DESIGN, FABRICATION AND TESTING OF A LOW COST GREEN HOUSE

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PROJECT REPORT

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INTRODUCTION

Agriculture has been a mainstay of human beings from time immemorial .This branch of applied science has derived its name from the Latin word ´ager' meaning land or field and ´cultura' meaning cultivation. Thus agriculture refers broadly to the technology of raising plants and animals . On the other hand Horticulture which is a part of agriculture in the present context is concerned with production, utilisation and improvement of fruits , vegetables , ornamental plants , spices and plantation crops including medicinal and aromatic plants.

Flowers are grown wherever man has established himself. Floriculture , a branch of Horticulture , is the art of growing, selling , designing and arranging flowers and foliage plants . In the tropical climates they are grown out of doors and limited quantities grown by amateurs and businessmen alike , enter the sales channel there . The compulsion to purchase floral products is greater in temperate and frigid climates where natural floral plants are not so abundant and where there is a need to establish ties with nature during the dormant winter season . A few tropical regions have recognised this need while in non-tropical areas, vast quantities of floral products are produced under protected environment.

The greenhouse industry as we know it today originated in Holland during its 'Golden age',the 1600s. The Royal courts of Europe had a taste for elegance and the means to afford it.Spring flowers in the winter and fruit out of season were very enticing The productive capacity of the large middle class and the trade channels of the merchant segment soon gave birth in The Netherlands to what is today the largest Greenhouse vegetable and cut flower industry exists with its center in the Westland areas as a direct descendant of this initial business.

Prior to 18th century, structure fabricated from wooden frames with glass or oiled paper cover and with or without artificial heating were used. In the late 19th century, the 'lean-to-type' greenhouses using glass sloping to the south side were introduced. Controlled environment agriculture in the form of greenhouses,low tunnels, cloches is being practised at commercial levels in many countries. This technology gives high productivity and permits production of crops under unfavourable land and climatic conditions where traditional cultivation would not be possible.

Cloches and low tunnels cover an individual plant or a row of plants.They do not permit artificial heating or cooling and hence they have usefulness under cold climates where the advantage of greenhouse effect is realised for keeping the young plants and seedlings warm. These structures also protect the plants from high winds intensive rains, hail and snow.

Our knowledge about plant physiology suggests that for a plant of given genetic make-up, the factors that affect the plant growth are light,temperature,air composition and nature of the root medium.Majority of engineering and agronomic practices modify and try to control the nature of the root medium. There is practically no way to substantially modify or control light, temperature, air composition parameters in open field cultivation. Therefore , crop production in open fields still remains to be contingent upon good weather conditions. With the increasing human population, rising level of sophistication, increasing competition for resources and unpredictable climatic changes, the traditional open field cultivation needs to be reassessed.

Agriculture in India has made excellent progress after Independence with the hybrid variety seeds, improved agronomic and engineering practices and plant protection activities. As a result, the food grain production in India has registered a marked increase during the last few years. The scenario has not been that rosy in the case of other crops such as vegetables, fruits etc. while all efforts must be made to harness the maximum potential of the available options, new ways of increasing productivity must also be pursued so that the society's expectations are fulfilled. Greenhouses provide the practical way of controlling the crop micro-climate. An year round supply of perishable commodities of superior quality than the field grown ones can be ensured by adopting the greenhouse method of cultivation.

There exists a tremendous potential for incorporating greenhouse technology in Indian agriculture. About 75mha of area comprising of problematic conditions can be made productive by bringing them under controlled environment agriculture. Farmers with small and marginal land holdings can increase their income by adopting the greenhouse form of intensive cultivation.If simple greenhouses of suitable sizes are available, the little gardening space with many rural and urban dwelling could be utilised for household vegetable and flower production.

The high initial investment and the short life span of covering material are being projected as the major hurdles for adoption of greenhouse cultivation. Adoption of existing designs of greenhouses with proper testing and modifications to suit the local conditions utilising locally available materials would be desirable. Structures with simple designs, low capital investment and of longer life span are preferred. Considering these facts and the contemporary relevance of a low cost greenhouse a study was proposed with the following specific objectives:

1. Design and fabrication of a low cost greenhouse.
2. Design of a cooling system for the greenhouse.
3. Control of the climatic parameters in the greenhouse.
4. Performance evaluation of the greenhouse.

REVIEW OF LITERATURE

This chapter briefly describes the research and devolopment activities done in the past few years in the greenhouse.

2.1.Greenhouse

Dalrymple (1973) defined greenhouses as framed or inflated structures covered with transparent or transluscent material in which crops may 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 cultural operations.

Greenhouse glazing acts as a selective radiation filter, so that solar radiation could pass through it, but the thermal radiation emitted by the objects within the greenhouse could not escape. This particular effect, called **Greenhouse Effect**, causes rise of temperature within the greenhouse. The closed boundaries check natural ventil ation thus permitting retention of radiant energy within the greenhouse, with enrichment of carbon-di-oxide and low water requirements. (Bohra , 1985)

Mears (1990) had discussed the possibilities of greenhouse technology in India .The Indian sub- continent which lies between 40° and 8° 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 greenhouses in plant production, plant culture etc. necessitates greenhouse systems.The evolution of environmental control systems along with greenhouse technology suitable for providing the plant environments under existing external agro-climatic condition is necessary in the area where the plants are to be produced .

2.2. Forms of controlled environment

Bohra (1985)had discussed the controlled environment agriculture in the form of low tunnels ,cloches, mulching and growth chambers, a brief account of which is given below :

Cloches and low tunnels cover an individual plant or a row of plants and do not permit artificial heating or cooling. They are used in cold climates where advantage of greenhouse effect is utilised for keeping the seedlings warm. The frame work may be of metal or wood with plastic film covering. Mulches is the simplest of all covered cultivation methods where the soil surface around the plants is covered with crop residues, leaves, plastic films etc. Mulching, to a limited extent can control soil temperature and moisture. Growth chambers or environmental chambers with the provision of precise control over temperature, humidity, ventil ation and light. They are used to study the growth dynamics of crops and arrive at optimum parameters for plant growth and to determine the various crop responses. Greenhouses through the active environmental control provides higher productivity even under unfavourable land and climatic conditions. Table 1. provides the comparison between conventional and controlled methods of crop production .

2.3. Design shapes

Several styles of greenhouses were designed to meet specific purpose.Greenhouses as they exist today are almost two centuries old; cloches and other simple plant growing structures are much older. Some of the greenhouse shapes which prevailed during eighteenth century are given in fig. 1.

Chandra (1985) had summarised the information available on greenhouse and classified the structures:

Table 1. Comparison among surface covered and open field cultivation method*

Sl. No.	Attributes	Open field	Mulching	Cloches and low tunnels	Greenhouses
1.	Crops generally grown	All crops	All crops	Horticultural crops	Horticultural crops
2.	Possibility of year round cultivation	Limited	Limited	In colder climates	In all conditions
3.	Labour requirements (Man-year/ha)	1	1-2	2-4	4-10
4.	Index of water use efficiency	1.0	1.3-1.5	1.3-1.5	1.3-1.5
5.	Passive environmental control	Maximum	Possible to some extent	Possible to some extent	Possible to some extent
6.	Active environmental control	Impractical	Impractical	Impractical	Generally practical
7.	Productivity index	1.0	1.5-3.0	3-5	5-15
8.	Net return Rs./ha/yr	4000-7000	6000-10000	10000-20000	10000-200000

* Adapted from proceedings of the summer institute on greenhouse design and environmental control

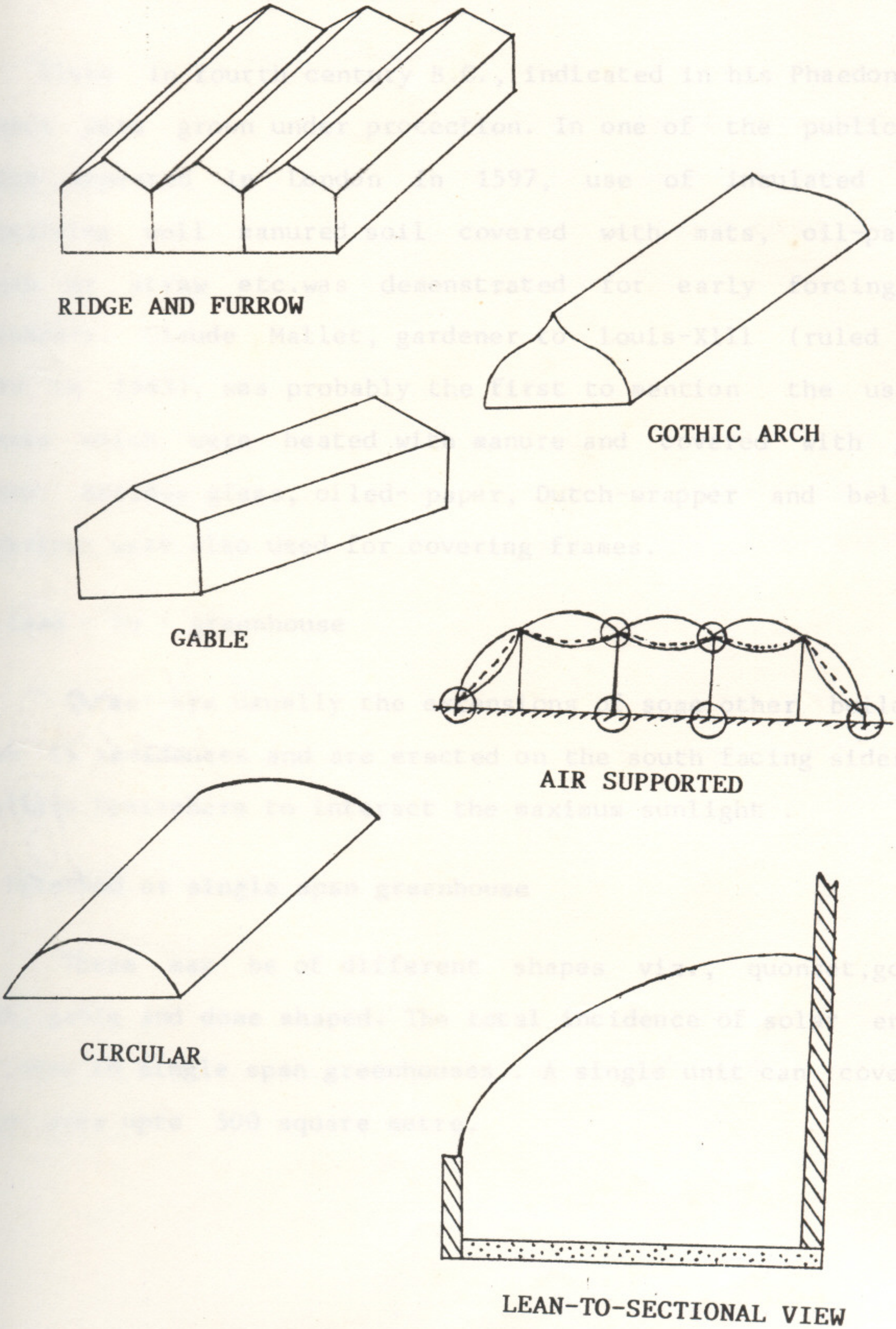


FIG.1 GREENHOUSE SHAPES

Plato in fourth century B.C., indicated in his Phaedon that plants were grown under protection. In one of the publication which appeared in London in 1597, use of insulated beds containing well manured soil covered with mats, oil-painted cloth or straw etc.was demonstrated for early forcing of cucumbers. Claude Mallet, gardener to Louis-Xlll (ruled from 1610 to 1643), was probably the first to mention the use of frames which were heated with manure and covered with glass panes. Besides glass, oiled- paper, Dutch-wrapper and bell-jar coverings were also used for covering frames.

1. Lean - to - greenhouse

These are usually the extensions of some other buildings such as residences and are erected on the south facing sides in Northern hemisphere to interact the maximum sunlight .

2. Detached or single span greenhouse

These may be of different shapes viz., quonset,gothic arch, gable and dome shaped. The total incidence of solar energy is more in single span greenhouses . A single unit can cover a floor area upto 500 square metre.

3. Ridge and furrow greenhouse

Multispan greenhouses and gutter connected greenhouses are synonymous with this catagory. For large greenhouse ranges these type of structures are economical, provided it is to be used for crops requiring similar crop environment.

4. Tower greenhouse

Where land costs are very high or where the land availabilities are constrained, greenhouses are made taller and muti-tiered cultivation is practised. These greenhouses are rarely found now-a-days.

5. Circular greenhouse

Here the door placement can be in any direction. The attractive appearance and the unique ventil ation system are noteworthy.

6. Pit greenhouse

These are located about one metre below the G.L.where temperature variations are minimal.Hence heating or cooling need is minimum.

7. Airsupported greenhouse

These are greenhouses without a rigid frame in which the roof is supported by air pressure from within. They differ from air inflated greenhouses which are supported by a frame and have air under pressure between two covering layers of film plastic to keep them apart for insulation purposes.

2.4. Environmental control in greenhouses

Environment plays a guiding role in determining the growth, development and yield of plants. To analyse the response of plants to the various environmental factors, requires maintanence of an environment in which the individual variables are controlled about a known set point. The set point for each factor must be capable of being varied over a wide range. An attempt has been made here to look into the major factors and their controls.

2.4.1. Temperature

Temperature is a dominant factor in the environment for the growth of plants. The rate of many physiological processes occuring in plants are markedly influenced by the temperature factor. The important role of temperature in growth might well be summarised in its effect on photosynthesis and respiration. Night temperature is also important in considering the balance betwen photosynthesis and respiration. The higher temperatures inside the greenhouse is due to :

1. The greenhouse is a closed space and heat transfer due to air movement does not takes place.

2. Greenhouse effect.

Greenhouse effect, means air and water molecules in the earth's atmosphere absorb long wave thermal radiation of more than 3 to 4 micron emitted by greenhouse surface. Glass is relatively transparent to the short wave length.i.e., 0.312 to 4.75 micron only.This opaqueness of glass to long wave radiation accounts for 22 per cent increase in temperature in glasshouses (Masterlez ,1977).

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

2.4.1.1. Greenhouse cooling

Under tropical conditions of India, the most important environmental control requirement for greenhouses is cooling. The high temperatures inside the greenhouse than the surrounding atmosphere and their detrimental effects on the plant characterestics had necessitated a highly effective cooling.

Davidson (1953) reported the high pressure mist system (10 to 32 kg / cm^2) for use in greenhouses. A fine mist fills the greenhouse atmosphere, cooling the air as it evaporates. Most mist evaporates before reaching the plant level, some settles on the foliage and reduces the leaf temperature.

Langhan (1954) devised low pressure misting systems with a working pressure of 2 to 5 kg / cm^2 Here the droplet size is larger and they do not evaporate quickly.

Convective air exchange through open roof or side ventil ators is also a method for cooling greenhouses. Meneses and Montero (1990) reported that a static permanent ventil ation caused a monthly average soil and air temperature drop of about

1.5 deg. centigrade when compared to partially ventilated greenhouses in which tomatoes were grown .

The amount of incoming solar radiant energy can be reduced by cooling. Willits (1991) found that shading act as an aid to cooling. White compounds were found to be superior, since they do not absorb solar energy.

Water film application on the roof was found to reduce the cooling load. To absorb infra-red radiation a water film must be atleast 1cm thick, but on sloping roof it is limited to 0.05 cm. Cooling is most effective when cold water is used in the water film.

Evaporative cooling

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

Water in the pads through the process of evaporation absorbs heat from the surrounding pad and frame as well as the air passing through the pad. Ayyash and Rasas (1990)found that the parameters affecting water consumption for the greenhouse cooling in a hot arid region include ambient temperature and the efficiency of the cooling system.

Monteiro et al (1990) 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 deg. centigrade.

Fan and pad EC systems are generally considered adequate for cooling the greenhouse. Majumdar et al (1990) made measurements of pad temperature in a greenhouse employing a fan-pad cooling system. The results indicated lower pad temperature than the wet bulb temperatures of the surrounding ambient air.Here low velocity large volume fans draw air through wet fibrous pads mounted on the opposite side of the end wall of the greenhouse. Both vertical and horizontal pads are used, however, vertical pads accumulate salts and thus creates openings that allow hot air to enter the greenhouse.

Bailey (1991) predicted the temperature and vapour pressure deficits obtained in greenhouse with fan and pad cooling using a simulated model. The inside greenhouse temperature gradient between cool ing pad and air extract fans is influenced by the extend of crop cover , the amount of external shading and the type of green house cladding.Placement of exhaust fans should not be more than 7.5m apart, otherwise warm areas may devolop.

2.4.1.2. Greenhouse heating

Heat must be supplied to the greenhouse at the same rate with which it is lost inorder to maintain a desirable temperature.In cold climates ,heat may be lost by transmission through the covering material, by infiltration through the leak points and by radiation from the warm objects inside the greenhouse.Heating can be done using steam ,forced hot air, infra-red radiations ,electricity etc. (Kachru ,1985).

2.4.2. Humidity

The humidity is induced by plant transpiration and by evaporation from irrigation water. For a crop which is well watered air humidity may not have any effect .Milbocker (1987) introduced a ventilated high humidity propagation and found that the application of excess water and the resultant soaking and cooling of propagation medium was eliminated.

Air humidities upto 70 per cent are safe from the point of view of pathological effects as an excess can be origin of viruses or diseases of plants. Zanon (1990) had discussed the condensation of droplets of water over the covering material owing to high humidity .This drastically reduces the light transmittance due to the deflection of rays by the spherical droplets.

Control of humidity and temperature

Several methods and controls are now available to control humidity while cascading the control along with temperature variations.Proper ventil ation of greenhouse accomplishes a fair control of temperature and humidity.

Sharma (1985) demonstrated some of the following instruments. A simple hygrometer consisting of a wet bulb and dry bulb thermometer can be used simultaneously besides simple indicating hygrometer, resistance hygrometer etc. for measuring the humidity.

Humidistats are commonly used humidity control devices whereas thermostats control the temperature. The measurement of temperature can be done with thermometers.

2.4.3. Light

Light is one of the most important climatic factor for many vital processes of the plant. Kochhar (1964) defined photosynthesis as the synthesis of simple carbohydrates from water and carbon-di-oxide in the chlorophyll- containing tissues of plants in the presence of sunlight.

Pandey et al. (1986) had discussed the various ways of light affecting photosynthetic process as follows :With the increasing light intensity, the rate of photosynthesis increases, but at stronger intensity it is not proportional to the increase in light intensity .Photosynthesis occurs in the visible spectrum of 350 to 750 nm. According to him plant characters like bulb formation, floral initiation, rhizome production etc. are all influenced by photoperiodism. Photoperiodism is the response of the plants to the relative length of day and night.

Ebel (1990) reported that the quantity of light and thermicity are factors which improve the agronomical results.

Light control

Bowman (1972) suggested that plastic or FRP should prove better in subtropical parts of India. Compared to glass these materials reduces the amount of solar energy entering the greenhouse.

Chandra (1985) reported that plants growing in open fields become light saturated at about 32,280 lx assuming that all leaves are exposed to the same intensity. The radiant flux density of full sunlight varies from 86,080 to 1,07,600 lx on a clear day. In energy units the requirement is 80 to 120 watts / cubic metre plant height.

Hanon (1989) conducted measurements of diffused and direct radiation in greenhouses. Glass was found to have the highest transmittance level.

Rosa (1989) reported that the solar irradiation inside the greenhouse depends upon the orientation.Single greenhouses can be oriented with its ridge East to West inorder to maximise the interior light intensity.An energy efficient greenhouse should make the best use of the available solar energy for its environmental control.

Castilla (1990) was of the view that lower radiation levels inside the multispan greenhouse is due to the light reducing materials of the structure.The yield was also lower subsequently.Thus the design and maintanence of the greenhouse frame will be based on maximising light intensity while the covering itself be generally based on other factors such as cost of construction ,use to which the greenhouse is put to.

Zanon (1990) remarked that photosynthesis measured as released carbon-di-oxide depends upon the light intensity and increases with luminosity.The increase was found in a definite range beyond which there was no effect.

2.4.4. Carbon-di-oxide

Carbon-di-oxide an essential raw material for the process of photosynthesis is present at a concentration of 300 ppm in atmosphere .Gaastra (1959) found that photosynthesis in lettuce, cucumber and tomatoes becomes increasingly inefficient at illuminance above 3000 lx of mercury lighting.

Increase in solar radiant energy and barometric pressure results in higher carbon-di-oxide levels; as humidity and temperature increase , carbon-di-oxide level tend to decrease. Zipori (1987) reported higher yields when carbon-di-oxide was applied during those parts of the day in which the temperature would have exceeded 30 degree centigrade in the closed greenhouse.Under normal conditions with carbon-di-oxide concentration,photosynthesis increases.

Cockshull (1988)suggested that the direct manipulation of growth related plant processes could lead to better standards of quality and more efficient production.

Critten (1991) had reviewed the dependence of photosynthesis of crops on light irradiance and carbon-di-oxide concentrations. Optimal concentration depend linearly on the irradiance levels, on the square root of the inverse of the ventilation rate and on the lettuce price to cost of carbon-di-oxide per kg.

Carbon-di-oxide enrichment

Carbon-di-oxide enrichment has long been known to be beneficial.Bohra (1985)found that increasing carbon-di-oxide concentration will increase photosynthesis under normal conditions ; the effect will be less at lower light levels .The response can be a shortened period between planting and production ,increased size of potted plants, longer stems ,faster seedling germination and growth or faster maturation of the flowers.

During photosynthesis carbon-di-oxide concentration decreases and increases during respiration. Hence carbon-di-oxide is appliied during day light hours.Vermeulen (1989)conducted a study in a glasshouse with various carbon-di-oxide levels with no supplementation. The result was higher yield in positive correlation with carbon-di-oxide levels.

2.4.5. Air circulation

Frequently ,air movement among the plants is relatively slow and the carbon-di-oxide utilised in the photosynthesis may not be replaced at the leaf surface at a rate sufficient to maintain the process.Increase in air circulation in the greenhouse may aid in preventing a deficient level of carbon-di-oxide utilised in the photosynthesis may not be replaced at the leaf surface at a rate sufficient to maintain the process. Increase in air circulation in the greenhouse may aid in preventing a deficient level of carbon-di-oxide at the leaf surface. (Chandra, 1985)

Pandey (1985)defined ventil ation as the exchange of cooler outer air by warmer air inside. The object is to remove surplus solar heat, to remove transpired water vapour and to supply carbon- di- oxide.

Holmberg (1987) developed a PE greenhouse structure in which rising warm air is removed through a ridge vent while drawing cooler air through side opening.

MATERIALS AND METHODS

This chapter presents the design and fabrication of a low cost greenhouse and the various experiments that are carried out in it.

3.1. Design considerations

Considerations for the establishment of a greenhouse are as follows:

(1). Crops to be grown and the market characterestics.

(2). Climatic condition from the point of view of problem identification .

(3). Availability of resources like fuel, water, soil, finance etc.

(4). Availability of managerial capabilities.

3.2. Design of cooling system of the greenhouse

Temperatures can be maintained in a greenhouse at any level with a well designed cooling system. Evaporative cooling system, also known as Fan and Pad cooling system, as presently conceived, is effective for cooling greenhouses as it appears to be economical and adaptable.It is based on the process of heat absorption during the evaporation of water. There are two main considerations in the system:

1. the rate at which warm air is to be removed allowing cool air to be drawn in and
2. the area of the pads.

The rate of air exchange is measured in cubic metre of air per hour (cmh). Normally the rate of removal of 144 cmh per square metre of the greenhouse floor is sufficient. This applies to green house under 300 m in elevation with an interior light intensity of 53800 lux and a temperature rise of 4 degree centigrade from the pads to the fans.

The ability of air to remove solar heat from the greenhouse depends upon its weight and not its volume. The rate of air removal from the greenhouse must increase as the elevation of the greenhouse site increases.Table 2. list factors (F elev.) used to correct the rate of air removal for elevation.

The rate of air removal is also dependent upon the light intensity in the greenhouse. As light intensity increases the heat input from the sun increases requiring a greater rate of air

Table 2. Correlation factor for the elevation (m) from sea level

Evaluation (m) under	300	450	600	900	1200	1500	1800	2100	2400
F_{elev}	1.00	1.04	1.08	1.12	1.16	1.20	1.25	1.30	1.36

Table 3. Correlation factor for the maximum interior light intensity (lux)

Light (lux) intensity	43050	48420	53800	59180	64560
F_{light}	0.80	0.90	1.00	1.10	1.20

Light (lux) intensity	69940	75320	80700	86080
F_{light}	1.30	1.40	1.50	1.60

Table 4. Correlation factor for pad to fan temperature variation (°C)

Temperature (°C)	6.0	5.0	4.4	4.0	3.3	3.0	2.0
F_{temp}	0.70	0.78	0.88	1.00	1.17	1.40	1.75

Table 5. Correlation factor for pad to fan distance (m)

Distance	6.0	7.5	9.0	10.5	12.0	13.5	15	16.5	18.0
F_{vel}	2.24	2.00	1.83	1.69	1.58	1.48	1.41	1.35	1.29

Distance	19.5	21.0	22.5	24.0	26.0	27.5	28.5	31
F_{vel}	1.24	1.20	1.16	1.12	1.08	1.05	1.02	1.00

removal from the greenhouse. Factor (F light) used to adjust the rate of air removal are listed in Table 3 .

Solar energy warms the air as it passes from the pad to the exhaust fans. Usually a 4 degree centigrade rise in temperature is tolerated across the greenhouse.If it becomes important to hold a more constant temperature across the greenhouse i.e., to reduce the rise in a temperature it will be necessary to raise the velocity of air movement through the greenhouse. Factor (F temp.) used for this adjustment is given in Table 4.

The fan and the pad should be placed on opposite walls. The distance between the pad and the fan is an important consideration in determining the wall to be used. A distance of 30m to 60m is the best. When the distance is reduced below 30m, the cross-sectional velocity becomes lower and the air often devolops a clammy feeling. Factor (F vel.) used to compensate for this are listed in Table 5 .

Stepwise calculation for devoloping a cooling system for this greenhouse are as follows :

1. The greenhouse floor width is multiplied by its length and by 144 to determine the quantity of air to be removed per hour under standard conditions.

standard cmh = L X W X 144

= 12 x 3 x 144

= 5184 cmh

2. A factor for the house (F house) is determined by multiplying the three factors: elevation, light inside the greenhouse and the temperature rise from the pad to the fans. These factors are found in Tables 2. to 4. respectively.

F house = F elev. x F light x F temp.

= 1.0 x 1.0 x 1.0

= 1.0

3. The factor for velocity (F vel.) from Table 4. corresponding to the length of the greenhouse is found out.

F vel. = 1.58

4. The cmh standard value from step 1. is multiplied either by F house or F vel., using which ever factor is larger -F vel.

in this case .This is the volume of air to be expelled from the greenhouse in one hour

Total cmh = cmh standard x F vel.

= 5184 x 1.58

= 8190 cmh

5.Fans should not be placed more than 7.5m else warm areas will devolop. Hence the total length of the wall housing the fan is divided by 7.5 to obtain the quantity of fan.

No. of fans = 3m / 7.5

= 0.5 , say, one number

6.The required fan size is calculated as follows:

Fan size = Total cmh / No. of fans

= $8190 m^3 / hr$

Fan selection

Rate of air removal required

from the greenhouse = $144 m^3 / hr$

Total floor area of greenhouse = $36 m^2$

Rate of air removal from the

greenhouse = 2.4 X 36

= $66.4\ m^3$ / min.

Volume of air inside the proposed

greenhouse = $120.6\ m^3$

Time required for one complete air

exhaustion = 120.6 / 86.4

= 1.4 min.

Air changes required per hour = 60 / 1.4

= 43 times

Total required rate of air removal

from the greenhouse = $8190\ m^3$ / hr

This requirement is under free air flow conditions. The fan delivers maximum volume under free air flow condition. When working against a resistance, the rate of air removal decreases. The resistance offered by the pad is to be determined.

A fan of maximum free air flow rate $10450 m^3$/ hr was selected, the specification is given in appendix -III

8. The pad area is determined next. One sq.metre of pad is required for each 2700 cmh. of fan capacity. Hence the required pad area is found to be 3 square metre.

9. The pad must cover the width of the wall in which it is to be installed.

$$\text{Pad height} = \text{Pad area} / \text{Pad width.}$$
$$= 3\ m^2 / 3m$$
$$= 1m$$

A pad of height 1.2m is purchased.

10. The pump capacity is equal to 30.30 X 10^{-2} per hour times the length of the pad and must be selected to have this flow rate for the given head under which it must operate.

$$\text{Pump capacity} = 30.30 \times 10^{-2}\ m^3 \text{ per hour.} \times \text{Pad length (m)}$$
$$= 30.30 \times 10^{-2} \times 3.0$$
$$= 0.9091\ m^3. \text{ per hour}$$

11. The sump size is equal to 2.24 X 10^{-2} m^3 per metre of pad length.

$$\text{Sump volume} = \frac{2.24 \times 10^{-2}\ m^3 \times \text{pad length}}{1m \text{ of pad length}}$$

$$= 2.4 \times 10^{-2} \times 3.0$$

$$= 0.0671\ m^3$$

3.3. Greenhouse structure

A greenhouse structure has three distinct segments ,viz., frame, glazing material and control and/or monitoring equipments. All the three components have different design life periods.

The frame work is the most important component of a greenhouse . It provides support for the glazing material and a place for control equipment. Wood is a common choice where it is cheaply available. Aluminium and steel are also used for frame work.

Many kinds of covering materials have been developed through the years to improve thermal environment. Prior to 1950, glass was the sole covering material. It has the greatest light transmittance , but the brittleness and the high average cost per year makes it inferior to plastic films. The high initial cost of PVC and FRP had made them less acceptable compared to the cost effective UV- resistant PE. It has approximately same light transmittance as of glass.

In the prevailing economic condition where capital is a scarce input , the choice often favours low initial investment greenhouses. Galvanised MS pipe as structural member in association with wide width UV stabilised PE film is a common option selected by greenhouse designers.

3.3.1. Structural members

The main structural members of the greenhouse are hoops, ridge lines, foundation material, structure for pad gripping , fan placement , the door and the ventil ator.

1. Hoops

These are the integral part of the plastic greenhouse. These are made out of galvanised MS pipes .A full length pipe was bend using a pipebender into a pentagonal shape with central angle 127 deg.The heights at the sides and the centre was 1.65m and 2.25m respectively .The pipes used were of size 20mm. Alength of 0.5m was buried in the holes made on the ground.

2. Foundation

These are meant to provide a firm support to the hoops.The pipes were buried in the ground to ensure stability to the frame work and grouted.

3. Ridge line mechanism

Inorder to keep the hoops at regular intervals,ridge lines were placed around the entire structure at equal interval.This mechanism provides structural stability and gives a firm support. The ridge line mechanism for the equally spaced hoops is a 25mm X 6mm flat fastened at the ridge line. The ridge line mechanism which is fabricated from MS strapping is looped over the crossing of the ridge and the hoop and tightened with bolts.

4. Structure for pad gripping and fan placement

A frame work was constructed with MS angle iron of size 25mm x 25mm X 5mm with a total length of 3.0m and height 1.2m and was placed on a 0.4 m high masonry brick wall on which a water return gutter is placed.It collects excess water from the pad in a sump.

A pair of 50mm diameter GI pipe of height 2.15m is buried upto a depth of 0.5 m. So as to render a firm support ,a concrete basement is given to the pipes. The fan is bolted on to the vertical supports through two MS flat iron pieces.

5.The door and ventilator

A wooden door of height 1.70 m and width 0.95m is provided. A ventilator, also made of wood, of length 1m and breadth 0.95m is made.

3.3.2. Plastic film

UV stabilised PE film of 250 micron thickness is used as greenhouse glazing. The width of the film was 7m and its length 40m.

3.3.3.Polygrip assembly

The PE covering of the greenhouse is to be firmly secured to the foundation pi pes, so that it can withstand windload, without being blown off. The mechanism has been so designed that while it holds PE firmly, puncturing is avoided. Two strips of 5cm width angle iron, a 15cm long MS flat and a nut and bolt constitute the assembly.

The PE film was stretched over this, which was firmly secured to the hoops as shown in plate 5.

3.4. Site selection and orientation of the greenhouse

The greenhouse was constructed in the instructional farm of KCAET ,Tavanur. The place is situated at 10° 53'33" North latitude and 76° East longitude . The climate of this place is warm and humid. The construction and experimentation was carried out during Nov. 1993.

Daily variation in the temperature and humidity was recorded throughout the experimental period. Provisions were made to drain away the accumulated water by excavating channels around experimental setup. An electric power distribution line adjacent to the site and a dependable supply of good quality water were provided. The greenhouse was oriented East-West.

3.5. Construction procedure

A 12m x 3m rectangle was marked on a cleaned area orienting the longer dimension in the East-West direction .This forms the floor of the plastic greenhouse. At the corners of the rectangle points were marked and holes of 3 cm diameter and 0.5 m depth were dug in a longitudinal row. Starting from one corner,

Plate 1. Overall view of the Greenhouse.

Plate 2. Structural view of the Greenhouse.

Plate 3. Fan end view of the Greenhouse.

Plate 4. Pad end view of the Greenhouse.

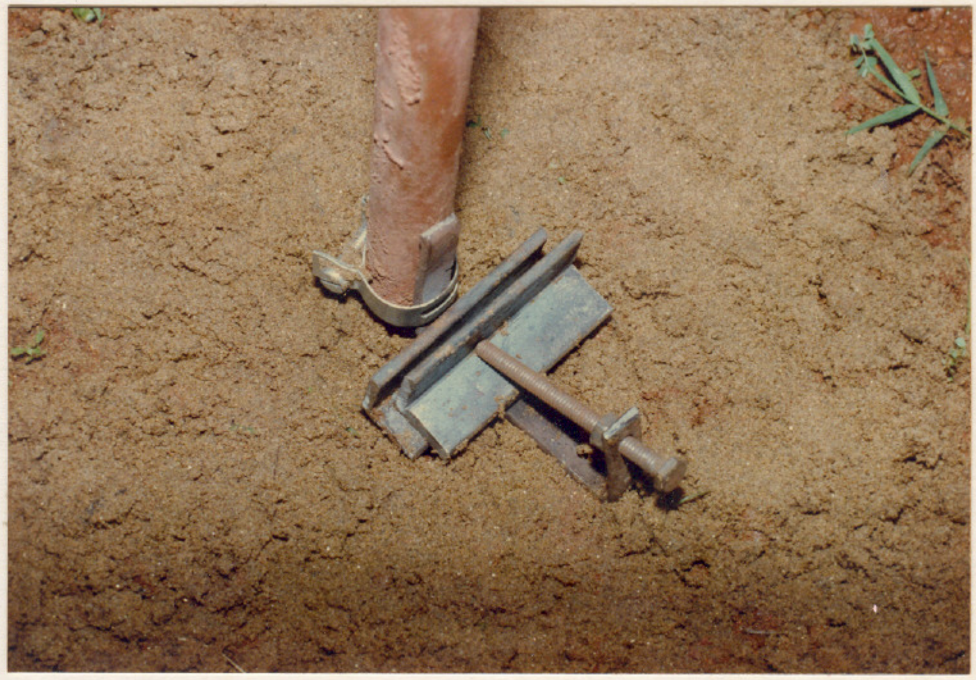


Plate 5. Polygrip assembly.

at every 1m interval holes were dug of the same size. The same was done in the other parallel row also. Care has been taken that all the dug holes should run in parallel. Hoops were placed in the dug holes and fixed by grouting. Care should be taken so that the hoops run parallel and attain a uniform height. The pad assembly is fixed projecting from the end hoop and resting on a masonry wall of 0.4m height from G.L.

PE film over the structure from one end to the other was spread without wrinkles keeping the edges together. The film was stretched equally at both ends with 0.5m length of the film spreading along the ground. The PE film was secured on to the structure by using the polygrip mechanism as shown in plate V.

After placing the fan and pad assembly, the remaining portion on either ends of the greenhouse is made airtight with PE film. The wooden door is provided along the length of the greenhouse. The ventilator is provided along the roof opposite to that of the door. The door and ventilator is bolted on to the supporting MS flat iron pieces bolted on to the hoops. The water is supplied to the cooling pads through two 25 mm diameter perforated PVC pipes.

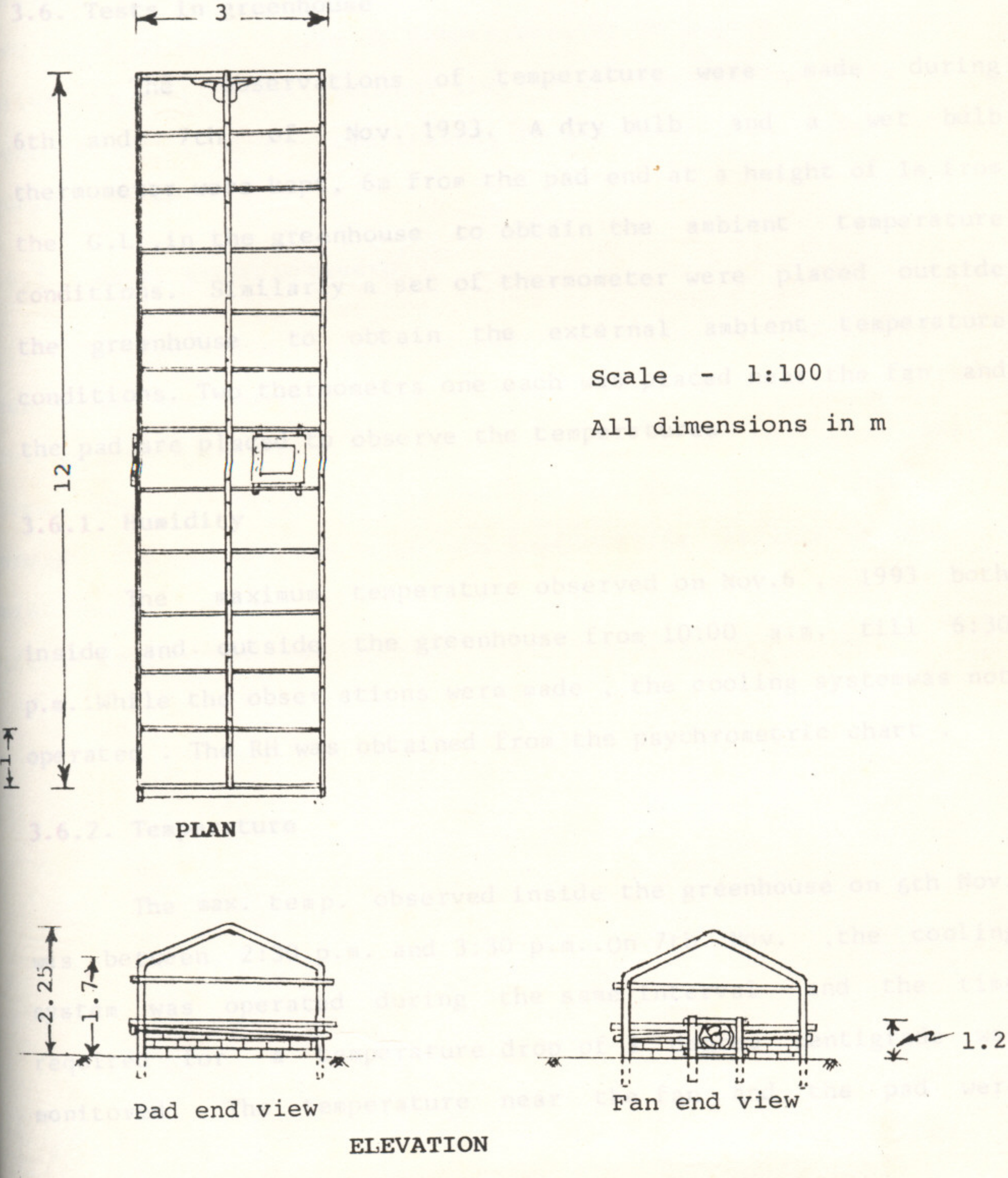


Fig.2. Plan and elevation views of Greenhouse.

3.6. Tests in greenhouse

The observations of temperature were made during 6th and 7th of Nov. 1993. A dry bulb and a wet bulb thermometer were kept, 6m from the pad end at a height of 1m from the G.L.,in the greenhouse to obtain the ambient temperature conditions. Similarly a set of thermometer were placed outside the greenhouse to obtain the external ambient temperature conditions. Two thermometrs one each was placed near the fan and the pad are placed to observe the temperatures.

3.6.1. Humidity

The maximum temperature observed on Nov.6 , 1993 both inside and outside the greenhouse from 10:00 a.m. till 6:30 p.m..While the obser ations were made , the cooling systemwas not operated . The RH was obtained from the psychrometric chart .

3.6.2. Temperature

The max. temp. observed inside the greenhouse on 6th Nov. was between 2:30 p.m. and 3:30 p.m..On 7th Nov. ,the cooling system was operated during the same interval and the time required for a temperature drop of 3 degree centigrade was monitored. The temperature near the fan and the pad were measured at the same time and the variation was noted. Care has been taken to keep inside db temperature at 30 degree centigrade during this interval.Whenever the inside temperature tend to shoot above 30 degree centigrade, it was restrained using the cooling system.

3.6.3. Water gauge pressure

The pressure difference created inside and outside the greenhouse was measured using a U-tube filled with water. This would approximately give the resistance of the pad which is 75mm thick. One end of the U-tube was inserted into the greenhouse through the pad and the other end kept outside it.Both the ends were held together with the PE film separating them. The difference in level was measured using a scale.

RESULTS AND DISCUSSION

This chapter highlights the results of the work and the results are analysed.

Greenhouse structure

The greenhouse structure of the specification had been constructed in the instructional farm of KCAET, Tavanur. The various materials and their costs are given in appendix-I. Water is supplied to the cooling pad from a nearby water distribution line. Provision was given for further tapping of water into the greenhouse in future. The excess water is drained. All tall vegetation likely to shade the site was removed and adequate light supply was ensured. The greenhouse was made air tight by sealing all the possible leak points. Observations were made on two consecutive days.

Test results

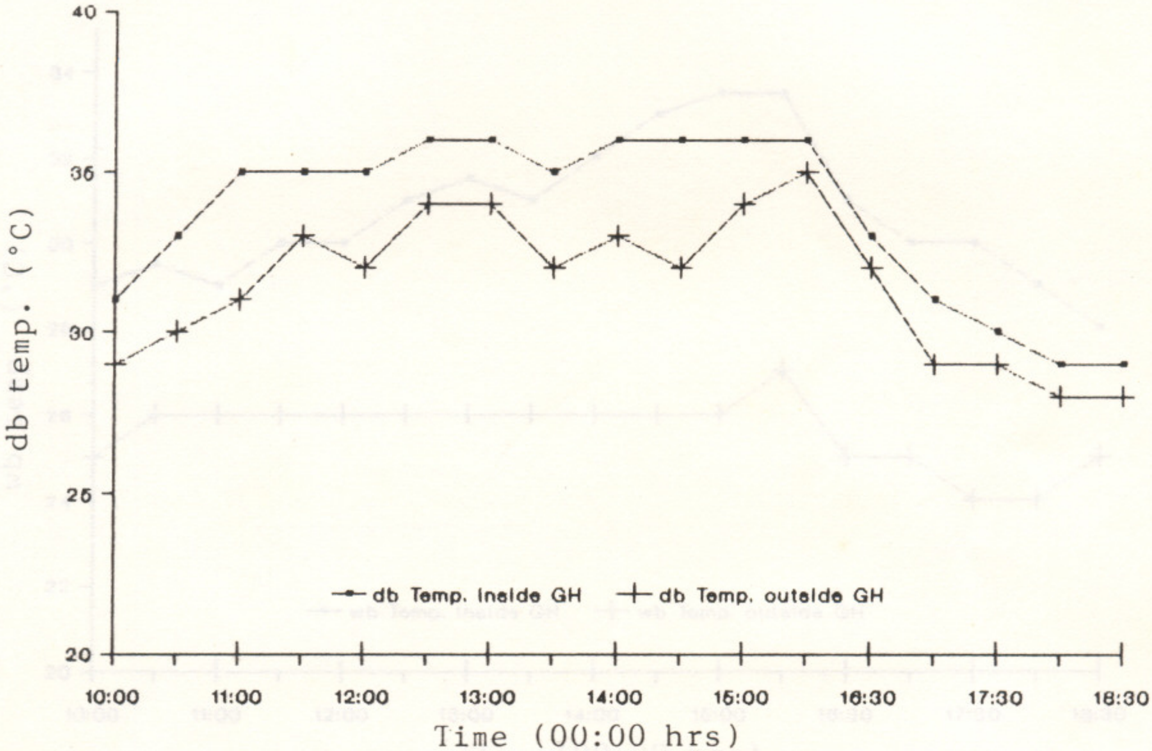
On day-I, db and wb temperature, both inside and outside the greenhouse was measured as depicted in Table 6 & 7. These hourly observations were plotted against

Table 6. Temperature observations inside the greenhouse without cooling

Time (00:00 hrs)	Temperature (°C)		RH (%)
	Dry bulb	Wet bulb	
10:00	31	29.0	85
10:30	33	29.5	70
11:00	35	29.0	55
11:30	35	30.0	55
12:00	35	30.0	55
12:30	36	31.0	55
13:00	36	31.5	55
13:30	35	31.0	50
14:00	36	32.0	85
14:30	36	33.0	75
15:00	36	33.5	80
15:30	36	33.5	80
16:30	32	31.0	90
17:00	31	30.0	95
17:30	30	30.0	100
18:00	29	29.0	100
18:30	29	28.0	100

Table 7. Temperature observations outside the greenhouse

Time (00:00 hrs)	Temperature (°C)		RH (%)
	Dry bulb	Wet bulb	
10:00	29	25	65
10:30	30	26	50
11:00	31	26	45
11:30	33	26	30
12:00	32	26	40
12:30	34	26	25
13:00	34	26	25
13:30	32	26	37
14:00	33	26	25
14:30	32	26	25
15:00	34	26	22
15:30	35	27	25
16:30	33	25	45
17:00	29	25	50
17:30	29	24	47
18:00	28	24	55
18:30	28	25	60



40
35
30
25
20
db temp. (°C)
10:00
11:00
12:00
13:00
14:00
15:00
16:30
17:30
18:30
Time (00:00 hrs)
db Temp. inside GH
db Temp. outside GH

Fig.3

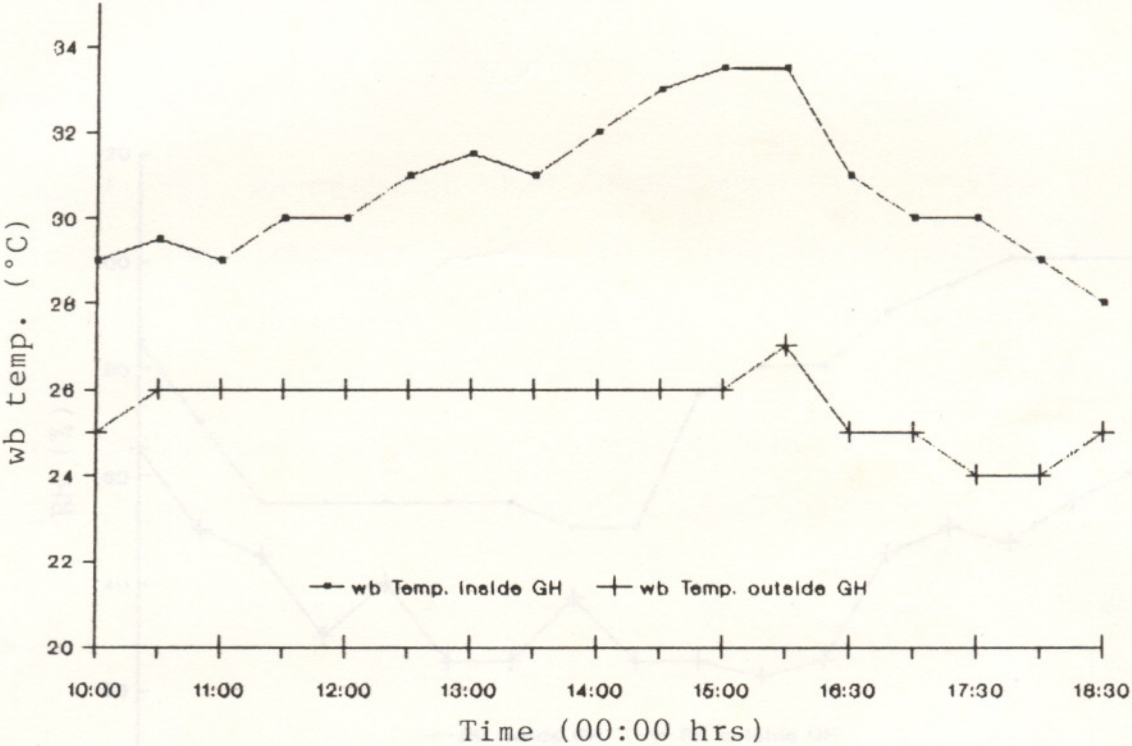
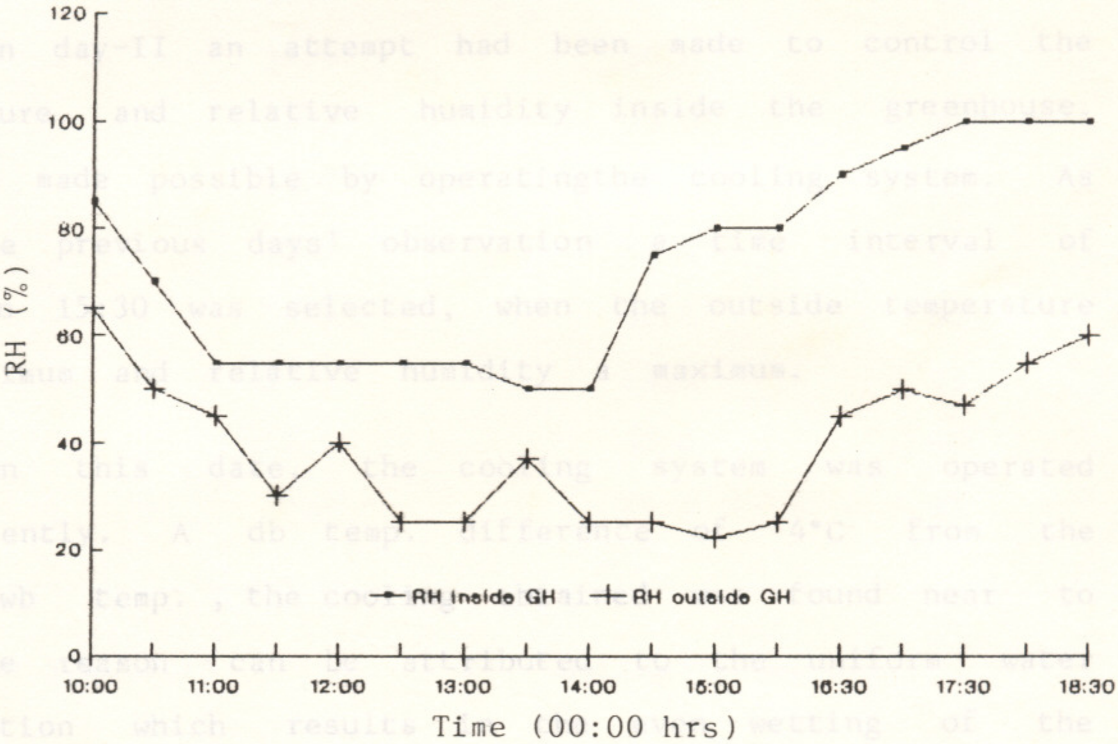

34
32
30
28
26
24
22
20
wb temp. (°C)
wb Temp. inside GH
wb Temp. outside GH
10:00
11:00
12:00
13:00
14:00
15:00
16:30
17:30
18:30
Time (00:00 hrs)

Fig.4



120
100
80
60
40
20
0
RH (%)
RH inside GH
RH outside GH
10:00
11:00
12:00
13:00
14:00
15:00
16:30
17:30
18:30
Time (00:00 hrs)

Fig.5

time of observation as depicted in figures 3 & 4. Greenhouse humidity was found to be aminimum when the outside and inside db temp. difference was a maximum.Fig.5 shows a comparison of this variation.

Performance evaluation

On day-II an attempt had been made to control the temperature and relative humidity inside the greenhouse. This is made possible by operatingthe cooling system. As per the previous days' observation a time interval of 14:30 to 15:30 was selected, when the outside temperature was maximum and relative humidity a maximum.

On this date, the cooling system was operated intermitently. A db temp. difference of 4°C from the outside wb temp. , the cooling obtained was found near to it. The reason can be attributed to the uniform water distribution which results in the even wetting of the pad area provided.

All leak points should be sealed so as to enhance cooling. Temperature measurements along the length of the greenhouse near the pad and fan as depicted in Table8.

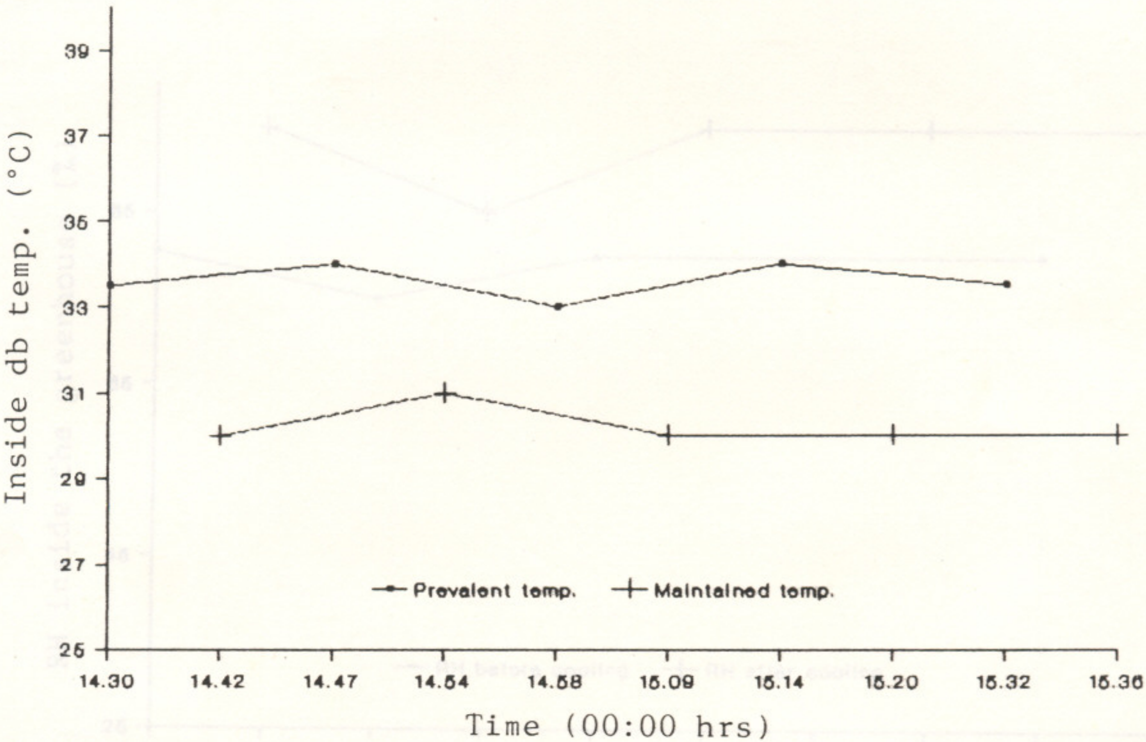
Table 8. Temperature observations while cooling

Time (00:00 hrs)	Temperatures inside the greenhouse (°C)		RH (%)
	Dry bulb	Wet bulb	
* 14:30	33.0	30.0	80
** 14:42	30.0	29.0	95
* 14:47	34.0	30.0	75
** 14:54	31.0	29.0	85
* 14:58	33.0	30.0	80
** 15:09	30.0	29.0	95
* 15:14	34.0	30.0	80
** 15:20	30.0	29.0	95
* 15:32	33.5	30.0	80
** 15:36	30.0	29.5	95

* Cooling system on ** Cooling system off

Table 9. Ambient external temperature conditions

Time (00:00 hrs)	Outside Temperature (°C)		RH (%)
	Dry bulb	Wet bulb	
14:30	36.0	25.5	44
14:42	36.0	25.5	44
14:47	36.0	26.0	45
14:54	36.0	26.0	45
14:58	36.0	26.5	45
15:09	35.0	26.5	50
15:14	36.0	26.5	45
15:20	35.0	26.5	55
15:32	34.0	27.0	60
15:36	34.5	27.0	55



Inside db temp. (°C)
39
37
35
33
31
29
27
25
Prevalent temp.
Maintained temp.
14.30
14.42
14.47
14.54
14.58
15.09
15.14
15.20
15.32
15.36
Time (00:00 hrs)

Fig.6

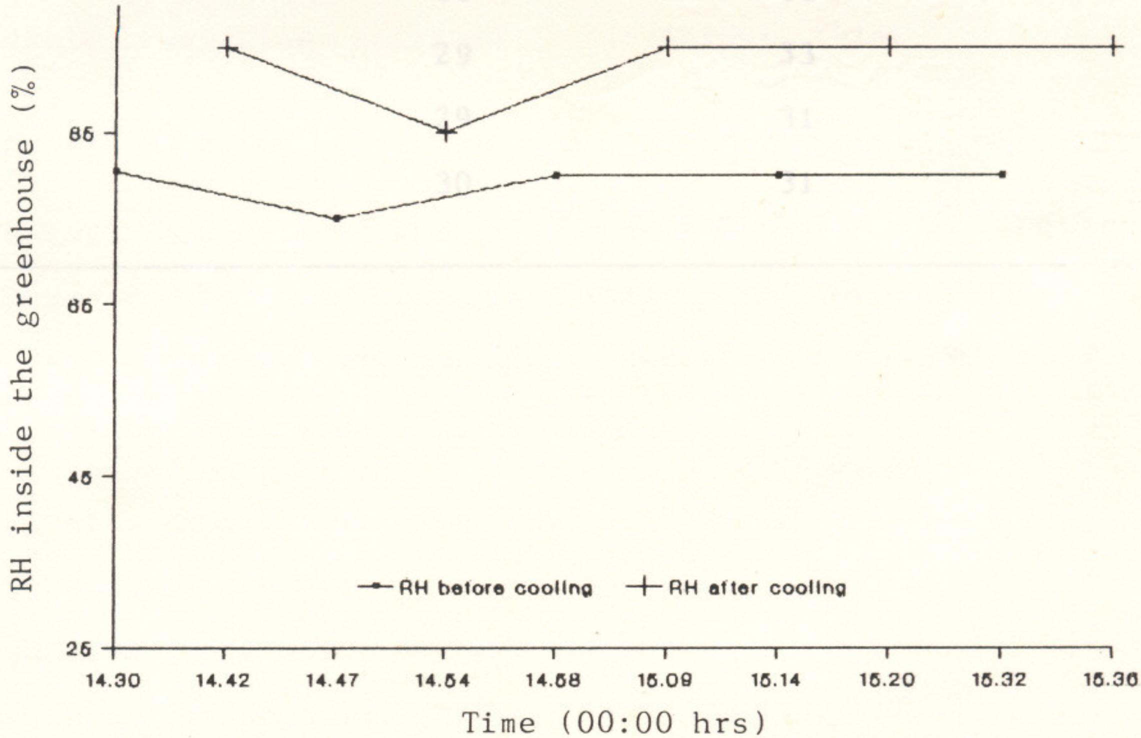

RH inside the greenhouse (%)
85
65
45
25
RH before cooling
RH after cooling
14.30
14.42
14.47
14.54
14.58
15.09
15.14
15.20
15.32
15.36
Time (00:00 hrs)

Fig.7

Table 10. Temperature observations near the fan end near the pad

Time (00:00 hrs)	db temperature near the (°C)	
	Cooling pad	Fan
14:40	30	33
14:50	30	31
15:00	29	33
15:15	29	31
15:35	30	31

showed a maximum difference of 3°C while cooling system is operating.Fig. 6. shows a fairly uniform temp. had been maintained inside the greenhouse with the cooling system.

Acomparison between RH obtained inside and outside the greenhouse is depicted in Fig. 7 clearly indicate that a perfect control over humidity was attained. Considerable variation attained substantiate this.

Standard water gauge

Water gauge pressure was measured using a U-tube and found to be 5mm. The measurement was done using a scale. For cooling pads of this specification the water gauge pressure was found to be 5mm.

Rate of air removal at 5mm SWG = $8350 m^3/hr$

Total greenhouse volume = $120.6\ m^3$

Time required for one complete air exchange from greenhouse = 139.17 / 120.6

= 1.16min.

Air exchanges per hour = 60 / 1.16

= 52

Required air ex changes per hour = 43

Thus it can be visualised that the cooling system design for the greenhouse had been upto the requirement.

Scope for further research

1. Automation of temperature and humidity control can be effected.
2. Recirculation of the cooling water can be done
3. Yield test can be conducted

SUMMARY AND CONCLUSION

Controlled environment agriculture is one of the promising measures for supplying foods under unfavourable conditions. Greenhouses, low tunnels and cloches are the different forms of controlled environment agriculture practised at commercial levels in many countries amongst which greenhouses are the best for active environmental control.

Greenhouses are framed structures covered with transparent materials in which crops are grown under controlled environment. Greenhouse glazing acts as a selective radiation filter so that solar radiation could pass through it but the thermal radiation emitted by the objects within the greenhouse could not escape. The retention of long wave radiation causes rise of temperature inside the greenhouse, the effect known as Greenhouse effect. Considering the importance of developing simple greenhouses of low capital investment, the project entitled "Design Fabrication and Testing of a Low Cost Greenhouse" was undertaken. The main objectives were

(i) Design and fabrication of the greenhouse

(ii) Design of the cooling system for the greenhouse

(iii) Control of the climatic parameters inside the greenhouse

(iv) Performance evaluation of the greenhouse.

A floor area of 36 m^2 with 12 m length and 3 m width was selected. The greenhouse was East-West oriented and pentagonal shaped with hoops placed at 1 m interval. A ridge line mechanism was provided to give lateral stability to the structure. PE film was spread without wrinkles and held on to the structure by the polygrip mechanism, so that puncturing of the sheet is avoided. Fan and pad were placed opposite to each other on shorter sides. The pad was placed on a masonry wall of 0.4 m height on which a water return gutter was placed. Water is supplied to the pads through two performated PVC pipes and excess water from the pads was drained.

Performance evaluation of the cooling system indicated a temperature reduction of 4°C than the outside db temperature with close proximity to the outside wb temperature. the cooling system further performed well enough to attain sufficient levels of RH. The resistance offered by the cooling pad was found to be 5 mm and the rate of air exchanges provided was found to be sufficient.

Thus we could conclude that the greenhouse design utilising locally available material for cooling pad had reduced the capital investment. Performance evaluation of the greenhouse revealed that the crop micro-climate had been modified significantly. The EC system could sufficiently maintain a lower temperature and higher RH inside the greenhouse while the reverse situation prevail outside.

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* Originals not seen

APPENDIX-I

Materials used for Greenhouse construction

	Material	Size	Quantity	Cost
1.	GI pipe Class B	20 mm	95 m	Rs.3325
2.	GI pipe Class B	51 mm	24 m	Rs. 216
3.	Angle iron	25mmx25mmx4mm	14 m	Rs. 368
4.	MS flat	25mmx4 mm	36 m	Rs. 420
5.	MS flat	50x5mm	2 m	Rs. 60
6.	Nut and bolt	6.0mm;50mm	85 nos	Rs. 60
7.	Nut and bolt	12mm;70mm	4 nos	Rs. 28
8.	Nut and bolt	6.0mm;12mm	4 nos	Rs. 5
9.	Cooling pad			Rs.1500
10.	Hinges	20mmX50mm	4 nos	Rs. 15
11.	Cement		50 kg	Rs. 125
12.	Exhaust fan		1 nos	Rs.3900
13.	Wood	50mmx25mm	15 m	Rs. 100
14.	Labour			Rs. 300
			Total	Rs.10,422

Appendix-II

Specification of greenhouse

Length	=	12m
Width	=	3m
Height at the centre	=	2.25m
Height at the sides	=	1.7m
Height of the door	=	1.0m
Width of the door	=	1.0m
Length of the ventilator	=	1.0m
Width of the ventilator	=	1.0m
Width of the gutter	=	100mm
Slope of the roof	=	1 in 2.7

Appendix - III

Specification of cooling pad

Length	:	3000mm
Height	:	1200mm
Thickness	:	76mm
Material	:	coir

Appendix -IV

Specification of thermometer

Range : -10 C to 110 C ; 4 nos

Specification of fan

Diameter	: 600mm
RPM	: 900
Rated current	: 2.5 amps
Voltage	: 230 volts
Circuit	: 50 c/s; 1 phase
Power	: 500 watt
Make	: Pilot
Air flow rate at zero static pressure	: 10450 m^3/ hr
Air flow rate at 2.5mm static pressure	: 9000 m^3/ hr
Air flow rate at 5.0mm static pressure	: 8350 m^3/ hr
Air flow rate at 7.5mm static pressure	: 7500 m^3/ hr
Air flow rate at 10mm static pressure	: 5450 m^3/ hr

DESIGN, FABRICATION AND TESTING OF A LOW COST GREEN HOUSE

By
GOVINDAN. S.
JENET. P. V.
JISSY. K. JACOB
MANOJ KUMAR. T. S.

ABSTRACT OF THE PROJECT REPORT

Submitted in partial fulfilment of the
requirement for the degree of

Bachelor of Technology in Agricultural Engineering

Faculty of Agricultural Engineering & Technology
Kerala Agricultural University

Department of Land Water Resources
and Conservation Engineering

Kelappaji College of Agricultural Engineering and Technology
Tavanur - 679 573
Malappuram

1993

ABSTRACT

Controlled environment agriculture is one of the promising measures for crop production under unfavourable climatic conditions amongst which greenhouses are the best for active environmental control.Farmers with small and marginal land holdings can increase their income by resorting to greenh ouse form of intensive cultivation. A greenhouse of simple design utilising locally available materials for cooling pad thereby reducing the capital investment had been constructed at the instructional farm, KCAET, Tavanur. The salient feature of this pentagonal shaped greenhouse is the fan and pad evaporative cooling system. It helped to control the ambient temperature inside the greenhouse as desired and limited the pad to fan *rise of temperature to 3°C. It was* also possible to maintain the relative humidity inside the greenhouse at sufficient levels. The pad resistance was found to be 5mm of standard water gauge.