion 55%, anti-dust, anti-drip, IR effective, cooling, diffused 70% anti-dust, anti drip/fogg
3	Insect net	40 mesh, 105 gsm
4	Shade net	Red, 50% monofilament, Tape type light diffusing – 90 gsm
5	HDPE sheet for sides	1400 micron
6	Aluminium profile	Triple spring locking, 0.9 mm thick with smooth edges and zig zag spring used for fixing
7	Foundation pipe	72 mm x 72 mm
	Pillar pipe	80 mm x 80 mm
	Structure arch	40 mm
	Arch support	25 mm
	Purlin pipe	32 mm

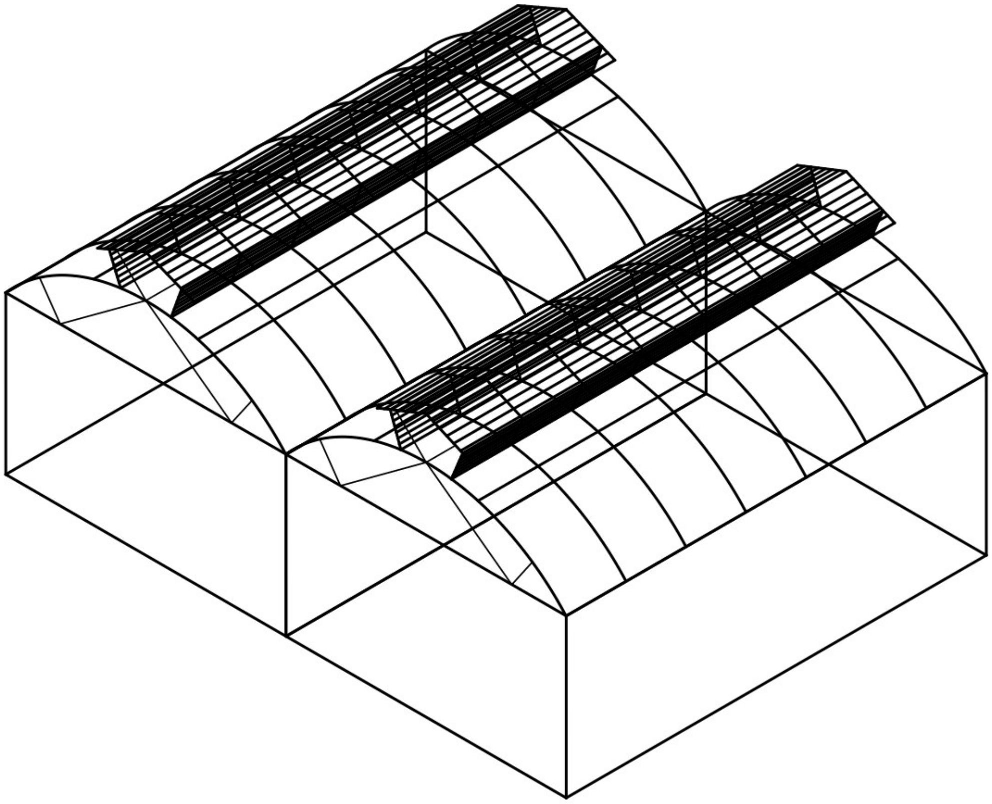

Fig. 3.4 Schematic diagram of new polyhouse

Plate 3.3 New polyhouse

3.2 SPECIFICATIONS OF MEASURING EQUIPMENTS

3.2.1 Photosynthetically Active Radiation (PAR)

3.2.1.1 MQ-300X: Line Quantum with 3 Sensors with Handheld Meter (PAR sensor)

Plate 3.4 PAR Sensor

Table 3.4 Specification of PAR sensor

Calibration Uncertainty	± 5%
Response Time	Less than 1 ms
Field of View	180°
Spectral Range	410 to 655 nm (wavelengths where response is greater than 50% of maximum)
Directional (Cosine) Response	± 5% at 75° angle
Temperature Response	0.06 ± 0.06 % per C
Operating Environment	0 to 50°C; less than 90% non-condensing relative humidity up to 30°C; less than 70% non-condensing relative humidity from 30 to 50°C; separate sensors can be submerged in water up to depths of 30m
Meter Dimensions	113. mm height, 59.9mm width
Sensor Dimensions	500 mm length, 15 mm width, 15 mm height
Mass	300g
Cable	2m of shielded, twisted-pair wire; additional

	cable available; TPR jacket (high water resistance, high UV stability, flexibility in cold conditions)

3.2.2 Light Intensity

3.2.2.1 HTC LX-103 Digital Lux Meter (Lux meter)

Plate 3.5 Lux meter

Table 3.5 Specification of lux meter

Manufacturer	HTC
Model No	HTC LX-103
Measuring Parameters	Light
Range	0 to 2,00,000 Lux
Accuracy	+3%
Resolution	0.01 Lux/0.01FC
Data Hold	Yes
Auto Power Off	Yes

Calibration	Provided along with and valid for 1 year, traceable to National Standards.
Accessories	Battery, Carry Case & Manual
Dimension	170 x 89 x 43 mm
Weight	350 g

3.2.3 Wet and dry bulb temperature

3.2.3.1 Zeal Masons Pattern Hygrometer P2505

Plate 3.6 Hygrometer

Specification:

Red Spirit -5/+50°C & +20/+120°F

3.2.4 Relative Humidity

Relative humidity is found by substracting the temperature on the wet-bulb thermometer from the temperature on the dry-bulb thermometer and using a relative humidity chart.

3.3 DATA COLLECTION

Following microclimatic parameters were recorded from old polyhouse, new polyhouse, cleaned and uncleaned rainshelter.

3.3.1 Temperature (℃)

Dry and wet air temperature inside the old polyhouse, new polyhouse, cleaned and uncleaned rainshelter and from outside were recorded daily at 10:00 am, 12:00 pm, 2:00 pm and 4:00 pm using thermo hygrometer.

3.3.2 Light Intensity (lux)

Maximum and minimum light intensity of both inside and outside of old polyhouse, new polyhouse, cleaned and uncleaned rainshelter were recorded daily at 10:00 am, 12:00 pm, 2:00 pm and 4:00 pm by using Lux meter.

3.3.3 PAR (µmol m^{-2} s^{-1})

Photosynthetically active radiation of both inside and outside of old polyhouse, new polyhouse, cleaned and uncleaned rainshelter were recorded daily at 10:00 am, 12:00 pm, 2:00 pm and 4:00 pm by using PAR sensor.

3.3.4 Relative Humidity (%)

Relative humidity of both inside and outside of old polyhouse, new polyhouse, cleaned and uncleaned rainshelter were computed from the readings of thermo hygrometer daily at 10:00 am, 12:00 pm, 2:00 pm and 4:00 pm.

3.4 STATISTICAL ANALYSIS OF DATA

The data related to microclimate were tabulated and analyzed using completely randomized design.

RESULTS AND DISCUSSION

CHAPTER IV

RESULTS AND DISCUSSION

A thorough comprehension of microclimate characteristics is necessary for greenhouse production that is sustainable. The plant micro climate influences both crop quality and yield. That is, crop yield and timing are significantly influenced by temperature; similarly, crop yield is influenced by light intensity and relative humidity. If a crop is growing successfully, it must be inexpensive and productive to grow in that specific microclimate.

The observed microclimatic parameters viz.wet and dry bulb temperature, relative humidity, light intensity during the course of experiment is presented and discussed below.

4.1 MICROCLIMATE ANALYSIS OF DIFFERENT PROTECTED STRUTURES

4.1.1 Light Intensity

Light intensity is a crucial element for plant growth because it controls numerous events on plant development. Maximum light intensity was recorded outside the greenhouse condition (84500 lux) during afternoon while minimum light intensity (4300 lux) was recorded inside the rainshelter which was not been cleaned. From the Fig 4.1, 4.2, 4.3 and 4.4, it was clear that minimum light intensity was recorded always under uncleaned rainshelter because of the deposition of dust and algae on cladding material. Around 14580 lux variation was observed between cleaned and uncleaned greenhouse similarly 7835 lux variation between old and new polyhouse. The variation of light intensity at different time in old polyhouse, new polyhouse, cleaned and uncleaned rainshelter is shown below.

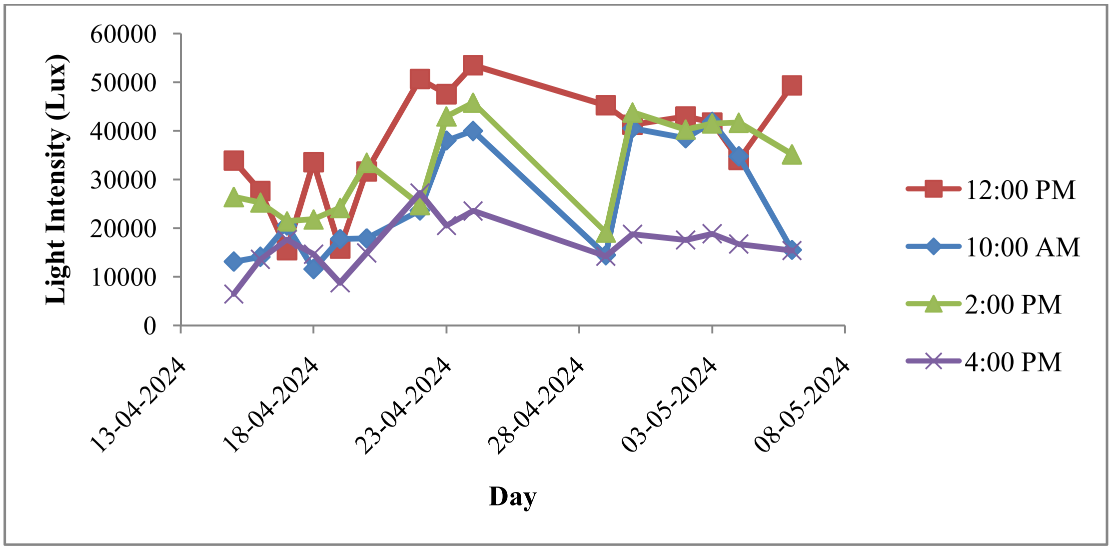

Fig. 4.1 Variation of light intensity at different time in old polyhouse

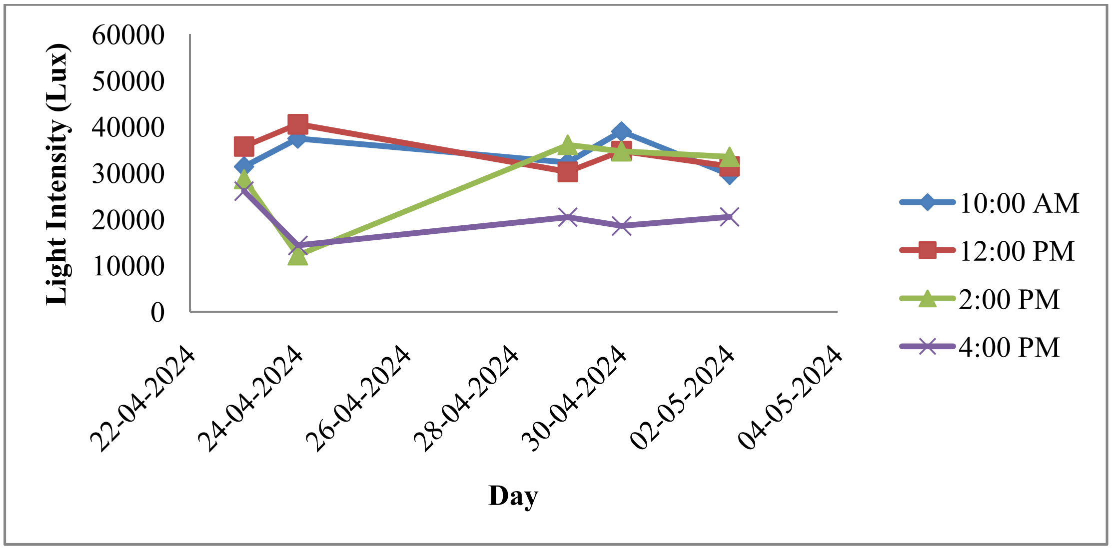

Fig. 4.2 Variation of light intensity at different time in new polyhouse

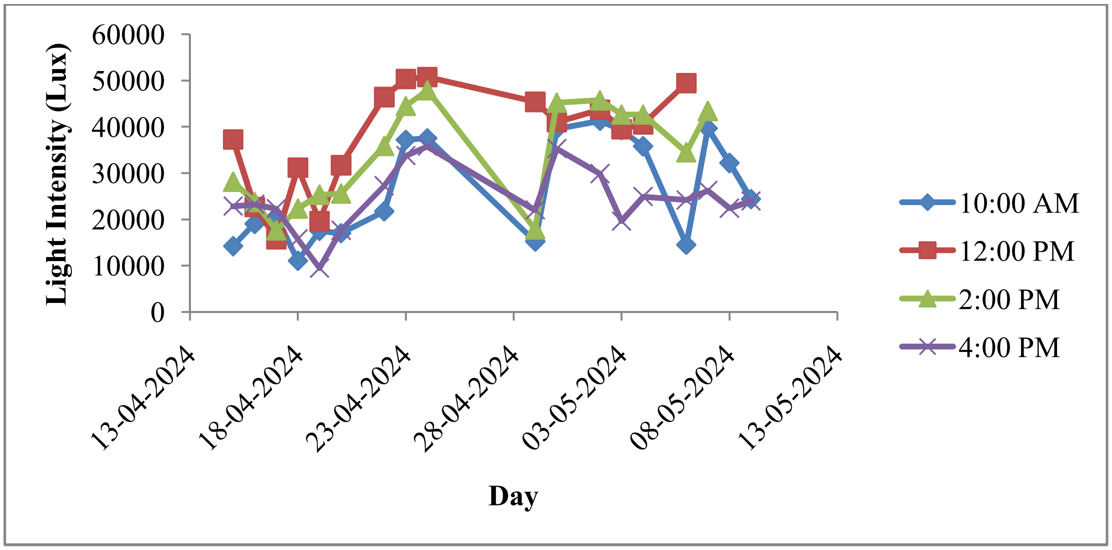

Fig. 4.3 Variation of light intensity at different time in cleaned rainshelter

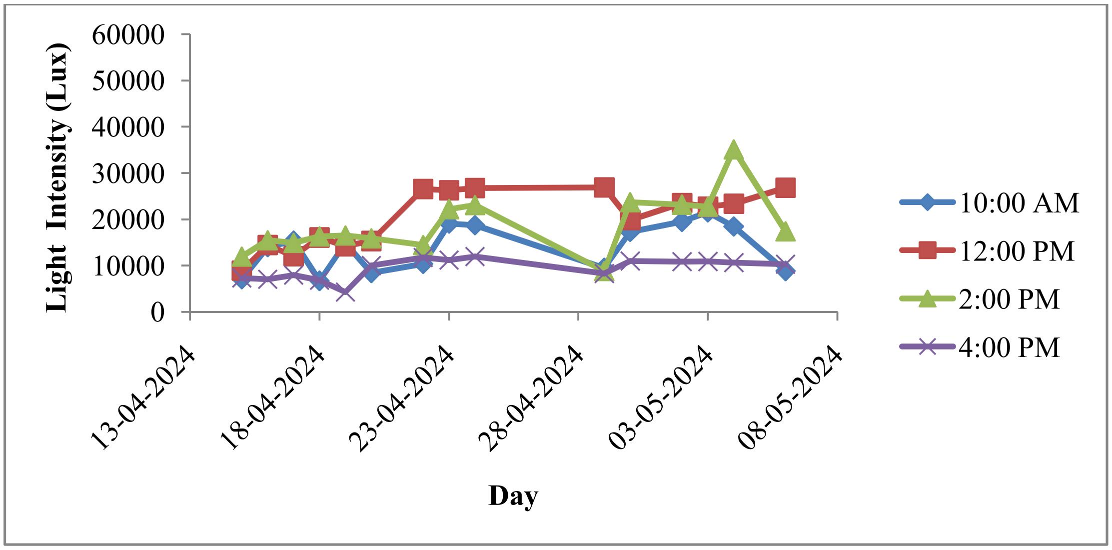

Fig. 4.4 Variation of light intensity at different time in uncleaned rainshelter

4.1.2 Photosynthetically active radiation

Along with light intensity, photosynthetically active radiation plays a vital role in crop growth and development. Adequate PAR exposure ensures the photosynthesis process. It affects critical growth parameters such as leaf size, stem length and overall biomass. Maximum PAR (1214.5 µmol m^{-2} s^{-1}) was recorded at 12 pm in old cleaned polyhouse and minimum PAR (123 µmol m^{-2} s^{-1}) was recorded at 4 pm in uncleaned rainshelter. The variation of PAR at different time in old polyhouse, new polyhouse, cleaned and uncleaned rainshelter was shown in below in Fig. 4.5, 4.6, 4.7 and 4.8.

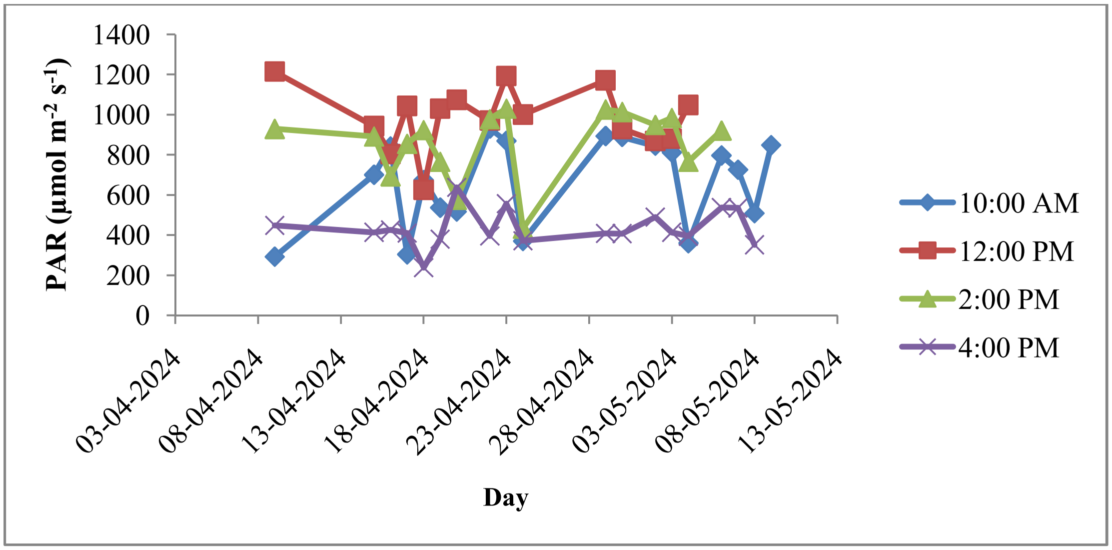

Fig. 4.5 Variation of PAR at different time in old polyhouse

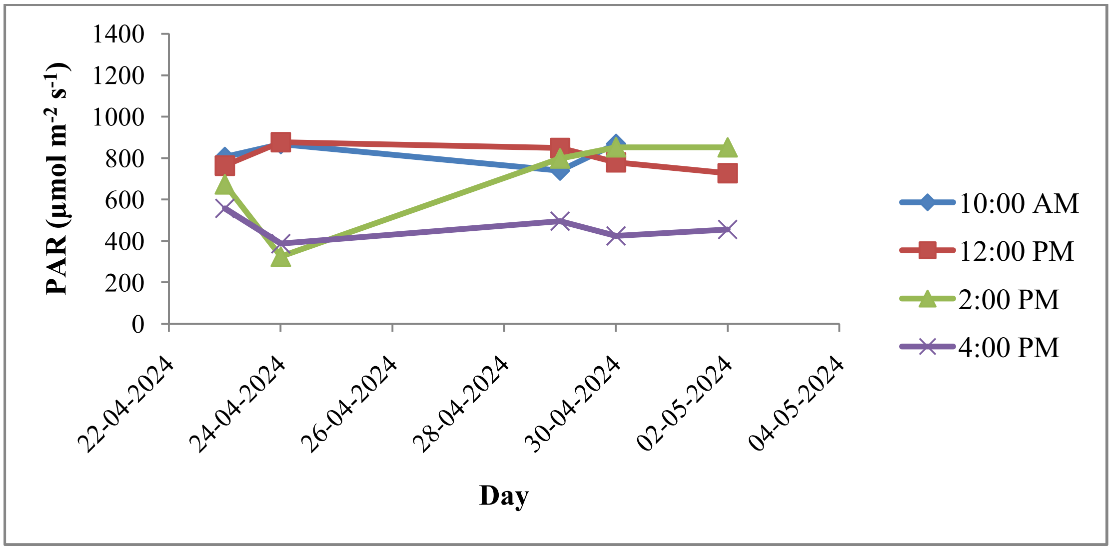

Fig. 4.6 Variation of PAR at different time in new polyhouse

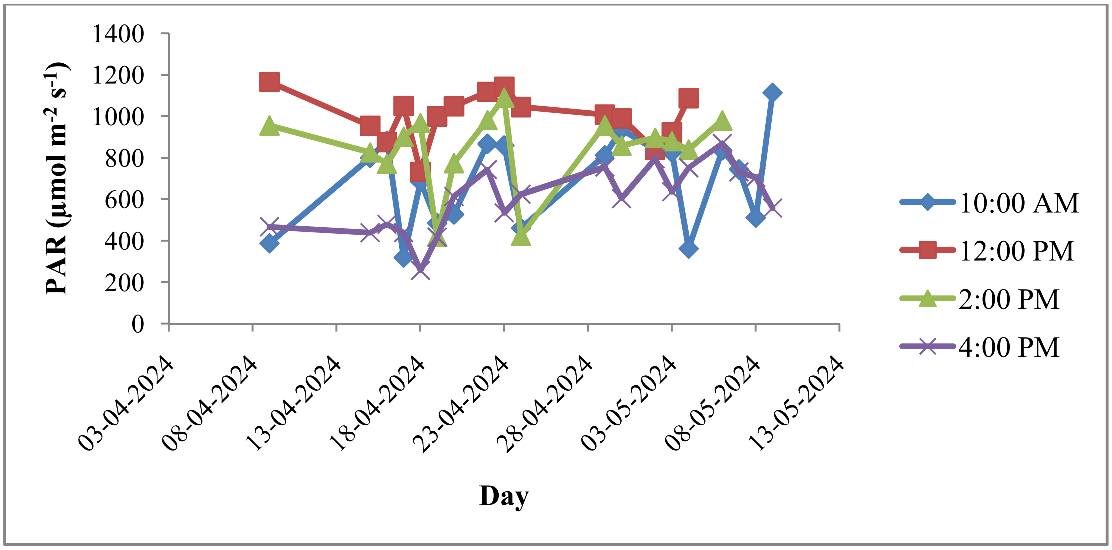

Fig. 4.7 Variation of PAR at different time in cleaned rainshelter

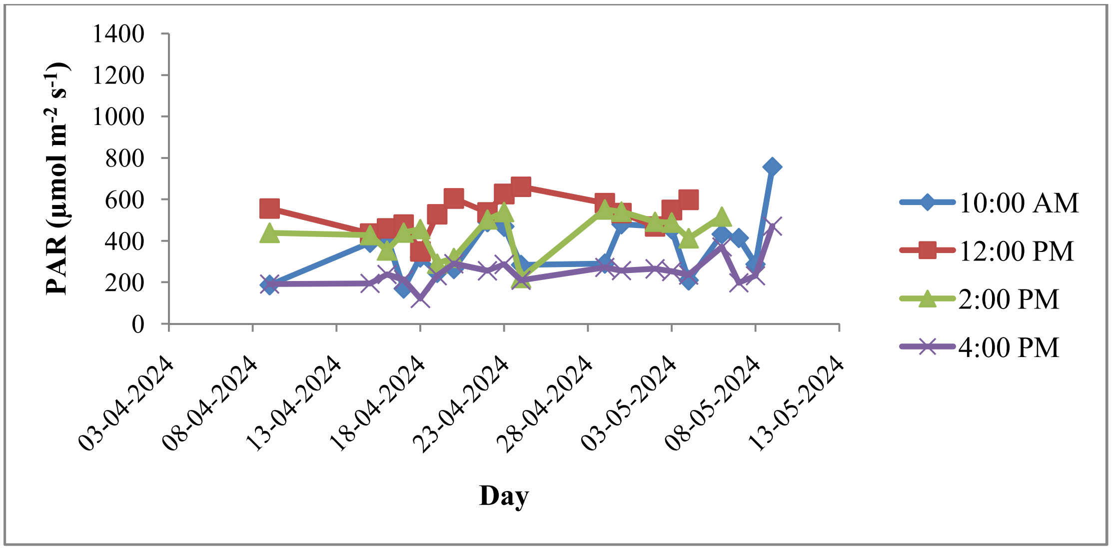

Fig. 4.8 Variation of PAR at different time in uncleaned rainshelter

4.1.3 Dry bulb temperature

The dry bulb temperature of old polyhouse, new polyhouse, cleaned and uncleaned rainshelter is shown in Fig. 4.9, 4.10, 4.11 and 4.12. The maximum temperature (42.5°C) was recorded at 12 pm under cleaned polyhouse and minimum temperature (34°C) at 4 pm under rainshelter without cleaning. Temperature inside the new polyhouse was lower than the old cleaned polyhouse due to heat dissipation because of greater height than old polyhouse. The transparency of cladding material was lost due to aging and deposition of algae which results in decrease in temperature inside the protected structures.

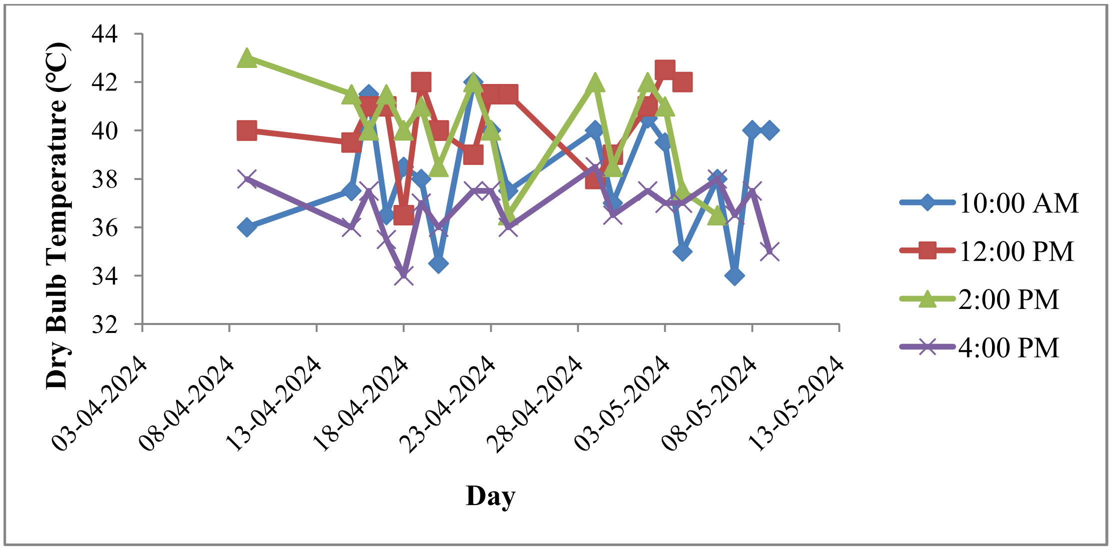

Fig. 4.9 Variation of DBT at different time in old polyhouse

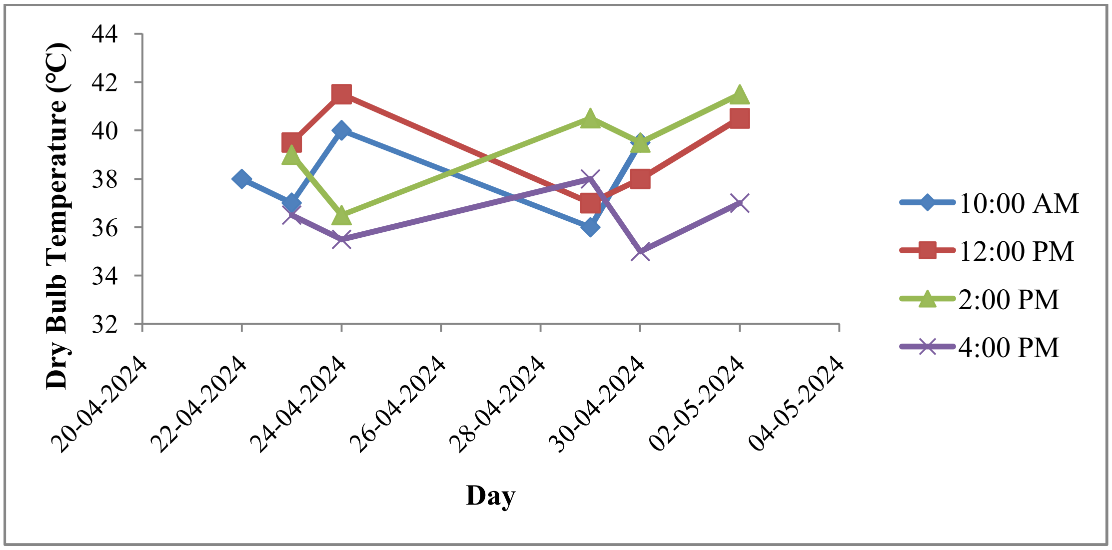

Fig. 4.10 Variation of DBT at different time in new polyhouse

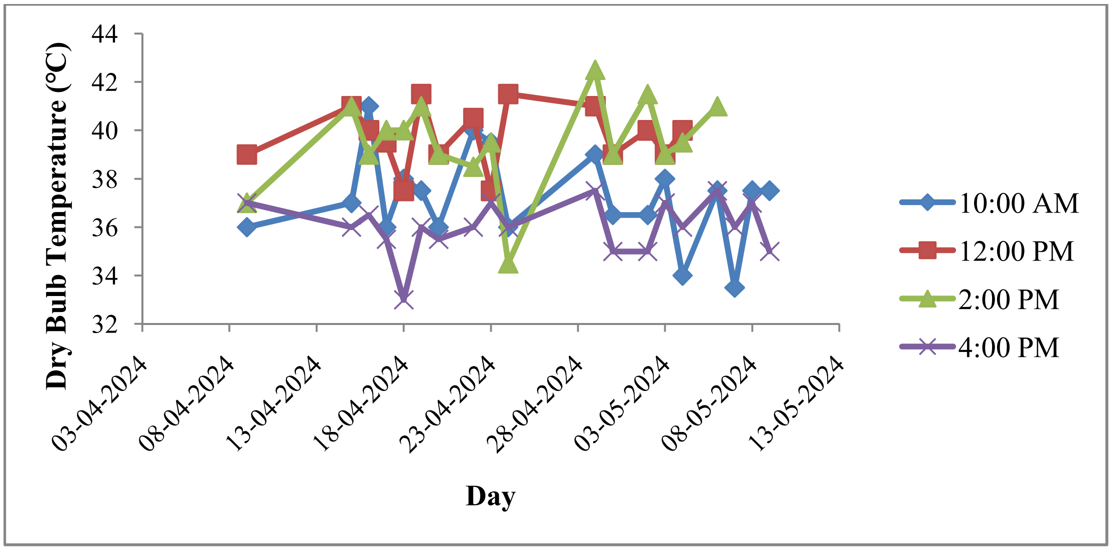

Fig. 4.11 Variation of DBT at different time in cleaned rainshelter

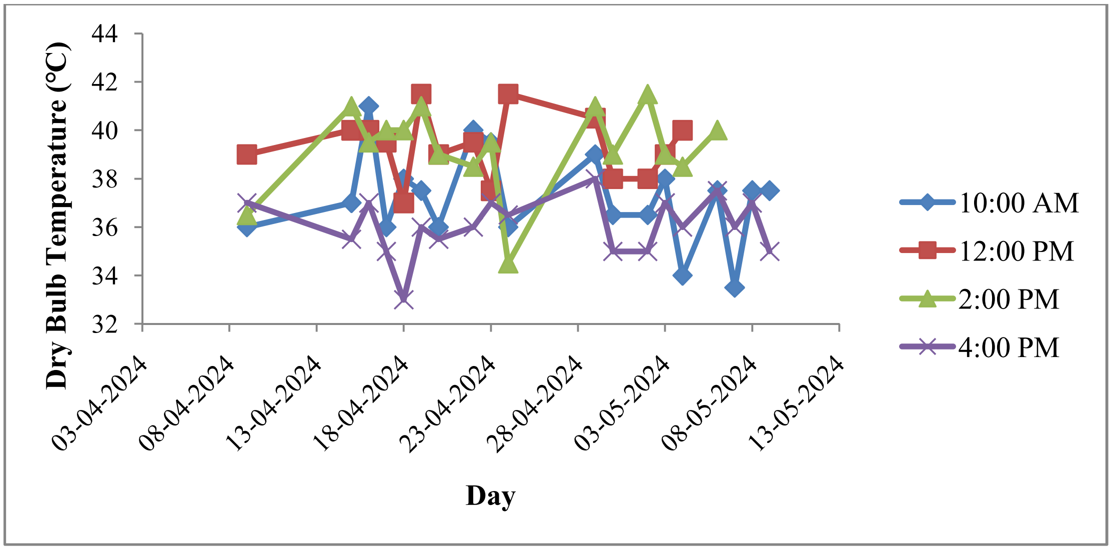

Fig. 4.12 Variation of DBT at different time in uncleaned rainshelter

4.1.4 Wet bulb temperature

The wet bulb temperature of old and new polyhouse and cleaned and uncleaned rainshelter is shown in Fig. 4.13, 4.14, 4.15 and 4.16. The maximum temperature (31°C) was recorded at 12 pm under cleaned polyhouse and minimum temperature (26°C) at 4 pm under rainshelter without cleaning. Temperature inside the new polyhouse was lower than the old cleaned polyhouse due to heat dissipation because of greater height than old polyhouse. The transparency of cladding material was lost due to aging and deposition of algae which results in decrease in temperature inside the protected structures.

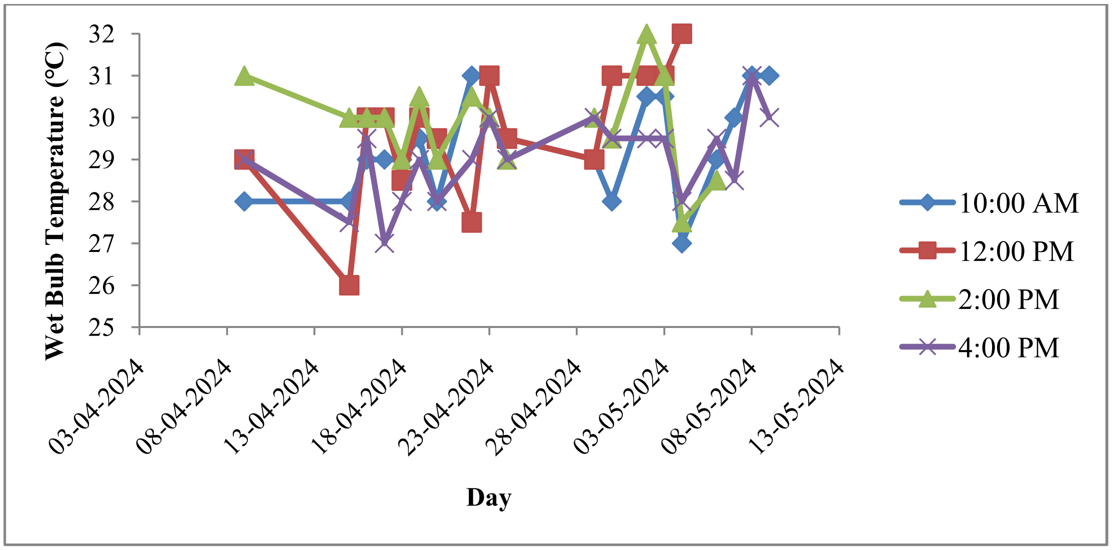

Fig. 4.13 Variation of WBT at different time in old polyhouse

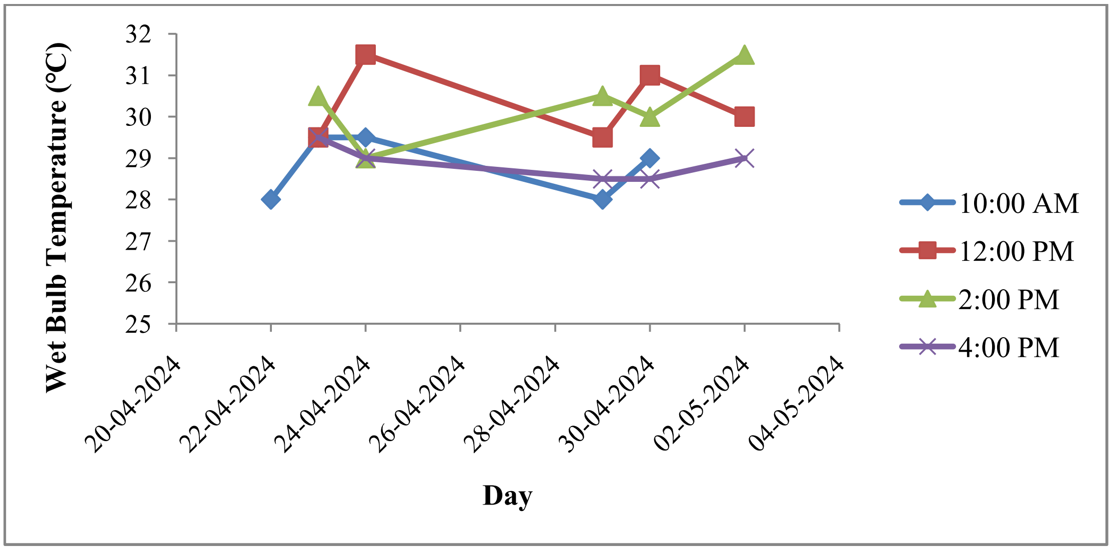

Fig. 4.14 Variation of WBT at different time in new polyhouse

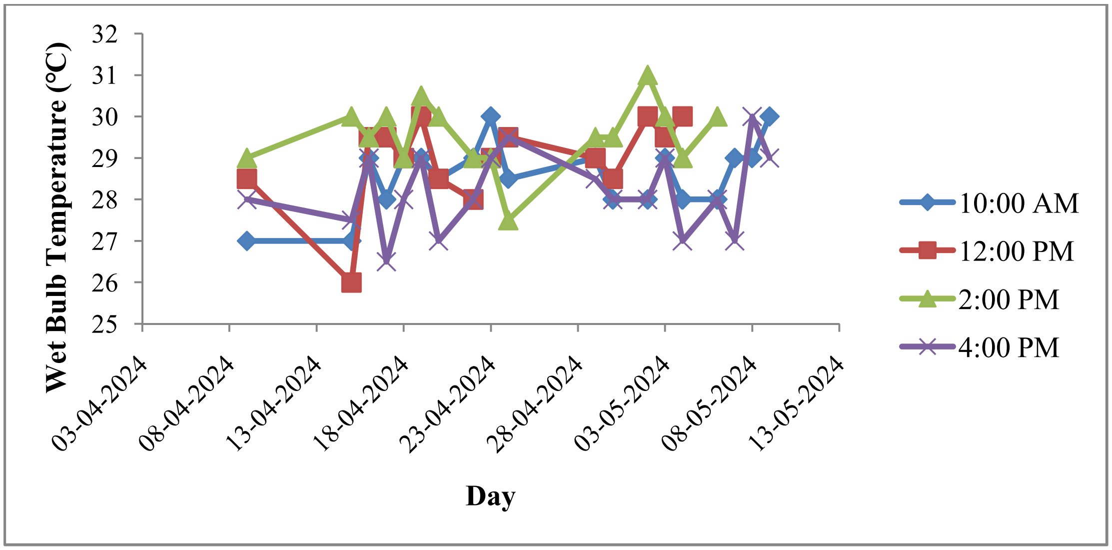

Fig. 4.15 Variation of WBT at different time in cleaned rainshelter

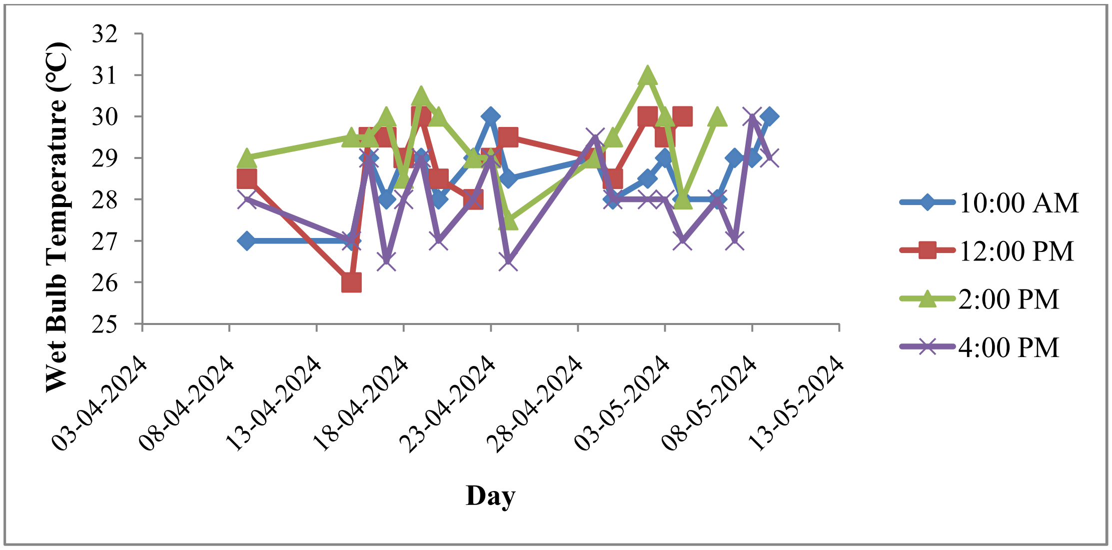

Fig. 4.16 Variation of WBT at different time in uncleaned rainshelter

4.1.5 Relative humidity

Along with temperature, relative humidity also plays a vital role in crop growth and production. The plant leaves control the transpiration which strongly influences the relative humidity. This limitation has its influence on incidence of pest and disease infestation. Maximum relative humidity (74.5%) was reported at 4 pm at old polyhouse while lowest humidity (40.8%) was reported at 12 pm in uncleaned rainshelter. The variation of relative humidity at different time in old polyhouse, new polyhouse, cleaned and uncleaned rainshelter is shown in Fig. 4.17, 4.18, 4.19 and 4.20.

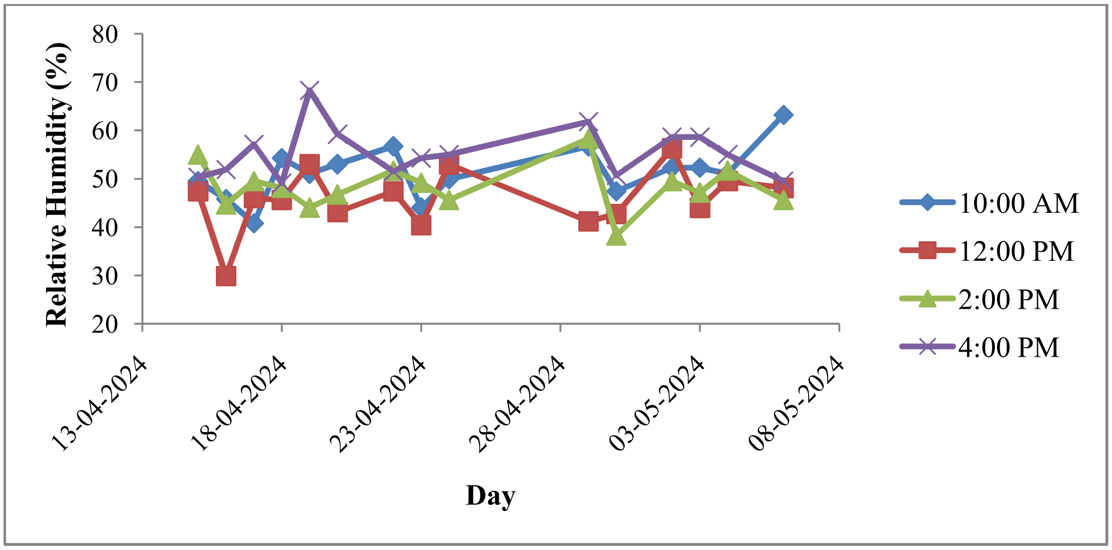

Fig. 4.17 Variation of relative humidity at different time in old polyhouse

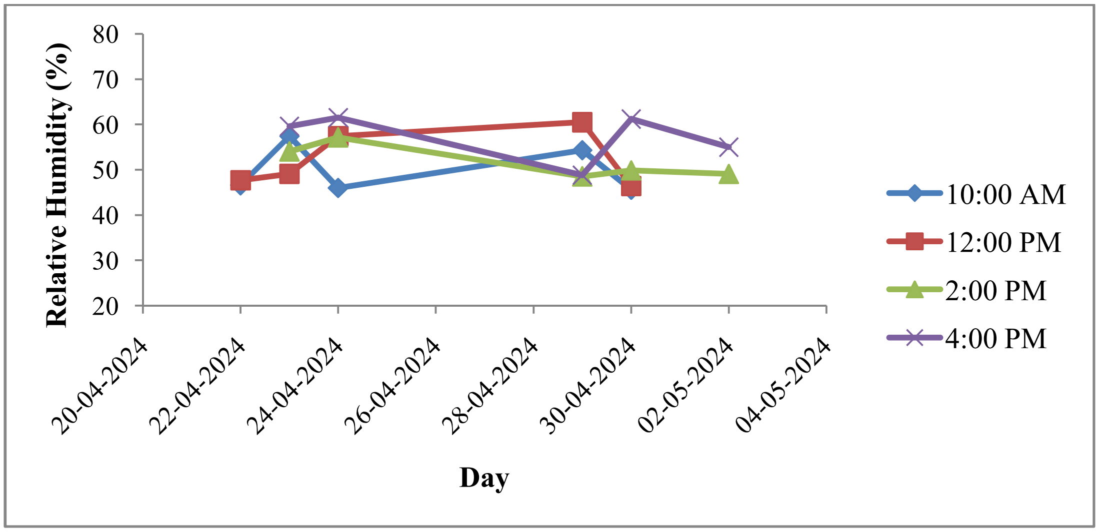

Fig. 4.18 Variation of relative humidity at different time in new polyhouse

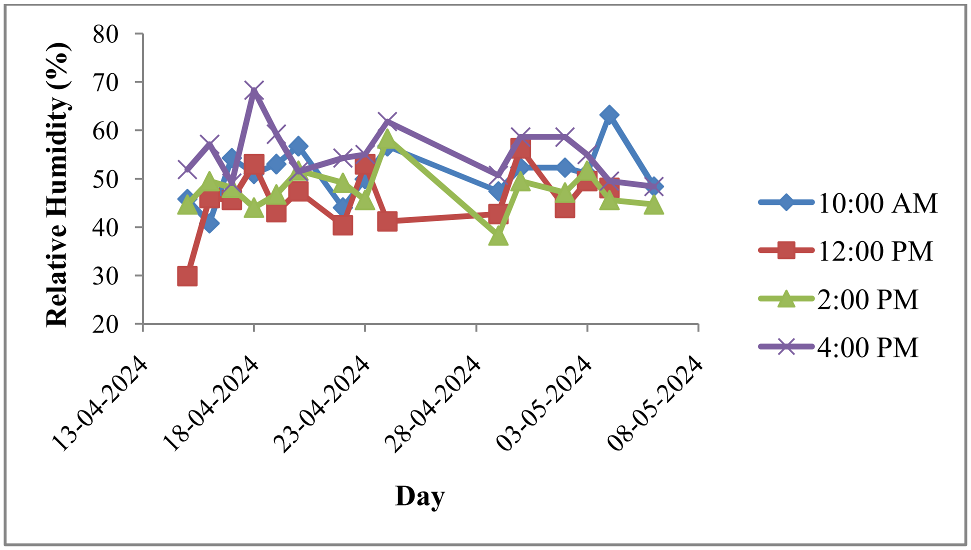

Fig. 4.19 Variation of relative humidity at different time in cleaned rainshelter

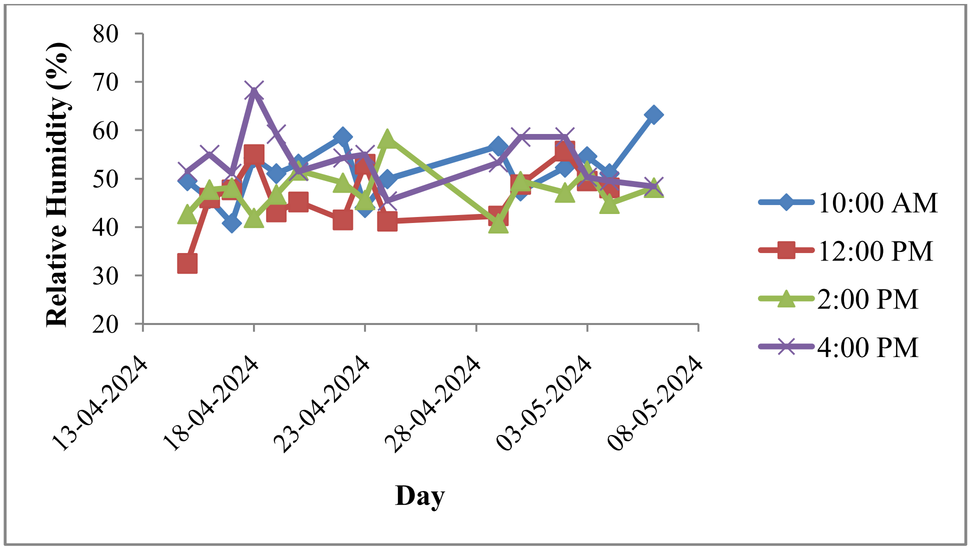

Fig. 4.20 Variation of relative humidity at different time in uncleaned rainshelter

4.2 CORRELATION BETWEEN DIFFERENT MICROCLIMATIC PARAMETERS

4.2.1 Relationship Between PAR and Light Intensity in Different Protected Structure

Table 4.1 Regression coefficient and equation of PAR and Light Intensity in different protected structures.

		PAR and Light Intensity				
Protected Structures	Regression equation / R^2	Power	Polynomial	Logarithmic	Linear	Exponential
Cleaned Rainshelter	Equation	$y = 0.884x^{0.655}$	$y = -1E-07x^2 + 0.021x + 215.2$	$y = 428.6\ln(x) - 3622.$	$y = 0.015x + 303.0$	$y = 366.6e^{2E-05x}$
	R^2	$R^2 = 0.578$	$R^2 = 0.557$	$R^2 = 0.564$	$R^2 = 0.555$	$R^2 = 0.529$
Uncleaned Rainshelter	Equation	$y = 0.164x^{0.803}$	$y = -4E-07x^2 + 0.033x - 14.61$	$y = 280.5\ln(x) - 2297.$	$y = 0.018x + 99.78$	$y = 163.5e^{5E-05x}$
	R^2	$R^2 = 0.81$	$R^2 = 0.783$	$R^2 = 0.772$	$R^2 = 0.756$	$R^2 = 0.726$
Old Polyhouse	Equation	$y = 0.368x^{0.739}$	$y = -2E-07x^2 + 0.032x + 31.87$	$y = 470.4\ln(x) - 4050$	$y = 0.018x + 198.3$	$y = 299.2e^{3E-05x}$
	R^2	$R^2 = 0.723$	$R^2 = 0.738$	$R^2 = 0.718$	$R^2 = 0.726$	$R^2 = 0.697$
New Polyhouse	Equation	$y = 0.071x^{0.892}$	$y = -2E-07x^2 + 0.030x - 42.11$	$y = 514.7\ln(x) - 4583.$	$y = 0.021x + 62.16$	$y = 227.2e^{4E-05x}$
	R^2	$R^2 = 0.945$	$R^2 = 0.922$	$R^2 = 0.906$	$R^2 = 0.919$	$R^2 = 0.927$

The regression coefficients between PAR and Light Intensity were ranged from 0.529 to 0.945 in different protected structures. The positive correlation coefficients indicate a positive relationship between PAR and Light Intensity values. As light intensity changes PAR also changes. The relationship between PAR and light intensity in different protected structures are shown in Table 4.1.

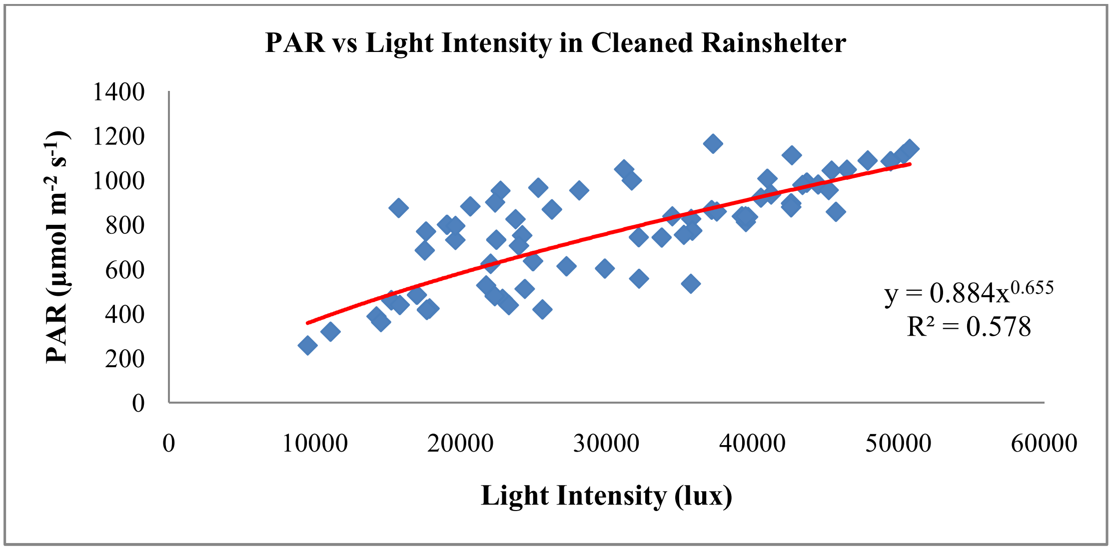

Fig. 4.21 Regression between PAR and Light Intensity in cleaned rainshelter

The regression coefficients between PAR and Light Intensity were ranged from 0.529 to 0.578 in cleaned rainshelter (Fig. 4.21). For rainshelter the line of best fit is with power trend line, as one variable varies as a power of another and the R^2 value is 0.578.

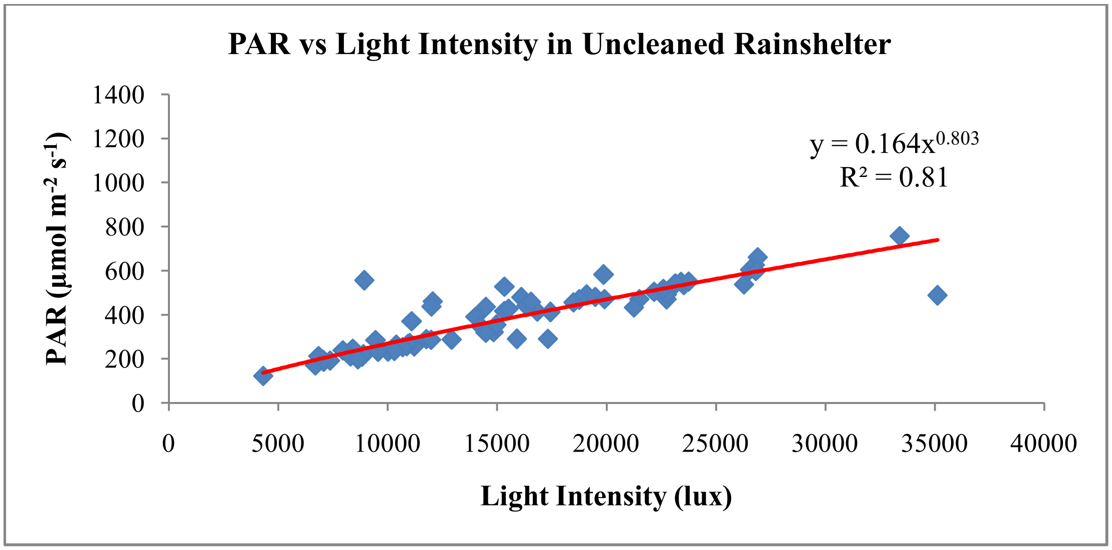

Fig. 4.22 Regression between PAR and Light Intensity in uncleaned rainshelter

The regression coefficients between PAR and Light Intensity were ranged from 0.726 to 0.81 in uncleaned rainshelter (Fig. 4.22). For this rainshelter, the line of best fit is with power trend line, as one variable varies as a power of another and the R² value is 0.81.

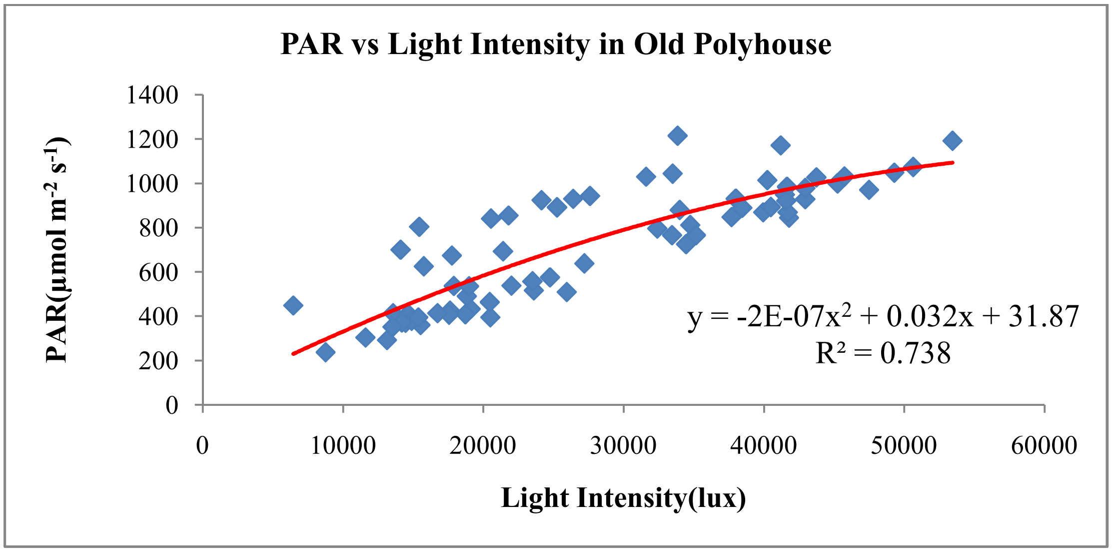

Fig. 4.23 Regression between PAR and Light Intensity in old polyhouse

The regression coefficients between PAR and Light Intensity were ranged from 0.697 to 0.738 in old polyhouse (Fig. 4.23). For this polyhouse the line of best fit is with polynomial trend line, as one variable varies as polynomially to another variable and the R² value is 0.738.

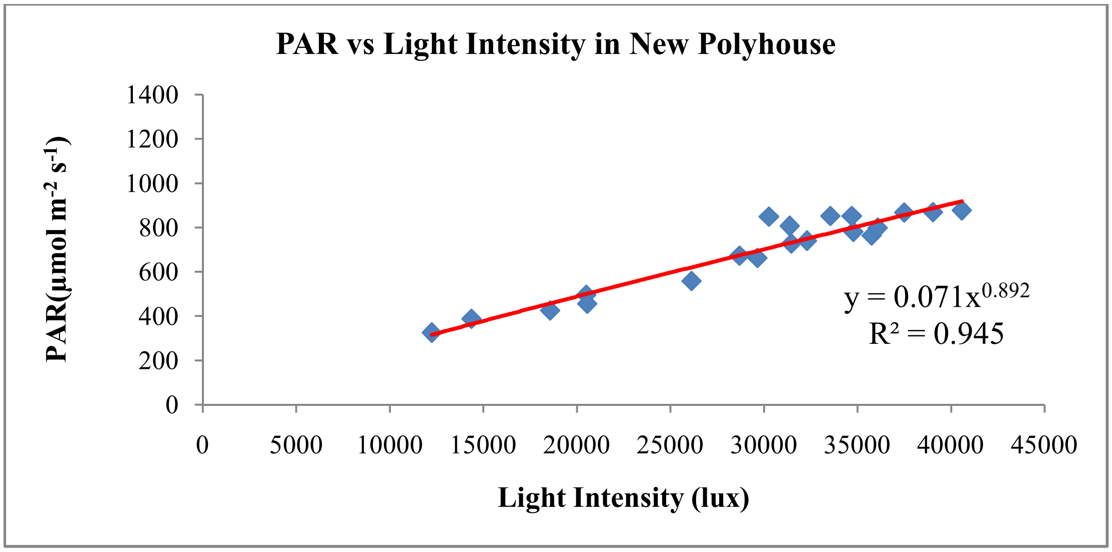

Fig. 4.24 Regression between PAR and Light Intensity in new polyhouse

The regression coefficients between PAR and Light Intensity were ranged from 0.906 to 0.945 in new polyhouse (Fig. 4.24). For this polyhouse the line of best fit is with power trend line, as one variable varies as power to another variable and the R² value is 0.945.

4.2.2 Relationship Between DBT and PAR in Different Protected Structures

The regression coefficients between DBT and PAR are ranged from 0.320 to 0.539 in different protected structures. The positive correlation coefficients indicate a positive relationship between DBT and PAR values. As DBT variable changes correspondingly PAR variable changes. The relationships between DBT and PAR in different protected structures are shown in Table 4.2.

Table 4.2 Regression coefficient and equation of DBT and PAR in different protected structures.

DBT and PAR in different protected structures						
Protected Structures	Regression equation/ R^2	Power	Polynomial	Logarithmic	Linear	Exponential
Cleaned Rainshelter	Equation	$y = 18.38x^{0.109}$	$y = -1E-06x^2 + 0.008x + 32.46$	$y = 4.108\ln(x) + 10.87$	$y = 0.006x + 33.13$	$y = 33.32e^{0.000x}$
	R^2	$R^2 = 0.43$	$R^2 = 0.431$	$R^2 = 0.421$	$R^2 = 0.430$	$R^2 = 0.436$
Uncleaned Rainshelter	Equation	$y = 21.87x^{0.092}$	$y = -2E-05x^2 + 0.028x + 30.90$	$y = 3.475\ln(x) + 17.35$	$y = 0.009x + 34.22$	$y = 34.31e^{0.000x}$
	R^2	$R^2 = 0.441$	$R^2 = 0.454$	$R^2 = 0.438$	$R^2 = 0.396$	$R^2 = 0.397$
Old Polyhouse	Equation	$y = 19.36x^{0.106}$	$y = -4E-06x^2 + 0.012x + 32.35$	$y = 4.094\ln(x) + 12.09$	$y = 0.006x + 34.11$	$y = 34.30e^{0.000x}$
	R^2	$R^2 = 0.531$	$R^2 = 0.539$	$R^2 = 0.531$	$R^2 = 0.528$	$R^2 = 0.527$
New Polyhouse	Equation	$y = 20.24x^{0.098}$	$y = -2E-05x^2 + 0.031x + 26.95$	$y = 3.730\ln(x) + 14.07$	$y = 0.006x + 34.08$	$y = 34.24e^{0.000x}$
	R^2	$R^2 = 0.343$	$R^2 = 0.379$	$R^2 = 0.339$	$R^2 = 0.317$	$R^2 = 0.320$

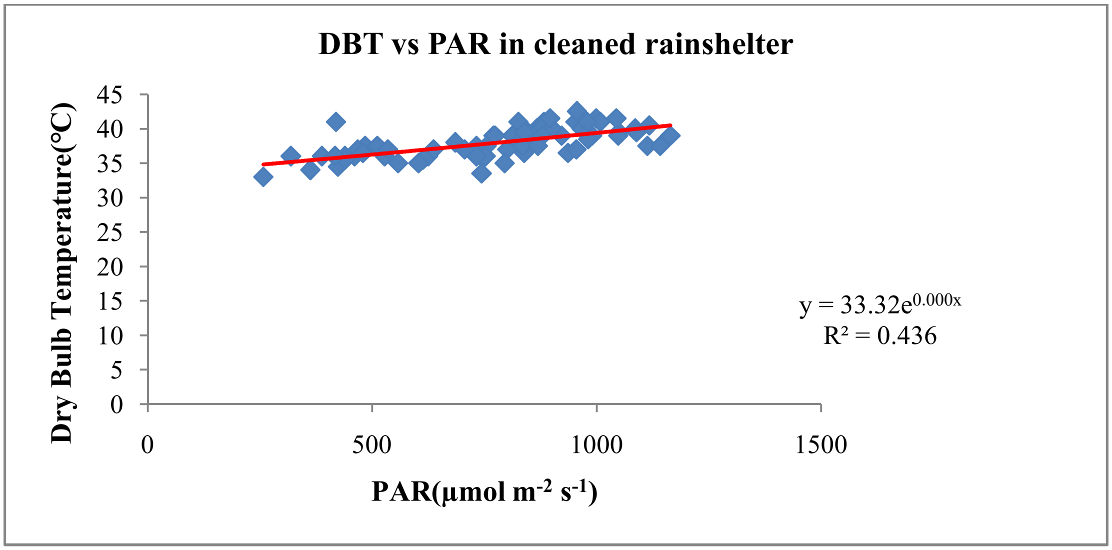

Fig. 4.25 Regression between DBT and PAR in cleaned rainshelter

The regression coefficients between DBT and PAR were ranged from 0.421 to 0.436 in cleaned rainshelter (Fig. 4.25). For this rainsheltr the line of best fit is with exponential trend line, as one variable varies as exponentially to another variable and the R^2 value is 0.436.

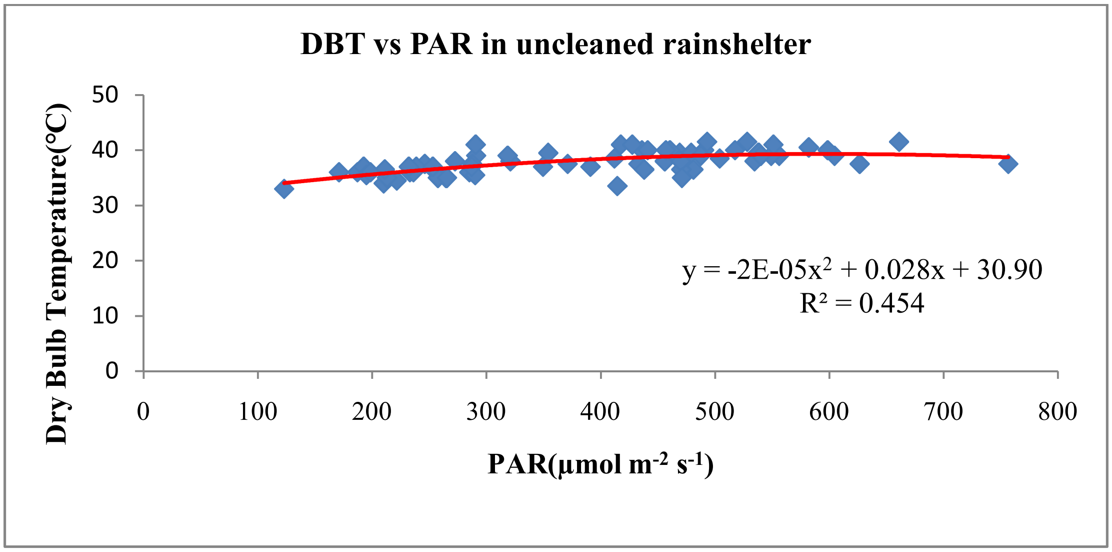

Fig. 4.26 Regression between DBT and PAR in uncleaned rainshelter

The regression coefficients between DBT and PAR were ranged from 0.397 to 0.454 in uncleaned rainshelter (Fig. 4.26). For this rainsheltr the line of best fit is with polynomial trend line, as one variable varies as polynomially to another variable and the R² value is 0.454.

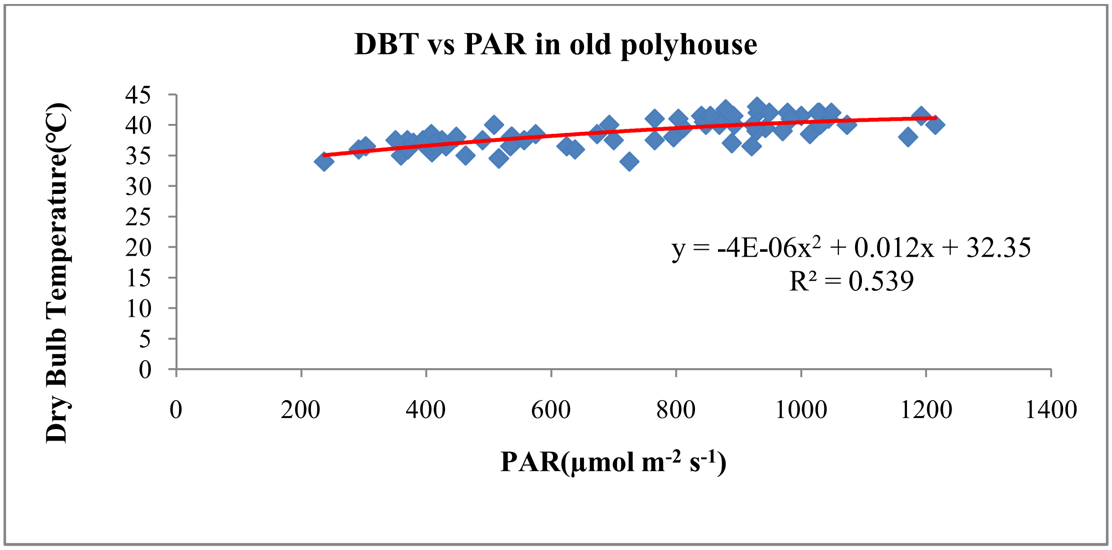

Fig. 4.27 Regression between DBT and PAR in old polyhouse

The regression coefficients between DBT and PAR were ranged from 0.527 to 0.539 in old polyhouse (Fig. 4.27). For this polyhouse the line of best fit is with polynomial trend line, as one variable varies as polynomially to another variable and the R² value is 0.539.

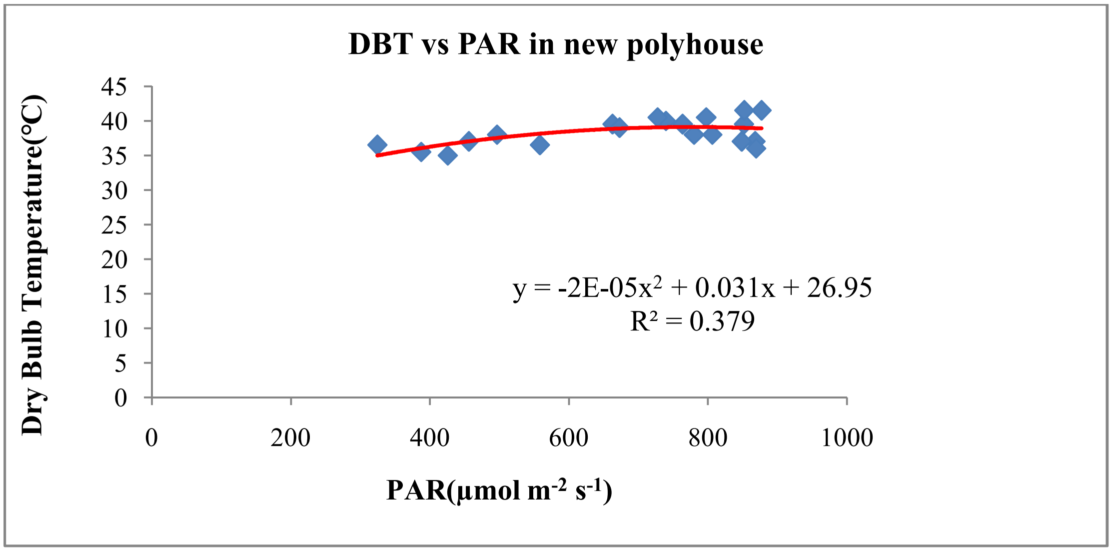

Fig. 4.28 Regression between DBT and PAR in new polyhouse

The regression coefficients between DBT and PAR were ranged from 0.317 to 0.379 in new polyhouse (Fig. 4.28). For this polyhouse the line of best fit is with polynomial trend line, as one variable varies as polynomially to another variable and the R^2 value is 0.379.

4.2.3 Relationship Between DBT and Light Intensity in Different Protected Structures

The regression coefficients between DBT and light intensity were ranged from 0.243 to 0.395 in different protected structures. The positive correlation coefficients indicate a positive relationship between DBT and light intensity values. As DBT variable changes correspondingly light intensity variable changes. The relationship between DBT and light intensity in different protected structures are shown in Table 4.3.

Table 4.3 Regression coefficient and equation of DBT and Light Intensity in different protected structures.

DBT and Light Intensity in different protected structures						
Protected Structures	Regression Equation/R^2	Power	Polynomial	Logarithmic	Linear	Exponential
Cleaned Rainshelter	Equation	$y = 17.89x^{0.073}$	$y = -9E\text{-}10x^2 + 0.000x + 34.23$	$y = 2.741\ln(x) + 9.869$	$y = 1E\text{-}04x + 35.00$	$y = 35.02e^{3E\text{-}06x}$
	R^2	$R^2 = 0.257$	$R^2 = 0.246$	$R^2 = 0.252$	$R^2 = 0.243$	$R^2 = 0.247$
Uncleaned Rainshelter	Equation	$y = 18.40x^{0.075}$	$y = -1E\text{-}08x^2 + 0.000x + 31.81$	$y = 2.807\ln(x) + 10.93$	$y = 0.000x + 35.21$	$y = 35.22e^{4E\text{-}06x}$
	R^2	$R^2 = 0.362$	$R^2 = 0.395$	$R^2 = 0.358$	$R^2 = 0.286$	$R^2 = 0.288$
Old Polyhouse	Equation	$y = 18.49x^{0.072}$	$y = -2E\text{-}09x^2 + 0.000x + 34.17$	$y = 2.805\ln(x) + 10.27$	$y = 0.000x + 35.65$	$y = 35.70e^{3E\text{-}06x}$
	R^2	$R^2 = 0.328$	$R^2 = 0.335$	$R^2 = 0.329$	$R^2 = 0.323$	$R^2 = 0.321$
New Polyhouse	Equation	$y = 14.97x^{0.091}$	$y = -4E\text{-}09x^2 + 0.000x + 31.61$	$y = 3.487\ln(x) + 2.585$	$y = 0.000x + 34.12$	$y = 34.28e^{4E\text{-}06x}$
	R^2	$R^2 = 0.356$	$R^2 = 0.362$	$R^2 = 0.352$	$R^2 = 0.346$	$R^2 = 0.348$

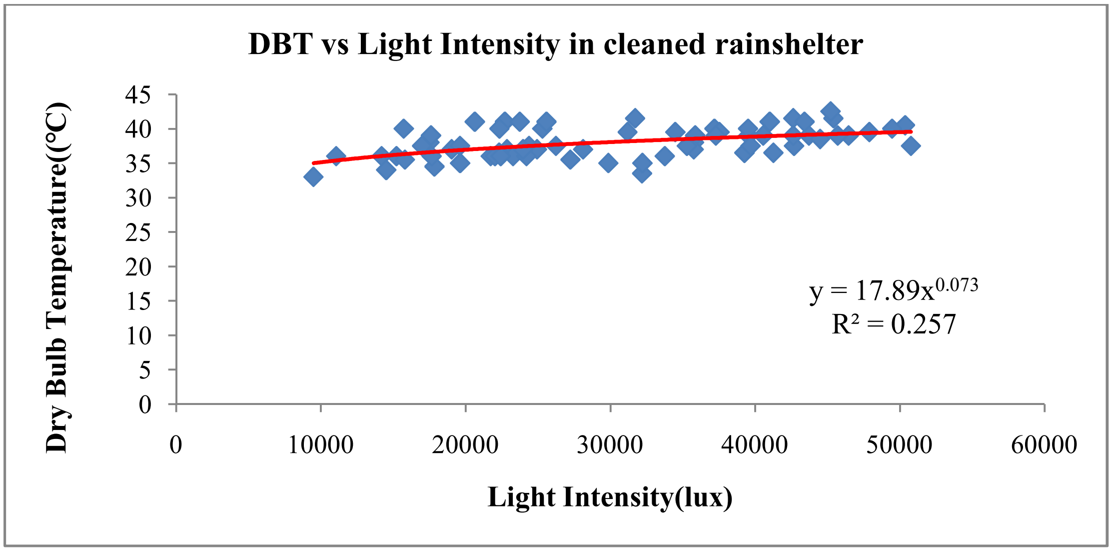

Fig. 4.29 Regression between DBT and Light intensity in cleaned rainshelter

The regression coefficients between DBT and light intensity were ranged from 0.243 to 0.257 in cleaned rainshelter (Fig. 4.29). For this rainshelter the line of best fit is with power trend line, as one variable varies as power to another variable and the R^2 value is 0.257.

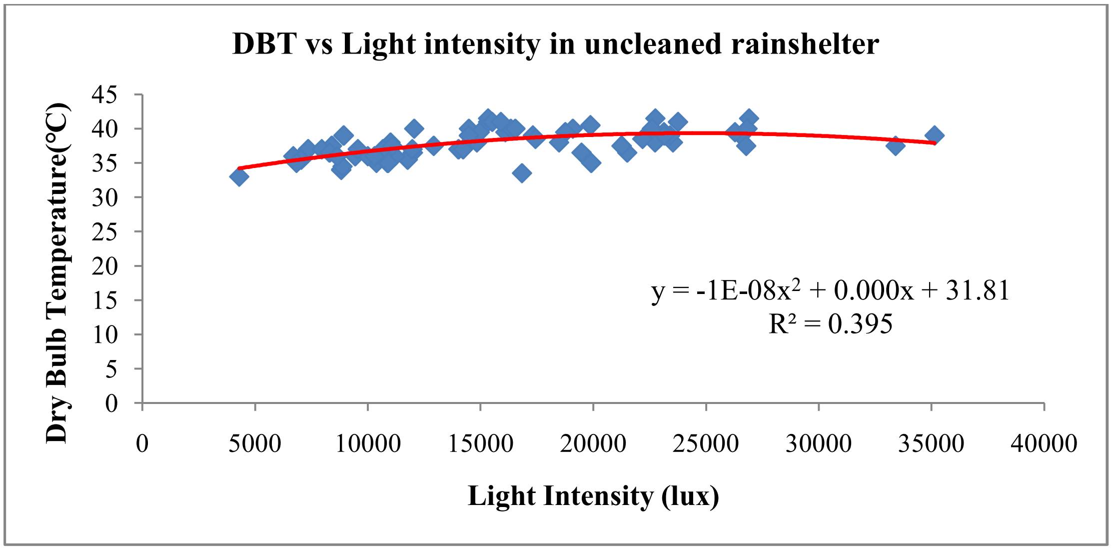

Fig. 4.30 Regression between DBT and Light intensity in uncleaned rainshelter

The regression coefficients between DBT and light intensity were ranged from 0.286 to 0.395 in uncleaned rainshelter (Fig. 4.30). For this rainshelter the line of best fit is with polynomial trend line, as one variable varies as polynomially to another variable and the R² value is 0.395.

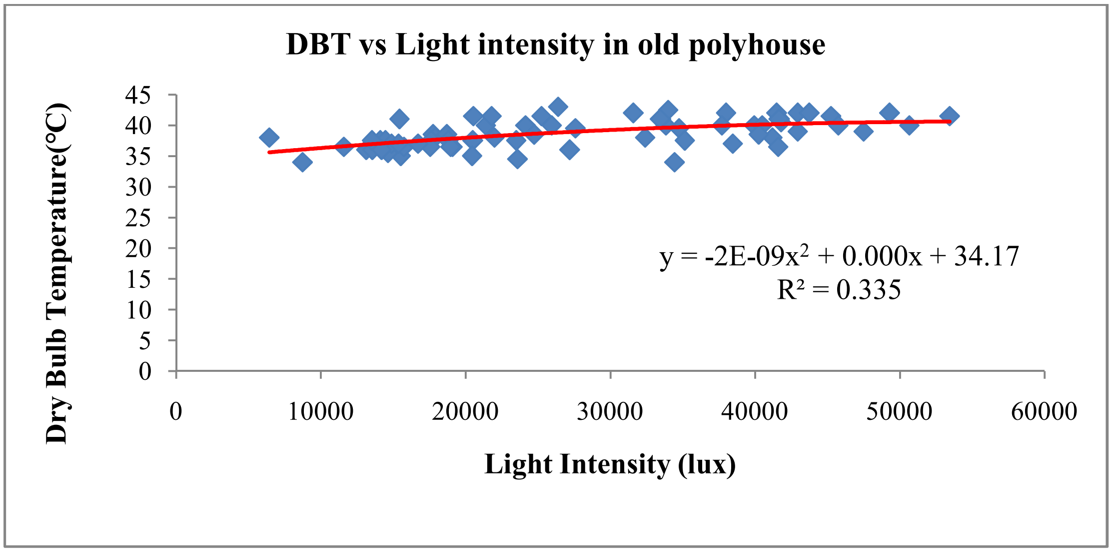

Fig. 4.31 Regression between DBT and Light intensity in old polyhouse

The regression coefficients between DBT and light intensity were ranged from 0.328 to 0.335 in old polyhouse (Fig. 4.31). For this polyhouse the line of best fit is with polynomial trend line, as one variable varies as polynomially to another variable and the R² value is 0.335.

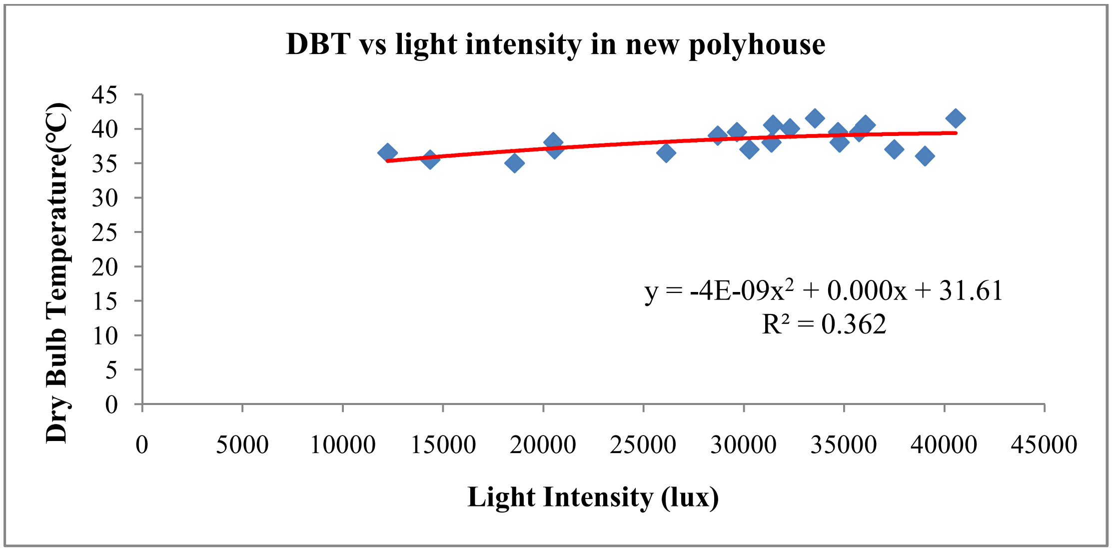

Fig. 4.32 Regression between DBT and Light intensity in new polyhouse

The regression coefficients between DBT and light intensity were ranged from 0.346 to 0.362 in new polyhouse (Fig. 4.32).For this polyhouse the line of best fit is with polynomial trend line, as one variable varies as polynomially to another variable and the R^2 value is 0.362.

4.3 COMPARISON OF DIFFERENT MICROCLIMATE IN DIFFERENT PROTECTED STRUCTURES

4.3.1 Average light intensity in different protected structures

The average light intensity in the inside of different protected structures is varying. In the case of rainshelters, it is mainly due to the dust and algal deposition on cladding material and in case of polyhouses, it was due to the change in height of structures. The light intensity were 30413.6, 15831.5, 27951.2, 29404.3 lux in cleaned rainshelter, uncleaned rainshelter, old polyhouse and new polyhouse respectively. The variation of light intensity in different protected structures is shown below in Fig.4.33. Average variation of 14582 lux light intensity is observed in between cleaned and uncleaned rainshelter while 1453 lux average light intensity is observed in between old and new polyhouse.

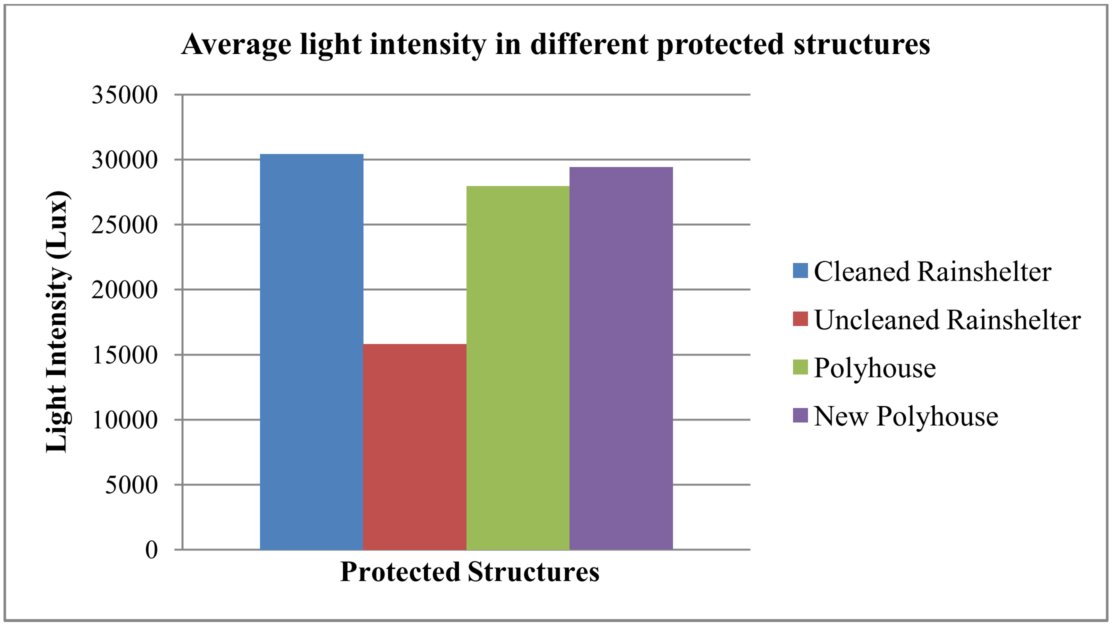

Fig. 4.33 Variation of light intensity in different protected structures

4.3.2 Average PAR in Different Protected Structures

The average PAR inside different protected structures is varying. In the case of rainshelters it is mainly due to the dust and algal deposition on cladding material and in case of polyhouses, it is due to the change in height of structures. The PAR is 770.435, 388.442, 717.449, 688.15 μ mol m^{-2} s^{-1} in cleaned rainshelter, uncleaned rainshelter, old polyhouse and new polyhouse respectively. The variation of PAR in different protected structures is shown in Fig. 4.34. An average variation of 382 μ mol m^{-2} s^{-1} has been observed between cleaned and uncleaned rainshelter. It indicates a 50% variation of PAR between cleaned and uncleaned rainshelter. It can clearly stated that even small layer deposition of algae on cladding material can hinder the PAR availability to the plants.

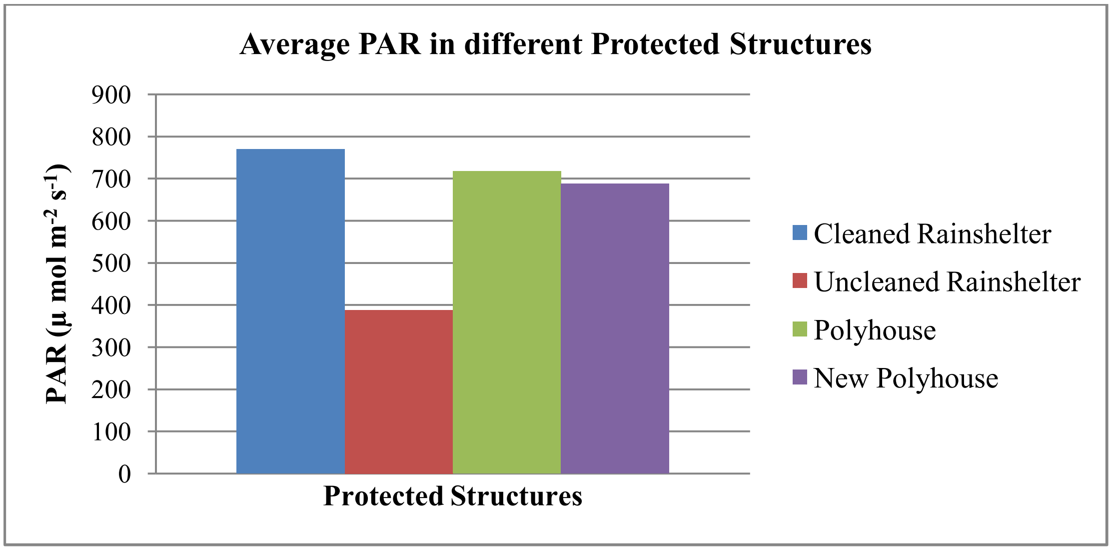

Fig. 4.34 Variation of PAR in different protected structures

4.3.3 Average DBT in Different Protected Structures

The average DBT inside different protected structures is varying. In the case of rainshelters it is mainly due to the dust and algal deposition on cladding material and in the case of polyhouses, it is due to the change in height of structures. The DBT were 37.96, 37.81, 38.7, 38.3 °C in cleaned rainshelter, uncleaned rainshelter, old polyhouse and new polyhouse respectively. The variation of DBT in different protected structures is shown below in Fig. 4.35.

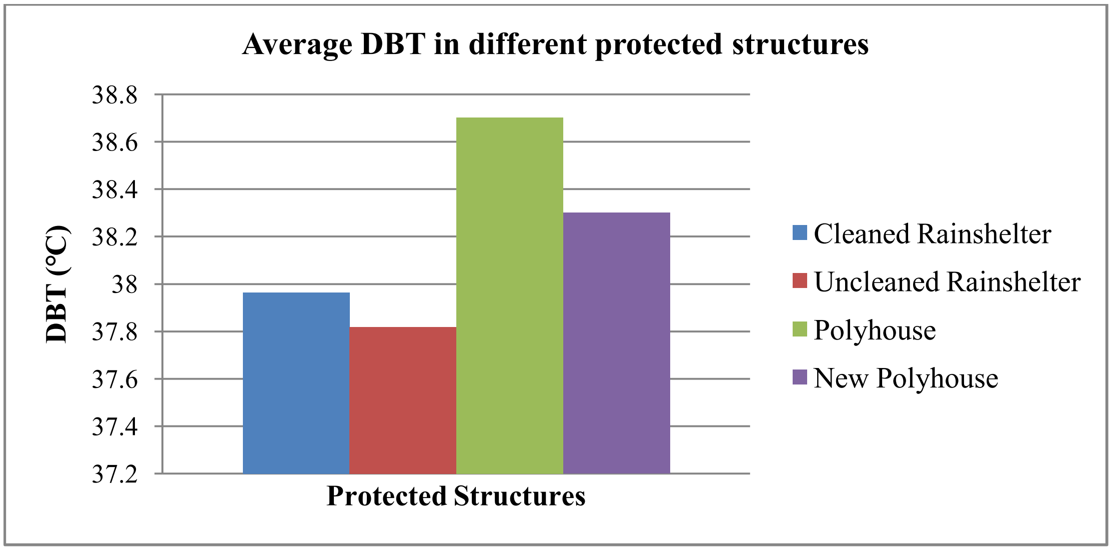

Fig. 4.35 Variation of DBT in different protected structures

4.3.3 Average Relative Humidity in Different Protected Structures

The average relative humidity inside different protected structures is varying. In the case of rainshelters, it is mainly due to the dust and algal deposition on cladding material and in the case of polyhouses, it is due to the change in height of structures. The relative humidity were 50.84, 50.75, 50.84, 52.78 % in cleaned rainshelter, uncleaned rainshelter, old polyhouse and new polyhouse respectively. The variation of relative humidity in different protected structures is shown below in Fig. 4.34.

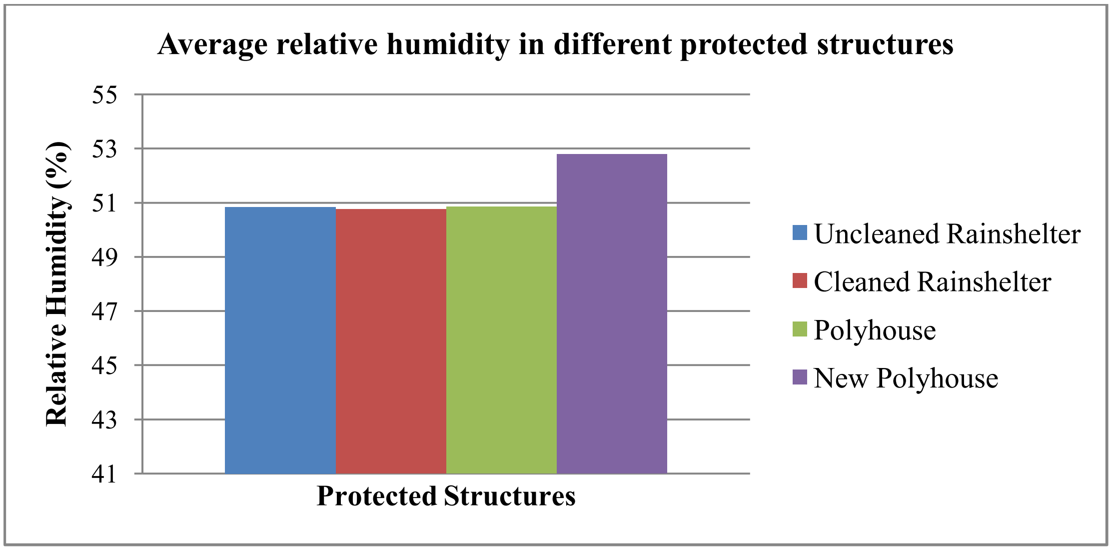

Fig. 4.36 Variation of relative humidity in different protected structures

4.4 COMPUTED INFORMATION

4.4.1 Light transmittance (%)

Light transmittance (%) = $\frac{\text{Lux (inside)}}{\text{Lux (outside)}}$

Table 4. Light transmittance in different protected structures

Protected Structure	Light Transmittance (%)
Polyhouse	66.6%
New Polyhouse	70.06%
Cleaned Rainshelter	72.47%
Uncleaned Rainshelter	37.77%

Due to the deposition of algae and dust on cladding material, around 50% variation of light transmission is observed in uncleaned rainshelter. As ageing increases the light transmission property of cladding material is gradually reducing.

4.4.2 Exceedance of temperature from desirable level

The optimum temperature in a greenhouse is the range that promotes the best possible growth for the plants being cultivated. This range varies depending on the type of plants, their growth stage and the external environmental conditions. Generally, for most plants, the ideal daytime temperature ranges between 20°C to 25°C (Singh and Peter, 2014). Exceedance of temperature is highly visible in all the different protected structures.

In old polyhouse, new polyhouse, cleaned and uncleaned rainshelter an average exceedance of temperature of 13.7, 13.3, 12.96 and 12.81°C respectively from the desirable limit is observed. An average range of 12°C to 14°C exceedance of temperature is visible in different protected structures during summer season.

4.4.3 Deviation of relative humidity from desirable limit

Relative humidity of the growing climate has its own importance as it governs most of the metabolic and photosynthesis activities of plants. It is observed that a relative humidity range of 55 to 65% is ideal for plant growth (Singh and Peter, 2014).

It is observed that in different protected structures the relative humidity is lower than the desirable value during summer season. Down side deviation of 4.16, 4.25, 4.16 and 2.21% was observed in different protected structures like cleaned rainshelter, uncleaned rainshelter, old polyhouse and new polyhouse respectively.

SUMMARY AND CONCLUSION

CHAPTER V

SUMMARY AND CONCLUSION

Kerala's agriculture sector, though traditionally a cornerstone of the state's economy, faces unique challenges and opportunities. The state's diverse topography and climate, coupled with small landholdings, have shaped its agricultural practices and output. Despite its potential, Kerala's agricultural productivity is declining, contributing only 20% to the state's revenue, mainly from small landholdings averaging 0.18 hectares. The state has rich soil, a humid tropical climate, and significant annual rainfall, but irregular rain patterns affect crop yields, leading to reliance on neighboring states for vegetables.

To boost agricultural productivity, adopting high-tech solutions like greenhouse technology is suggested. Greenhouses have been used for over 150 years globally but gained commercial traction in India post-1988. These structures, covered with UV-stabilized polyethylene, optimize growing conditions by utilizing the "greenhouse effect" to enhance crop growth and productivity. Benefits include high-quality produce, increased income from small holdings, off-season cultivation, and better water management. The cladding material of a polyhouse is pivotal in creating an optimal growing environment, ensuring plant health and enhancing the overall productivity of the agricultural system. It significantly influences various aspects of the microclimate within the structure, including temperature, humidity, light transmission and protection from external elements. Greenhouse films, made from polymers like EVA, EBA, and LDPE, and additives such as UV stabilizers and IR absorbers, have evolved to be more durable and effective. Features like diffuse films, anti-dust coatings, and anti-drip properties enhance light transmission and reduce crop diseases. Kerala offers various greenhouse types, with naturally ventilated ones being common.

However, challenges include reduced light transmission over time, marketing issues, demand fluctuations and pest attacks, leading to crop failures after initial success. The study aims to investigate these crop failures in greenhouse farming.

Hence the study “” was conducted in different protected structures located in Precision Farming Development Centre of KCAET Tavanur. The study was undertaken with the objective to identify the various microclimatic parameters governing the growth and yield of plants and determination of correlation between important microclimatic parameters.

A comprehensive recording of microclimatic parameters like light intensity, PAR, wet and dry bulb temperature, relative humidity was done in old aged polyhouse, new polyhouse, cleaned and uncleaned rainshelter. A statistical analysis for light intensity, PAR and dry bulb temperature under different protected structures were conducted to determine the correlation between these parameters and also helps to recognize the hidden pattern underlying in it. Each parameters shows a positive polynomial and power relationship.

From the results of experiment, the variation of microcimatic parameters like temperature, relative humidity, PAR and light intensity was analyzed for both polyhouses and rainshelter. Maximum dry bulb temperature (42.5°C) was recorded inside the cleaned old polyhouse at 12 pm and minimum dry bulb temperature (34 °C) was reported inside the uncleaned rainshelter at 4 pm. The rise in temperature in the cleaned old polyhouse is due to the increased transparency of cladding material which results in better transmission of solar radiation into the polyhouse, while in new polyhouse due to the greater central height the temperature found is comparatively low. Likewise, maximum wet bulb temperature (31°C) was observed at 12 pm in old polyhouse and minimum wet bulb temperature (26°C) at 4 pm in uncleaned rainshelter. Also, maximum relative humidity (74.5%) was reported at 10 am at old polyhouse while minimum relative humidity (40.8%) was reported at 10 am in uncleaned rainshelter. Furthermore, Maximum light intensity (49300 lux) was recorded inside old polyhouse at 12 pm and minimum light intensity (4300 lux) was observed under uncleaned rainshelter at 4 pm. Similarly, maximum PAR (12414.5 µmol m^{-2} s^{-1}) were observed at 12 pm in old cleaned polyhouse and minimum PAR (123 µmol m^{-2} s^{-1}) were observed at 4 pm in uncleaned rainshelter.

Major conclusions of present study are:

1. From the observations, it is found that there is 50% reduction in both light intensity and PAR in the uncleaned portion of the rainshelter. It is seen that even a small layer deposition of dust and algae on cladding material considerably hinders both light and PAR availability to the plants.
2. In the case of temperature, about 12°C to 14°C exceedance is found in different protected structures during summer season, plausibly giving significant negative impact for the plant growth and yield.
3. It was found that strong positive correlation was existing between light intensity and PAR and it was maximum in the case of new polyhouse.
4. No significant correlation was observed between DBT and light intensity and also between DBT and PAR.
5. In order to avoid the reduction in light intensity and PAR, the cladding material requires frequent cleaning and a workable protocol in this regard is to be developed.
6. More detailed studies are required to get more insights into the micro climatic variations and their impact on crops. .

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CHAPTER VI

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MICROCLIMATIC CHARACTERISTICS OF DIFFERENT TYPES OF PROTECTED STRUCTURES

By

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ABSTRACT OF PROJECT REPORT

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DEPARTMENT OF SOIL AND WATER CONSERVATION ENGINEERING

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2024

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, farmers are abandoning this cultivation method citing crop failures after the initial phase. One significant issue is the reduction of light transmission caused by algal growth and dust deposits on the cladding material, which negatively impacts the microclimate and growth and yield parameters within the greenhouse.

To investigate this problem, an experiment was conducted at the Precision Farming Development Centre (PFDC) at KCAET Tavanur. The study compared the performance of cladding material in different protected structures, including an old polyhouse, a new polyhouse, and cleaned and uncleaned rainshelter. The findings indicated that even a small layer of algae on the cladding material could hinder the light intensity and photosynthetically active radiation (PAR) to the plants by as much as 50%. Additionally, temperature exceedance ranging from 12°C to 14°C from the desirable limit were observed among different protected structures during the summer season. Regular cleaning of the cladding material was felt as essential to reduce the light transmission loss into the protected structures for effective crop growth and yield. Hence it is imperative to develop cleaning protocols for the protected structures to make this technology viable in Kerala conditions.