Greenhouse

A Reference Manual

National Committee on Plasticulture Applications in Horticulture
Department of Agriculture & Cooperation
Ministry of Agriculture, Government of India
New Delhi

Greenhouse

A Reference Manual

National Committee on Plasticulture Applications
in Horticulture (NCPAH)

Department of Agriculture & Cooperation
Ministry of Agriculture, Government of India
New Delhi

January, 2011

Technical Manual : NCPAH/TB/2010-11/3

First Edition : January, 2011

Published by : National Committee on Plasticulture Applications in Horticulture (NCPAH)

Editorial Team : Krish S Iyengar
Ashok Gahrotra
Alok Mishra
Krishna Kumar Kaushal
Mohit Dutt

Address:
National Committee on Plasticulture Applications in Horticulture
Department of Agriculture & Cooperation
Ministry of Agriculture, Government of India
10th Floor, International Trade Tower
Nehru Place, New Delhi - 110 019
www.ncpahindia.com

Acknowledgement: We would like to thank PFDCs-Bangalore, Bhopal and Lucknow and Dr Pitam Chandra, Director, CIAE, Bhopal for their valuable contributions in making this manual possible.

Printed at Venus Printers and Publishers, New Delhi - 110028

डॉ. गोरख सिंह
DR. GORAKH SINGH

बागवानी आयुक्त
भारत सरकार, कृषि मंत्रालय
(कृषि एवं सहकारिता-विभाग)
कृषि भवन, नई दिल्ली - 110001
Horticulture Commissioner
Government of India
Ministry of Agriculture
(Department of Agriculture & Cooperation)
Krishi Bhawan, New Delhi - 110001

Foreword

The Greenhouse Technology is an appropriate intervention for crop production, particularly in hostile climatic conditions. It has the potential to give manifold production of quality produce round the year from small land holdings compared to the open field cultivation. A greenhouse works on the principle that crop production is influenced not only by heredity but also by the micro-climate around the plant. The components of climate are – light, temperature, relative humidity, air composition and nature of root medium. Under a greenhouse, these factors can be well controlled so that the plant gets best environment for production. However, the concept holds good only, if the design of the greenhouse is suitable as per the climatic conditions. The design and construction of a greenhouse is a specialized activity, which is undertaken by professional organization. Any faulty design can kill the crop in no time; hence same is of greater importance.

For the adoption of greenhouse technology by farmers, the government of India has made provision for subsidy @ 50% of the total cost of greenhouse including micro irrigation system with fogging & misting devices under centrally sponsored schemes of NHM & HMNH. In most of the states, the scheme is implemented through Horticulture Departments.

Keeping the above point in mind, this document has been prepared for guiding the state agencies with regard to design & specifications of the greenhouse for implementation of the scheme. I am confident that it will serve the purpose for which it has been intended and benefit all stake holders.

21st January, 2011

(Gorakh Singh)

Contents

About the Manual

Precision farming in horticulture has been found very useful for achieving higher level of production, quality and productivity. Agriculture in India has been not only a means of livelihood but a way of life for millions of farmers. It provides livelihood to nearly 65% of the population. The pressure on account of population, urbanization, industrialization etc resulted in declining avg. land holding. Today small & marginal farmers contribute nearly 42% of marketable surplus. Greenhouse can provide answers for round the year cultivation under climatic uncertainties as well as price fluctuations. In spite of these handicaps, India has attained self-sufficiency in food production and stands second in fruit and vegetable production in the world. To fulfill the overall demand there is need to adopt hi-tech Plasticulture Applications and Precision Farming method not only to improve productivity, quality and economics of production but also have salutary impact on the environment.

Greenhouse technology is an agro-system that presents important productive advantages in comparison to open-air cultivation. Greenhouse protects crops from extreme climatic factors - temperature, high winds, heavy rains, storms, insects and diseases. It maximizes the productivity per unit area with genetic potentiality of the crop being fully exploited. Off-season vegetables can be grown, which fetch high prices in the market. Greenhouse has been used in raising healthy nurseries & quality planting materials.

Looking at the advantages of greenhouse technology, the Government of India has been providing financial assistance for adoption of Naturally Ventilated Greenhouse and Greenhouse with Fan and Pad Cooling System (Forced Ventilated Greenhouse) under the National Horticulture Mission (NHM) and Horticulture Mission for North East and Himalayan States (HMNEHS) - centrally sponsored schemes for holistic development of horticulture in the country. The pattern of assistance is 50% of the cost limited to an area of 4000 sqm per beneficiary.

National Committee on Plasticulture Applications in Horticulture (NCPAH) has prepared this reference manual as a ready reference for farmers, entrepreneurs, scheme implementing officials & related practitioners on greenhouse. The focus of the manual is to provide information on basic concepts, design and technical specifications, optimal temperature band for different crops, crop cycle of vegetables, cost-economics etc.

It is hoped that the reference manual would help all stakeholders & end users to take maximum advantages by adopting Greenhouse Technology for changing lives and spreading smiles for millions of beneficiaries in the country.

1. Introduction

A greenhouse is a framed structure made of GI pipe/MS angle/ Wood/ Bamboo and covered with a transparent/translucent material fixed to frame with grippers. Besides irrigation, it has control/monitoring equipment, which is considered necessary for controlling environmental factors such as temperature, light, relative humidity etc. and is necessary for maximizing plant growth and productivity. Thus, the greenhouse is an enclosed area, in which crops are grown under partially or fully controlled conditions. The cladding material is of plastic (Polyethylene) film and acts like a selective radiation filter that allows solar radiation to pass through it but traps the thermal radiation emitted by the inside objects to create greenhouse effect.

The greenhouse protects the plants from adverse climatic conditions and provides an appropriate amount of light, temperature, humidity, carbon-dioxide etc. to achieve optimum yield with excellent quality. The reason for building a greenhouse is to get faster growth by raising humidity and controlling temperatures. Labor, energy and capital are the major three cost factors in a typical modern greenhouse production system. Greenhouse technology is highly relevant under Indian conditions due to variant agro-climatic conditions of the country.

2. Advantages

- Provides favorable micro climatic conditions for the plants.
- Cultivation in all seasons is possible.
- Higher yield with better quality per unit area.
- Conserves moisture thus needs less irrigation.
- More suitable for cultivating high value/ off - season crops.
- Helps to control pest and diseases.
- Helps in hardening of tissue cultured plants.
- Helps in raising early nurseries.
- Round the year propagation of planting material is possible.
- Protects the crops from wind, rain, snow, bird, hail etc.
- Generates self- employment opportunities for educated youth.

3. Potentialities of greenhouse technology

- Cultivation is possible under extreme climatic conditions.
- Export of hybrid seeds, ornamentals plants and tissue culture plants.
- Suitable for Biotechnology and genetic engineering.
- Cultivation of rare and exotic medicinal, aromatic and ornamental species.
- Production of high value, low volume horticultural crops.
- Supply of high quality fresh fruits/vegetables and flowers for cities.
- Production of healthy planting materials.

The choice of crops to be raised in a greenhouse depends on the size of the structure and economics of crop production.

4. Types of greenhouse

Keeping in view the Indian climatic conditions, two types of greenhouse have been taken into consideration under the Govt. of India schemes (NHM & HMNEHS) for subsidy, and they are Naturally Ventilated Greenhouse and Greenhouse with Fan & Pad Cooling System. There is also a provision of subsidy for the low cost greenhouses made of wooden and bamboo structure.

A. **Naturally ventilated greenhouse** - best suited for areas where temperature ranges between 15 ℃ to 30 °C. The structure should have a provision of sufficient number of openings for ventilation. The percentage of ventilation will be up to 60% of the floor area depending upon climatic conditions. The openings may be side wall vent or roof vent or both to exchange air (hot/cold) flow inside the greenhouse. During the summer period the openings are provided need to ensure efficient air movement and should be fully airtight during winter period.

B. **Greenhouse with fan and pad cooling system** - best suited for hot dry climatic conditions such as Northern plains where temperature goes above 30 °C,. The system is working on the principle that when water evaporates and heat is absorbed from surroundings. This is possible by drawing cool air into greenhouse through wet pad located at one end of the wall, where hot air is replaced by co-axial fans mounted on the opposite end of wall. The excessive temperature causes various

damages to the morphology and physiological processes of plants such as flower shedding, leaf scorch, poor fruit quality, excessive transpiration, shortened life span of the plants and low net photosynthesis due to excessive respiration etc. Hence, it is important to maintain air temperature inside the greenhouse ranging between 20 °C to 28 °C for better crop growth.

Operation of Fan & Pad cooling system

Fan and pad system is controlled by a thermostat. Thermostatically controlled fans let the outside air into the greenhouse and remove inside air out of it. The capacity of fan should be 1m^3 for each m^3 of greenhouse volume per minute so as to ensure a complete renewal (or at least three quarters of it) or (50 to 60 renewals per hour) under tropical conditions.

Orientation criteria for mounting fan & pad

The orientation of the multi span greenhouse with fan & pad cooling system should be made in such a way to take advantages of prevailing wind direction. Wet pad should be mounted on the wall of greenhouse facing winds and fan on the leeward side. The temperature gradients inside the greenhouse decide the need for Fan & Pad system. The root vents should be on the leeward side to prevent structural damage to the greenhouse.

Factors to reduce uneven temperature are as follows:

- Seal all cracks and holes in the structure.
- Limit the maximum distance between fan & pad to 25 m.
- Increase the number of fans for efficient air flow.
- Provide additional misting facility that saves water.
- In case of saline/brackish water, use horizontal pad as water flows downwards through the pads has a self cleaning effect.
- The water used for wetting the pad should be stored in an underground tank and provision to be made for recirculation.
- Uniform water pressure of the system must be maintained to keep the pad adequately wet.
- The cooling efficiency of greenhouse can be increased by using shadenet of up to 50% shade factor.

5. Design considerations for greenhouse

5.1 Site selection

While selecting the site for construction of a greenhouse, following points should be considered for the optimum growth and development of plant:

- The site should be free from shadow.
- The site should be at a higher level than the surrounding land with adequate drainage facility.
- Availability of good quality irrigation water and electricity to run the fan & pad cooling system.
- pH of the irrigation water should be in the range of 5.5 to 7.0 and EC between 0.1 to 0.3 mS/cm.
- pH of the soil should be in the range of 5.5 to 6.5 and EC between 0.5 to 0.7 mS/cm respectively.
- Proximity to motorable road to take advantages of market for inputs supply & sale proceeds.
- Soil need to be changed or sterilized after every 3 to 4 years preferably to avoid built up of soil pathogens. Alternatively, artificial media can be an option for cultivation.

5.2 Orientation

Correct orientation can provide good environmental conditions inside the greenhouse. Following points should be considered while deciding the orientation of a greenhouse depending upon light intensity and direction & velocity of wind.

- Orientation of the single span greenhouse should be directed towards East-West and North - South in case of multi-span for taking advantage of available sun-shine.
- Gutter should be made in North - South direction in multi span greenhouse.
- Slope along the gutter should not be more than 2%.
- Slope along the gable side should not be more than 1.25%.
- In naturally ventilated greenhouse, ventilators should open on the leeward side.

- Single span greenhouse should have long axis perpendicular to the direction of wind to protect it from wind damage.
- Wind breaks, should be placed at least 30 meters away on North - West side of the greenhouse.

In case of tropical region, there is low availability of solar radiation and sky remains cloudy during the rainy season. Hence, effective ventilation is very important to control the temperature and humidity by keeping proper orientation of the greenhouse.

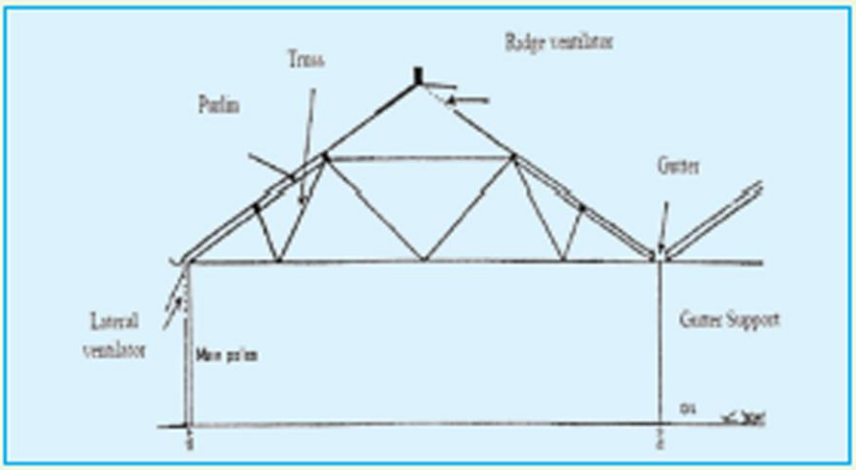
5.3 Size

The size of the greenhouse needs to be selected based on availability of the land. The cost may vary depending upon the types of greenhouse and number of suppliers' present in the region. Depending upon the market access and experience of greenhouse cultivation, it is suggested to start with a naturally ventilated greenhouse having minimum size of 100 sqm as it would require less initial capital investment along with operational expenditure. However, experienced farmers / entrepreneurs may decide to go for larger size greenhouse depending on their scale of operation and project costs.

5.4 Height

Height is one of the most important aspects of greenhouse design. The height of the structure directly impacts natural ventilation, stability of the internal environment and crop management. The ideal centre height of naturally ventilated small greenhouse (up to 250 sqm) should be in the range of 3.5 m to 4.5 m and 5.5 m to 6.5 m in case of large size greenhouses. The side/gutter height should be in between 2.5 m to 3 m and 4.5 m to 5 m for small and large size greenhouses respectively. Both types of greenhouse can be made in single or multi-span structures. A multi-span greenhouse can be constructed for an area more than 200 sqm and is economical in terms of construction material & required control/ monitoring equipments. Height of the greenhouse having fan & pad cooling system should be slightly lesser than the naturally ventilated greenhouse and in any case not be more than 5.5 m.

5.5 Parts of the greenhouse



6. Indian standards for Greenhouse

The Bureau of Indian standards (BIS) has formulated following standards with respect to greenhouse technology:

1. IS 14462: 1997 - Recommendations for layout, design and construction of greenhouse structures
2. IS 14485: 1998 - Recommendations for heating, ventilating and cooling of greenhouse
3. IS 15827: 2009 - Plastics films for greenhouses – specifications

7. Criteria for selecting greenhouse structure

As far as possible, galvanized iron (GI) pipe based greenhouse must conform to ISI Trade mark with minimum 2 mm wall thickness. The structure should have following features:

- ✓ Stub type-anchoring foundation, Galvanized and nut bolted structure having options for future expansion.
- ✓ Strong enough to withstand various types of load such as Live load, Dead load, Crop load, Wind and Snow load.
- ✓ Single piece G.I. gutter 500 mm wide & 1 mm thick.
- ✓ Aerodynamic shape along all peripheries to resist high wind velocity.
- ✓ The structure is designed to resist wind velocity up to 150 Km/hr.
- ✓ Provision for fixing of UV stabilized plastic film with aluminum/G.I. profiles & zigzag spring lock.
- ✓ Strong enough to support the load of internal service systems and plant foliage.

- ✓ Use 200 micron UV stabilized plastic film conforming to Indian Standard IS 15827: 2009.
- ✓ Easy to service, cover and recover with cladding material.
- ✓ Easy to operate.
- ✓ Cost effective.

8. Technical specifications

Considering the above criteria, suggested technical specifications suggested for a naturally ventilated greenhouse are given in **annexure 1A & 1B** and for greenhouse with fan & pad cooling system in **annexure 2**.

9. The design drawing of different types of greenhouse

The basic designs of various types of greenhouse are given in **annexure 3.**

10. Wood/ Bamboo based naturally ventilated greenhouse/ Rain-shelter greenhouse

Wooden/Bamboo based naturally ventilated greenhouse (also called rain-shelter in heavy rain fall areas) are made of Casurina, Nilgiri, etc or Bamboo. The poles made of these materials preferably may be treated either with turpentine or coal tar at one end that will be placed in the foundation pits. Aluminum profiles with spring or wooden battens may be used for fixing the UV stabilized polyethylene films. The wooden/bamboo poles and other supporting materials used in the greenhouse structure need to be strong enough to withstand different types of load - wind load, crop load etc. To withstand such loads, the recommended specifications of outer diameter of wooden/bamboo poles lies between 8 cm -10 cm for main poles and 6 cm - 8 cm for purlins & trusses. Preferably, all parts of the structure are fitted with the help of nails or nut-bolts.

The suggested technical specifications for a wooden or bamboo structure greenhouse are given in **annexure 4.**

11. Cladding materials

There are two types of plastic films normally used for greenhouse cladding - single layer (monolayer) clear transparent UV stabilized film and specialty

films such as diffused, anti drip, anti-dust, anti-sulphur etc. The selection of the film would depend on the crops to be grown in the greenhouse and various chemical treatments given during the production cycle. As per the Indian Standard (IS 15827: 2009) the plastic films should have following important properties:

Important properties of covering materials

Sl. No.	Type of plastic films	Characteristics	Uses
i)	Normal film	a) Good Transparency more than 80% b) Low Greenhouse Effect	Forcing and Semi-Forcing crops
ii)	Thermic clear film	a) Good Transparency b) High infrared (IR) effectiveness	As normal film, when greater infrared (IR) effectiveness is desired
iii)	Thermic diffusion	a) Diffusion Light b) High infrared (IR) effectiveness	As normal film, when greater infrared (IR) effectiveness and diffusing light is desired

12. Important Climatic factors influencing plant growth

The importance of climatic factors and its desired level influences physiological characteristics of crops in a greenhouse are given below:

Sl. No.	Climatic Factors	Important for	Desirable level in Greenhouse
1.	Radiation / Light	Photosynthesis, Photo-morphogenesis Photoperiodism	50,000 lux*
2.	Temperature	Cell division & elongation, respiration, photosynthesis water uptake, transpiration etc.	18 °C - 25 °C
3.	Relative humidity	Quality of plant	60% - 80%
4.	Carbon dioxide (CO_2)	Photosynthesis	350 ppm - 1000 ppm
5.	Air movement/ wind movement	Influences temperature, relative humidity & CO_2 concentration in the greenhouse, structural stability	Inflow: Outflow ratio should be 1:1 per hour
6.	Rainfall/ precipitation	Influences RH, structural stability	—

Source:** Internet researchable* ****1 lux = 1 lumen/square meter

13. Important Research Studies (through PFDCs) on flowers, vegetables & nursery cultivation

Based on the research studies carried out by the Precision Farming Development Centres (PFDCs) and others on different crops, information on suggested crop cycle, climatic requirement, cost of cultivation & payback period best suited for greenhouse cultivation is given below. However, the above may vary from place to place and as per the experiences of growers.

13.1 Suggested crop cycle

Crops	Periods/Crop cycle month	
	Transplanting	Harvesting
Tomato	Varieties available for round the year cultivation	
Green Capsicum / Colour Capsicum - Spinach 2 season or Okra	August - September April - May February	April - March July - August May - June
Cucumber - Cauliflower / Leafy vegetable / Okra	November - December April - May	March - April October - November
Muskmelon / Water melon	February - March	June
Propagation of fruit crops etc.	3 cycle round the year	
Flowers	Round the year	

13.2 Climatic requirement for flowers & vegetables

The climatic factors such as temperature, relative humidity and light intensity and their desired level for optimum growth of some selected crops is given below:

Sl. No.	Name of crop	Temperature (°C)		Humidity (%)	Light Intensity (lux)
		Day	Night		
Flowers					
1.	Carnation	16 - 20	10 - 12	60 - 65	40000 - 50000
2.	Chrysanthemum a) Cut flower b) Pot	 22 - 24 23 - 26	 15 - 16 16 - 19	 60 - 65 60 - 65	 35000 - 40000 35000 - 40000
3.	Gerbera	20 - 24	18 - 21	60 - 65	40000 - 50000

4.	Orchid	22 - 24	18 - 20	70 - 80	25000 - 30000
5.	Anthurium	22 - 25	18 - 20	70 - 80	25000 - 30000
6.	Rose	24 - 28	18 - 20	65 - 70	60000 - 70000
Vegetables					
7.	Tomato	22 - 27	15 - 19	50 - 65	50000 - 60000
8.	Cucumber	24 - 27	18 - 19	60 - 65	50000 - 60000
9.	Capsicum	21- 24	18 - 20	50 - 65	50000 - 60000
Nursery					
10.	Nursery	22 - 27	16 -19	50 - 65	50000 - 60000

Source: Internet researchable

13.3 Indicative cost of cultivation of crops grown under greenhouse

	Crops	Avg. cultivation cost (₹/sq m)
Vegetables	Capsicum & Tomato	105
Flower	Gerbera & Carnation	500
Nursery	Mango, Guava & Aonla etc.	225

13.4 Indicative payback period of 500 Sqm Greenhouse

The average payback period of 500 sqm greenhouse in case of nursery production is 10 - 11 months, flowers 18 - 19 months and vegetables 22 - 23 months respectively.

Annexure 1A

Suggested Technical specifications of Naturally Ventilated Greenhouse

Sl. No.	Items	Description/Specifications
1	Product	**Naturally Ventilated Greenhouse**
2	Size	100 m^2 - 300 m^2
3	Bay size	6 m x 3-4m, Width of greenhouse should be at least 35 % of the desired length.
4	Ridge height	3.5 m to 4.5 m
5	Vents	Ridge vent should have 80-90 cm and side vent depending upon the requirement and opening

		should be fixed with 40 mesh UV stabilized nylon insect screen.
6	Gutter height	2.5 m to 3 m from floor area
7	Gutter slope	2% slope need be provided in civil foundation work/ structure
8	Gutter material	20 gauge or 1 mm thick GI sheet with perimeter of 500 mm or more preferably of single length without joint
9	Structural design	The structural design need to be sound enough to withstand wind speed minimum 150 km/hr and minimum load of 25 kg/m². There should be provision for opening one portion at either side for entry of small tractor/power tiller for intercultural practices. The firm needs to highlight design features and list of greenhouse clients.
10	Structure	Complete structure made of galvanized steel tubular pipes or equivalent section conforming Indian Standards having wall thickness 2mm, structural member should be joined with fasteners properly.
	Columns	48/42 mm OD, 2 mm thick
	Trusses	Bottom & top cord 42 mm OD, 2 mm thick
	Trusses member & Purlin	33 mm OD, 2 mm thick
	Purlin member & others	25 mm, 2 mm thick
	Foundations	Insert GI pipes of minimum 42 mm OD or more to have foundation depth of 48 cm or more depending upon soil type and prevailing wind condition, grouted with cement concrete mixture of 1:2:4 using telescopic insertion of column.
	Fasteners	All nuts & bolts must be of high tensile strength and galvanized.
11	Entrance room & Door	One entrance room of size 3 m x 3 m x 3 m (L x W x H) need to be provided and covered with 200 micron UV stabilized transparent plastic film. Two hinge doors of size 2 m width & 2.5 m height double leaf made in plastic/FRP sheets mounted in suitable strong frame.

12	Cladding material	UV stabilized 200 micron transparent Plastics films conforming Indian Standards (IS 15827: 2009), multilayered, anti drip, anti fog, anti sulphur, diffused, clear and having minimum 85% level of light transmittance.
13	Fixing of cladding materials	All ends/joints of plastic film need to be fixed with two way aluminum profiles with suitable locking arrangement along with curtain top. Wooden batons or PVC grippers need not be used.
14	Spring Insert	Zigzag high carbon steel with spring action wire of 2-3 mm diameter must be inserted to fix shade net into Aluminum Profile.
15	Curtains and insect screen	Roll up UV stabilized 200 micron transparent plastic film as curtains need be provided should be equal to height on all sides having automatic type motor operated crank mechanism. However, provision for manual opening and closing of curtains need also be provided.40 mesh nylon insect proof nets (UV stabilized) of equivalent size need to be fixed inside the curtains. Anti flapping strips is suggested to ensure smooth functioning of the curtain.
16	Shadenet	UV stabilized 50% shading net with motor/manually operated mechanism for expanding and retracting. Size of net should be equal to the floor area of greenhouse.
17	Drip Irrigation System with fogging & misting facility	Drip irrigation system under greenhouse need to be selected on the basis of crop spacing (design on spacing 45cm x 45 cm) along with fogging and misting facilities. The spacing considered for calculation The suggested bill of materials are Sand Filter 5 m^3/hr, Screen Filter 10 m^3/hr, Control Valve 63 mm, Control Valve 50mm, By-pass Assembly - 1.5", Air Release Valve 1", Non Return Valve1.5", Throttle Valve 1.5'', Flush Valve 50mm, Venturi 1.5" Assembly with manifold, PVC pipe 63 mm/6 kg/ cm^2, PVC pipe 50 mm/6 kg/cm^2, PE plane lateral 16 mm, Emitting pipe lateral 16mm- @ 0.45m spacing, hanging type micro sprinkler nozzle (four-way take-off assembly) for very fine water particles (foggers & mister) to be fixed in PE pipe of diameter 16mm, Water tank of capacity 2000 liter and fittings & accessories.
18	Footpath	1m wide and 10 cm thick footpaths should be provided in the centre (length x width) & made of cement concrete ratio of 1:2:4.

19	Curtain wall/ Apron	22 cm brick wall of 1m height (24 cm below and 80 cm above ground level on all the four sides. The wall needs to be plastered and water proofing cement with 1:6 ratio.
After sales services *(The firm have to provide)*		
20	Warranty	Free maintenance for one year from the date of installation.
21	Training	Free training for operation, maintenance & production for one year.
22	Testing	All plastic materials used in the greenhouse should be tested by the CIPET for quality assurance (If necessary).

Annexure 1B

Suggested technical specifications of Naturally Ventilated Greenhouse

Sl. No.	Items	Description/Specifications
1	Product	**Naturally Ventilated Greenhouse**
2	Size	500 m^2 /1000 m^2
3	Bay size	8m x 4m, Width of greenhouse should be at least 35 % of the desired length.
4	Ridge height	6.5m to 7m
5	Ridge Vent	80-90 cm opening fixed with 40 mesh nylon insect screen
6	Gutter height	4 - 4.5 m from floor area
7	Gutter slope	2% slope need be provided in civil foundation work/ structure
8	Gutter material	20 gauge or 1 mm thick GI sheet with perimeter of 500 mm or more preferably of single length without joint
9	Structural design	The structural design need to be sound enough to withstand wind speed minimum 150 km/hr and minimum load of 25 kg/m^2. There should be provision for opening one portion at either side for entry of small tractor/power tiller for intercultural practices. The firm needs to highlight design features and list of greenhouse clients.
10	Structure	Complete structure made of galvanized steel tubular pipes or equivalent section conforming Indian Standards having wall thickness 2mm, structural member should be joined with fasteners properly.

	Columns	76 mm OD, 2 mm thick
	Trusses	Bottom & top cord 60 mm OD, 2 mm thick
	Trusses member	48 mm OD, 2 mm thick
	Purlin	42 mm OD, 2 mm thick
	Purlin member & others	33/25 mm, 2 mm thick
	Foundations	Insert GI pipes of minimum 60 mm OD or more to have foundation depth of 75 cm or more depending upon soil type and prevailing wind condition, grouted with cement concrete mixture of 1:2:4 using telescopic insertion of column.
	Fasteners	All nuts & bolts must be of high tensile strength and galvanized.
11	Entrance room & Door	One entrance room of size 3 m x 3 m x 3 m (L x W x H) need to be provided and covered with 200 micron UV stabilized transparent plastic film. Two hinge doors of size 2 m width & 2.5 m height double leaf made in plastic/FRP sheets mounted in suitable strong frame.
12	Cladding material	UV stabilized 200 micron transparent Plastics films conforming Indian Standards (IS 15827: 2009), multilayered, anti drip, anti fog, anti sulphur, diffused, clear and having minimum 85% level of light transmittance.
13	Fixing of cladding materials	All ends/joints of plastic film need to be fixed with two way aluminum profiles with suitable locking arrangement along with curtain top. Wooden batons or PVC grippers need not be used.
14	Spring Insert	Zigzag high carbon steel with spring action wire of 2-3 mm diameter must be inserted to fix shade net into Aluminum Profile.
15	Curtains and insect screen	Roll up UV stabilized 200 micron transparent plastic film as curtains need be provided up to 3.0 m height on all sides having automatic type motor operated crank mechanism. However, provision for manual opening and closing of curtains need also be provided.40 mesh nylon insect proof nets (UV stabilized) of equivalent size need to be fixed inside the curtains. Anti flapping strips is suggested to ensure smooth functioning of the curtain.
16	Shadenet	UV stabilized 50% shading net with motor/manually operated mechanism for expanding and retracting. Size of net should be equal to the floor area of greenhouse.

17	Drip Irrigation System with fogging & misting facility	Drip irrigation system under greenhouse need to be selected on the basis of crop spacing (design on spacing 45cm x 45 cm) along with fogging and misting facilities. The spacing considered for calculation The suggested bill of materials are Sand Filter 5 m^3/hr, Screen Filter 10 m^3/hr, Control Valve 63 mm, Control Valve 50mm, By-pass Assembly 1.5", Air Release Valve 1", Non Return Valve 1.5", Throttle Valve 1.5", Flush Valve 50mm, Venturi1.5" Assembly with manifold, PVC pipe 63 mm/6 kg cm^2, PVC pipe 50 mm/6 kg/cm^2, PE plane lateral 16 mm, Emitting pipe lateral 16mm- @ 0.45m spacing, hanging type micro sprinkler nozzle (four-way take off assembly) for very fine water particles (foggers & mister) to be fixed in PE pipe of diameter 16mm, Water tank of capacity 5000 liter and fittings & accessories.
18	Footpath	1m wide and 10 cm thick footpaths should be provided in the centre (length x width) & made of cement concrete ratio of 1:2:4.
19	Curtain wall/ Apron	22cm brick wall of 1m height (24 cm below and 80 cm above ground level on all the four sides. The wall needs to be plastered and water proofing cement with 1:6 ratio.
After sales services *(The firm have to provide)*		
20	Warranty	Free maintenance for one year from the date of installation.
21	Training	Free training for operation, maintenance & production for one year.
22	Testing	All plastic materials used in the greenhouse should be tested by the CIPET for quality assurance (If necessary).

Annexure 2

Suggested technical specifications of Greenhouse with Fan & Pad cooling System

Sl. No.	Items	Description/Specifications
1	Product	**Greenhouse with Fan & Pad Cooling**
2	Size	500 m^2 /1000 m^2
3	Bay size	8m x 4m, Width of greenhouse should be at least 35% of the desired length.
4	Ridge height	5 m to 5.5 m

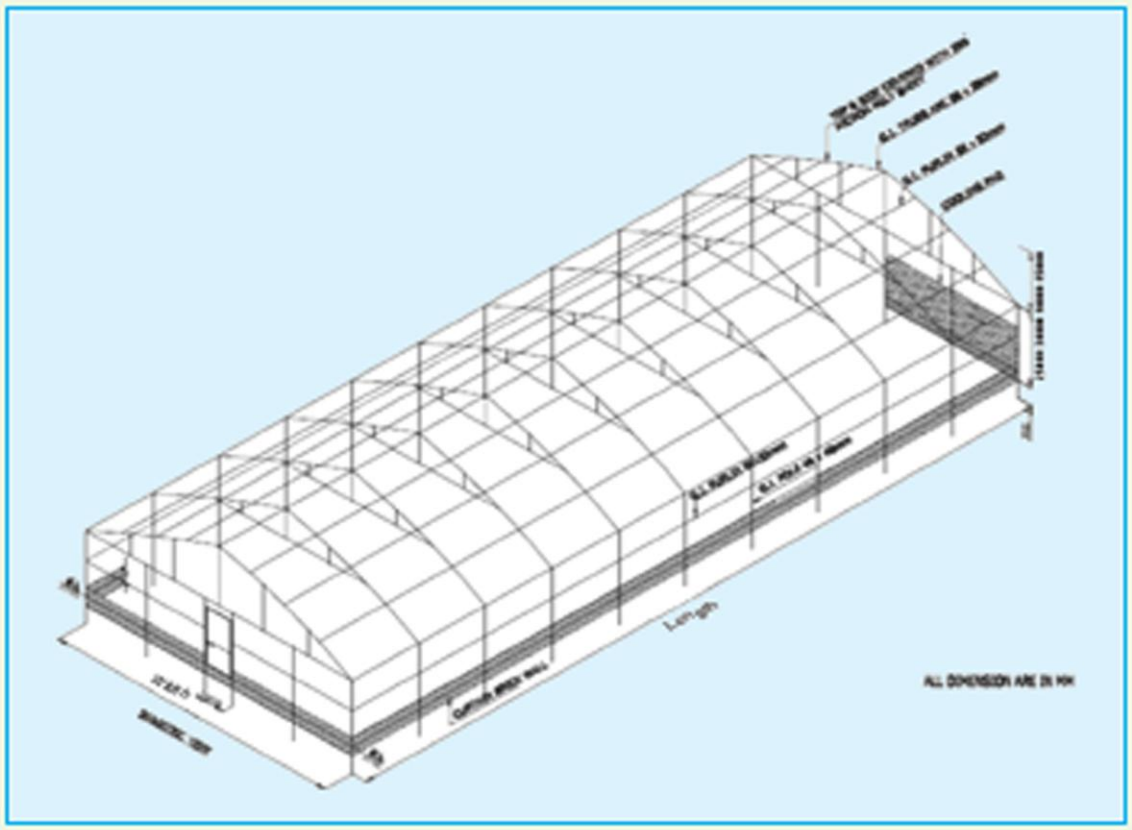
5	Ridge Vent	80-90 cm opening fixed with 40 mesh nylon insect screen
6	Gutter height	4 m to 4.5 m from floor area
7	Gutter slope	2% slope need be provided in civil foundation work/ structure
8	Gutter material	20 gauge or 1 mm thick GI sheet with perimeter of 500 mm or more preferably of single length without joint
9	Structural design	The structural design need to be sound enough to withstand wind speed minimum 150km/hr and minimum load of 25 kg/m^2. There should be provision for opening one portion at either side for entry of small tractor/power tiller for intercultural practices. The firm needs to highlight design features and list of greenhouse clients.
10	Structure	Complete structure made of galvanized steel tubular pipes or equivalent section conforming Indian Standards having wall thickness 2mm, structural member should be joined with fasteners properly.
	Columns	76 mm OD, 2 mm thick
	Trusses	Bottom & top cord 60 mm OD, 2 mm thick
	Trusses member	48 mm OD, 2 mm thick
	Purlin	42 mm OD, 2 mm thick
	Purlin member & others	33/25 mm, 2 mm thick
	Foundations	Insert GI pipes of minimum 60 mm OD or more to have foundation depth of 75 cm or more depending upon soil type and prevailing wind condition, grouted with cement concrete mixture of 1:2:4 using telescopic insertion of column.
	Fasteners	All nuts & bolts must be of high tensile strength and galvanized.
11	Entrance room & Door	One entrance room of size 3 m x 3 m x 3 m (L x W x H) need to be provided and covered with 200 micron UV stabilized transparent plastic film. Two hinge doors of size 2mwidth & 2.5 m height double leaf made in plastic/FRP sheets mounted in suitable strong frame.
12	Cladding material	UV stabilized 200 micron transparent Plastics films conforming Indian Standards (IS 15827: 2009), multilayered, anti drip, anti fog, anti sulphur, diffused, clear and having minimum 85% level of light transmittance.

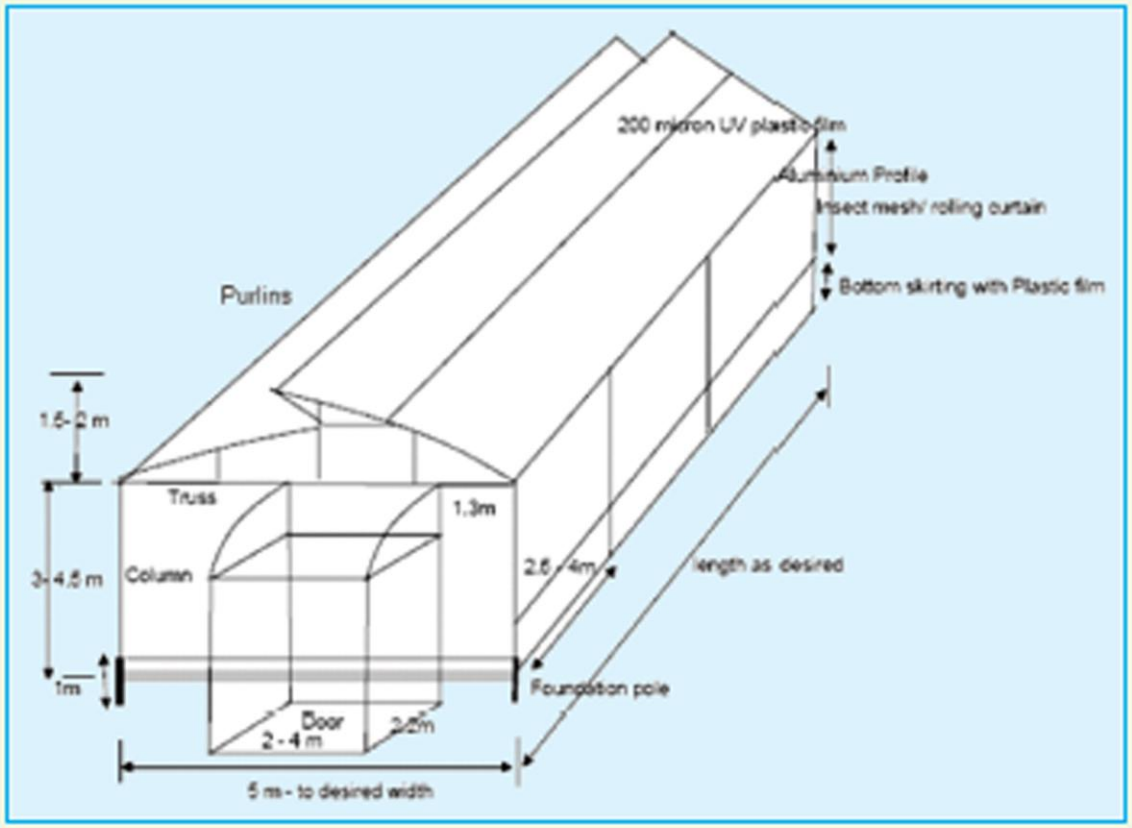
13	Fixing of cladding materials	All ends/joints of plastic film need to be fixed with two way aluminum profiles with suitable locking arrangement along with curtain top. Wooden batons or PVC grippers need not be used.
14	Spring Insert	Zigzag high carbon steel with spring action wire of 2-3 mm diameter must be inserted to fix shade net into Aluminum Profile.
15	Co-axial fan	Co axial fan (ISI mark) of minimum 1200 mm diameter containing 6 numbers of GI sheet blades, frame is of GI sheet materials followed by aluminum louver.
16	Cellulose pad for cooling	Cellulose pad of thickness 4" - 6" thick, height: 5', width as desired equipped with anodized Aluminum frame. Cooling pad complete with all necessary framing material (aluminum) as required for distribution and return, gutter, down spout cap and drip pan, plumbing kit, pump 220 Volt single phase, 50 cycle, drilled PVC piping cap, pad retainer, all suspension hardware, metal flashing required to seal pad for vent opening over flow 20 mm PVC & 40 mm standard sink drain.
17	Circular pump with accessories for cooling pad	Circular pump with required capacity & accessories to be provided for wetting & circulating the pad area.
18	Digital controller with sensory devices	The necessary digital controller with sensory device & accessories of standard quality (at least two units for 500 sqm area) should be provided to operate the fan & pad system to control temperature & humidity inside the Greenhouse.
19	Electric wiring inside greenhouse	Use copper wire to withstand desired load of required electrical gadgets/appliances with ISI mark.
20	Shadenet	UV stabilized 50% shading net with motor/manually operated mechanism for expanding and retracting. Size of net should be equal to the floor area of greenhouse.
21	Drip Irrigation System with fogging & misting facility	Drip irrigation system under greenhouse need to be selected on the basis of crop spacing (design on spacing 45cm x 45 cm) along with fogging and misting facilities. The spacing considered for calculation The suggested bill of materials are Sand Filter 5 m^3/hr, Screen Filter 10 m^3/hr, Control Valve 63 mm, Control Valve 50mm, By-pass Assembly 1.5", Air Release Valve 1", Non Return Valve 1.5", Throttle Valve 1.5'', Flush Valve 50mm, Venturi 1.5"

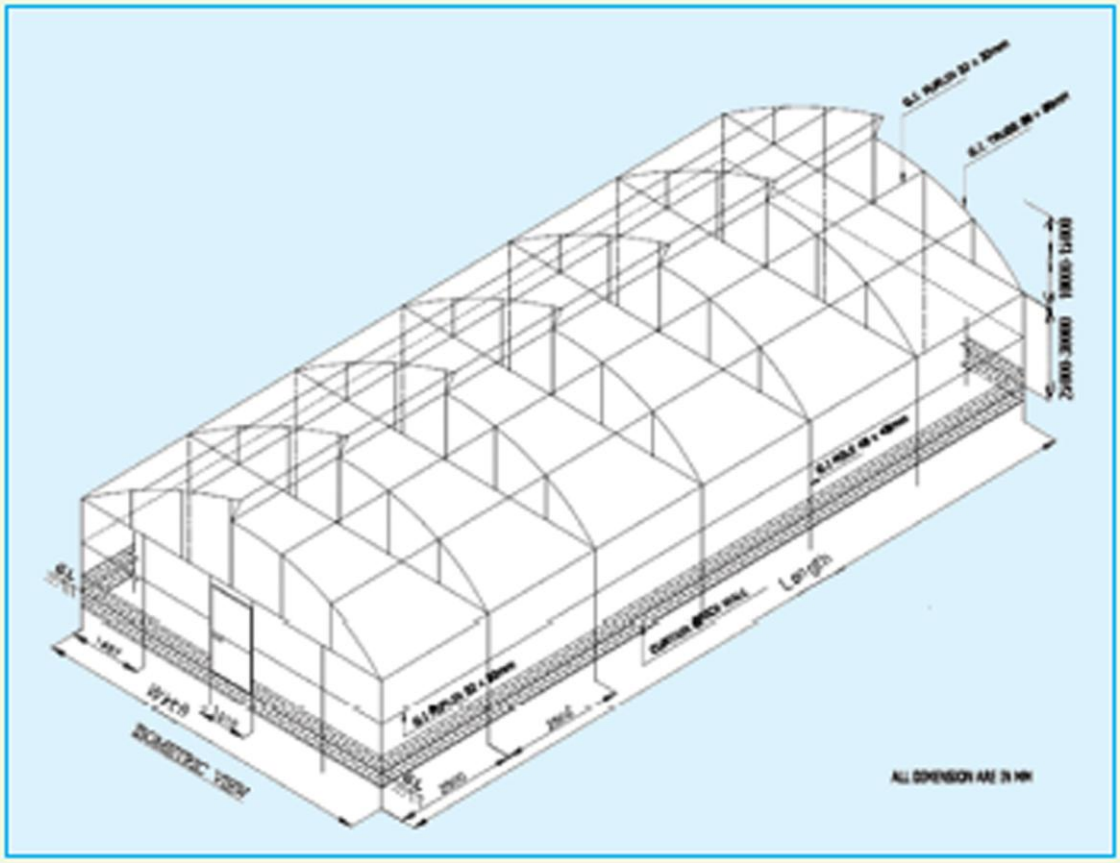
		Assembly with manifold, PVC pipe 63 mm/6 kg cm^2, PVC pipe 50 mm/6 kg/cm^2, PE plane lateral 16 mm, Emitting pipe lateral 16mm- @ 0.45m spacing, hanging type micro sprinkler nozzle (four-way take off assembly) for very fine water particles (foggers & mister) to be fixed in PE pipe of diameter 16mm, Water tank of capacity 5000 liter and fittings & accessories.
22	Footpath	1m wide and 10 cm thick footpaths should be provided in the centre (length x width) & made of cement concrete ratio of 1:2:4.
23	Curtain wall/ Apron	22cm brick wall of 1m height (24 cm below and 80 cm above ground level on all the four sides. The walls need to be plastered and water proofing cement with 1:6 ratio.
Note: Optional items - provision to be made for opening & closing of ventilation system in case of power failures.		
24	Curtains and insect screen	Roll up UV stabilized 200 micron transparent plastic film as curtains need be provided up to 3.0 m height on all sides having automatic type motor operated crank mechanism. However, provision for manual opening and closing of curtains need also be provided.40 mesh nylon insect proof nets (UV stabilized) of equivalent size need to be fixed inside the curtains. Anti flapping strips is suggested to ensure smooth functioning of the curtain.
After sales services *(The firm have to provide)*		
25	Warranty	Free maintenance for one year from the date of installation.
26	Training	Free training for operation, maintenance & production for one year.
27	Testing	All plastic materials used in the greenhouse should be tested by the CIPET for quality assurance (If necessary).

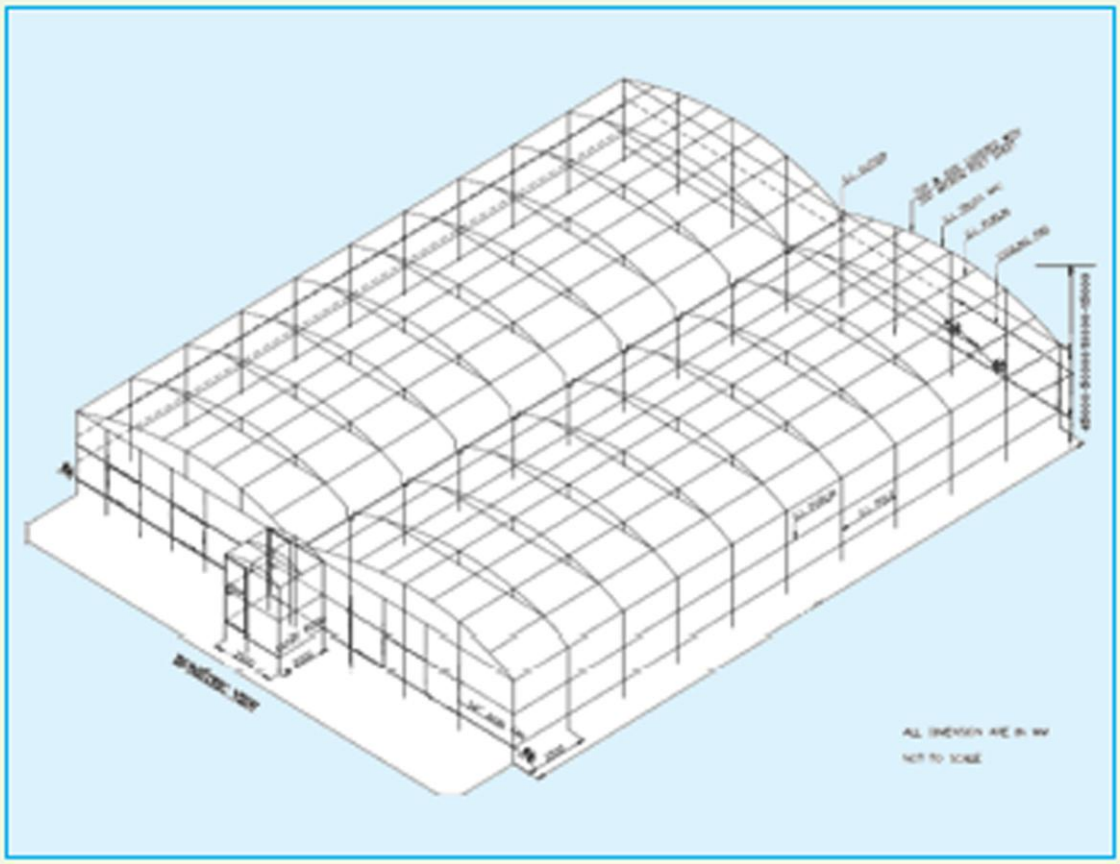
Annexure 3

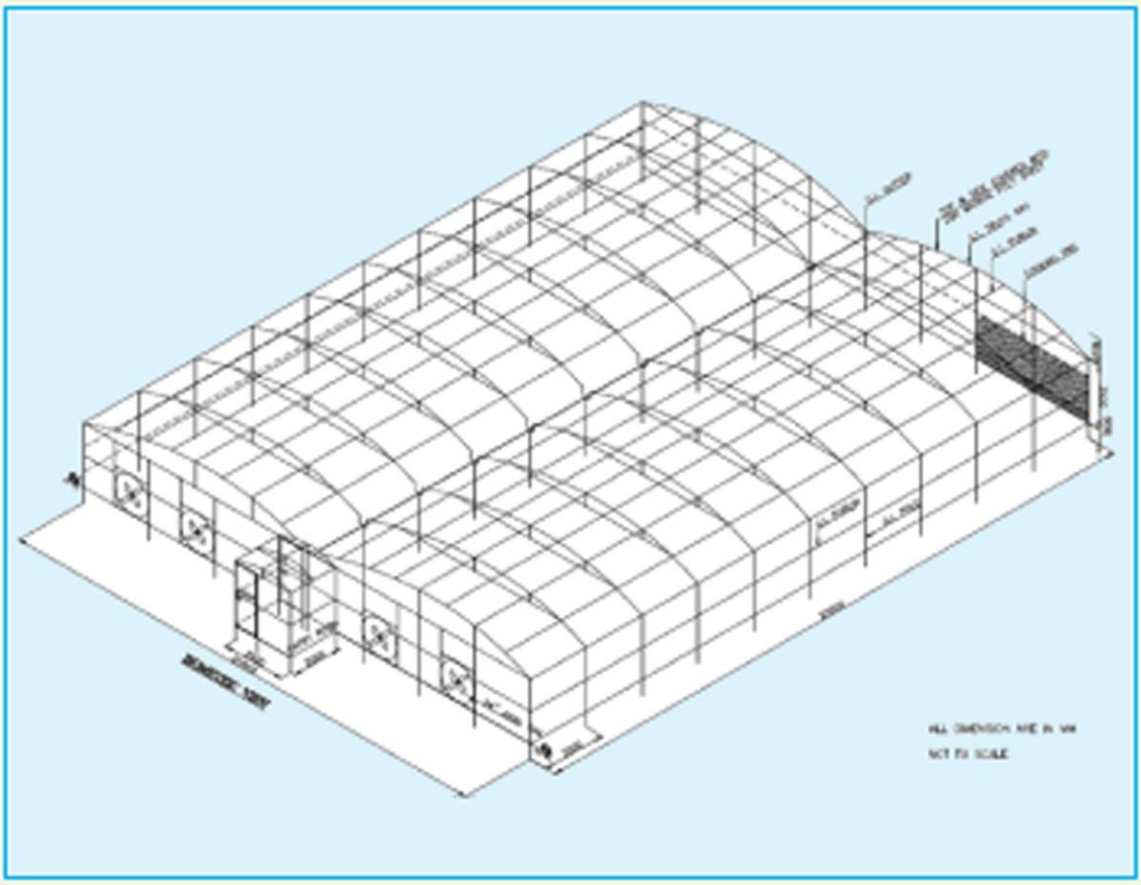
Basic design and specifications of saw tooth type greenhouse






Width
Length
ALL DIMENSION ARE IN MM


ALL DIMENSION ARE IN MM
NOT TO SCALE



Annexure - 4

Suggested technical specifications for Wooden/Bamboo based greenhouse/Rainshelter greenhouse

Sl. No.	Items	Description/Specifications
1.	Product	**Naturally Ventilated Greenhouse (Wood/Bamboo based)**
2.	Size	100 m^2 - 250 m^2
3.	Width of greenhouse	At least 35 % of the desired length of greenhouse
4.	Ridge height	3.5 m to 4 m
5.	Ridge Vent	80 cm to 90 cm opening fixed with 40 mesh nylon insect screen
6.	Gutter height	2.25m – 2.75 m from floor area
7.	Gutter slope	The gutter slope should be at least 2% in foundation structure

8.	Structural design	The structural design should be sound enough to withstand wind speed minimum 130 km/hr and minimum load of 20 kg/m². There should be provision for opening one portion at either side for entry of small power tiller for intercultural practices.
9.	Structure	Complete structures are made of strong Wooden Bamboo posts. The post should have dimension 8 cm -10 cm diameter for central post, side post and Gutter post/ tie beam etc. and diameter 6 cm - 8 cm for Post Plate, Supporting post, Trusses/ members/ sticks/others structural members for joining each other properly.
	Treatment of poles	The post must be treated with different type of preservatives to protect it from termites/ fungal attacks. The recommended preservatives are Coal Tar Creosote, Copper Zinc Naphthenates and Abietates, Boric Acid and Borax, Copper-Chrome-Arsenic (CCA) Composition, Acid-Curpric-Chromate Composition & Copper-Chrome-Boric Composition.
	Fasteners	All nuts & bolts, nails, Aluminum /MS strip of 2 cm width must be of high tensile strength and galvanized & if required, there should be provision of PP/ Coir & Jute ropes for anchoring the structure.
10	Entrance room & Door	Two entrance door of size 2.5m x 1.5m must be provided as per the requirements and covered with 200 micron UV stabilized transparent plastic film.
11	Cladding material	UV stabilized 200 micron transparent Plastic films conforming Indian Standards (IS 15827: 2009), multilayered, anti drip, anti fog, anti sulphur, diffused, clear and having minimum 85% level of light transmittance.
12	Fixing of cladding materials	All ends/joints of plastic film need be fixed with two way aluminum profile with suitable locking arrangement along with curtain top.
13	Spring Insert	Zigzag high carbon steel with spring action wire of 2-3 mm diameter must be inserted to fix shade net into Aluminum Profile.
14	Curtains and insect screen	Roll up UV stabilized 200 micron transparent plastic film as curtains need be provided up to recommended gutter height on all sides having provision for manual opening and closing of curtains should also be provided. 40 mesh nylon insect proof

		nets (UV stabilized) of equivalent size need to be fixed inside the curtains. Anti flapping strips is suggested to ensure smooth functioning of the curtain.
15	Shadenet	UV stabilized 50% shading net with manually operated expanding and retracting mechanism. Size of net should be equal to floor area of the greenhouse.
16	Footpath	1m wide and 10 cm thick footpaths should be provided in the centre (length x width) & made of cement concrete 1:2:4.
After sales services		
17	Warranty	The firm to provide Warranty free maintenance for one year from the date of installation.
18	Testing	All plastic materials used in the greenhouse should be tested by the CIPET for quality assurance (If necessary).
19	Training	Free training for operation, maintenance & production for one year.

15. Subsidy on Greenhouse

Government of India has been providing subsidy @ 50% of the total cost indicated below for adoption of this technology by farmers with a maximum ceiling up to 4000 square meter per beneficiary under National Horticulture Mission (NHM) and Horticulture Mission for North East & Himalayan states (HMNEH).

Items	Pattern of Assistance (Rs. /Sqm) up to 4000 Sqm. per beneficiary		
	Tubular structure	Wooden structure	Bamboo structure
Greenhouse with Fan & Pad system	1465	—	—
Naturally Ventilated Greenhouse	935	515	375

Disclaimer: The data, information and suggestions contained in this document are given purely as a guide. NCPAH undertakes no responsibility for the results derived from their adoption.