DEVELOPMENT AND EVALUATION OF GREENHOUSE AUTOMATION SYSTEM USING MICROCONTROLLER

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2019

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PROJECT REPORT

Submitted in partial fulfilment of the requirement for the degree

Bachelor of Technology

In

Agricultural Engineering

Faculty of Agricultural Engineering and Technology

Kerala Agricultural University

Department of Soil and Water Conservation Engineering

Kelappaji College of Agricultural Engineering and Technology

Tavanur P.O-679573 Kerala, India

2019

DECLARATION

We hereby declare that this project entitled **“DEVELOPMENT AND EVALUATION OF GREENHOUSE AUTOMATION SYSTEM USING MICROCONTROLLER”** is a bonafide record of project work done by us during the course of study and that the report has not previously formed the basis for the award to us of any degree, diploma, associateship, fellowship or other similar title of another university or society.

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Place: Tavanur

Date: 31-01-2019

CERTIFICATE

Certified that the project entitled **“DEVELOPMENT AND EVALUATION OF GREENHOUSE AUTOMATION SYSTEM USING MICROCONTROLLER”** is a record of project work done jointly by **Ms. Aardra K, Mr. Sandeep Kumar Ray and Ms. Shili K** 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.

Place: Tavanur

Date: 31-01-2019

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ACKNOWLEDGEMENT

First of all, with an open heart, we thank the "**God Almighty**" for his invisible helping hand that guided us through the right way to pursue our journey to the completion of this project.

It is our prerogative to express profound gratitude and respect to our guide, **Dr. Jinu. A**, Asst. Professor, Department of Soil and water Conservation Engineering, KCAET, Tavanur for his inexplicable support and guidance throughout our endeavor.

We are also indebted to **Dr. Sathyan K. K**, Dean, Kelappaji College of Agricultural Engineering and Technology, Tavanur, for providing us with the necessary support and permissions to carry out our work with ease.

Our following hearty gratitude to all the **Technicians,** especially in the workshop and laboratories and the **Staff and Labourers** of KCAET, for their untiring effort and dedication for the fabrication of the unit and valuable help without whom our work would never have been completed.

We also wish to remember and gratify **our Parents**, who always bless us for our betterment and pray for our success.

Words do fail to acknowledge our dear **friends** for their support, encouragement and help which have gone a long way in making this attempt a successful one.

Finally, we thank **all those**, who directly or indirectly helped us.

Aardra K

Sandeep Kumar Ray

Shili K

SYMBOLS AND ABBREVIATIONS

%	Percentage
&	And
AM	Ante Meridian
Asst.	Assistant
/	Per
º	Degree
ºC	Degree Celsius
Dept.	Department
E.g.	Example
Etc.	Etcetera
et al	And others
GM	Genetically Modified
Kg	Kilogram
Kpa	Kilopascal
t/ha	Tonne per hectare
viz	Namely
ie	that is
KCAET	Kelappaji College of Agricultural Engineering And Technology
DC	Direct current
pm	Prime meridian
$FeCl_3$	Ferrious Chloride

V	Volt
GSM	Global system for mobile communication
Sq.m	Square metre
M	Metre
‘	Minutes
||	Seconds
N	North
E	East
RH	Relative humidity
PFDC	Precision farming development centre
LCD	Liquid crystal display
PCB	Printed circuit board
KB	Kilobytes
mA	Microampere
MHz	Megahertz
mm	Millimetre
g	Gram
CO_2	Carbon dioxide
pH	Pouvoir hydrogen
WSN	Wireless sensor network
IDE	Integrated development environment
W	Watt
LED	Light emitting diode

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JINU SIR

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INTRODUCTION

CHAPTER 1

INTRODUCTION

Crop cultivation has been around for a longtime. It plays a crucial role in the continuous development of human civilization. Traditional crop cultivation requires a tremendous amount of hard work and attention and there are several disadvantages in implementing traditional cultivation techniques:

- Weather dependent factors: plants growth and development are primarily governed by the weather conditions.
- Pests and diseases: plants growing under traditional cultivation technique are significantly affected by pests and diseases.

It was discovered that there are indications that already many thousands years ago civilizations in countries such as China, Egypt and India employed means of protection against cold, wind and excessive solar radiation. These methods of protection were employed only to provide a short-term protection for plants against harsh climate conditions. However, no further development occurred until the late 15th century and early 16th century, when European explorers brought back exotic plants acquired in the course of their travels. Many were tropical plants that could not endure the cold European climates. The result was the creation of greenhouses and these early greenhouses were originally referred to as “*giardini botanic*” also known as “botanical gardens”.

A greenhouse allows the growers to produce plants in places where the climate would otherwise be unfeasible for the growing of plants. The production of crop plants is independent of the geographic location and the time of the year. The greenhouse also provides shelter for the plants, protects them from harsh weather conditions, insects and diseases. It allows the plants to grow under optimum conditions, which maximizes the growth potential of the plants. The quality and productivity of crop plants is highly dependent on the management quality and a good management scheme is defined by the quality of the information gathered from the greenhouse environment.

Every greenhouse operates on a simple physical principle called "the greenhouse effect". The greenhouse effect is the process by which radiation from a planet's atmosphere warms the planet's surface to a temperature above what it would be without its atmosphere.

Earth receives energy from the Sun in the form of ultraviolet, visible, and near-infrared radiation. About 26% of the incoming solar energy is reflected to space by the atmosphere and clouds, and 19% is absorbed by the atmosphere and clouds. Most of the remaining energy is absorbed at the surface of Earth. Since the earth's surface is colder than the Sun, it radiates at wavelengths that are much longer than the wavelengths that were absorbed. Most of this thermal radiation is absorbed by the atmosphere and warms it. The atmosphere also gains heat by sensible and latent heat fluxes from the surface. The atmosphere radiates energy both upwards and downwards; the part radiated downwards is absorbed by the surface of Earth. This leads to a higher equilibrium temperature than if the atmosphere were absent.

Greenhouse covering material is transparent to incoming short wave radiation and opaque to the reflected long wave radiation. This long wave radiation is trapped inside the greenhouse by the covering or cladding material. This causes the increase in greenhouse temperature.

The greenhouse system is a complex system. Any significant changes in one climate parameter could have an adverse effect on another climate parameter as well as the development process of the plants. Therefore, continuous monitoring and control of these climate factors will allow for maximum crop yield. Temperature, humidity, light intensity and CO_2 are the four most common climate variables that most growers generally pay attention to. However, looking at these four climate variables will not give the growers the full picture of the operation of the greenhouse system.

Greenhouses have a very extensive surface where the climate conditions can vary at different points. It is very common to install only one sensor in a fixed point of the greenhouse as representative of the main dynamics of the system. One of reasons behind this is that typical greenhouse installations require a large amount of wires and cables to distribute sensors and actuators. Therefore the system becomes complex and expensive and the addition of new sensors or actuators at different points in the greenhouse is thus quite limited. Not to mention, modern greenhouses are typically big, therefore measurement point increases are unavoidable. As a result, a dramatic increase in installation cost is almost certain.

Although the concept of automation and control system in greenhouse is the same as its industrial applications, but there are borders which distinct these two fields of control. Special environmental and biological sensors beside other control and instrumentation materials capable of working under a very humid environment and still not going out of calibration, together with an algorithm to adjust itself with diverse dynamic situations with respect to particular growing stages, microclimatic variables and crops requirements as well as considering geographical and natural factors, are what make the greenhouse control different from industrial automation and control.

In general, automation in a greenhouse environment involves automation of climate control (control air temperature, air circulation and air exchange, RH control and management), light level control and shade curtain management, carbon dioxide (CO2) control, irrigation, chemical treatment and nutrient supply management. The term environment refers to the plants surrounding. Greenhouse automation is all about an efficient, accurate and modern intensive-agriculture, which judicially utilizes all available natural resources, recycles the information within the system, and claims higher productivity, higher returns, better quality while remain environment friendly. Greenhouse automation is also associated with better management through process optimization.

Automated greenhouse systems are capable of determining and maintaining the right amount of environmental parameters like temperature, humidity etc for the plant. Automation of greenhouse is the process of the automatic monitoring and controlling of climatic parameters which directly or indirectly govern the plant growth and hence their production. Automated greenhouse is to ease people when they wish to grow plants. It helps to monitor the situation, when they are not at home. In order to control the climate factors and environment autonomously, it is required a computer software equipment. Commonly used sensors for greenhouse automation include those devices that sense temperature, relative humidity etc. Arduino can be used as an integrated automation technique which can be simply called a tiny computer, consisting of a microcontroller board and its software.

Arduino is a tool for making computers that can sense and control more of the physical world than a desktop computer. It's an open-source physical computing platform based on a simple microcontroller board, and a development environment for writing software for the board.

Arduino can be used to develop interactive objects, taking inputs from a variety of switches or sensors, and controlling a variety of lights, motors, and other physical outputs. Arduino projects can be stand-alone, or they can communicate with software running on the computer (e.g. Flash, Processing, and MaxMSP.) The boards can be assembled by hand or purchased preassembled; the open-source IDE (Integrated Development Environment) can be downloaded for free.

The Arduino programming language is an implementation of Wiring, a similar physical computing platform, which is based on the Processing multimedia programming environment.

Specific objectives are:

- Development of greenhouse using Arduino Microcontroller.
- Performance evaluation of developed greenhouse automation system.

REVIEW OF LITERATURE

CHAPTER 2

REVIEW OF LITERATURE

The world population is estimated to be increasing day by day, but the space is being limited. So, hi-tech agricultural practices such as green house can be constructed to take an advantage over the space limitation and looking forward into the higher productivity. A green house with an efficient cooling system promises higher and uniform production rate even in the hot climatic conditions.

2.1 GREEN HOUSE

Green house is a structure primarily of glass or sheets of clear plastics, in which temperature and humidity can be controlled for the cultivation or protection of plants. Greenhouse can also be defined as the sophisticated structure providing ideal conditions for satisfactory plant growth and production throughout the year**.**

According to Dalrymple (1973), greenhouses are framed or inflated structures covered with transparent or translucent material in which crops can be grown under the conditions of at least partially controlled environment and which are large enough to allow a person to walk within them to carry out agricultural operations, The transparent or translucent material acts like a selective filter which allows the solar radiations emitted by the objects within the greenhouse. This effect known as greenhouse effect, increases the temperature within the greenhouse. The level of carbon dioxide as well as humidity increases inside the greenhouse due to the retention of radiant heat inside the greenhouse. Thus it reduces the water requirement of plants due to the increased humidity as a result of transpiration losses.

As per Masterlez (1977), a greenhouse is a structure covered with transparent material that utilizes solar radiant energy to grow plants.

Mears (1990), had discussed the possibilities of greenhouse technology in India. The Indian subcontinent which lies between 40^0 and 80^0 north of equator, with regions of extreme temperature conditions where open field cultivation is not feasible; greenhouse technology makes a significant contribution. The spectra of agro climatic zones in India and the need for modern research in controlled environment, commercial use of greenhouse in plant production, plant culture etc. necessitates greenhouse systems.

The green houses gained importance because of the following advantages (Khan *et al.* 1995)

1. High productivity per unit area as the genetic potential is fully exploited.
2. Excellent quality produce free from any blemishes.
3. Higher extent of bud or graft take and extended period of grafting.
4. Easy to protect from pests and diseases.
5. Getting the produce early in the season with minimum requirement of water.

Tiwari *et al.* (2006) highlights the design and technology for cooling of greenhouse and presents a state-of the-art review on its applicability in tropical and subtropical regions. The detailed review presented in this paper indicated that existing cooling technologies are not enough. There is a necessity to develop cheap and effective technology suitable to local climatic conditions to boost up the greenhouse industry. They designed a naturally ventilated greenhouse with larger ventilation areas (15– 30%), provided at the ridge and sides covered with insect-proof nets (20–40 mesh size) with covering material properties of near infrared radiation (NIR) reflection during the day and far infrared reflection during night is suitable for crop production throughout year in tropical and subtropical regions.

A greenhouse in a particular climate can create an environment suitable for certain species but it may not produce a same suitable environment at a different location. This means that the creation of specified environment related to the existing ambient conditions which in turn affect the method as well as the economic feasibility of creating such an environment.

2.2 PERFORMANCE OF VEGETABLE CROPS UNDER POLYHOUSE

Backer (1989) reported that sweet pepper grown with alternative high and low humidity during day and night (vapour pressure deficit range 0.30 to 0.75 Kpa) under greenhouse gave more fruit set (16.70 %) and more number of fruits (10.9 per plant) as compared to continuous high (0.75 Kpa) or low humidity. There was no significant effect on fruit shape and maturity.

More *et al.* (1990) reported that cucumber variety ‘Poinset’ gave a yield of 1.70 kg/ plant under polyhouse as compared to fewer yields in open conditions, during winter months under North Indian conditions due to low temperatures.

Gomez *et al.* (1994) conducted a comparative study among capsicum cultivars planted on 2nd June. They were assessed for flowering dates, beginning of cropping and full cropping, yield in each of four harvests and total yield, and percentage of fruits in four different weight groups.

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

Ganesan (1999) conducted a study to define the effect of changes in microclimate produced by poly greenhouse conditions on plant growth characteristics and fruit yield of tomato. The UV stabilized plastic film covered greenhouse recorded higher day temperature than the open environment but relative humidity at 8 AM was lower inside the greenhouse except from May to August. The light intensity inside the greenhouse was lower than in the open field. Height of the plant, number of nodes, internodal length, total dry matter production and average fruit weight increased under greenhouse conditions as compared to open field condition. The fruit yield inside the greenhouse was nearly two times more than in the open field condition.

Von (1999) reported that the main advantage with greenhouse farming is that the production can be got throughout the year, which is not possible in the open field farming due to heavy rainfall and wind, especially in tropical regions.

Nazzareno *et al.* (2002) evaluated GM parthenocarpic eggplants in three field trials. Two greenhouse spring trials have shown that these plants out yielded the corresponding untransformed genotypes, while a summer trial has shown that improved fruit productivity in GM eggplants can also be achieved in open field cultivation.

Santos *et al.* (2009) compared the effects of the protected cultivation and open field on growth of *Lactuca sativa* plants through morphological parameters. The morphological parameters evaluated were fresh and dry leaf matter, fresh and dry stem matter, fresh and dry plant matter, leaf number, leaf area and absolute growth rate. The leaf fresh matter suffers significant effect, which for the treatment under protected cultivation was higher that the treatment carried out with plants in open field in all evaluated points. The plant dry matter production on 28th day after transplanting increased by 56.56 %, when compared with open field condition. The leaf number shown significant difference on the 14th and 21th day after transplanting, in which the treatment under protected cultivation resulted in an increase of 64.2% on 14th day after the transplanting, when compared with open field condition.

Parvej *et al.* (2010) compared the phenological development and production potentials of two tomato varieties viz. BARI Tomato-3 and Ratan under polyhouse and open field conditions. Photosynthetically active radiation inside the polyhouse was reduced by about 40 % compared to the outside while air and soil temperatures always remained higher. From December to February the mid day air temperature under polyhouse and open field varied from 31.8 to 39.1 ºC and 23.3 to 31.1 ºC respectively, indicating about 8 ºC higher air temperature inside polyhouse and during that time the average air temperature inside polyhouse was about 28 ºC, which was optimum for the growth and development of tomato plants. Relative humidity was lower inside the polyhouse as compared to open field. Flowering, fruit setting and fruit maturity in polyhouse plants were advanced by about 3, 4 and 5 days, respectively compared to the crop raised in open field condition. Polyhouse plants had higher number of flower clusters/plant, flowers/cluster, flowers/plant, fruit clusters/plant, fruits/cluster and fruits/plant, and fruit length, fruit diameter, individual fruit weight, fruit weight/plant and fruit yield over open field condition. The fruit yield obtained from the polyhouse was 81 t/ha against 57 t/ha from the open field.

Carvalho *et al.* (2013) evaluated morphological behaviour of the initial phase of the black string bean crop with and without addition of nitrogen fertilization and in different cultivation shading environments. Both with the absence as well as with the addition of nitrogen fertilization in the black cowpea crop, more elevated values of height and diameter of stem in the plants cultivated in the external environment in relation to the shaded environment were observed.

Rajasekar *et al.* (2013) took up studies to screen ten vegetables for cultivation under shade net house (33% shade) and open field for year round production of vegetables. Tomato, eggplant, chilli, cucumber, cluster bean, radish, amaranthus, coriander and capsicum were grown in the summer and winter. The influence of environmental variables temperature, relative humidity and light intensity were studied. Relative humidity was always higher under shade net house than in open field during both seasons. Light intensity in the shade net house was lower than in the open field. Mean weekly temperature during summer and winter were higher under open field conditions than in the shade net house. Lower temperature caused plant height, number of branches, inter-nodal length, average fruit weight and yield per plant to be higher in the shade net house than in the open field.

2.3 ENVIRONMENTAL CONTROL IN GREENHOUSES

The distinctive feature of greenhouse cultivation as compared to outdoor cultivation is the presence of a barrier between the crop and the environment. The presence of a cover, characteristic of greenhouses, causes wanted or unwanted, a change in the climatic condition as compared to those outside: radiation and air velocity are reduced, temperature and water vapor pressure of the air increase and fluctuations in carbon dioxide concentration are much stronger. Each of these changes has its own impact on growth, production and quality of the greenhouse crop, some of them being detrimental. This passive changes in the greenhouse weather, traditionally referred to as greenhouse climate in combination with fluctuating outside weather conditions, force the grower into an active role with respect to climate conditioning (Bakker, 1995).

2.3.1 TEMPERATURE

Kachru *et al.* (1985) reported that desirable temperatures can be maintained in a greenhouse with a well designed cooling and / or heating systems. Various techniques viz., ventilation, roof shading, maintaining water film on the glass and evaporative cooling has been suggested for greenhouse cooling. For heating purposes one could use hot water or steam and run it through coils in various arrangements, forced hot air, infrared heat or electricity to increase the temperature in winter months.

Kempkes (1985) carried out studies to gain an insight into the vertical temperature differences in greenhouse. Temperature distribution was monitored with a network of 54 thermocouples in four compartments in which tomatoes were grown. The results showed that temperature differences produced differences in yield.

Tomalty (1988) recorded the maximum and minimum temperatures inside and outside a passive solar greenhouse located at Arcosanti in the Arizona desert. It was concluded that the greenhouse provided a better environment for vegetable growth than the outside environment.

Thomas (1989) recorded the maximum and minimum temperature, relative humidity and light intensity at 15 points inside a low cost greenhouse. They indicated that relative humidity and temperature profiles do not change significantly.

Galansauco (1992) studied on the physiological and production differences between greenhouse and open air bananas in Canary Islands. Temperature was the main factor governing banana growth and development. Greenhouse banana exhibited greater height.

Olympios (1992) during his studies on the effect of temperature, humidity and carbon dioxide enrichment in raising cucumber seedlings in Mediterranean countries found that for maximum growth, high temperature must accompanied by high relative humidity.

Temperature is the only environment factor which has a direct effect on the sink strength of individual organs of the plants and consequently in commercial practice, temperature constraints are primarily used for control of biomass partitioning in greenhouse crops. Besides the effect on growth and development, temperature has effects on production through maintenance of the respiration. The average temperature has significant effect on growth and also the difference in day and night temperature affects the morphology ie. leaf area and to a large extent internode length. It has its own effects on the energy balance of the system (Bakker, 1995)

2.3.2 HUMIDITY

Hand (1988) carried out investigations to find the effects of atmospheric humidity on greenhouse crops. He reported that, from a crop production stand point the test strategies to maintain a high humidity during the day to avoid too high a humidity at night. Such a regime will maximize the quality of output and minimize the risk of plant diseases.

Pelletier (1988) during the trails with cucumber grown with or without misting to maintain relative humidity at 70 per cent, the yield has increased and the plant losses are decreased.

In another trail the misting system was operated either when a minimum humidity (70 per cent) or a minimum temperature (26 to 30 °C) was reached. Control based on temperature was more difficult to achieve and gave high humidities leading to increased disease incidence although yield was not affected. In an unshaded house, misting decreased the air temperature by 8°c.

High humidity has significant impact on the energy balance of the crop as on average the major fraction of the incoming solar radiation is transferred to latent heat. Temporary shifting of this fraction to lower values implies a significant increase of convective and thermal heat exchange, consequently a much higher leaf temperature. Also, sudden changes in humidity can cause heat injury because of water uptake cannot match the transpiration rate. Long term exposure to high or low humidity has beneficial as well as detrimental effects on growth and production. The adhesion of stigma in the flower may be strongly influenced by the varying humidity as well as key processes such as pollination is also influenced by humidity. This constraint has its influence on incidence of pest and diseases and has a key role in maintaining the quality of product (Bakker, 1995).

2.4 GREENHOUSE HEATING

In colder climates, heat is lost through the covering materials or by infiltration through the leak points or by radiation from warm objects inside the greenhouse. In order to maintain the heat loss from the greenhouse, heat is supplied at the same rate using steam, forced hot air, infrared radiations, electricity etc (Masterlez, 1977).

2.5 GREENHOUSE COOLING

India, being a tropical country requires cooling as an environmental control measure in greenhouses. The air temperature and humidity can be maintained at desirable levels by natural convection or forced movement of air inside the greenhouse with or without the evaporation of water for cooling (Masterlez, 1977).

Dayan *et al.* (2006) conducted a study on cooling of roses in green house. Rose flowers produced in greenhouses during the Israeli summer are of poor quality, due presumably to the high temperatures and low air humidity obtained with natural ventilation (NV). Several variants of commercial cooling methods were tested to reduce the duration of high temperature exposure in greenhouses. The treatments included were: NV, with and without shading, and forced ventilation with and without an evaporative pad. Modified concepts issued from a steady state energy balance model set a frame for analyzing the course of action of the treatments. The cooling treatments hardly reduced average temperatures of air, plant, or flower. Due to morphology, the plant absorbed most of the radiant energy entering the greenhouse, and most of it was removed as latent heat. In comparison to NV, the treatments produced limited additional cooling because each of them reduced the transpiration rates.

Kumar *et al.* (2009) carried out a study on design and technology for greenhouse cooling in tropical and subtropical regions. High summer temperature is a major setback for successful greenhouse crop production throughout year. The main intent of the paper is to present a comprehensive review on the design and technology for cooling of greenhouse during summer months. Effect of characteristic design parameters on greenhouse microclimate and the applicable cooling technologies have been discussed. A detailed survey of literature revealed that, apart from cooling, studies on greenhouse design, evaluation of new cladding materials for greenhouse covering and natural ventilation with respect to local climate and agronomic condition is necessary to achieve desirable benefits. Analysis of the earlier studies revealed that a naturally ventilated greenhouse with larger ventilation areas (15–30%), provided at the ridge and sides covered with insect-proof nets of 20–40 mesh size with covering material properties of NIR (near infrared radiation) reflection during the day and FIR (far infrared radiation) reflection during night is suitable for greenhouse production throughout year in tropical and subtropical regions. The detailed review presented in this paper indicated that existing cooling technologies are not enough and widely accepted to cater the needs of greenhouse grower. There is a necessity to develop cheap and effective technology suitable to local climatic conditions to boost up the greenhouse industry.

Lee *et al.* (2010) conducted a study on cooling capacity assessment of semi closed green houses. The study was based on the study conducted by Dutch researchers and Ooteghemon significant benefits of closed greenhouse systems. Results of this study were used on Ohio conditions estimated that 90% and 92% of CO2 loss through cooling and dehumidification ventilations when an elevated CO2 level of 800 ppm must be maintained. This study also found that for Wooster, Ohio to achieve economical year-round closure, due to the larger weather variation and lack of accessibility to aquifers, a better economical return would be expected with semi-closed designs that allow the greenhouse to vent when the heat load is approaching a certain per cent of peak levels. The study also determines the amount of heat which can be recovered with thermal storage. The models used for the above analyses were evaluated using data collected in a greenhouse located at Wooster, Ohio. Convection and infiltration heat loss prediction were validated during cloudy and clear sky nights. The results gave prediction disagreements of 0.2% to 2% and 30% under cloudy and clear sky conditions, respectively. Also evaluated was the potential recoverable heat from ventilation exhaust. Result showed that ventilation time prediction disagreement were -8.2% and 0.8%, when net solar radiation transmittances were estimated at 0.54 and 0.57, respectively. Although further improvements of this model could be done, the data processing framework established for the heat recovery strategy evaluation is valuable for the assessment of potential benefits of semi closed greenhouse.

Ganguly *et al.* (2011) presented a comprehensive review of the literature that deal with ventilation and cooling technologies applied to agricultural greenhouses. The representative application of each technology as well as its advantages and limitations are discussed. Advance systems employing heat storage in phase change materials, earth-to-air heat exchangers and aquifer coupled cavity flow heat exchangers have also been discussed. For an agricultural greenhouse equipped with cooling and artificial ventilation system, availability of uninterrupted electric supply is important. To achieve grid independence, dedicated power generation and storage systems need to be integrated with the greenhouse. The relevant literature on such power generation system for greenhouse application has been reviewed and is discussed here. This review concludes by identifying some important areas where further research needs to be undertaken.

Wang *et al.* (2015) conducted a research based on the Technology and Studies for Greenhouse cooling. The main purpose of this paper is to present some technologies and studies for greenhouse cooling in summer. In this paper, some applicable and practical cooling technologies have been discussed. Test and investigation respectively conducted three cooling measures such as natural ventilation, evaporate-cooling and shading cooling. There are some respectively differences among them. All of the methods have disadvantages and advantages. The choice of efficient cooling method depends on many aspects, such as local climate, agronomic condition, design and covering materials. To achieve desirable benefits, the combination of different cooling methods is necessarily used. The study reveals that Evaporation cooling is the most effective cooling method for controlling the temperature and humidity inside a greenhouse. However, its suitability is restricted to the respective region and climate when the humidity level is high. The entry of un- wanted radiation or light can be controlled by the use of shading. Researches show that shade net application with different perforated mesh size and their evaluation with respect to local climate and region are necessary to get cooling benefits in summer.

2.6 VENTILATION

The process of exchanging air inside the greenhouse with outside air is known as ventilation of the green house. It is required to be done to remove surplus solar heat, to remove transferred water vapour and to supply carbon dioxide. The volume of air exchanged per unit floor area is called the ventilation rate. Sometimes it is expressed as internal air volume exchange per unit of time (Bakker, 1995).

2.6.1 FORCED VENTILATION SYSTEM

Natural ventilation has its own limitations regarding the ventilation rate and the air exchange for high ventilation rates, other means of forced ventilation system are to used. Exhaust fans of sufficient capacity can lower the temperature by 3 to 6°C and a larger reduction in temperature is affected using some evaporative cooling system.

Forced ventilation system can be accomplished by ventilation through perforated convecting tubes or by evaporative cooling (Bakker, 1995).

2.6.2 EVAPORATIVE COOLING

Evaporative cooling works by exploiting two different forms of heat energy known as ‘sensible heat’ and ‘latent heat’.

When the warm air in an evaporative cooling system passes over the system’s liquid water source, some of the heat energy contained in the air is transferred to the water. This causes it to evaporate and form water vapour. Some of the sensible heat from the air is therefore transformed into latent heat contained in the water vapour, causing the overall air temperature to drop.

As water evaporates, heat is absorbed and this is the principle employed in evaporative cooling of greenhouses. The degree of cooling obtained from an evaporative system is directly related to the wet bulb depression that occurs with a given set of climatic conditions (Masterlez, 1977).

Landsberg *et at.* (1979) made a computer analysis of the efficiency of evaporative cooling in which the air entering the greenhouse was cooled to the wet bulb temperature of the outside air. The results showed that in a greenhouse filled with freely transpiring plants, the air temperature in a glass house could be reduced by 10to 15per cent in spite of a high level of solar radiation.

Monteiro (1981) studied the effects on air water fogging systems on the greenhouse climate. Results indicated that the evaporative cooled greenhouse lowered its temperature by an average of 3 °C.

Abdulla (1986) conducted experiments on performance in a fan and pad cooled greenhouse at Saudi Arabia. Environmental conditions were monitored outside and at three locations along the centre line of the multi span, fan and pad evaporatively cooled greenhouse. These measurements showed a horizontal temperature gradient of 4.3 °c from the wetted pad to the exhaust fan and a vertical temperature gradient of 4.2 °C from the greenhouse to height of 15 m.

Chandra *et al.* (1989) conducted experiments on evaporative cooling of plastic greenhouses. An experimental plastic covered greenhouse of 4 X 6m floor dimension was installed with a fan and pad system of evaporative cooling. Measurements of temperature, humidity, solar radiation inside and outside the green house and water consumption were made to study the resulting greenhouse thermal environments. The observed greenhouse temperatures were found to be within 2 °c of those predicted by a simple thermal analysis.

Garzoli (1989) reported that the evaporative cooling is normally the most effective means of cooling. It is based on the process of heat absorption during evaporation of water.

Bailey (1990) developed a simulation model to predict the temperature and vapour pressure deficits obtained in greenhouse with fan and pad cooling, The inside greenhouse temperature gradient between cooling pad and air extract fans is influenced by the extend of crop cover, the amount of external shading and the types of greenhouse cladding. Placement of exhaust fans should not be more than 1.5m apart, otherwise warm areas may develop.

Boulard *et al.* (1993) proposed a greenhouse climatic model, incorporating the effects of natural ventilation and evaporative cooling. Linearization of the greenhouse heat and water balance equation leads to a simple system of two equations with two unknowns which represent quite well the complex coupling mechanism between ventilation and fog observed insitu. The model predicts that a minimum inside temperature can be reached for a certain combination of these cooling processes. Crop temperature and transpiration were also estimated using the Penman Monteith approach and the energy balance of the crop. Good agreement between measured and computed values of air temperature, air humidity, crop temperature and transpiration was observed.

Govindan *et al.* (1993) constructed a low cost greenhouse at the instructional farm of K.C.AE.T., Tavanur. The salient feature of that pentagonal shaped greenhouse was the fan and pad evaporative cooling system used to control the temperature inside the greenhouse as desired. It was also possible to maintain the relative humidity at sufficient levels inside the greenhouse. The pad resistance was found to be 5mm of standard water guage.

Ajayambika (1995) built and tested a low cost greenhouse at the instructional farm of K.C.A.E.T., Tavanur. The size of the greenhouse was 12X3m and the structure was gable shaped. A fan of maximum air flow rate of 10450 m3/h and a pad of size 3000X 1200 mm was found necessary to satisfy the cooling requirement. The maximum temperature recorded inside the greenhouse was 47.6 °c without cooling and 38.5°C with cooling. The polythene cover transmitted 60 per cent of the solar radiation incident on it. The average efficiency of the pad was 65 per cent.

Majumdar *et al.* (1995) conducted study on the prediction of the cooling pad temperature in a fan and pad cooling system used in greenhouse. Measurements of pad temperature have been made in an experimental greenhouse employing a fan and pad cooling system. The results indicated that the pad temperature to be lower than the wet bulb temperature of the surrounding ambient air. An analysis of relevant energy exchanges permitted the formation of a differential equation, which estimated the time dependent pad temperatures when solved numerically. The predicted and measured pad temperatures were within 2 °C.

2.7 GREENHOUSE AUTOMATION

Automated greenhouses do exist for large scale greenhouses. Companies such as Grow Ponics and Climate Control Systems Inc provide services that maintain the environment as well as helping to reduce energy costs and waste. To do this, the systems need to monitor and manage a range of factors, such as: temperature, humidity, amount of light, wind speed and direction, CO2 levels, water flow, pH and the amount of fertiliser needed.

Jain *et al.* (2001) developed a mathematical model to study the thermal behavior after evaporative cooling (fan and pad type) in the greenhouse. A computer program based on MatLab software has been used for computational purposes. The cooling system parameters, like length of greenhouse, height of cooling pad and mass flow rate were optimized against the maximum temperature in zone-I and zone-II. The temperature in the greenhouse increased along the length of the greenhouse due to receiving solar incident radiation. The predicted average temperature in zone-I and zone-II shown fair agreement with experimental values.

Waghmare *et al.* (2011) experimentally proved that the hardware develop by Cypress Inc. was the best solution which works on low power with less complexity and high reliability for greenhouse control. In the future, if parameter still increase, then for WSN technology with currently available bandwidth, may not be sufficient. Then WSN with cognitive radio technology may be the solution. This advancement in precision agriculture through Wireless Sensor Network in greenhouse control is extremely useful. This has scope in developing countries in globe, where agriculture is the main business.

Fahmy *et al.* (2012) presented an evaporative cooling system to reduce the air temperature inside the greenhouse that affects the greenhouse environment and consequently the growing of cultivated plants. A control technique was proposed to fix the greenhouse inside temperature and relative humidity at the optimal values (i.e., 20˚C and 70% respectively) that are suitable for growing of marjoram herb. The proposed cooling system temperature controller was designed to adjust the air volume flow rate of the fan by adjusting the speed of the fan motor in pad-fan system; to fix the greenhouse inside temperature at 20˚C. On the other hand, the humidity controller operates between dehumidify and humidify modes for removing unwanted atmospheric moisture accumulating within the greenhouse or to add the needed moisture to the air by means of humidification, to fix the greenhouse inside relative humidity at 70%. Also, a mathematical modeling and MATLAB SIMULINK model for the different components of the evaporative cooling system were presented .

Khandelwal (2012) described the design of fully automated greenhouse management system. The automatic greenhouse sensor design helped in increasing the productivity of plants. They were not only providing automatic control over the devices like shade, light, motor pump but also tackled with the critical conditions like fire, absence of light and rain. Thus with this construction, productivity of cropping could be continuously increased so that it can handle famine problem around the world.

Kolawole *et al.* (2013) used Microcontroller based Green House control device in the automatic control and monitoring of equipments and quantities such as screening installations, heating, cooling, lighting, temperature, soil moisture level and other quantities/conditions in a green house, with effective monitoring of all quantities therein, hence eliminating need for human monitoring. With an enhancable feature it integrated and automated by turning ON or OFF all monitoring devices in the house as well as providing suggestions for remedies when the need arises. This was due to the MCU technology that can be easily modified and re-modified with portability. There was also an alarm circuit to call the attention of the supervisor. This study focused on determining the effectiveness and functionality of green house control device.

Shamshiri (2013) provided a relatively detailed discussion about different control variable, their ideal levels and interaction with the environment in a tropical greenhouse. The automation levels and different control strategies which were either in the research and experiment phases or have been already commercialized to use in real greenhouses were also discussed. The ideal level of temperature and RH for greenhouse production of tomato and the 20-year weather data were presented to show the natural potential of the tropical environment in providing a comfortable condition for plant growth. They concluded that plant physiology and environmental changes in tropical greenhouse together with analyzing the control parameters and their interactions with environment, engineering modeling, simulation concepts and control hardware/software materials, support a more efficient and successful designing of the automation control software/hardware system that can properly control and monitor environmental parameters for data analysis and evaluating performance.

Eldhose *et al.* (2014) used automated greenhouse monitoring system consists of various sensors, namely soil moisture, temperature and light. These sensors sensed various parameters temperature, soil moisture and light intensity and were then sent to the PIC microcontroller and control action taken by the PIC to compare with preset values. AGMS eliminated risk of greenhouse not being maintained at specific environmental conditions due to human error and labour cost can be reduced and it is eco-friendly. Pests were eliminated by this system and also the quality of yield were increased.

Abdullah *et al* (2015) built a wireless remote control system with environmental parameters such as temperature, CO2, humidity, light, pH factor detection etc. They tested their greenhouse project in different places whether it works without any error or not and they delighted to get positive feedback regarding their project implemented in Botanical Garden. The framework had effectively overcome very a few inadequacies of the existing frameworks by lessening the force utilization, upkeep and intricacy, in the meantime given an adaptable and exact manifestation of keeping up nature.

Enokela *et al.* (2015) designed and built an automated greenhouse control system and this work was meant to protect seedlings in nurseries from intruders. This system produced healthier crops since pests were usually kept away from the greenhouse enclosure. The system's reaction time to restoration of variations of microclimatic parameters suffers from a few seconds delay because of the program scan cycle and the electro-mechanical relays used. The system was fully automated as it does not require any form of adjustment from the user. The microclimatic parameters were also available at a remote terminal for the user to read and to monitor the performance of the greenhouse.

Ali (2016) designed a microcontroller (Atmega32) based system to monitor and control greenhouse temperature, humidity, and intensity of light is designed. The system comprises of microcontroller (Atmega32), temperature sensor (LM35), humidity sensor (HS1101), light sensor(LDR), LCD(2*16) and actuators (water pumps, heater, fans and lights). When any change in temperature, humidity or light cross a safety threshold which has to be maintained to protect the crops, the sensors sensed the change and the microcontroller read this from the data at its input ports after being converted to a digital form by the analog to digital converter to control the temperature, humidity and intensity of light by actuating water pumps, heater, fans and lights respectively according to the necessary condition of the crops. Parameters level sensed from the sensor will be displayed in the LCD. The result that obtained show that the system performance is quite reliable and has successfully overcome quite a few shortcomings of the existing systems by reducing the power consumption, maintenance and complexity, at the same time providing a flexible and precise form of maintaining the environment.

Attalla *et al.* (2016) built an automated greenhouse with the purpose of investigating the watering system's reliability and if a desired range of temperatures can be maintained .The microcontroller used to create the automated greenhouse was an Arduino UNO. This project utilized two different sensors, a soil moisture sensor and a temperature sensor. The sensors were controlling the two actuators which are a heating fan and a pump. The heating fan is used to change the temperature and the pump is used to water the plant .The watering system and the temperature control systems were tested both separately and together. The result showed that the temperature could be maintained in the desired range. Results from the soil moisture sensor were uneven and therefore interpret was unreliable.

Deshmukh *et al.* (2016) represented the need of Automated Greenhouse and how much effective they can be in good yield of crops. As plant grows, they need certain environmental parameters for its proper growth like humidity, temperature, light. Also, Automated Greenhouse Monitoring ignores the need of human operators to take care of the plants. To monitor the greenhouse parameters like humidity, temperature, soil moisture and light properly, a control system was needed. This control system comprised of greenhouse data acquisition PIC Microcontroller along with temperature, humidity and light and pH sensor. For monitoring and storing the values of these environmental parameters PIC18F452 based circuit was used. Based on the values stored, the above system compared the stored values with threshold values set for particular plant and control the actions of cooler, heater and water pump. Greenhouse monitoring and control software collected, displayed and recorded the collected data i.e., values of various parameters, also controlled greenhouse environment. In addition to this, the system also consisted of solar inverter for backup. For displaying the stored values, they have used LCD. This system was very useful for proper cultivation and maximum yield of crops.

Rowinski (2016) designed and build a greenhouse controller that can maintain the environment, by acting upon live sensor readings and be able to display the status of the system to the owner. The temperature and humidity readings were compared to second device, a Sensirion SHTC1. The two devices gave very similar results with the temperature generally having a difference of 0.2 degrees and the humidity generally having a difference of 3%. There were no comparison devices available to see if the lux or soil moisture values were accurate.

Trivedi *et al* (2016) offered a design of fully automated greenhouse management system. From the experiment it could be seen that it is fulfilling all requirements related greenhouse monitoring. The automatic greenhouse sensor design could help in increasing the productivity of plants.

Weisensel *et al* (2016) designed and built a working prototype monitoring and control system for one room of the Buller greenhouse. This system allowed user to obtain temperature, humidity and light intensity readings as well as send temperature control commands remotely. This was achieved using Arduino microcontrollers and XBee wireless transceivers. The processes of hardware design, software design, integration, and testing of the prototype system have been described. The project was broken down into four main sections: monitoring, control, wireless communication and the web server/GUI. Each individual section was unit tested before it was integrated into the final design. A fully integrated prototype was built and bench tested to ensure proper functionality before installation into the greenhouse. The system performed as designed and was able to remotely monitor and control the greenhouses temperature. Through the successful testing of the prototype it has been demonstrated that this system could be expanded to cover all rooms in the greenhouse.

Bhatt *et al* (2017) developed a system in which people can monitor and manage growing conditions of their greenhouse. The use sensor nodes, internet connection, and the cloud delivered real-time updates about plants and help people grow plants more efficiently. This project provided a solution for automating greenhouse activities and irrigation activities. Implementation of such a system in the field helped to improve the yield of the crops and overall production, and with its quality to cost ratio, it was affordable to the majority of the agricultural community and also to agro-based industries.

Byregowda *et al* (2017) designed an automated greenhouse monitoring system consists of various sensors, namely soil moisture, temperature and light. These sensors sensed various parameters temperature, soil moisture and light intensity and were then sent to the Arduino and control action taken by the Arduino to compare with preset values. AGMS eliminated risk of greenhouse not being maintained at specific environmental conditions due to human error and labour cost can be reduced and it is eco-friendly. Pests were eliminated by this system and also the quality of yield can be increased. This system consisted of various sensors, namely soil moisture, temperature and light. These sensors sensed various parameters temperature, soil moisture and light intensity and were then sent to the Arduino. The microcontroller constantly monitored the digitized parameters of the various sensors and verified them with the predefined threshold values and checked if any corrective action were to be taken for the condition at that instant of time. An array of actuators were used in the system such as relays, contactors, and changeover switches etc. They were used to turn on AC devices such as motors, coolers, pumps, sprayers. The values of the parameters were updated to a web page created on html code. It got refreshed after every 5 seconds. All the parameter values were displayed on the web page. The status of the output devices were also updated to the same webpage as if it is ON or OFF.

Dongarsane *et al* (2017) proposed an advanced solution for monitoring the weather conditions in greenhouse and make the information visible anywhere in the world. The technology behind this is Internet of Things (IoT), which was an advanced and efficient solution for connecting the things to the internet and to connect the entire world of things in a network. The system dealt with monitoring and controlling the environmental conditions like temperature, relative humidity, with sensors and send the information to the web page and then plotted the sensor data as graphical statistics. The data updated from the implemented system can be accessible in the internet from anywhere in the world.

Wali *et al* (2017) done a step-by-step approach in designing the microcontroller based system for measurement and control of the four essential parameters for plant growth, i.e. temperature, humidity, soil moisture and light intensity, has been followed also image processing was used to detect the health of the plants for proper and healthier growth. The results obtained from the measurement have shown that the system performance is quite reliable and accurate. The system has successfully overcome quite a few shortcomings of the existing systems by reducing the power consumption, maintenance and complexity, at the same time providing a flexible and precise form of maintaining the environment. Also, integration of all these technologies was not a daunting task and was successfully carried out.

MATERIALS AND METHODS

CHAPTER 3

MATERIALS AND METHODS

3.1 GENERAL

3.1.1 LOCATION

The experiments were conducted in a naturally ventilated research polyhouse from November to January of 2018-19. The research polyhouse located at PFDC, KCAET, Tavanur, Kerala. The site is situated on the cross point of 10^{o} 51‘18‖ N latitude and 75^{o} 59‘ 11‖ E longitude at an altitude of 8.54 m above mean sea level.

3.1.2 CLIMATE

Agro climatically, Tavanur falls within the borderline of Northern zone and Central zone of Kerala. Major part of the rainfall in this region is obtained from South - West monsoon. The area has a relative humidity average of about 62%. The mean maximum temperature of the area is about 42.1°C and mean minimum temperature of the area is about 22°C.

3.2 ARDUINO

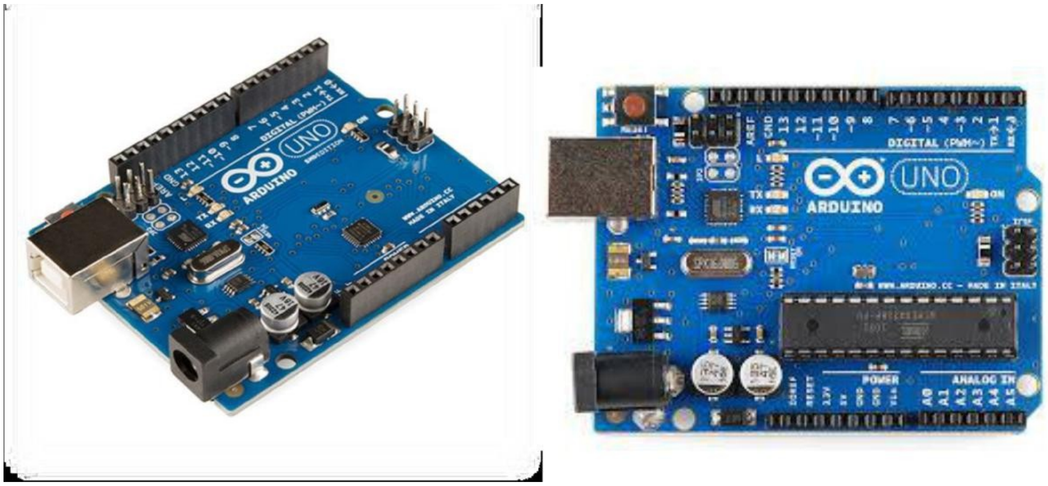

Fig. 3.1 Arduino Uno hardware

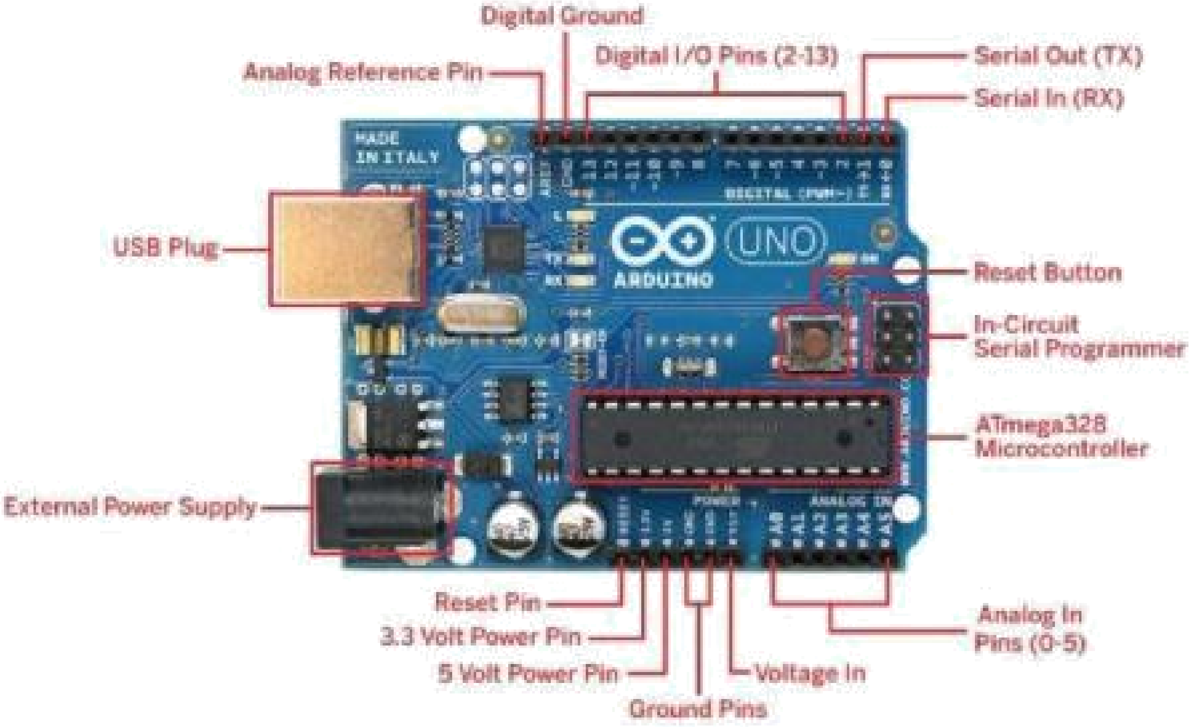

Fig. 3.2 Arduino Uno pin configuration

Arduino is an open-source electronics platform based on easy-to-use hardware and software intended for anyone making interactive products. The prototyping Arduino boards are able to read inputs - light on a sensor, a finger on a button, or a Twitter message - and turn it into an output - activating a motor, turning on an LED, publishing something online. One can tell the board what to do by sending a set of instructions to the microcontroller on the board. To do so the Arduino programming language based on wiring (another development platform) is used, along with the Arduino Software (IDE), based on processing (a similar programming language).

The specifications of the Arduino Uno board used for the study are as follows:

Microcontroller	ATmega328P
Operating Voltage	5V
Input Voltage (recommended)	7-12V
Input Voltage (limit)	6-20V
Digital I/O Pins	14 (of which 6 provide PWM output)
PWM Digital I/O Pins	6
Analogue Input Pins	6
DC Current per I/O Pin	20 mA
DC Current for 3.3V Pin	50 Ma
Flash Memory	32 KB (ATmega328P) of which 0.5 KB used by boot loader
SRAM	2 KB (ATmega328P)
EEPROM	1 KB (ATmega328P)
Clock Speed	16 MHz
Length	68.6 mm
Width	53.4 mm
Weight	25 g

For the purpose of the study, the board was powered from the computer itself using which the coding was done. For field installations, the Uno board can be powered via the USB connection or with an external power supply. External (non-USB) power can come either from an AC-to-DC adapter (wall-wart) or battery. The adapter can be connected by plugging a 2.1mm centre-positive plug into the board's power jack. Leads from a battery can be inserted in the “GND” and “Vin” pin headers of the POWER connector.

The board can operate on an external supply from 6 to 20 volts. If supplied with less than 7 V, however, the 5V pin may supply less than five volts and the board may become unstable. If using more than 12V, the voltage regulator may overheat and damage the board. The recommended range is 7 to 12 volts.

3.3 BREADBOARD

Fig 3.3 Breadboard

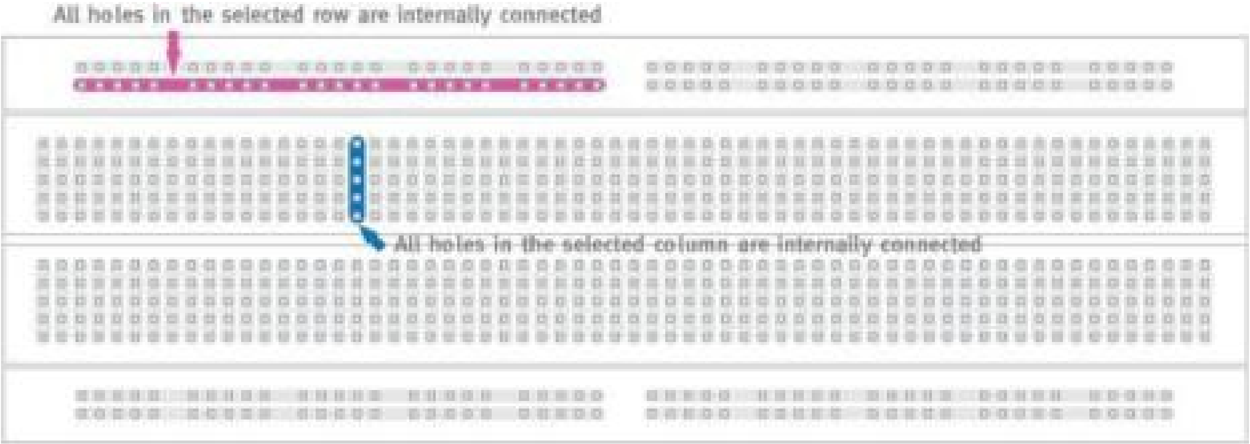

Fig 3.4 Breadboard connections

A breadboard is a construction base for prototyping of electronics without having to solder them. It is used to build and test circuits quickly before finalizing any circuit design. The breadboard has many holes into which circuit components like ICs and resistors can be inserted. The bread board has strips of metal which run underneath the board and connect the holes on the top of the board. The metal strips are laid out as shown above. The top and bottom rows of holes are connected horizontally while the remaining holes are connected vertically. A modern solder less breadboard consists of a perforated block of plastic with numerous tin plated phosphor bronze or nickel silver alloy spring clips under the perforations.

The clips are often called tie points or contact points. The number of tie points is often given in the specification of the bread board. The spacing between the clips (lead pitch) is typically 0.1 in (2.54 mm). To use the bread board, the legs of components are placed in the holes. Each set of holes connected by a metal strip underneath forms a node. A node is a point in a circuit where two components are connected. Connections between different components are formed by putting their legs in a common node. The long top and bottom row of holes are usually used for power supply connections. The rest of the circuit is built by placing components and connecting them together with jumper wires or solid conductor wires, for ease of use. Typically the spring clips are rated for 1 ampere at 5 volts and 0.333 amperes at 15 volts (5 watts).

Terminal strips are the main areas, to hold most of the electronic components. In the middle of a terminal strip of a breadboard, one typically finds a notch running in parallel to the long side. The notch is to mark the centre line of the terminal strip. The clips on the right and left of the notch are each connected in a radial way; typically five clips (i.e., beneath five holes) in a row on each side of the notch are electrically connected. The five clip columns on the left of the notch are often marked as A, B, C, D, and E, while the ones on the right are marked F,G, H, I and J.

Bus strips are to provide power to the electronic components. A bus strip usually contains two columns: one for ground and one for a supply voltage. However, some breadboards only provide a single-column power distributions bus strip on each long side. Typically the column intended for a supply voltage is marked in red, while the column for ground is marked in blue or black. Some manufacturers connect all terminals in a column. Others just connect groups of, for example, 25 consecutive terminals in a column. The breadboard used for the study is of this type. This design provides a circuit designer with some more control and flexibility in designing the circuit. Bus strips typically run down one or both sides of a terminal strip or between terminal strips. On large breadboards additional bus strips can often be found on the top and bottom of terminal strips.

3.4 JUMPER WIRES

Fig. 3.5 Jumper wires (male - to - male)

A jumper wire (or simply jump wire) is a short electrical wire with a solid tip at each end (or some times without them, simply tinned), which is normally used to interconnect the components in a breadboard. They are used to transfer electrical signals from anywhere on the breadboard to the input/output pins of a microcontroller. Jump wires are fitted by inserting their end connectors into the slots provided in the breadboard that beneath its surface has a few sets of parallel plates that connect the slots in groups of rows or columns depending on the area. The end connectors are inserted into the breadboard, without soldering, in the particular slots that need to be connected in the specific prototype. For the purpose of the study, jumper wires with insulated terminals were used. When using those with insulated solid tips the arrangement of the elements and ease of insertion of the insulated jump wire connectors on the breadboards allows increasing the mounting density of both –components and jump wires- without fear of short-circuits. The jumper wires vary in size and colour to distinguish the different working signals. Variation of jump wires with insulated terminals as per male-female combinations:

a) Male to Male (solid tips at both ends)
b) Male to Female (solid tip at one end and slot at the other end)
c) Female to Female (slots at both ends)

3.5 Humidity sensor

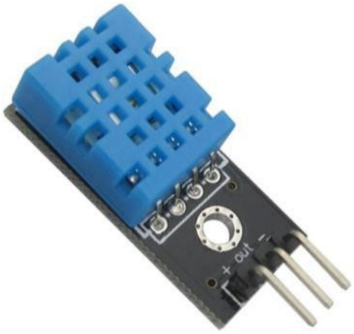

Fig. 3.6 DHT 11 Humidity Sensor

Humidity is defined as the amount of water present in the surrounding air. This water content in the air is a key factor in the wellness of mankind. Humidity is defined as the amount of water present in the surrounding air. This water content in the air is a key factor in the wellness of mankind. Hence, sensing, measuring, monitoring and controlling humidity is a very important task.

This DHT11 Humidity Sensor features a humidity sensor complex with a calibrated digital signal output. By using the exclusive digital-signal acquisition technique and humidity sensing technology, it ensures high reliability and excellent long-term stability. This sensor includes a resistive-type humidity measurement component that connects to a high performance 8-bit microcontroller, offering excellent quality, fast response, anti interference ability and cost-effectiveness.

Each DHT11 element is strictly calibrated in the laboratory by the manufacturer and the calibration coefficients are stored as programmes in the OTP memory, which are used by the sensors internal signal detecting process. The single-wire serial interface makes system integration quick and easy. Its small size, low power consumption and up-to-20 meter signal transmission making it the best choice for various applications, including those most demanding ones. The component is 4-pin single row pin package. It is convenient to connect and easy to use even for novices in electronics.

The DHT11 calculates relative humidity by measuring the electrical resistance between two electrodes. The humidity sensing component of the DHT11 is a moisture holding substrate with the electrodes applied to the surface. When water vapor is absorbed by the substrate, ions are released by the substrate which increases the conductivity between the electrodes. The change in resistance between the two electrodes is proportional to the relative humidity. Higher relative humidity decreases the resistance between the electrodes while lower relative humidity increases the resistance between the electrodes. The DHT11 converts the resistance measurement to relative humidity on a chip mounted to the back of the unit and transmits the humidity readings directly to the Arduino Uno.

3.6 TEMPERATURE SENSOR

Fig. 3.7 LM35 Temperature Sensor

The LM35 series are precision integrated-circuit temperature sensors, whose output voltage is linearly proportional to the Celsius temperature. The LM35 is operates at -55˚ to +120˚C.

3.6.1 Features of LM35 Temperature Sensor:

- Calibrated directly in ˚ Celsius (Centigrade)
- Rated for full l −55˚ to +150˚C range
- Suitable for remote applications
- Low cost due to wafer-level trimming
- Operates from 4 to 30 volts
- Low self-heating,
- ±1/4˚C of typical nonlinearity

3.6.2 Operation of LM35:

The LM35 can be connected easily in the same way as other integrated circuit temperature sensors. It can be stuck or established to a surface and its temperature will be within around the range of 0.01˚C of the surface temperature. This presumes that the ambient air temperature is just about the same as the surface temperature; if the air temperature were much higher or lower than the surface temperature, the actual temperature of the LM35 die would be at an intermediate temperature between the surface temperature and the air temperature.

3.7 PCB COPPER CLAD

Fig 3.8 PCB Copper Clad

A printed circuit board also commonly known as PCB is a mechanical substrate that supports and electrically connects electronic components using conductive tracks, pads and other features etched from copper sheets laminated onto a non-conductive substrate. Components such as resistors, capacitors etc are soldered on a PCB.

Types of Copper Clad PCB:

- Single sided paper phenolic PCB
- Single sided glass epoxy PCB
- Double sided PCB

3.8 LCD DISPLAY

Fig 3.9 LCD Display

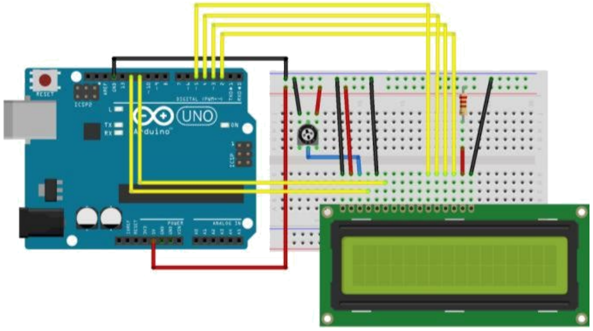

Fig 3.10 LCD Pin Connections

LCD (liquid crystal display) is the technology used for displays in notebook and other smaller computers. Like light-emitting diode (LED) and gas-plasma technologies, LCDs allow displays to be much thinner than cathode ray tube (CRT) technology. LCDs consume much less power than LED and gas-display displays because they work on the principle of blocking light rather than emitting it.

An LCD is made with either a passive matrix or an active matrix display display grid. The active matrix LCD is also known as a thin film transistor (TFT) display. The passive matrix LCD has a grid of conductors with pixels located at each intersection in the grid. A current is sent across two conductors on the grid to control the light for any pixel. An active matrix has a transistor located at each pixel intersection, requiring less current to control the luminance of a pixel. For this reason, the current in an active matrix display can be switched on and off more frequently, improving the screen refresh time.

Some passive matrix LCD's have dual scanning, meaning that they scan the grid twice with current in the same time that it took for one scan in the original technology. However, active matrix is still a superior technology.

3.9 POTENTIOMETER

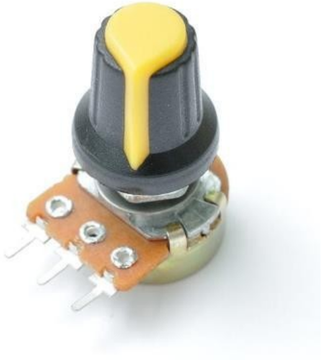

Fig 3.11 Potentiometer

The measuring instrument called a potentiometer is essentially a voltage divider used for measuring electric potential (voltage); the component is an implementation of the same principle, hence its name. Potentiometers are commonly used to control electrical devices such as volume controls on audio equipment. Potentiometers operated by a mechanism can be used as position transducers, for example, in a joystick. Potentiometers are rarely used to directly control significant power (more than a watt), since the power dissipated in the potentiometer would be comparable to the power in the controlled load.

3.10 RELAY MODULE

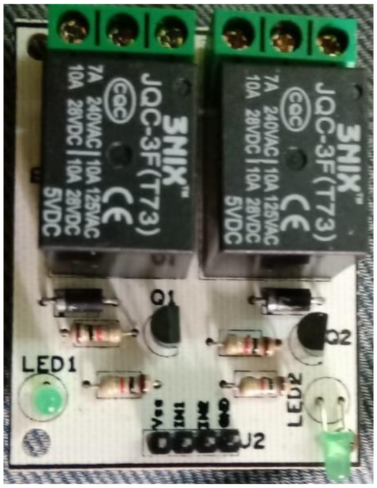

Fig 3.12 Relay Module

A relay is an electrically operated switch. Many relays use an electromagnet to mechanically operate a switch, but other operating principles are also used, such as solid-state relays. Relays are used where it is necessary to control a circuit by a low-power signal (with complete electrical isolation between control and controlled circuits), or where several circuits must be controlled by one signal.

A simple electromagnetic relay consists of a coil of wire wrapped around a soft iron core, an iron yoke which provides a low reluctance path for magnetic flux, a movable iron armature, and one or more sets of contacts (there are two in the relay pictured). The armature is hinged to the yoke and mechanically linked to one or more sets of moving contacts. It is held in place by a spring so that when the relay is de-energized there is an air gap in the magnetic circuit. In this condition, one of the two sets of contacts in the relay pictured is closed, and the other set is open. Other relays may have more or fewer sets of contacts depending on their function. The relay in the picture also has a wire connecting the armature to the yoke. This ensures continuity of the circuit between the moving contacts on the armature, and the circuit track on the printed circuit board (PCB) via the yoke, which is soldered to the PCB.

When an electric current is passed through the coil it generates a magnetic field that activates the armature and the consequent movement of the movable contact either makes or breaks (depending upon construction) a connection with a fixed contact. If the set of contacts was closed when the relay was de-energized, then the movement opens the contacts and breaks the connection, and vice versa if the contacts were open. When the current to the coil is switched off, the armature is returned by a force, approximately half as strong as the magnetic force, to its relaxed position. Usually this force is provided by a spring, but gravity is also used commonly in industrial motor starters. Most relays are manufactured to operate quickly. In a low-voltage application this reduces noise; in a high voltage or current application it reduces arcing. When the coil is energized with DC, a diode is often placed across the coil to dissipate the energy from the collapsing magnetic field at deactivation, which would otherwise generate a voltage spike dangerous to semiconductor circuit components. Such diodes were not widely used before the application of transistors as relay drivers, but soon became ubiquitous as early germanium transistors were easily destroyed by this surge. Some automotive relays include a diode inside the relay case.

3.11 AIR COOLER

Fig 3.13 Air Cooler

Air cooler is a device that cools air through the evaporation of water. Evaporative cooling differs from typical air conditioning systems, which use vapor-compression or absorption refrigeration cycles. Evaporative cooling uses the fact that water will absorb a relatively large amount of heat in order to evaporate (that is, it has a large enthalpy of vaporization). The temperature of dry air can be dropped significantly through the phase transition of liquid water to water vapor (evaporation). This can cool air using much less energy than refrigeration. In extremely dry climates, evaporative cooling of air has the added benefit of conditioning the air with more moisture for the comfort of building occupants.

3.12 EXHAUST FAN

Fig 3.13 Exhaust Fan

Exhaust fans work by sucking hot or humid air out of a small, localised area, allowing fresh air to enter from elsewhere (perhaps a doorway or vent) in order to replace it. The warm air that's drawn out using an exhaust fan is then pulled through a ducting system and expelled outside. Some exhaust fans employ sensors that allow them to automatically activate when they sense that there's steam in the room.

3.13 OBSERVATIONS

3.13.1 Weather Parameters

Following weather parameters were recorded inside the polyhouse. The parameters are measured daily at one hour interval from 9.00 am to 4.00 pm for 7days without automation and for a week with automation system separately.

3.13.1. 1 *Temperature (^{0}C)*

Fig 3.15 Mercury Thermometer

Air temperatures inside and outside the poly house are recorded using mercury thermometer.

3.13.1.2 *Relative Humidity (%)*

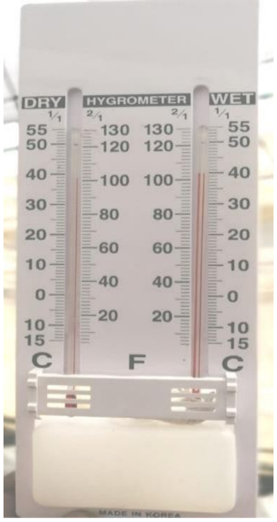

Fig 3.16 Dry and Wet Bulb Thermometer

The relative humidity inside and outside the poly house were recorded using dry bulb and wet bulb thermometer.

3.13.1.3 *Light Intensity (lux)*

Fig 3.16 Lux Meter

The solar light intensity is measured using lux meter.

3.13.1.4 *Air Velocity (m/h)*

Fig 3.17 Digital Anemometer

The velocity of air flowing inside and outside the polyhouse is measured using a digital anemometer.

3.14 CIRCUIT DESCRIPTION & PROGRAMMING

In this system Arduino is the heart of whole system which takes control over the process. When sensors sense any change in environment or in soil Arduino comes in action and process the required operation.

3.14.1 Circuit Description

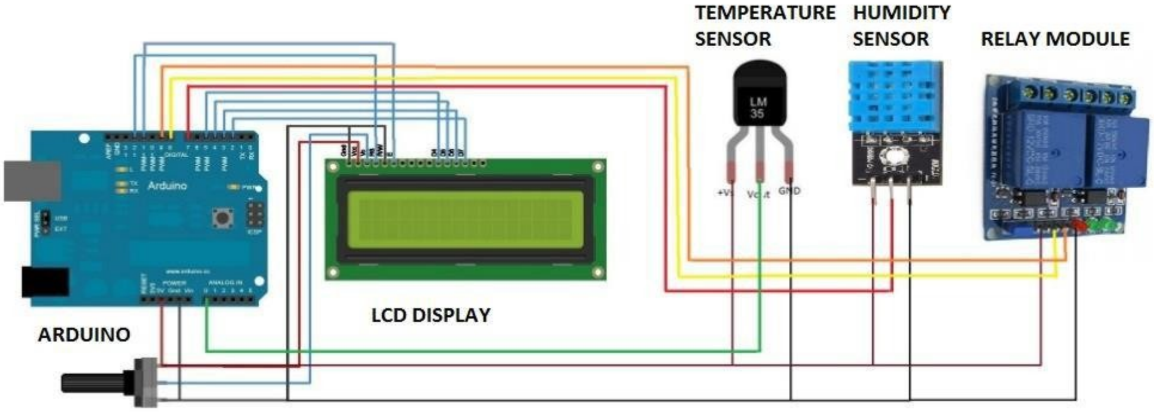

Fig 3.18 CIRCUIT DIAGRAM

3.14.2 ARDUINO CODING

The code uploaded in Arduino for the working of the full circuit is as follows:

```
#include <LiquidCrystal.h>

#include <dht.h>

dht DHT;

#define DHT11_PIN 7

float temp;

const int t = 8;

const int h = 9;
```

```
LiquidCrystal lcd(12, 11, 5, 4, 3, 2);


void setup()

{


pinMode(t, OUTPUT);

  pinMode(h, OUTPUT);

  lcd.begin(16,2);

      Serial.begin(9600);

}

void loop()

{

   temp = analogRead(A0);

  temp = temp*0.48828125;

   lcd.clear();


lcd.setCursor(0,2);

     lcd.print("TEMP:");

     lcd.setCursor(8,1);

     lcd.print(temp);

     lcd.setCursor(12,1);

     lcd.print("c");
```

```
    Serial.print("TEMP:");
 Serial.print(temp);
 Serial.print("*C");
   if(temp > 30)
   {
    digitalWrite(t,HIGH);


     }
     else{


      digitalWrite(t,LOW);
     }




 int chk = DHT.read11(DHT11_PIN);


lcd.setCursor(0,0);
lcd.print("Humidity =");
lcd.setCursor(10,0);
lcd.print(DHT.humidity);
Serial.print("Humidity =");
Serial.println(DHT.humidity);
```

```
    if (DHT.humidity < 68)

    {

     digitalWrite(h,HIGH);



    }

    else{

      digitalWrite(h,LOW);

    }

  delay(2000);

}
```

3.14.3 Circuit Diagram of PCB

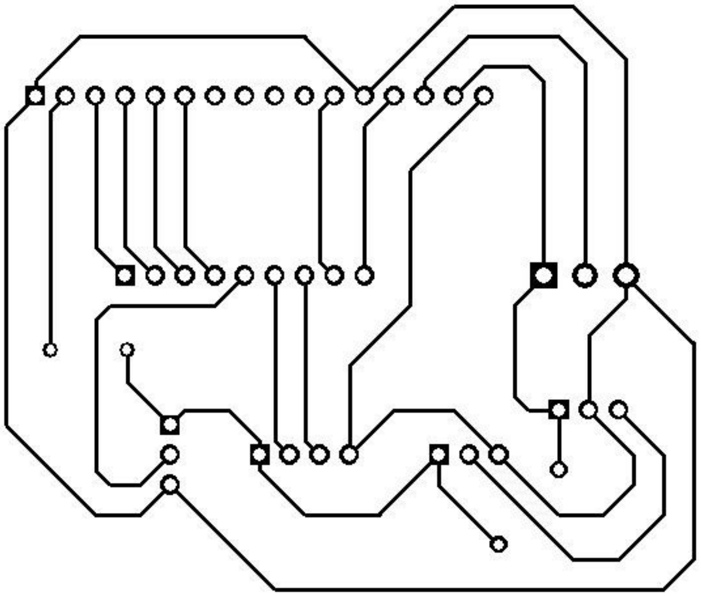

Fig 3.19 Circuit Diagram of PCB

3.14.3.1 *PCB Fabrication*

- The design for PCB fabrication is done by using Dip Trace.
- The design is checked to make sure that none of the circuit is break or short circuited. This circuit has to be printed to the copper clad.

Fig 3.20 Copper

- Before that clean the copper clad so as to remove the oxide layer deposited over it over time.

Fig 3.21 Cleaned Copper Clad

- A laser-jet printer and a photography paper should be used to print the circuit.

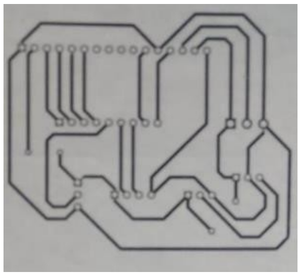

Fig 3.22 Circuit Printed on Paper

- Hot the iron (press) and put a hard surface on table.
- Put the copper clad on it and the printed layout inverted over the copper clad and apply constant heating with press over it.
- Applying little force over it exactly for 1 and a half minute to 2 minutes all over.
- After pressing put it under some water and gently scrap of the paper over the copper clad.
- The press should be kept at a setting of cotton because a little high heat can damage the copper clad hence PCB won't work.

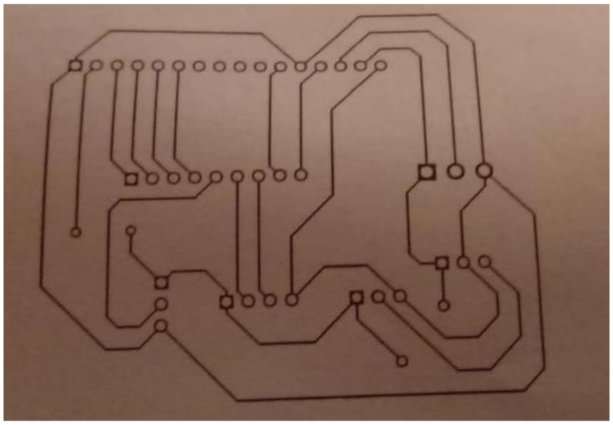

Fig 3.23 Circuit printed on the Copper Clad

- Put the printed board in $FeCl_3$ diluted acid and keep agitating the solution having the board for like 15 minutes.

- $FeCl_3$ used was diluted by just approximation. High concentration won't do great harm but can dissolve copper tracks too so $FeCl_3$ should be diluted but not too much then it can take a day or two to finish.

Fig 3.24 Printed Copper Clad dipped in $FeCl_3$ Solution

- Check if all the copper have left the board's surface and afterwards clean it with water and wash it like any usual dish (utensil) with a scrub but try to wipe only in one direction and will get visible golden brownish tracks.

- As soon as wash it dry it with tissue and spray acrylic spray so as to protect copper from reacting from gases in atmosphere.

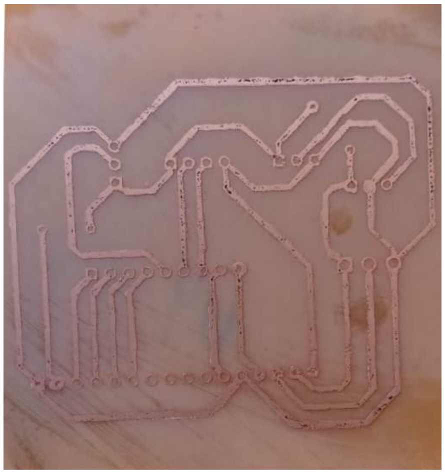

Fig 3.25 PCB Board

- Use hand drill to drill connections.

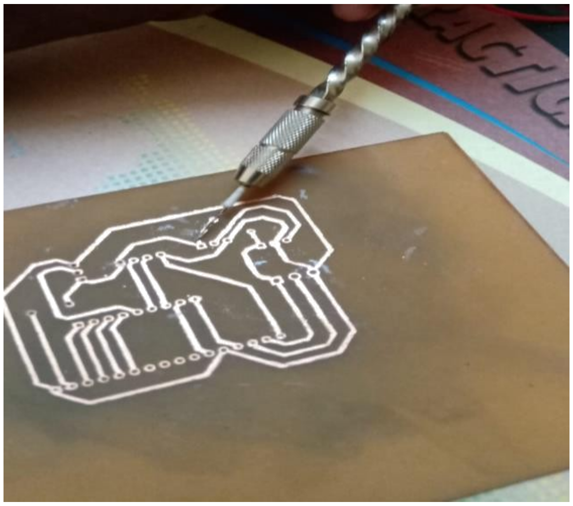

Fig 3.26 PCB board drilling

- All the connections are then soldered to the PCB board.

Fig 3.27 PCB board soldered with connections

3.14.4 WORKING OF THE AUTOMATION SYSTEM

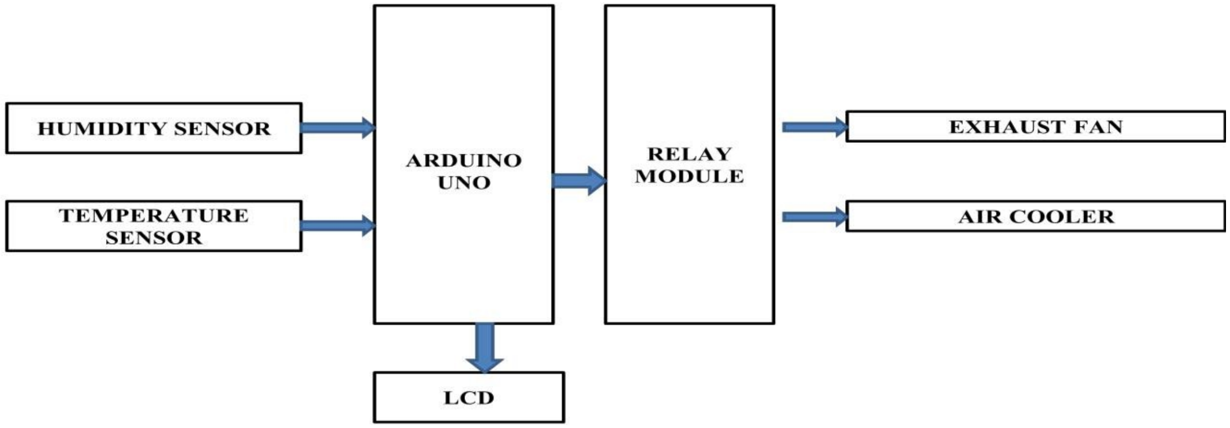

Fig 3.28 Connection Diagram

The control strategy for individual parameters to be controlled as follows:

It requires a threshold limit. When the temperature or moisture is above the threshold limit, cooling system is activated to cool the greenhouse environment .When the temperature drops below the threshold limit, the fan is deactivated. Humidity control is also done in a similar manner as the temperature is controlled, humidity is increased by using an air cooler. When the reading from the humidity exceeds the threshold value the cooler is turned off and when the value becomes less than the threshold value the cooler is turned on. This on and off of the cooling device is controlled using a relay module. A relay is an electromagnetic switch operated by a relatively small electric current that can turn on or off a much larger electric current. The heart of a relay is an electromagnet (a coil of wire that becomes a temporary magnet when electricity flows through it). Relay is a kind of electric lever: switch it on with a tiny current and it switches on ("leverages") another appliance using a much bigger current. Many sensors are incredibly sensitive pieces of electronic equipment and produce only small electric currents. But oftenit is needed to drive bigger pieces of apparatus that use bigger currents. Relays bridge the gap, making it possible for small currents to activate larger ones. That means relays can work either as switches (turning things on and off) or as amplifiers (converting small currents into larger ones).

The data is given to the Arduino is by using two sensors, ie temperature sensor and humidity sensor, The Arduino compares the readings from the temperature sensor as well as humidity sensor continuously to the threshold values of temperature sensor and moisture sensor, the increase and decrease in the reading results in the switching of relay from on to off condition.

RESULTS AND DISCUSSIONS

CHAPTER 4

RESULTS AND DISCUSSIONS

The work entitled Development and Evaluation of Greenhouse Automation System using Microcontroller was undertaken to automate greenhouse system with real time sensing based on parameters such as temperature and relative humidity. The study was done in a naturally ventilated greenhouse located in KCAET college,Tavanur, near PFDC office. The result of this work is explained in this chapter.

4.1 ASSEMBLING THE ARDUINO SYSTEM AND CODING

The Arduino Uno board and the components were assembled according to the circuit diagram. The Arduino home screen looks like:

```
void setup() {
  // put your setup code here, to run once:

}

void loop() {
  // put your main code here, to run repeatedly:

}
```

Fig. 4.1 Arduino home screen

To verify and compile the written code, i.e., to check for errors in the code the “Verify / Compile” command was used.

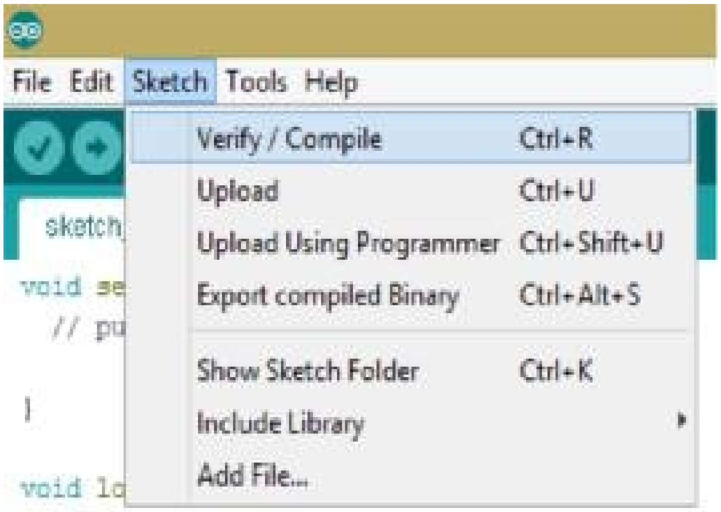

Fig 4.2 Compiling a code in Arduino

Then the program was uploaded to the Arduino board using the “Upload” command.

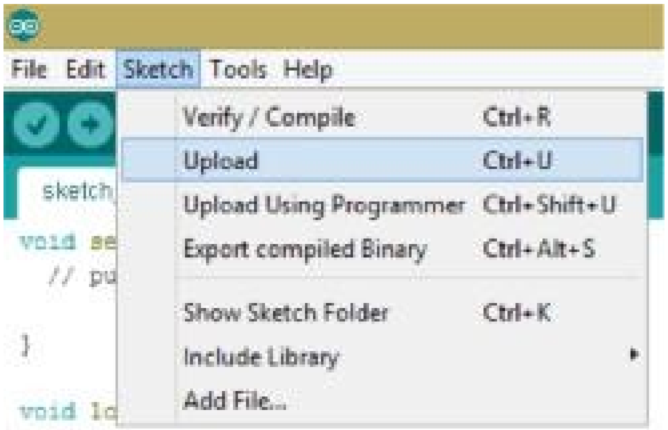

Fig. 4.3 Uploading the code to the Arduino board

To see the running status of the system, the “Serial Monitor Command” was used.

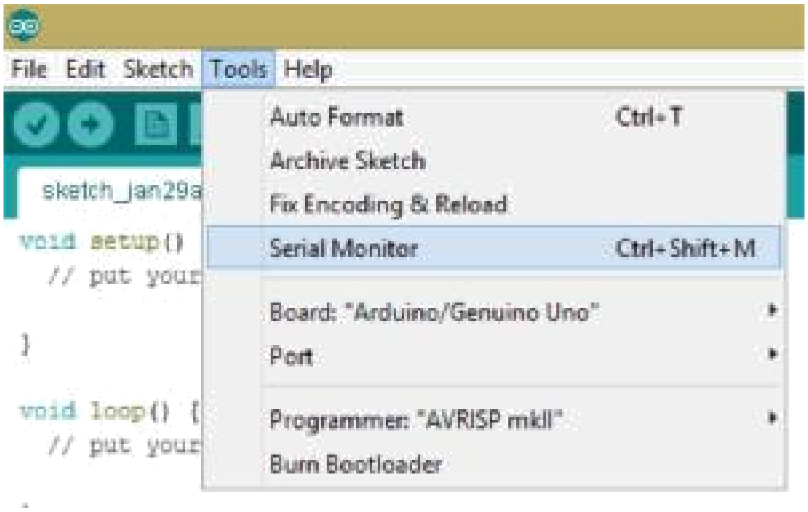

Fig. 4.4 Serial Monitor command

The serial monitor shows the readings from the humidity and temperature sensor. A sample of what the serial monitor showed during the testing of the sensors is shown next.

```
TEMP:36.62*CHumidity =43.00
TEMP:36.62*CHumidity =43.00
TEMP:36.13*CHumidity =43.00
TEMP:36.62*CHumidity =44.00
TEMP:36.13*CHumidity =44.00
TEMP:36.62*CHumidity =44.00
TEMP:36.62*CHumidity =43.00
TEMP:36.13*CHumidity =43.00
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TEMP:36.13*CHumidity =44.00
TEMP:36.13*CHumidity =44.00
TEMP:36.13*CHumidity =44.00
```

Fig 4.5 Serial Monitor window during sensor testing

4.2 COMPARISON OF CLIMATIC DATA

The climatic parameters such as temperature, relative humidity and intensity of solar radiation inside and outside of the naturally ventilated greenhouse are measured before the installation of automation system in the greenhouse from 24-11-2018 to 30-11-2018. And the climatic parameters are again measured after the installation of automation system about 1 week. Here the climatological parameters before and after automation are measured and its variation is analysed. The measurements are taken inside and outside the greenhouse at an interval of 1 hour from 9.00am to 4.00pm.

4.2.1 WITHOUT AUTOMATION SYSTEM

The following table shows the weather parameters from 9.00am to 4.00pm inside the naturally ventilated greenhouse before installation of automation system for 7 days (24-11-2018 to 30-11-2018). The outside climatic parameters are also observed and the relative humidity of most shaded portion outside the greenhouse is considered.

4.2.1.1 AIR TEMPERATURE

The daily peak air temperature inside the greenhouse are noted and tabulated in the following table 4.1. The table shows that there was a gradual increase in air temperature from morning to noon and a decrease in temperature from noon to evening inside the greenhouse. The maximum air temperature found inside the polyhouse was about 36.5°C.

Table 4.1 Daily air temperatures

Time	Inside	Outside
9:00	30	29
10:00	31.4	31
11:00	32	31.6
12:00	33.8	32
1:00	35.6	34.5
2:00	36.5	35
3:00	33	32.3
4:00	32	31.2

A
temperatur

e against graph has plotted for the analysis of the above data (figure 4.2)

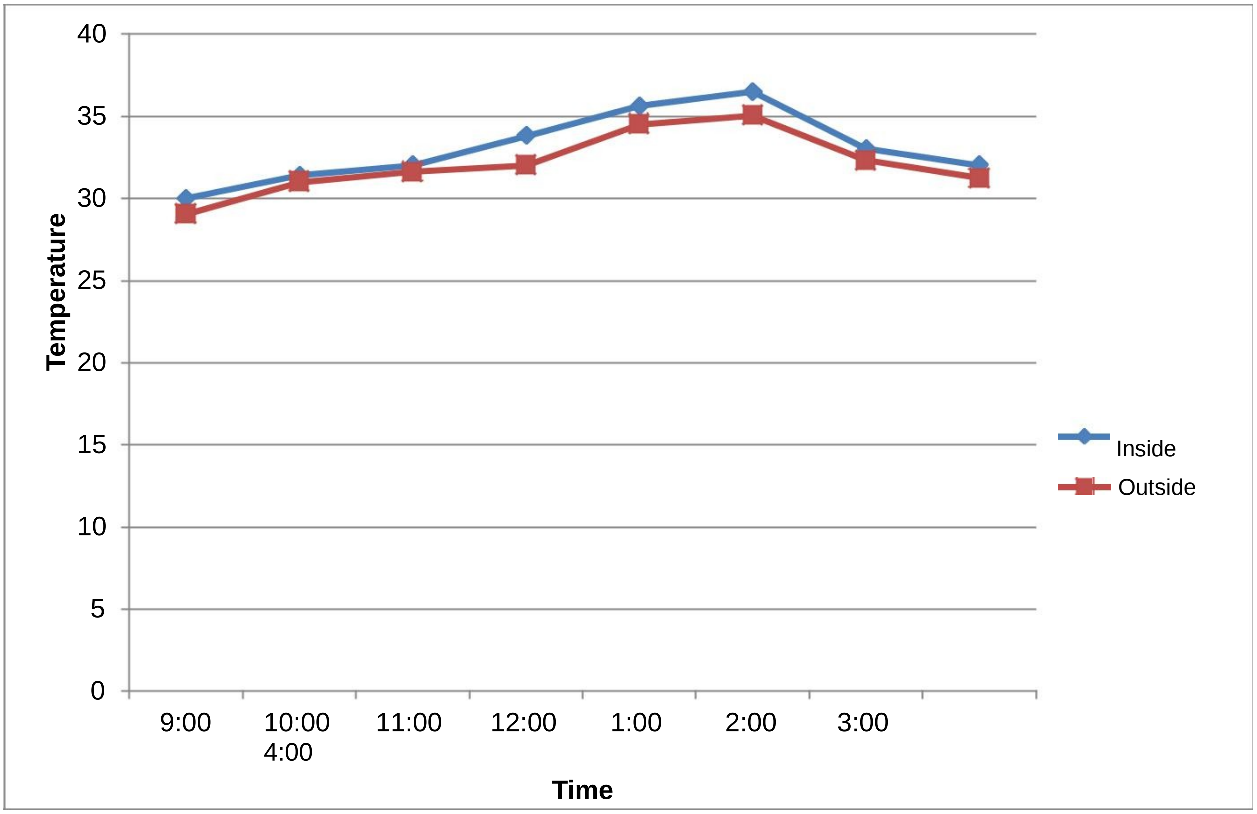


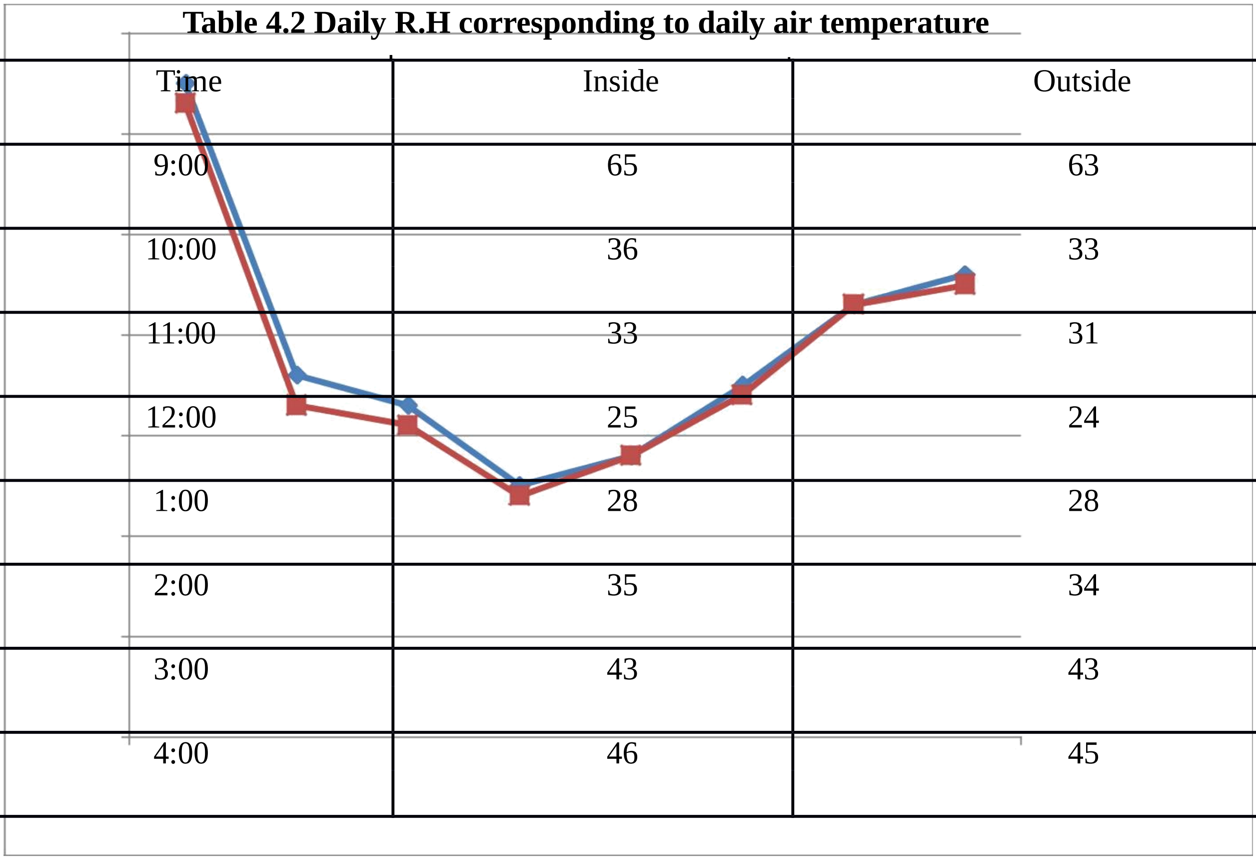
Figure 4.6 Temperature vs time graph for the polyhouse without automation system

4.2.1.2 RELATIVE HUMIDITY

The daily average relative humidity corresponding to the daily air temperatures are tabulated and a relative humidity vs time graph has plotted.

Table 4.2 Daily R.H corresponding to daily air temperature

Time	Inside	Outside
9:00	65	63
10:00	36	33
11:00	33	31
12:00	25	24
1:00	28	28
2:00	35	34
3:00	43	43
4:00	46	45



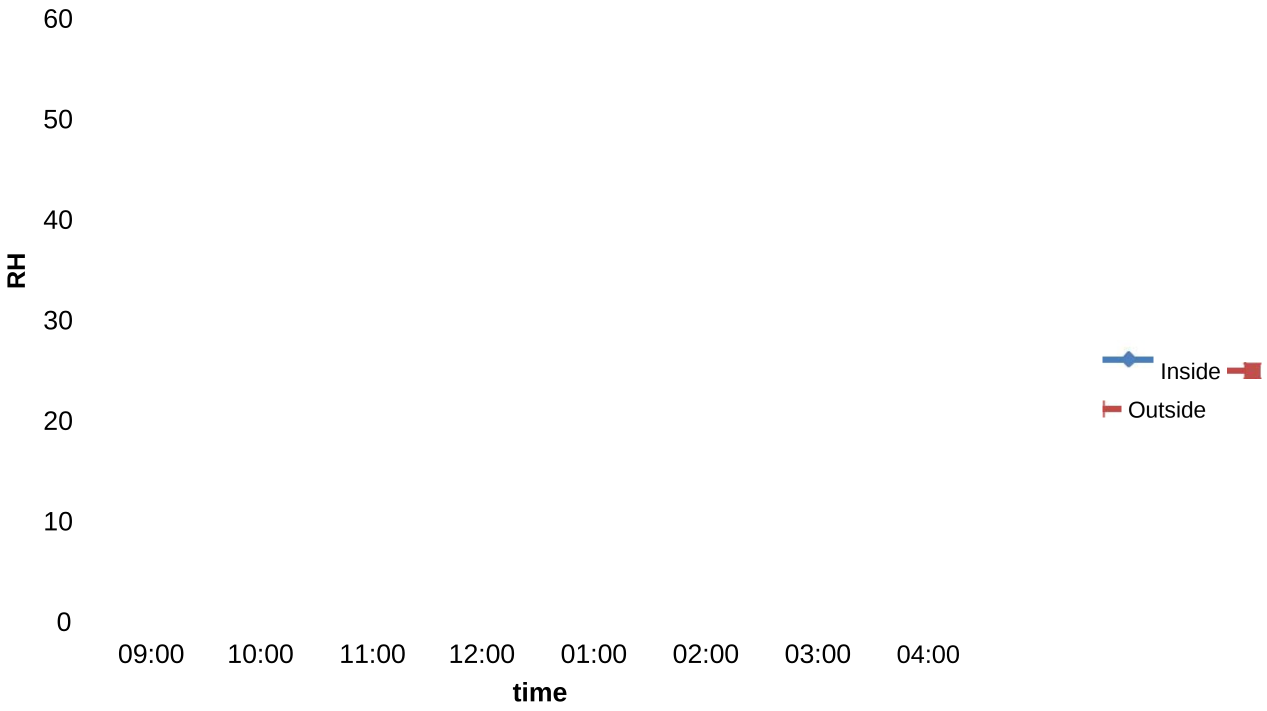


Figure 4.7 R.H vs time graph for the polyhouse without automation system

4.2.1.3 SOLAR LIGHT INTENSITY

The daily average solar light intensity corresponding to the daily air temperatures are tabulated and a solar light intensity vs time graph has plotted.

Table 4.3 Daily intensity of solar radiation corresponding to daily temperature

Time	Inside	Outside
9:00	15000	30000
10:00	17500	38000
11:00	20000	45000
12:00	22000	51000
1:00	25000	53000
2:00	27000	55000
3:00	20000	40000
4:00	17000	30000

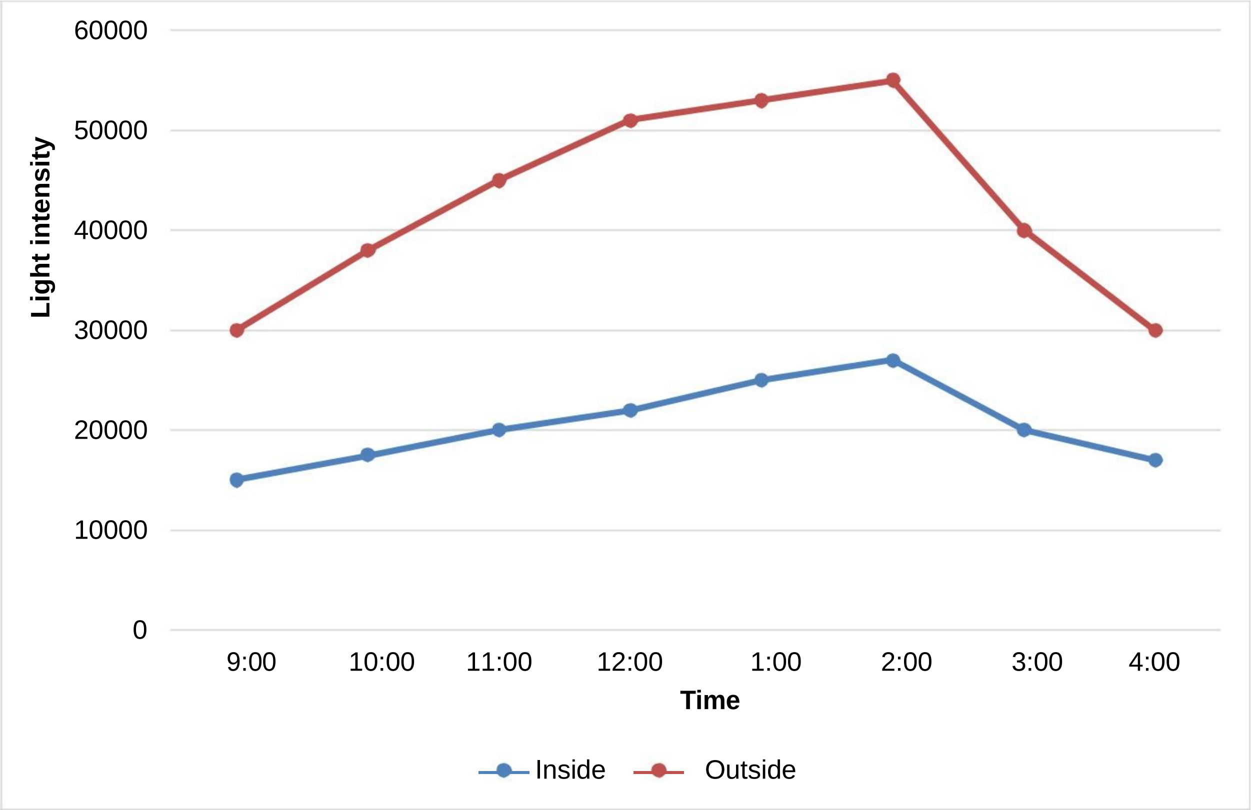


Figure 4.8 Light intensity vs time graph for the polyhouse without automation system

4.2.1.3 AIR VELOCITY

The daily average air velocity corresponding to the daily peak air temperatures are tabulated as follows:

Table 4.4 Daily air velocity corresponding to daily temperature

Time	Inside	Outside
9:00	0	0.9
10:00	0	1
11:00	0	1.1
12:00	0	1.2
1:00	0	1
2:00	0	0.8
3:00	0	0
4:00	0	1

From this data we could find that,

- The temperature gradually increases from the morning to noon and decreses from noon to evening inside the greenhouse.
- There is an average increase of about 1°C in temperature inside the poly house from outside.
- As temperatures over 33°C will result in poor growth and yield, an advanced cooling system is necessary to enhance the crop performance.

4.3.1 WITH AUTOMATION SYSTEM

4.3.1.1AIR TEMPERATURE

The daily air temperature inside the greenhouse after installing the exhaust fan are noted and tabulated in the following table

Table 4.5 Daily air temperatures

Time	Inside	Outside
9:00	31	29.5
10:00	31.5	31
11:00	32.2	31.4
12:00	33	32
1:00	32.5	32
2:00	35	34
3:00	32.8	32
4:00	31.9	30.5

A temperature against graph has plotted for the analysis of the above data

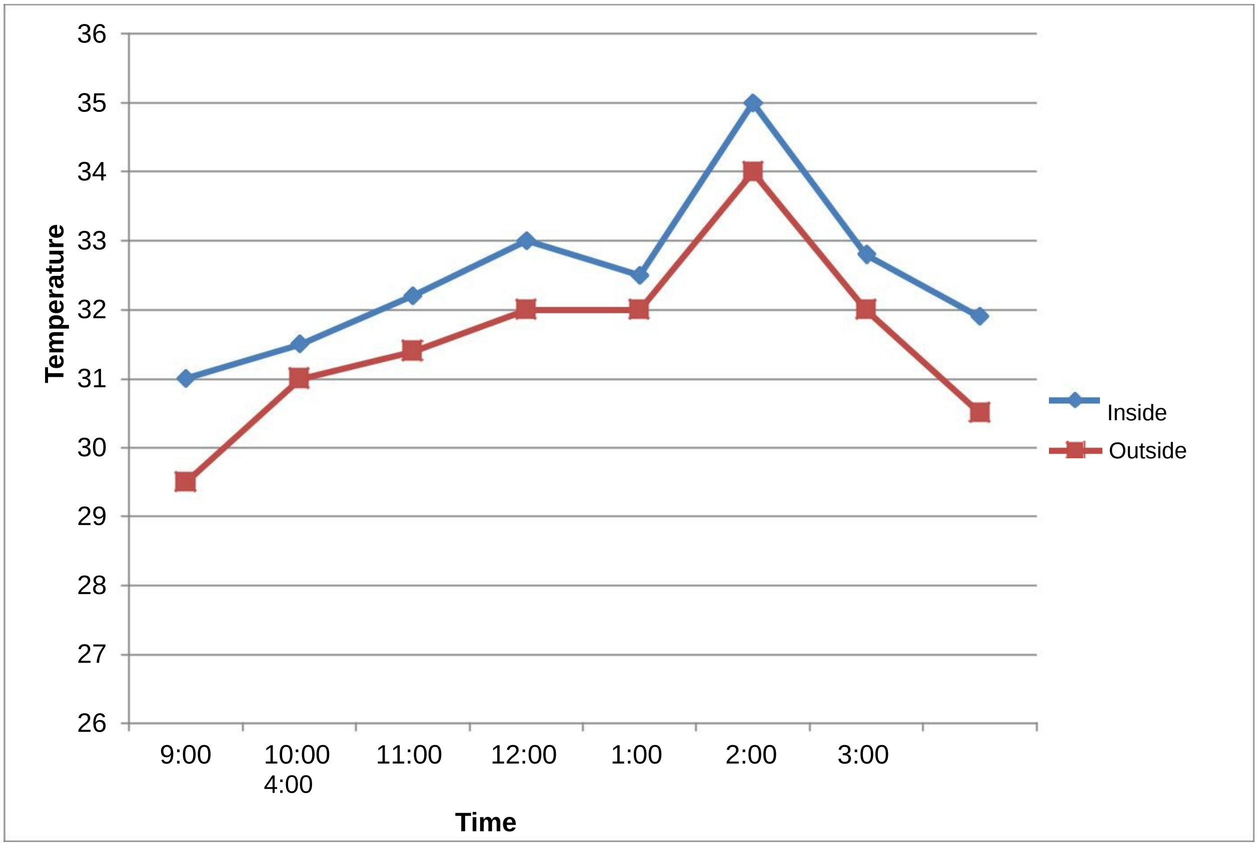


Figure 4.9 Temperature vs time graph for the polyhouse with automation system

With the installation of the exhaust fan and automation system the temperature inside the greenhouse which were harmful for the plant growth decreased by a factor of $2^{O}C$.

4.3.1.2 RELATIVE HUMIDITY

The daily average relative humidity corresponding to the daily air temperatures after installing air cooler are tabulated and a relative humidity vs time graph was plotted.

Table 4.6 Daily R.H corresponding to daily air temperature

Time	Inside	Outside
9:00 am	71	64
10:00 am	68	34
11:00 am	64	32
12:00 noon	60	25
1:00 pm	53	29
2:00 pm	57	35
3:00 pm	63	44
4:00 pm	68	46

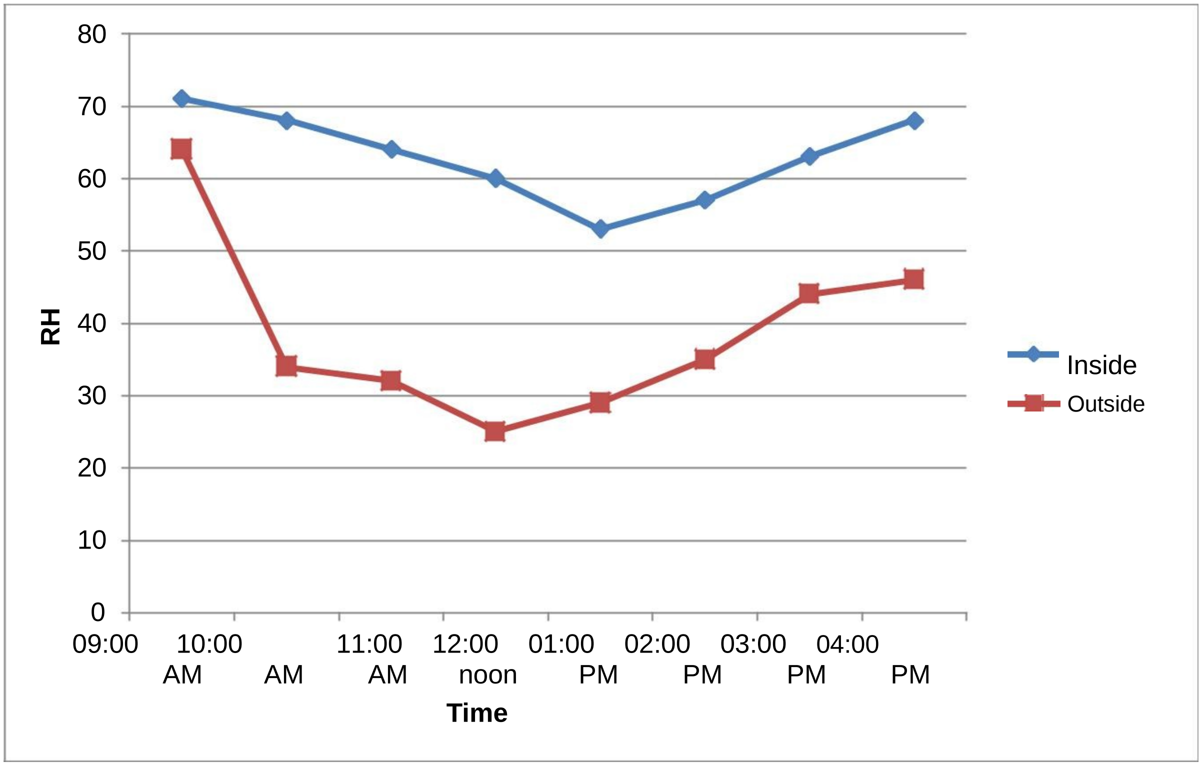


Figure 4.10 Temperature vs time graph for the polyhouse with automation system.

4.2.1.3 SOLAR LIGHT INTENSITY

The daily average solar light intensity corresponding to the daily air temperatures are tabulated and a solar light intensity vs time graph has plotted.

Table 4.7 Daily intensity of solar radiation corresponding to daily temperature

Time	Inside	Outside
9:00	13500	14050
10:00	13700	20500
11:00	14090	30800
12:00	14700	59300
1:00	20400	63500
2:00	22500	64000
3:00	21200	60000
4:00	17000	58400

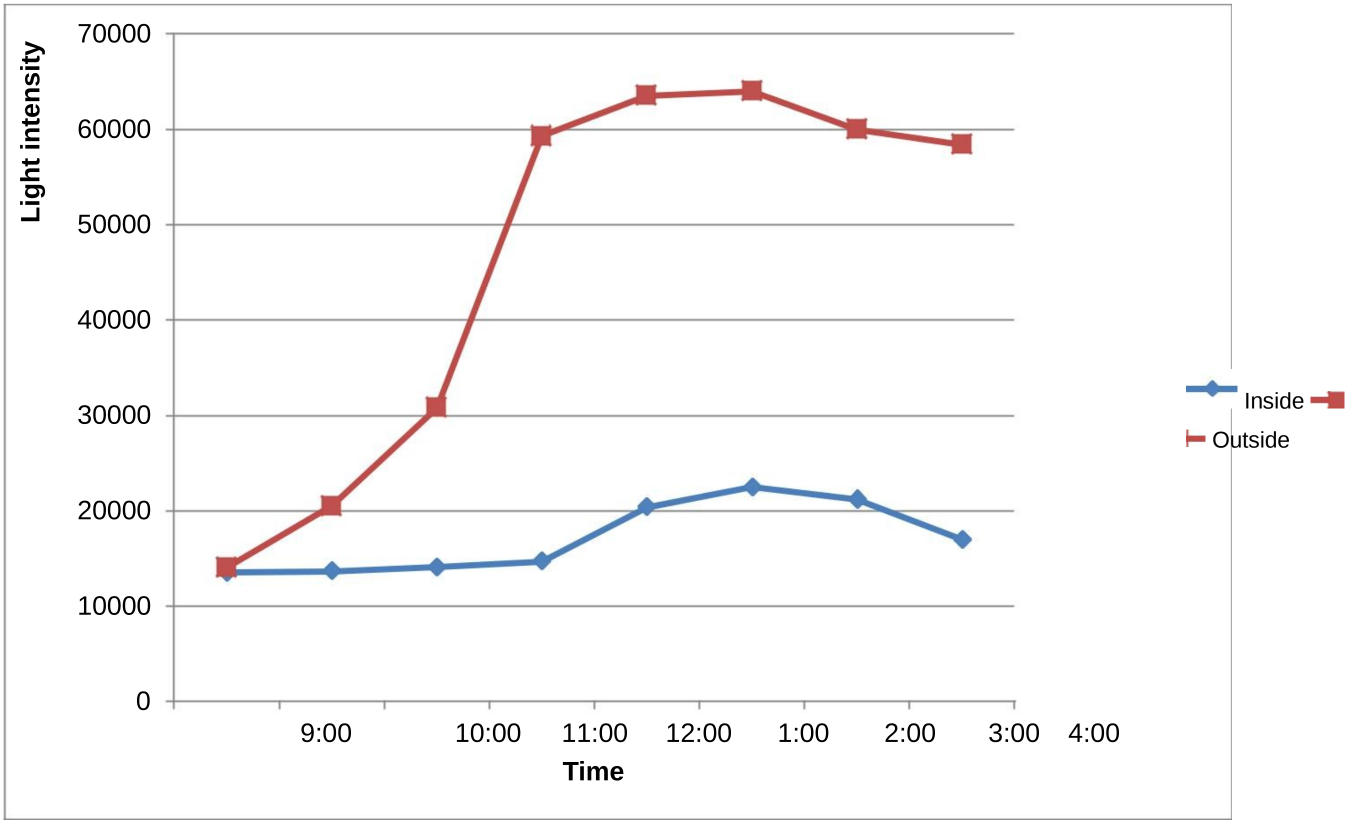


Figure 4.11 Light intensity vs time graph for the polyhouse without automation system

The automation system installed was working successfully and it was found that the relative humidity and temperature inside the polyhouse were changed according to the desired threshold limit.

SUMMARY AND CONCLUSION

SUMMARY AND CONCLUSION

CHAPTER 5

SUMMARY AND CONCLUSION

The study entitled **"**Development and Evaluation of Greenhouse Automation System using Microcontroller was taken up to fabricate an automation system for naturally ventilated greenhouse situated in the KCAET campus and its performance is analyzed by a comparing the variation of microclimatic factors inside the green house during a certain time period.

The experiments were conducted in a naturally ventilated research polyhouse having a floor area of 40sq.m (8mx 5m) from November 2018 at typical days. The research polyhouse located at PFDC, KCAET, Tavanur, Kerala. The site is situated on the cross point of 10o 51'18‖ N latitude and 75o 59' 11‖ E longitude at an altitude of 8.54 m above mean sea level.

First of all the microclimatic parameters such as temperature, relative Humidity, air velocity and light intensity inside and outside greenhouse before the installation of automated cooling system are observed from 24-11-18 to 30-11-18.The measurements are taken at an interval of 1hr from 9.00 am to 4.00 pm. Temperature is measured by using ordinary mercury thermometer. Relative humidity is measured with dry bulb and wet bulb thermometers and light intensity is measured using lux meter. Outside the greenhouse, temperature and humidity of most shaded part is noted and its variation is studied.

The automation system consisted of Arduino which is the heart of an automation system, a temperature sensor(LM35), a humidity sensor(DHT11), a PCB, relay, an exhaust fan and an air cooler. The automation system worked according to the coding program given to the Arduino microcontroller.The sensors sense the temperature and humidity inside the greenhouse and give the input to the Arduino. During the programming the limit set for the temperature is 35^{o}C and relative humidity is 68%.When the temperature and humidity inside the greenhouse exceeds this limit,the Arduino comes to action and the output of Arduino is given to the relay as its input.The relay which is an electric switch turn on and off the exhaust fan and air cooler accordingly.

The measurement of climatological parameters such as temperature, relative humidity, air velocity and light intensity inside and outside greenhouse are taken from after the installation of automated cooling system. The measurements are taken an interval of 1 hr from 9.00 am to 4.00pm. The measurements obtained before and after the installation of system was observed. Those readings are plotted in a graph against time. We have set a limiting value for both temperature and relative humidity as 35ºC and 68% respectively. So the system automatically works when it reaches the limiting value ie, the exhaust fan will get ON when temperature goes above 35 ^{o}C and cooler ON when RH will goes below 68% and both will OFF when temperature goes below 35 ^{o}C and RH goes above 68%.

The observation reveals that the temperature and relative humidity variation is controlled to some extend after the installation of automation system when it is compared to the previous case. The optimum temperature range needed for the growth of crops is 35 ^{o}C and if the temperature goes beyond this value, the plant growth will be affected. Without the automation system,during the noon time the temperature inside the greenhouse was around 36^{o} C. After the installation of the automation system the temperature inside the polyhouse during this time got reduced to a range of 34^{o}C which is not so harmful for the growth of plants.

The optimum range of relative humidity needed for the plant growth is around 60-70%.If the relative humidity increases beyond this limit, it will cause negative impact to the plants and also if the relative humidity is below this limit,it is harmful for the plants. After the installation of cooler the relative humidity inside the greenhouse was maintained atn this range. Only during the extreme noon time the cooler was not able to increase the relative humidity to the desired range.

The solar radiation intensity before and after the installation of the automation system have no much difference. Due to the shade of buildings and trees and also due to the infestation of fungus on the cladding material, the solar radiation intensity inside the greenhouse is very small compared to the solar radiation intensity outside the greenhouse.

The automation system was able to control the humidity and temperature inside the greenhouse. If it is modified there is large scope for the proper monitoring of the microclimate parameters inside a greenhouse. It can be modified to be used for controlling irrigation, soil moisture, fertilizer application rates etc. By connecting a GSM the user will be able to monitor all these without going to the greenhouse. The user will get the message on his mobile phone about the appropriate reading of the microclimate parameters. The system is advantageous in the sense that it reduces drudgery on the human beings. It is a low cost system with many advantages like controlling the system while sitting at home etc. Only a 5V power is needed to charge the Arduino. Overall the automation system was successful.

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APPENDICES

APPENDIX I

WITHOUT AUTOMATION SYSTEM

24/11/2018

Time	Temperature (^{o} C)		Humidity (%)		Air velocity (m/s)		Light intensity (lux)	
	Inside	Outside	Inside	Outside	Inside	Outside	Inside	Outside
9:00 am	28.4	24.4	53	51	0		2600	45000
10:00 am	32.2	32.3	56	43	0		8000	59500
11:00 am	34.7	32.2	39	38	0		8550	62500
12:00 noon	36.5	34.1	34	33	0		9840	67000
1:00 pm	42.7	38.5	34	33	0		12400	72000
2:00 pm	43.5	40.5	29	29	0		1310	74000
3:00 pm	35.4	29.8	46	44	0		2700	6300
4:00 pm	32.7	28.5	41	39	0		3900	18300

25/11/2018

Time	Temperature (^{o}C)		Humidity (%)		Air velocity (m/s)		Light intensity (lux)	
	Inside	Outside	Inside	Outside	Inside	Outside	Inside	Outside
9:00 am	28.5	24.4	53	51	0	0.9	2700	17000
10:00 am	32.2	32	56	43	0	1.1	8000	25000
11:00 am	37.2	35.5	30	30	0	1.1	11450	32000
12:00 noon	39.3	38	37	27	0	1.1	12400	36000
1:00 pm	42.7	38.5	33	33	0	1.2	12400	38000
2:00 pm	37.4	36.2	36	32	0	0.9	4000	33000
3:00 pm	35.4	33.9	31	30	0	1.3	3410	18000
4:00 pm	33.1	32.9	41	40	0	1.1	1500	11000

26/11/2018

Time	Temperature (^{o} C)		Humidity (%)		Air velocity (m/s)		Light intensity (lux)	
	Inside	Outside	Inside	Outside	Inside	Outside	Inside	Outside
9:00 am	28.4	24.4	53	51	0	0.7	2600	45000
10:00 am	34.8	35.2	37	36	0	0.9	9980	55300
11:00 am	35.7	32.2	39	38	0	0.7	8550	62500
12:00 noon	37.7	35.4	33	40	0	1.1	8460	63100
1:00 pm	42.7	38.5	34	33	0	1.3	11500	64000
2:00 pm	44.5	41	28	27	0	0.9	9800	72000
3:00 pm	35.5	33.9	32	30	0	1.1	3690	36000
4:00 pm	34.7	33.6	42	36	0	1.3	3500	28000

27/10/2018

Time	Temperature (^{o} C)		Humidity (%)		Air velocity (m/s)		Light intensity (lux)	
	Inside	Outside	Inside	Outside	Inside	Outside	Inside	Outside
9:00 am	28.9	27.7	44	41	0	0.9	5300	18000
10:00 am	30.3	28.3	36	33	0	1.3	4500	22000
11:00 am	36.4	33.4	36	37	0	1.2	8550	25000
12:00 noon	34.8	33.2	33	28	0	1.3	4580	32000
1:00 pm	36.4	34.5	31	30	0	0.9	6650	45000
2:00 pm	36.8	34.7	31	34	0	1.1	5100	58000
3:00 pm	35.6	34.9	44	43	0	0.7	3600	19000
4:00 pm	30.6	28.5	47	47	0	1.1	2040	12000

28/11/2018

Time	Temperature (^{o} C)		Humidity (%)		Air velocity (m/s)		Light intensity (lux)	
	Inside	Outside	Inside	Outside	Inside	Outside	Inside	Outside
9:00 am	32.5	28.7	65	63	0	0.7	5810	23000
10:00 am	35.8	35	36	33	0	1.1	1000	50800
11:00 am	36.4	32.4	33	31	0	1.2	1090	60700
12:00 noon	40.5	37.4	26	24	0	1.2	15600	64000
1:00 pm	38.7	36.7	28	28	0	1.1	11300	58000
2:00 pm	36.8	34.7	32	34	0	1.3	6000	29300
3:00 pm	34.6	32.4	43	43	0	0.9	43000	17400
4:00 pm	32.4	28.9	46	45	0	0.7	3600	15300

29/11/2018

Time	Temperature (^{o} C)		Humidity (%)		Air velocity (m/s)		Light intensity (lux)	
	Inside	Outside	Inside	Outside	Inside	Outside	Inside	Outside
9:00 am	32.6	32	56	55	0	0.7	4500	18000
10:00 am	34.3	32.5	45	45	0	0.9	7300	35000
11:00 am	35.9	35.1	41	40	0	0.7	7600	47000
12:00 noon	40.1	41	39	39	0	1.1	12600	51000
1:00 pm	40.9	38.6	45	45	0	1.3	9600	48000
2:00 pm	33.4	32.8	51	47	0	0.9	2800	14100
3:00 pm	33.4	31.8	54	53	0	1.1	3200	12500
4:00 pm	30.4	28.4	57	55	0	1.3	2900	8200

30/11/2018

Time	Temperature (^{o} C)		Humidity (%)		Air velocity (m/s)		Light intensity (lux)	
	Inside	Outside	Inside	Outside	Inside	Outside	Inside	Outside
9:00 am	26.1	26	70	65	0	0.7	1600	8100
10:00 am	27.8	27.5	68	68	0	1.1	4510	16650
11:00 am	29.7	29.3	51	51	0	1.2	4000	19400
12:00 noon	35.4	33.4	47	45	0	1.2	7200	26610
1:00 pm	38.2	37.2	31	32	0	1.1	6200	26600
2:00 pm	50.1	36.9	30	28	0	1.3	6600	32000
3:00 pm	36.9	34.3	36	35	0	0.9	5010	28000
4:00 pm	32.5	32.2	41	41	0	0.7	2800	8200

APPENDIX II

WITH AUTOMATION SYSTEM

3/01/2019

Time	Temperature (^{o} C)		Humidity (%)		Air velocity (m/s)		Light intensity (lux)	
	Inside	Outside	Inside	Outside	Inside	Outside	Inside	Outside
9:00 am	26.5	24.4	71	64	0	0.7	1600	8100
10:00 am	31.2	29	68	34	0	1.1	4510	16650
11:00 am	33.2	30.5	64	32	0.3	1.2	4000	19400
12:00 noon	34.3	33	60	25	1.1	1.2	7200	26610
1:00 pm	35.9	35.5	53	28	1.4	1.1	6200	26600
2:00 pm	35.7	35.2	57	34	1.3	1.3	6600	32000
3:00 pm	35.4	33.9	63	43	1.1	0.9	5010	28000
4:00 pm	33.1	32.9	68	45	0.9	0.7	2800	8200

4/01/2019

Time	Temperature (^{o} C)		Humidity (%)		Air velocity (m/s)		Light intensity (lux)	
	Inside	Outside	Inside	Outside	Inside	Outside	Inside	Outside
9:00 am	27.5	25.4	70	63	0	0.7	1700	8200
10:00 am	30.2	28	67	33	0	0.9	4610	17650
11:00 am	32.2	31.5	63	31	0.4	0.7	4500	20400
12:00 noon	33.3	32.9	59	24	1.2	1.1	7300	27610
1:00 pm	34.9	33.5	52	27	1.3	1.3	6300	26600
2:00 pm	35.7	35.1	56	33	1.2	0.9	6700	33000
3:00 pm	35.2	33.7	62	43	1.1	1.1	5110	29000
4:00 pm	33.2	32.5	67	44	0.7	1.3	3000	8300

5/01/2019

Time	Temperature (^{o} C)		Humidity (%)		Air velocity (m/s)		Light intensity (lux)	
	Inside	Outside	Inside	Outside	Inside	Outside	Inside	Outside
9:00 am	28.5	25.4	72	66	0	0.7	1600	8100
10:00 am	33.2	31	69	36	0	1.1	4510	16650
11:00 am	34.2	32.5	65	34	0.3	1.2	4000	19400
12:00 noon	34.3	33.5	61	27	1.1	1.2	7200	26610
1:00 pm	34.9	34.5	55	29	1.4	1.1	6200	26600
2:00 pm	33.7	33.2	54	37	1.3	1.3	6600	32000
3:00 pm	32.4	31.9	64	45	1.1	0.9	5010	28000
4:00 pm	32.1	31.5	69	47	0.9	0.7	2800	8200

6/01/2019

Time	Temperature (^{o} C)		Humidity (%)		Air velocity (m/s)		Light intensity (lux)	
	Inside	Outside	Inside	Outside	Inside	Outside	Inside	Outside
9:00 am	25.5	24.4	71	64	0	0.7	1600	8100
10:00 am	30.2	29	68	34	0	1.1	4510	16650
11:00 am	32.2	30.5	64	32	0.3	1.2	4000	19400
12:00 noon	33.3	33	60	25	1.1	1.2	7200	26610
1:00 pm	34.9	35.5	53	28	1.4	1.1	6200	26600
2:00 pm	35.7	35.2	57	34	1.3	1.3	6600	32000
3:00 pm	35.4	33.9	63	43	1.1	0.9	5010	28000
4:00 pm	33.1	32.9	68	45	0.9	0.7	2800	8200

7/01/2019

Time	Temperature (^{o} C)		Humidity (%)		Air velocity (m/s)		Light intensity (lux)	
	Inside	Outside	Inside	Outside	Inside	Outside	Inside	Outside
9:00 am	31	27.4	70	65	0	0.7	1600	8100
10:00 am	32.1	30.2	65	35	0	1.1	4510	16650
11:00 am	32.7	31.5	61	31	0.3	1.2	4000	19400
12:00 noon	33	32.3	58	26	1.1	1.2	7200	26610
1:00 pm	34	33.5	54	28	1.4	1.1	6200	26600
2:00 pm	33.5	31.2	58	35	1.3	1.3	6600	32000
3:00 pm	33	32.3	64	46	1.1	0.9	5010	28000
4:00 pm	32.1	31.9	68	48	0.9	0.7	2800	8200

8/01/2019

Time	Temperature (^{o} C)		Humidity (%)		Air velocity (m/s)		Light intensity (lux)	
	Inside	Outside	Inside	Outside	Inside	Outside	Inside	Outside
9:00 am	29.9	27.4	73	66	0	0.7	1600	8100
10:00 am	31.8	29.5	65	36	0	1.1	4510	16650
11:00 am	32.3	31.5	61	34	0.3	1.2	4000	19400
12:00 noon	33.5	33	58	26	1.1	1.2	7200	26610
1:00 pm	34	33.5	52	29	1.4	1.1	6200	26600
2:00 pm	33	32.2	57	35	1.3	1.3	6600	32000
3:00 pm	32.5	31.9	64	45	1.1	0.9	5010	28000
4:00 pm	32.1	30.9	67	48	0.9	0.7	2800	8200

9/01/2019

Time	Temperature (^{o} C)		Humidity (%)		Air velocity (m/s)		Light intensity (lux)	
	Inside	Outside	Inside	Outside	Inside	Outside	Inside	Outside
9:00 am	28.7	27.4	69	65	0	0.7	5300	8100
10:00 am	31.4	29.5	67	35	0	1.1	6900	16650
11:00 am	32.9	31.5	63	33	0.3	1.2	8400	19400
12:00 noon	33	32.1	59	26	1.1	1.2	15810	26610
1:00 pm	34.5	33.5	52	29	1.4	1.1	17125	26600
2:00 pm	34	33.2	56	36	1.3	1.3	18588	32000
3:00 pm	33	31.9	62	45	1.1	0.9	13456	28000
4:00 pm	32	30.9	66	47	0.9	0.7	7200	8200

DEVELOPMENT AND EVALUATION OF GREENHOUSE AUTOMATION SYSTEM USING MICROCONTROLLER

By

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ABSTRACT

Submitted in partial fulfilment of the requirement for the degree

Bachelor of Technology

In

Agricultural Engineering

Faculty of Agricultural Engineering and Technology

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2019

ABSTRACT

Today a major problem in Kerala is its heavy dependency on neighbouring states for food products. One of the main reasons for decline in agriculture in our state is the lack of availability of cheap labour in our state. This problem can be overcome by automation in agriculture. The introduction of “automated greenhouse system” can bring a green revolution in agriculture. Introducing this system can help in increasing the cultivation in a controlled environment. Greenhouse environment, used to grow plants under controlled climatic conditions for efficient production, forms an important part of the agriculture and horticulture sectors. Appropriate environmental conditions are necessary for optimum plant growth, improved crop yields, and efficient use of water and other resources. Automating the data acquisition process of the soil conditions and various climatic parameters that govern plant growth allows information to be collected with less labour requirements.

The study entitled **“**Development and evaluation of greenhouse automation system using microcontroller” was taken up to fabricate an automated system for naturally ventilated greenhouse situated in the KCAET campus and which is suitable for the climatic conditions of Kerala. For analyzing the performance of the automation system, the climatological parameters inside and outside greenhouse before and after the installation of automation system are observed from 24-11-18 to 06-12-18 at an interval of 1hr from 9.00 am to 4.00 pm. And it was found that the automation system installed was successful in reducing the temperature and for maintaining the required relative humidity inside the greenhouse.