DEVELOPMENT OF A LOW COST GREENHOUSE AND DRIP HYDROPONIC STRUCTURE FOR VEGETABLE PRODUCTION IN SOUTH-WEST NIGERIA

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ABSTRACT

Greenhouse and drip hydroponic structure was developed and constructed for field experimentation at the experimental farm site of the Department of Agricultural and Environmental Engineering, Federal University of Technology, Akure, Nigeria. The use of greenhouse with hydroponic structure is very important in Nigeria Agricultural system to ameliorate food insecurity especially fresh vegetable production and consumption. The system involved economic use of water and nutrients for vegetable production. This ensures availability of vegetables all year round. The cost of purchasing and installing a commercial greenhouse in Nigeria is on the high side. It cost about N2,500,000.00 to install 12 m × 10 m × 3 m greenhouse. To ensure affordability of this important medium, a low cost greenhouse of the similar dimension with the ready-made greenhouse was designed and constructed. The greenhouse was designed by calculating for structural members such as footings, column and truss. The construction of the greenhouse was carried out in accordance with British standard structural design analysis, orthographic and isometric view. Each component was constructed with proper tolerance, dimension and specification as indicated in the drawing. Wooden strips were nailed to make the net grip to the assembly. The construction of the drip hydroponic soilless farming structure was carried out in accordance with Engineering Standards for Fabrication. Each component was constructed following appropriate tolerance, dimension and specification as shown in the design. Three of fifty litres reservoirs were installed inside of the greenhouse for water/nutrients supply to plants.

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1.0 INTRODUCTION

People have realised the importance of farming practice, even in small plots in view of the population explosion in the sub-saharan Africa continent. Planting in control environment coupled with hydroponic farming has been a new and growing research interest in Nigeria recently. The main purpose of greenhouse and soilless farming technique is to provide a good growing condition for high value fruits and vegetables all year round. It is a common practise in developed countries. Low cost greenhouse design have tendency to meet the following challenges: poor accessibility to fresh fruits and vegetables. Inaccessibility to fresh vegetables as a result of distance, which largely contribute to insecurity (Henriques et al., 2015). Weather patterns that often lead to heavy rains or drought that can disrupt crop production (Plumecocq et al., 2018). The agricultural sector of
Nigeria economy needs a new and effective technology with ideas that will continually improve the productivity, profitability and sustainability of its major farming practices (Sanusi, 2010; Plumecocq et al., 2018). By increasing agricultural productivity, these ideas can also contribute to economic development, because of the significant role agriculture plays in Nigeria. Almost all crops are usually grown in conventional farming. This practice of farming under natural and open field condition have been in existence from the time immemorial. In most of the temperate regions of the world, where the climate is not favourable for cultivation or region where the support system (soil) is poor (riverine area) and urban centre, where there is limitation on land for cultivation, measures have been put in place to grow high value crops continually and all year round by eliminating adverse weather effects on the crops (Shakuntala and Anil, 2015). Some of these measures include soilless farming methods, greenhouse etc. Soilless farming is a method of growing without soil. Soilless farming is considered as a modern day practice, but growing plants in containers above ground has been tried at various times throughout the ages. Growers go into soilless farming because of the difficulty and cost of controlling soil born pests and diseases, soil salinity, lack of soil fertility, water shortage etc. These methods of farming are better carried out inside greenhouse.

Greenhouse technology is the technique of providing favourable environmental condition for plant growth. It is the technology of farming in which plants are protected from adverse effect of wind, cold, precipitation, excessive radiation, extreme temperature, insects and diseases. This technology of farming provides a very important ideal micro climate favourable to the plants by designing and constructing greenhouse where environmental conditions are modified and any plant can be grown at any place and at any time of the year thereby making such crops available all year round (Anil et al., 2006; Santosh, 2017).

Greenhouse can be defined as a framed or inflated structures covered with transparent or translucent materials large enough to grow crops under partial or full controlled environmental conditions to get optimum growth and productivity (Reddy, 2015). This research work aims to develop low cost greenhouse and drip flow technique hydroponic structure for planting vegetable in south west Nigeria.

2.0 MATERIALS AND METHODS

2.1 Material of Construction

The choice of materials and quantities for construction of greenhouse and drip hydroponic structure is summarised in Table 1 - 4. Selection of iron pipe as poles plays a crucial role in the strength of the greenhouse. The idea behind choosing plastic roofing sheets is to produce some level of sunshine effects in the greenhouse. Wire mesh as glazing materials allow free flow of air in and out of the greenhouse.

2.2 Development of Greenhouse Members

The component members of greenhouse contribute to its cost of installation and therefore to minimise the cost of the structure, it is important to design a simple structure that requires minimum materials which provide the greatest potentials for cost reduction.

2.2.1 The Structure

The frame structure of the greenhouse is 4100 mm by 3060 mm with height at the front elevation being 2050 mm and at the back being 1750 mm using materials such as square pipe, screw, nails, and wire net, planks as constructional member. The vertical heights were chosen to allow for enough growing room for the vegetables plants when planting and harvesting and working conditions of staff. The difference in height yields a slope which is necessary for a rooftop water harvesting system for the hydroponic structure.
Table 1: Materials of construction for the various parts of the greenhouse

<table>
<thead>
<tr>
<th>Sections</th>
<th>Materials of Construction</th>
</tr>
</thead>
<tbody>
<tr>
<td>Footings</td>
<td>Concrete (gravel, sand and water) was used for the foundation.</td>
</tr>
<tr>
<td>Column</td>
<td>Iron pipe of different sizes and planks were used for the frame.</td>
</tr>
<tr>
<td>Glazing</td>
<td>The material used as wall covering for this greenhouse was wire mesh and net so that there would be natural ventilation.</td>
</tr>
<tr>
<td>Truss/Roofing</td>
<td>Irons, Planks and Plastic roofing sheets were used.</td>
</tr>
</tbody>
</table>

Table 2: Materials of construction and sizes of the various parts of the drip hydroponic structure

<table>
<thead>
<tr>
<th>Sections</th>
<th>Materials of Construction</th>
</tr>
</thead>
<tbody>
<tr>
<td>Frame</td>
<td>4” x 4” planks as frame for the hydraulic structure, 2” x 2” planks as frame for the reservoir.</td>
</tr>
<tr>
<td>Reservoir</td>
<td>50 litres buckets were used as reservoir for nutrient solution, 5 litres bowl for recovering the excess solution, Disposable plastic bottles, Rice husk Sawdust.</td>
</tr>
<tr>
<td>Connection Fittings</td>
<td>4” PVC pipes, 2” PVC Pipes, Controls, Couplings, Stoppers, T-connectors, Elbow, Abro gums.</td>
</tr>
</tbody>
</table>

Table 3: Sizes/Quantities of materials used for the construction of the greenhouse

<table>
<thead>
<tr>
<th>Materials with Sizes</th>
<th>Quantities</th>
</tr>
</thead>
<tbody>
<tr>
<td>2” Square pipe</td>
<td>16</td>
</tr>
<tr>
<td>1” Square Pipe</td>
<td>4</td>
</tr>
<tr>
<td>2 Flat Bar</td>
<td>1</td>
</tr>
<tr>
<td>Electrode</td>
<td>1</td>
</tr>
<tr>
<td>Hinges</td>
<td>4</td>
</tr>
<tr>
<td>2” x 3” Planks</td>
<td>20</td>
</tr>
<tr>
<td>1” x 2” Planks</td>
<td>20</td>
</tr>
<tr>
<td>1&quot;x 6&quot; Planks</td>
<td>10</td>
</tr>
<tr>
<td>Iron Net</td>
<td>2 rows</td>
</tr>
<tr>
<td>Nails/Screw</td>
<td>5kg</td>
</tr>
<tr>
<td>Sand</td>
<td>15kg</td>
</tr>
<tr>
<td>Gravel</td>
<td>25kg</td>
</tr>
<tr>
<td>Cement</td>
<td>25kg</td>
</tr>
<tr>
<td>Plastic Corrugated Roofing Sheet</td>
<td>1 bundle</td>
</tr>
</tbody>
</table>
Table 3: Sizes/Quantities of materials used for the construction of the greenhouse

<table>
<thead>
<tr>
<th>Materials with Sizes</th>
<th>Quantities</th>
</tr>
</thead>
<tbody>
<tr>
<td>4&quot; x 4&quot; Planks</td>
<td>6 pieces</td>
</tr>
<tr>
<td>4&quot; PVC Pipes</td>
<td>12 pieces</td>
</tr>
<tr>
<td>Sawdust</td>
<td>5kg</td>
</tr>
<tr>
<td>Ricehusk</td>
<td>5kg</td>
</tr>
<tr>
<td>4&quot; Clips</td>
<td>12</td>
</tr>
<tr>
<td>Control switch</td>
<td>6</td>
</tr>
<tr>
<td>50 liters Bowl</td>
<td>3</td>
</tr>
<tr>
<td>1/2&quot; PVC Pipes</td>
<td>3</td>
</tr>
<tr>
<td>1/2&quot; Elbow</td>
<td>10</td>
</tr>
<tr>
<td>3/4&quot; x 1/2&quot; T-connector</td>
<td>4</td>
</tr>
<tr>
<td>Bowl (5 litres)</td>
<td>3</td>
</tr>
<tr>
<td>1/2&quot; Caplock</td>
<td>30</td>
</tr>
<tr>
<td>Abro gum</td>
<td>2</td>
</tr>
<tr>
<td>Disposable Plastic Bottle</td>
<td>30</td>
</tr>
<tr>
<td>Male and female socket</td>
<td>1</td>
</tr>
<tr>
<td>4&quot; Blog</td>
<td>12</td>
</tr>
<tr>
<td>1/2&quot; T connector</td>
<td>30</td>
</tr>
<tr>
<td>3/4&quot; Pipes</td>
<td>1</td>
</tr>
<tr>
<td>3/4&quot; Adaptor</td>
<td>1</td>
</tr>
</tbody>
</table>

column/(Column perimeter*d)
Where N = Dead load factor = 1.4
= (1.4*3.47*1000)/(300*50)
= 0.243 N/mm² < 0.8*fcu/2

4. Checking for punching shear
Critical perimeter = column perimeter + 8*1.5d
= 200+(8*1.5*50)
= 800
Area within perimeter = (200+3(50))²
= 15750 mm²
Punching shear force
= 53.98 (0.32-0.01575)
=16.42 KN
Punching shear stress
= (16.42*1000)/(800*50)
= 0.12 N/mm²
Therefore the pad base is adequate.

2.2.2 Footings Design
The greenhouse was designed by calculating the footings which sustain the applied loads, moments and forces and the induced reactions and to ensure that any settlement that may occur shall be as uniform as possible and the safe bearing capacity of soil is not exceeded. Foundation base check for footings of the greenhouse is given below:
Dimension of the Column: 50 by 50 by 3.71 kg
Taking roof load as 1.5KN/m²
Take, fcu = 25N/mm²
Where, fcu = characteristic strength of concrete
Taking footing dimension as 300 mm by 300 mm and d = 50 mm

1. Total load from column = Roof load + Imposed load + Column self-weight
   = 1.5 + 1.6 + 3.71/10
   = 3.1 + 0.37
   = 3.47 KN.

2. Earth pressure = N*total load from column/column perimeter²
   Where N = Dead load factor = 1.4
   =(1.4*3.47)/0.3²
   = 53.98 KN/m²

3. Checking for shear at column surface:
   Shear stress = N* total load from column/(Column perimeter*d)

2.2.3 Column Design
Section design of the frame members were carried out by adopting code reference section design— BS 5950: Part 1. There was footing foundation for every 2" Square pipe used as column member that constitutes the greenhouse. Design of column for the greenhouse is given below:

1. Design Conditions are as given below:
   Design Code: BS5950-2K
   Material: 43C (Pf = 275 N/mm², Es = 205000 N/mm²)
   Section Size: b = 50 x 50 x 2.5/47.5
   Effective Length L = 0 mm,
   L = 2050 mm, L = 1000 mm
   Effective Length Fact Kx = 0.90,
   Ky = 0.90
   Equivalent uniform moment factors
   Mx = 1.00, My = 1.00, Mz = 1.00, M = 1.00

2. Member Force and Moment
   Fx = 3.40 KN
   My = 0.00, My = 0.00 KN-m
   F = 0.00, F = 0.00 KN

Unit: cm
   As = 4.75
   Ix = 18
   Iy = 18
   rx = 1.94
   ry = 1.94
   zx = 7.16
   zy = 7.16
3. Classify Section
Determine classification and design strength of hollow or solid box (Built-up)

i. $\varepsilon = \sqrt[275]{p_1} = 1.00$
ii. b/t = BTR = 18.00
iii. BTR < 28 * $\varepsilon$ (Class 1: Plastic)

Determine classification and design strength of web

i. d/t = HTR = 18.00
ii. HTR < Max [80*\(\varepsilon\)/(1+\(\gamma\)), 40*\(\varepsilon\)] (Class 1: Plastic)

4. Check Axial Capacity
a). Check slenderess ratio of axial compression member (Kl/r)

\[Kl/r = 95.01 < 200 \rightarrow \text{ok}\]

b). Calculate axial compressive capacity (Pcx).

i. $\lambda_c = 0.2 \times \sqrt{\pi^2 E_y/P_y} = 17.15$
ii. $\eta = a \times (\lambda_c - \lambda_3) / 1000 = 0.0000$
iii. $P_c = (\pi^2 E_y / \lambda_c^2) = 1 \quad \# \text{N/mm}^2$
iv. $\phi = (P_c + (\eta + 1) P_y) / 2 = 1 \quad \# \text{N/mm}^2$
v. $P_{cx} = A_y \times (P_c + P_y) / [(\phi + \sqrt{\phi^2 - P_c \times P_y}] = -1 \quad \# \text{N/mm}^2$

c). Calculate axial compressive capacity (Pcy).

i. $\eta = a \times (\lambda_c - \lambda_3) / 1000 = 0.2725$
ii. $P_c = (\pi^2 E_y / \lambda_c^2) = 224.13 \text{ N/mm}^2$
iii. $\phi = (P_c + (\eta + 1) P_y) / 2 = 280.10 \text{ N/mm}^2$
iv. $P_{cy} = A_y \times (P_c + P_y) / [(\phi + \sqrt{\phi^2 - P_c \times P_y}] = 71.44 \text{ KN}$

5. Check Interaction of Combined Capacity

i. $R_{max} = F_c / (A_e \times P_c) + M_x / M_{cx} + M_y / M_{cy} = 0.026$

ii. $R_{max} = F_c / P_{cx} + m_y M_y / M_{cy} (1 + 0.5 F_c / P_{cx}) + 0.5 m_x M_x / M_{cy} = -1 \quad \# 10$

iii. $R_{max} = F_c / P_{cy} + 0.5 m_x M_x / M_{cx} + m_y M_y / M_{cy} (1 + 0.5 F_c / P_{cy}) = 0.048 \text{maxR}$

iv. $R_{max} = m_x M_x (1 + 0.5 F_c / P_{cx}) + m_y M_y (1 + 0.5 F_c / P_{cy}) + m_z M_z (1 + 0.5 F_c / P_{cz}) = -1 \quad \# 10$

v. $R_{max} = \text{Max}[R_{max1}, R_{max2}, \ldots] = -1$

#10 < 1.000 → ok

2.2.4 Truss Design
Section designs of the truss loading members were carried out by adopting code reference section design BS 648 for dead load; BS 6399 for imposed load and CP 3 Chapter V; Part 2:1972 for Wind loading. This was done for every truss member that constitutes the truss loading of the greenhouse.

Code References:
Dead Load - BS 648
Imposed Load - BS 6399
Wind Loading - CP 3:
Chapter V; Part : 1972 : table 3 & 8
Truss Centers / Bays @ = 4100 mm
Truss Height = 600 mm
Truss Span = 4100 mm

Load Factors
Dead Load Factor = 1.4
Imposed Load Factor = 1.6
Wind Load Factor = 1.2
Misc Load Factor = 1.2

Wind Loading Parameter
S1 = 1
S2 = 0.85
S3 = 1
Basic Wind Speed, $V = 45 \text{ m/s}$
Design Wind Speed,
$V_{S} = V \times S1 \times S2 \times S3 = 45 \times 1 \times 1 \times 0.85$
Design Wind Speed, $V_S = 38.25 \text{ m/s}$
Dynamic Pressure, $q = (0.613 \times (V_S^2)) / 1000$
Dynamic Pressure, $q = (0.613 \times (38.25^2)) / 1000$
Dynamic Pressure, $q = 0.9 \text{ KN/m}^2$

Loaded Element 1
Dead Load:
Steel Sheeting = 0.075 KN/m$^2$
Insulation = 0.02 KN/m$^2$
Purlins / Fixings = 0.09 KN/m$^2$
Services etc = 0.1 KN/m$^2$
Truss Self Weight / Bracing = 0.2 KN/m$^2$
Length of Element = 600 mm
Total Dead Load = (0.075 + 0.02 + 0.09 + 0.2 + 0.1) \times 5 \times 0.6
Total Dead Load = 1.46 KN
Imposed Load:
Imposed Load = 0.75 KN/m²
Horizontal Length = 0 mm
Total Imposed Load = 0.75 x 5 x 0
Total Imposed Load = 0 KN

Wind Loading:
Roof Element Slope = 90
Wind Angle at 0 degree, Cpe = 0.85, Cpi = -0.2
Total Wind Load at Angle 0 = DynamicPressure x TrussCenters x Length x (Cpe + Cpi)
Total Wind Load at Angle 0 = 0.9 x 5 x 0.6 x (0.85 + 0.2)
Total Wind Load at Angle 0 = 1.76 KN

Wind Angle at 90 degree, Cpe = 0.7, Cpi = 0.2
Total Wind Load at Angle 90 = DynamicPressure x TrussCenters x Length x (Cpe + Cpi)
Total Wind Load at Angle 90 = 0.9 x 5 x 0.6 x (0.7 + 0.2)
Total Wind Load at Angle 90 = 2.43 KN

Loaded Element 4
Dead Load:
Steel Sheeting = 0.075 KN/m²
Insulation = 0.02 KN/m²
Purlins / Fixings = 0.09 KN/m²
Services etc = 0.1 KN/m²
Truss Self Weight / Bracing = 0.2 KN/m²
Length of Element = 600 mm
Total Dead Load = (0.075 + 0.02 + 0.09 + 0.2 + 0.1) x 5 x 0.6
Total Dead Load = 1.46 KN

Imposed Load:
Imposed Load = 0.75 KN/m²
Horizontal Length = 600 mm
Total Imposed Load = 0.75 x 5 x 0.6
Total Imposed Load = 2.25 KN

Wind Loading:
Roof Element Slope = 0
Wind Angle at 0 degree, Cpe = 0.85, Cpi = -0.2
Total Wind Load at Angle 0 = DynamicPressure x TrussCenters x Length x (Cpe + Cpi)
Total Wind Load at Angle 0 = 0.9 x 5 x 0.6 x (0.85 + 0.2)
Total Wind Load at Angle 0 = 1.76 KN

Wind Angle at 90 degree, Cpe = 0.7, Cpi = 0.2
Total Wind Load at Angle 90 = DynamicPressure x TrussCenters x Length x (Cpe + Cpi)
Total Wind Load at Angle 90 = 0.9 x 5 x 0.6 x (0.7 + 0.2)
Total Wind Load at Angle 90 = 2.43 KN

Loaded Element 8
Dead Load:
Steel Sheeting = 0.075 KN/m²
Insulation = 0.02 KN/m²
Purlins / Fixings = 0.09 KN/m²
Services etc = 0.1 KN/m²
Truss Self Weight / Bracing = 0.2 KN/m²
Length of Element = 600 mm
Total Dead Load = (0.075 + 0.02 + 0.09 + 0.2 + 0.1) x 5 x 0.6
Total Dead Load = 1.46 KN

Imposed Load:
Imposed Load = 0.75 KN/m²
Horizontal Length = 600 mm
Total Imposed Load = 0.75 x 5 x 0.6
Total Imposed Load = 2.25 KN

Wind Loading:
Roof Element Slope = 0
Wind Angle at 0 degree, Cpe = 0.85, Cpi = -0.2
Total Wind Load at Angle 0 = DynamicPressure x TrussCenters x Length x (Cpe + Cpi)
Total Wind Load at Angle 0 = 0.9 x 5 x 0.6 x (0.85 + 0.2)
Total Wind Load at Angle 0 = 1.76 KN

Wind Angle at 90 degree, Cpe = 0.7, Cpi = 0.2
Total Wind Load at Angle 90 = DynamicPressure x TrussCenters x Length x (Cpe + Cpi)
Total Wind Load at Angle 90 = 0.9 x 5 x 0.6 x (0.7 + 0.2)
Total Wind Load at Angle 90 = 2.43 KN

Loaded Element 12
Dead Load:
Steel Sheeting = 0.075 KN/m²
Insulation = 0.02 KN/m²
Purlins / Fixings = 0.09 KN/m²
Services etc = 0.1 KN/m²
Truss Self Weight / Bracing = 0.2 KN/m²
Length of Element = 600 mm
Total Dead Load = (0.075 + 0.02 + 0.09 + 0.2 + 0.1) x 5 x 0.6
Total Dead Load = 1.46 KN
Imposed Load:
Imposed Load = 0.75 KN/m²
Horizontal Length = 600 mm
Total Imposed Load = 0.75 x 5 x 0.6
Total Imposed Load = 2.25 KN

Wind Loading:
Roof Element Slope = 0°
Wind Angle at 0 degree, Cpe = 0.85, Cpi = -0.2
Total Wind Load at Angle 0° = DynamicPressure x
TrussCenters x Length x (Cpe + Cpi)
Total Wind Load at Angle 0° = 0.9 x 5 x 0.6 x (0.85 + -0.2)
Total Wind Load at Angle 0° = 1.76 KN

Wind Angle at 90 degree, Cpe = 0.7, Cpi = 0.2
Total Wind Load at Angle 90° = DynamicPressure x
TrussCenters x Length x (Cpe + Cpi)
Total Wind Load at Angle 90° = 0.9 x 5 x 0.6 x (0.7 + 0.2)
Total Wind Load at Angle 90° = 2.43 KN

Loaded Element 16

Dead Load:
Steel Sheeting = 0.075 KN/m²
Insulation = 0.02 KN/m²
Purlins / Fixings = 0.09 KN/m²
Services etc = 0.1 KN/m²
Truss Self Weight / Bracing = 0.2 KN/m²
Length of Element = 600 mm
Total Dead Load = (0.075 + 0.02 + 0.09 + 0.1) x 5 x 0.6
Total Dead Load = 1.46 KN

Imposed Load:
Imposed Load = 0.75 KN/m²
Horizontal Length = 600 mm
Total Imposed Load = 0.75 x 5 x 0.6
Total Imposed Load = 2.25 KN

Wind Loading:
Roof Element Slope = 0°
Wind Angle at 0 degree, Cpe = 0.85, Cpi = -0.2
Total Wind Load at Angle 0° = DynamicPressure x
TrussCenters x Length x (Cpe + Cpi)
Total Wind Load at Angle 0° = 0.9 x 5 x 0.6 x (0.85 + -0.2)
Total Wind Load at Angle 0° = 1.76 KN

Wind Angle at 90 degree, Cpe = 0.7, Cpi = 0.2
Total Wind Load at Angle 90° = DynamicPressure x
TrussCenters x Length x (Cpe + Cpi)
Total Wind Load at Angle 90° = 0.9 x 5 x 0.6 x (0.7 + 0.2)
Total Wind Load at Angle 90° = 2.43 KN

Loaded Element 20

Dead Load:
Steel Sheeting = 0.075 KN/m²
Insulation = 0.02 KN/m²
Purlins / Fixings = 0.09 KN/m²
Services etc = 0.1 KN/m²
Truss Self Weight / Bracing = 0.2 KN/m²
Length of Element = 600 mm
Total Dead Load = (0.075 + 0.02 + 0.09 + 0.2 +
0.1) x 5 x 0.6
Total Dead Load = 1.46 KN

Imposed Load:
Imposed Load = 0.75 KN/m²
Horizontal Length = 600 mm
Total Imposed Load = 0.75 x 5 x 0.6
Total Imposed Load = 2.25 KN

Wind Loading:
Roof Element Slope = 0°
Wind Angle at 0 degree, Cpe = 0.85, Cpi = -0.2
Total Wind Load at Angle 0° = DynamicPressure x
TrussCenters x Length x (Cpe + Cpi)
Total Wind Load at Angle 0° = 0.9 x 5 x 0.6 x (0.85 + -0.2)
Total Wind Load at Angle 0° = 1.76 KN

Wind Angle at 90 degree, Cpe = 0.7, Cpi = 0.2
Total Wind Load at Angle 90° = DynamicPressure x
TrussCenters x Length x (Cpe + Cpi)
Total Wind Load at Angle 90° = 0.9 x 5 x 0.6 x (0.7 + 0.2)
Total Wind Load at Angle 90° = 2.43 KN

2.3 Construction of the Greenhouse
The construction of the greenhouse was carried out in accordance with the structural design analysis and orthographic and isometric view as shown in Figure 1 and Figure 2. Each component was constructed with proper tolerance, dimension and specification as indicated in the drawing. The footings are the base of the greenhouse. The whole weight of the structure rests on the footings. These were excavated to the size of 300mm by 300mm and depths of 50mm with the aid of spade and digger and casted using concrete mix of ratio 1:2:4.
The frame is the skeleton of the greenhouse and it sustains the whole weight of the structure. The frames were cut with the aid of hand saw from square pipes and planks to the dimension specified in the drawing. The joints of the frames were track-welded, nailed, checked for level and full-welded after check with electrode. Nets were used as covering materials for the frame. The nets were nailed to the square pipes with the aid of hammer and raced with planks. The truss is constructed with planks of different sizes. It is sloping flat truss type that slope toward back elevation of the structure. The plastic corrugated roofing sheets were used to cover the truss.

2.4 Development of drip hydroponic structure

Construction of the drip hydroponic soilless farming structure was carried out in accordance with the orthographic and isometric view as shown in Figure 3 and 4. Each component was constructed with proper tolerance, dimension and specification as indicated in the drawing. The plank served as the frame/tower in which the hydroponic planting structure rests. Prior to the construction of the tower for the soilless farming system, it is important to measure the required space for the drawn hydroponic structure. The stand/tower was constructed using 4” x 4” planks. A saw was used to

Figure 1: Orthographic view of the greenhouse
cut the planks while hammer was used to nail the pieces of the planks together. Front side of the horizontal supports was 1" lower than the other to ensure proper drainage. After the stand/tower was constructed, the 4" x 4" x 72" round PVC pipes were laid on the frame. Power drill fitted with 3" diameter hole saw were used to drill hole on 4" x 4"x 72" round PVC pipes for the cups formed from disposable rubber bottles where the seeds/seedlings of vegetable were planted/transplanted.
3.0 CONCLUSION
These structures were developed and used to evaluate growth and yield indices of tomato, spinach and cayenne pepper and the outcome was highly encouraging when compared to conventional method of farming. The method can be recommended to farmers for vegetables production in urban cities where there is no availability of fertile soil or where the distance to available and fertile soil is not within the reach. Also, people in riverine and oil spillage areas can make use of this low-cost greenhouse and hydroponic structure for production of vegetable all year round.

REFERENCES