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Construction of a Mini Greenhouse Structure in Tropical Savannah Grassland Climatic Region (Nigeria) For Vegetable Production

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ABSTRACT: This research work focuses on the construction of a mini sized greenhouse structure for the purpose of research activities. The construction type was the convention type of greenhouse with an arch roof and mesh net as the wall around it. The construction was done using galvanized steel pipes, bolts and nuts, ultraviolent treated plastic film and insect nets. The greenhouse structure surface area is 202.16m^2, volume is 10,024m^3 and the conductive heat loss is 19,909Watts. The cost economics gave an approximate cost of ₦1,950/m^2. The greenhouse structure was constructed in an area where trees are in order to break down the wind velocity to non-destructive one. The structure was stability and would withstand some of the known environmental condition, as the structure is slated to last for about 5 years after construction.

Keywords: Greenhouse structure; Ultraviolent treated, Surface Area; Volume; and Conductive heat loss

I. INTRODUCTION

Greenhouse farming technology implies production of plants for economic use in a covered structure that allows rapid harvesting of solar radiation and modification of agro climatic conditions conducive for plant growth and development. The technology embraces infrastructure modeling, selection of plants for adaptation, production economics, agronomic management and commercial potential, etc.

"A greenhouse is a framed or an inflated structurecovered with a transparent or translucentmaterial which permits at least partial control ofplant environment and which are large enough topermit a person to carry out cultural operations"(Chandra and Panwar, 1987). While full advantageis taken of the available sunshine for cropproduction by way of selecting proper coveringmaterials, the enclosure provides an opportunityto control the other environmental parameters.As a result, greenhouse crop productivity is largely independent on outdoor environmental conditions. The purpose of growing crops under greenhouseconditions is to extend their cropping season and to protect them from adverse environmental conditions, such as extreme temperatures and precipitation, and from diseases and pests (Hanan et al.,1978).

II. METHODOLOGY

The materials used in the construction of the greenhouse include, bolts and nuts, galvanized steel pipes, ultraviolent treated plastic cover and net, concrete and reinforced steel wires. Figure 1 shows the isometric drawing of the structure.

2.1 Construction Procedures

The construction procedures were divided into two namely;

- Framing
- Covering

Framing: this step was achieved using a 2" and 1 ½" diameter galvanized steel pipes of 2millimetres thickness each. The pipe was closed and perforated at eachend to enable firm joint with the aid of bolts and nuts. Moreover, five 2" diameter steel pipes of length 5.6 metreswere bent to form an arch roof while ten 2" diameter steel pipes were of height 2 metres with a bend of length 0.2 metres at about 45^0 angle. While the 1 ½" diameter galvanized steel pipes was used to for connection between each 2" diameter steel pipes.

Covering: The roof was covered using ultraviolet (uv) treated plastic film and the front and back view was completely covered with uv treated net. Also, an allowance of one by twelve metres was

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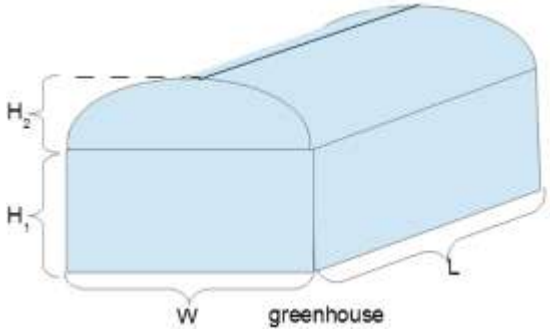
given for each of the side of structure which was covered with the net. The was done for proper ventilation and to also prevent crop burnt related hazards

2.3 Design Calculations

Greenhouse Surface Area (arched roof)



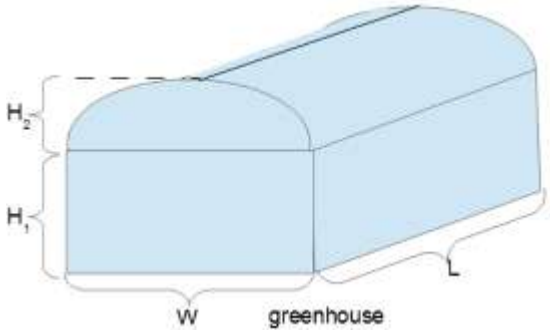
$$\text{Greenhouse}_{\text{surface area}} = f(LW, H_1, H_2)$$
$$\text{Greenhouse}_{\text{surface area}} = f(12.6, 3, 1.2)$$
$$\text{Greenhouse}_{\text{surface area}} = 202.16\ \text{m}^2$$

The **Surface Area of a Greenhouse (arched roof)** calculator computes the exterior surface area of a greenhouse based on simple measurements.

- (W) Width of the greenhouse (under the gable).
- (L) Length of the greenhouse (perpendicular to gable).
- (H_1) Height of main area
- (H_2) Height of the gable

Greenhouse Surface Area (SA):
The surface area of a greenhouse is useful in many ways including the calculating material needs and convection heat loss.

Greenhouse Volume (arched roof)
The **Greenhouse Volume (arched roof)** calculator computes the interior volume of a greenhouse based on simple measurements.



- (W) Width of the greenhouse (under the gable).
- (L) Length of the greenhouse (perpendicular to gable).
- (H_1) Height of main area
- (H_2) Height of the gable

Greenhouse Volume: The volume (**V**) is returned in cubic meter.
The volume calculation is a simple computation using the lateral area of the green house defined by the rectangle of ($H_1 \times W$) and half of a ellipse $\left(\frac{1}{2} \times \pi \times \frac{W}{2} \times H_2\right)$ all times the (L) the length.

$$\text{Greenhouse}_{\text{vol}} = \left(\left(\frac{\pi}{4} \times W \times H_2\right) + (H_1 \times W)\right) \times L$$
$$\text{Greenhouse}_{\text{vol}} = \left(\left(\frac{\pi}{4} \times 6 \times 1.2\right) + (3 \times 6)\right) \times 12$$

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$$\text{Greenhouse}_{\text{vol}} = 10{,}024.36\ \text{m}^3$$

The volume of a greenhouse is useful in many ways. It is most often needed for calculating the heating and moisture (humidity) needs of the greenhouse.

Conductive Heat Loss

The **Conductive Heat Loss** computes the heat loss (**HL**) based on the surface area (**A**), temperature variance (**vT**) and the U factor of the surface material.

- (**A**) This is the surface area
- (**vT**) This is the maximum temperature variance (indoor to outdoor)
- (**U**) This is the insulating coefficient.

Conductive heat loss is the transfer of heat through a membrane. For application in spaces such as greenhouses, the transfer of concern is typically warmth from within the greenhouse that is lost through the skin of the greenhouse into the outside environment. The equation for the conductive heat loss is relatively simple:

$$\text{CHL} = \text{A} \times \text{vT} \times \text{U}$$

Where:

- CHL is the Conductive Heat Loss
- A is the surface area
- vT is the maximum temperature variance (indoor to outdoor)
- U is the insulating coefficient.

Insulating Coefficient

The U value is published for many material.

- 0.7 double layered plastic

Note: U factor is the reciprocal of R factor which is used to rate insulation materials (e.g. fiberglass batting). Considering the extreme cases for the maximum temperature variance. Assuming the variance is 7°C.The result of the equation is Joule required to compensate for the conductive heat loss.

$$\text{CHL} = \text{A} \times \text{vT} \times \text{U}$$

$$\text{CHL} = 202.16\text{m}^2 \times 7\text{°C} \times \frac{0.7\text{BTU}}{\text{hr ft}^2}\text{°F}$$

$$\text{CHL} = 19{,}909\ \text{W}$$

Heat loss through wall

The heat loss, or norm-heating load, through walls, windows, doors, ceilings, floors etc. can be calculated as

$$\text{H}_\text{t} = \text{AU}(\text{t}_\text{i} - \text{t}_0)$$

where

- H_t = transmission heat loss (W)
- A = area of exposed surface (m^2)
- U = overall heat transmission coefficient (W/m^2K)
- t_i = inside air temperature (°C)
- t_o= outside air temperature (°C)

2.3Materials Selection

The following are some criteria for material selection:

- Availability and price: (cost of the material, labour and equipment, and maintenance there of).
- Specialization of workers and equipment needed.
- Safety.
- Speed of manufacturing.
- Consumption (natural water and energy) resources.
- The material properties (mechanical stiffness, strength,ductility;technology:physical,chemical and mechanical), modulation, composition and adaptation to the environment in which it was located.
- Reaction to water, weather and fire.

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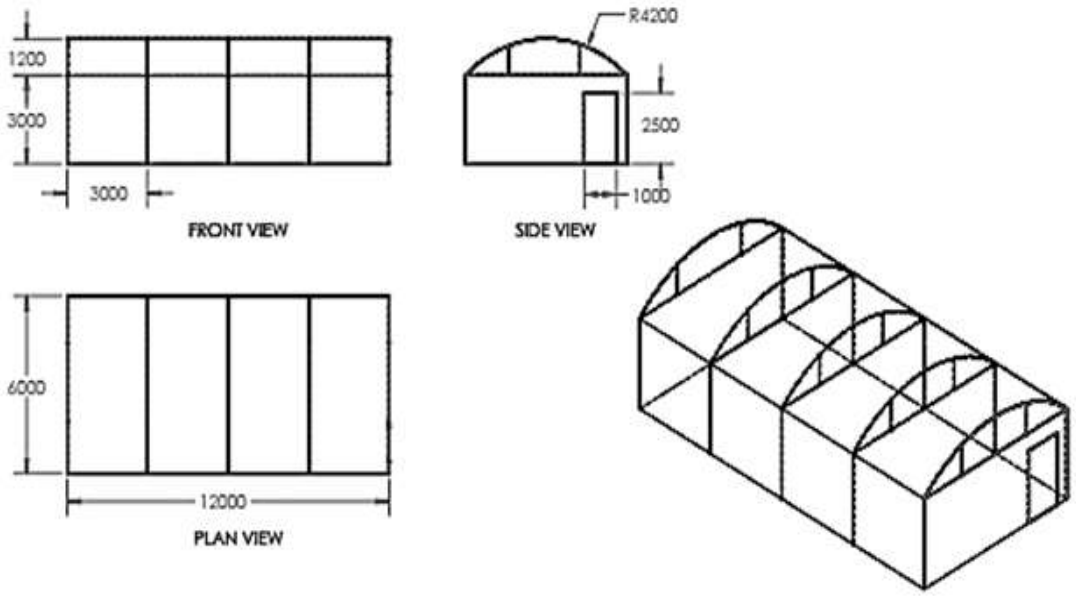

Figure 1: The isometric sketch of the greenhouse structure

2.4 Cost Economics of High Cost Greenhouse

The cost estimates may varyconsiderably due to crop, cladding material and environmental control system. The list of materials and their costs are stated below in Table 1. The cost per unit area can be estimated at approximately One thousand and fifty naira only (₦1,950) per square meter (m^2).

Table 1: Cost Economics of the Mini greenhouse structure ($202m^2$)

S/N	SPECIFICATIONS	QUANTITY	RATE(₦)	TOTAL COST(₦)
1	UV treated Plastic film (200 microns)	$100m^2$	750	75,000
2	UV treated Insect net	$140m^2$	700	98,000
3	Potted Drip system	400	300	120,000
4	Clamps & Couplings		30,000	30,000
5	Labour & Construction Cost		50,000	50,000
6	Miscellaneous		20,000	20,000
	Total			393,000

III. RESULT AND DISCUSSION

3.1 Construction Observations:

The greenhouse was constructed in a conventional style pattern at 30 degree, so as to avoid water retention at the roof. Hoop type idea was early conceived but later changed to a conventional/ post and raft type due to: The simple construction of embedded post and rafters. This design is among the strongest with the rafters lending support to the roof. Advantages over hoop houses are; simple straight forward design. Maximize usage of space along the side wall, more efficient circulation of air, particularly alongside walls. While hoop house is not as sturdy as conventional one and the design allows water to shed from its exterior. As the pictorial view can be seen in Plate 1 and 2.

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Plate 1: Front view

Plate 2: Side view

IV. CONCLUSION

Since weather conditions are changing dramatically around the planet, new forms of cultivation are needed more than ever. A greenhouse is one of the best options for improving the autonomous cultivation process; thus, researchers are looking for waysof improving the complete greenhouse performance. The mini greenhouse was constructed for research purposes and the structure shows stability with reference to the environmental condition as their trees around the structure to break down wind velocity to non-destructive one. The greenhouse temperature will be monitored under various crop grown inside and observe whether there would be need f0r shading net in order to reduce heat generation inside the greenhouse.

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