 Household scale of greenhouse design in Merauke

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Abstract. Merauke is one of the areas that still use conventional methods in agriculture. The agricultural business does not run the maximum during the year because agricultural products quite difficult to obtain in the market. In the rainy season, the intensity of rain is very high, the water condition is abundant and hard to be channeled due to topography/soil contour conditions average, otherwise in the dry season the water is quite difficult to obtain. The purpose of this research is to compare the thermal conditions between greenhouse with auylastic and plastic bottle roof. This research is experimental, measurement of thermal conditions in Greenhouse using measuring weather station. Greenhouse design with Quonset type with area of 24 m². The result of this research are greenhouse with paranet + UV plastic roof has an average temperature of 28.7 °C, 70.4% humidity and 0.5 m/s wind speed, while the greenhouse with paranet + plastic bottle roof has an average temperature of 26.2 °C, humidity 66.4% and wind speed 0.9 m/s. Conclusion is Greenhouse with paranet + plastic bottle roof more thermally comfortable than greenhouse with paranet + UV plastic roof.

Keywords: Greenhouse, Thermal Comfort, Merauke

1. Introduction
High public demand for horticultural commodities such as vegetables and fruits certainly has a great impact on business opportunities in the field of horticulture cultivation. Of course to get good results, it requires good and appropriate cultivation techniques. There are several factors that influence the cultivation process of plants, such as; sunlight, nutrition, temperature, humidity and so on. So it takes a controlled environment in the cultivation of plants in order to improve crop yield, both in quality and quantity.

One of the techniques in crop cultivation is by used Greenhouse. The use of Greenhouse in the cultivation of plants aims to provide an environment close to the optimum conditions for plant growth or commonly called the method of cultivation of plants in a controlled environment agriculture. Merauke is one of the areas that still use conventional methods in agriculture, in certain periods some agricultural products quite difficult to obtain in the market. Because in the rainy season, the intensity of rain is very high, the condition of water is abundant and difficult to flow due to the condition of the flat ground, meanwhile in the dry season the water is quite hard to come by. So that the agricultural business does not run the maximum during the year. For example in the rainy seasons vegetables are difficult to obtain, because the soil content is quite wet so it do not grow optimally.

With the existence of Greenhouse is expected that the agricultural process can take place throughout the year and the harvest can continue to increase. However, the use of Greenhouse for agricultural business especially for the Merauke area still does not exist. The lack of understanding by
the community regarding the design and development of Greenhouses in accordance with the wet tropical climate is a major obstacle. Greenhouse is intended for small farmers, so Greenhouse made should be cheap and easy. Inexpensive in terms of materials used while easy in terms of manufacture and installation. Considering the above Greenhouse is made using used materials (used bottles, red onion sacks and others) and natural materials (wood, bamboo and others) are all quite easy to come by.

This study aims to provide an understanding to the community about how to design Greenhouse for the tropics area, to make a Greenhouse simulation for household-scale with easy design and cheap material. so it is hoped that the results of this research can be used as a reference in designing Greenhouse to support the community in doing business in the field of horticulture cultivation, in this case small business for household.

From the background researchers found several problems, among others:
1. How to design Greenhouse with household-scale by using cheap and easy material by installation?
2. What are the thermal condition values (Temperature, Humidity, and Wind Speed) present in both Greenhouse?

1.1. Greenhouse

Greenhouse is due to the presence of plants grown in it that look green from the outside because of the transparent (translucent) Greenhouse wall by utilizing solar radiation for plant growth. Buildings for the production of common plants are called Greenhouse or Glasshouse or Plant House. The last term appears since the construction of Greenhouse no longer use glass, but also plastic and fiberglass for technical and economic reasons. In the tropics area, Greenhouse serves as a protector of plants against rainfall and excessive sunlight. In addition Greenhouse also has another functions such as:

1) Avoid exposure to rainwater that can damage crops.
2) Avoid land from muddy conditions.
3) Prevent the entry of rain water into the growing medium (because it can dilute nutrient solution).
4) Reduce the intensity of incoming light so leaves do not burnt.
5) Reduce the level of pest attack (plant disturbing organisms).
6) Photosynthesis can take place perfectly.

The use of Greenhouse in the cultivation of plants is one way to provide an environment that is closer to the optimum conditions for plant growth. Greenhouse was first developed and commonly used in subtropical climates. Greenhouse use is primarily intended to protect plants from too low temperatures in winter.

Light required by the plant can enter into the greenhouse while the plant is protected from unfavorable environmental conditions, namely the air temperature is too low, rainfall is too high, and the wind is too tight. In Greenhouse, environmental parameters that affect plant growth, i.e sunlight, air temperature, air humidity, nutrient supply, wind speed, and carbondioxide concentrations can be controlled more easily. The use of Greenhouse allows the modification of the environment that is not suitable for plant growth to be closer to the optimum conditions for plant growth.

The Greenhouse structure interacts with climate parameters around Greenhouse and creates a microclimate within it that is different from the climate parameters around Greenhouse. This is called the Greenhouse effect. According to Bot (1983), Greenhouse effect is caused by two things:

• Air movement within the Greenhouse is relatively small or stagnant. Due to the closed Greenhouse structure and the rate of air exchange within the Greenhouse with a very small external environment. This causes the air temperature inside the Greenhouse to tend to be higher than outside.
• The shortwave solar radiation that enters the Greenhouse through the roof is converted into long-wave radiation. This long wave radiation can not get out of Greenhouse and is trapped inside. This gives rise to the Greenhouse effect that causes increased air temperatures in the Greenhouse.
Shortwave radiation into the Greenhouse is converted into long waves as it passes through the cover material, i.e. roof and wall and reflected by both the floor and the Greenhouse construction section. Long wave radiation trapped inside the Greenhouse causes an increase in the air temperature inside the Greenhouse. To overcome these problems, it is necessary to note the form of Greenhouse and air circulation in it (Boutet and Terry, 1987).

At first, Greenhouses in subtropical climates are built using glass as roofs and walls. This is especially so if the Greenhouse is built for plant production facilities throughout the year. Glass is the main ingredient in making Greenhouse.

The desired micro climate in a Greenhouse also aims to improve the cultivation of crops both in quality and quantity. A plant house in a subtropical region should be equipped with a climate regulator, while in tropical areas like Indonesia, what Greenhouse should do is protect the plants from rain, direct wind and excessive sunlight.

Greenhouses are more effectively applied to areas with evenly distributed topography, considering the production of making crop houses easier and cheaper in areas with flat topography rather than areas with wavy topography, while also taking into account more equitable sunlight reception.

1.2. Greenhouse Design for a Wet Tropical Climate

In the wet tropical climate, the plant house serves as a good crop protection building on the cultivation of plants with soil media and with hydroponics system. For areas with wet tropical climates such as in Indonesia the concept of a plant house with umbrella effect is considered more appropriate. Plant houses are more designated to protect the plants from rain, wind and pests. In addition, the plant house was built to reduce the intensity of excessive solar radiation, reduce the evaporation of water from leaves and media, as well as facilitate the care of the plants.

Based on the function then it is not appropriate if the design of the house plants in the area with wet tropical climate using the design of subtropical plant houses are generally developed with the concept of Greenhouse effect. For areas with wet tropical climates, the design of plant houses that have been developed in sub-tropical climates need to be adapted to the concept of the umbrella effect. The design of the plant house located in wet tropical climate is often called adapted Greenhouse.

The design of Greenhouse need to pay attention to several things as follows:

- The ventilation openings must meet the standard openness criteria in Greenhouse in the wet tropics of 60% of the floor area.
• For areas with wet tropical climates, the orientation of the plant house should extend east and west so that the roof of the plant house facing north and south. This allows sunlight to be able to plant more evenly throughout the day.
• The furnishings where the recommended plant is placed are materials that have insulating properties, so they do not heat heat. For example furniture material made of wood.
• Greenhouse roofing materials recommended are Polyethylene and UV Stabilizer and wall material using net / screen which also serves as ventilation openings. However, consider the effects of rain water splashes into the Greenhouse.
• Recommended flooring materials are compacted or grassblocked soil, so it does not radiate heat and there should be no pavement around the Greenhouse.
• The greenhouse must have enough sunlight from morning to evening, meaning that Greenhouse should not be blocked by other buildings or tree shade that can block out the sun. In addition to the presence of buildings and trees near the Greenhouse will cause obstruction of wind flow required for natural ventilation (Sri dkk, 2008).

Ventilation is the process of exchanging air from inside to outside Greenhouse or vice versa to transfer heat from sun radiation, increasing the concentration of carbon dioxide in air, and preventing air humidity from being too high (Meiske, 2004). There are two types of ventilation namely; natural ventilation and mechanical ventilation. Natural ventilation occurs because of the difference in air pressure between the position inside and outside the building due to wind and thermal factors, where air will flow or exchange through the ventilation openings. Mechanical ventilation usually uses equipment such as exhaust fan, evaporative cooling pad and fogging installation / fog system and Greenhouse is equipped with utilities that is drip irrigation or sprinkler system (Sri dkk, 2008).

2. Method

2.1. Research Stages
Research is covers the Greenhouse thermal studies (dimensions, supporting elements of Greenhouse building, temperature, humidity, wind speed and solar radiation), planning and making household-scale Greenhouse design, Greenhouse Making/Assembling, Greenhouse Test (strength, thermal conditions in Greenhouse ) and the thermal conditions outside Greenhouse.

2.2. Location and Time of Research
The research location was conducted in KampungYasaMulya, Tanah Miring District, MeraukeRegency. Before the Greenhouse was built in the research area, Greenhouse was first assembled in the UNMUS Architecture Department laboratory. Research time is planned for 3 (Three) years.

2.3. Data collection techniques and tools
Data collection in research activities is very important because it relates to the availability of data needed to answer the problems in the study, so the conclusions are correct. Therefore, research data collection methods should be done correctly (Sugiyono, 1994). Data collection conducted in this research is as follows:
1. Observation
Observation is the activity of direct observation of an object using all the five senses (Sugiyono, 1994). Data collection tools are: Camera, Measuring Instruments (Weather Station, Soil Test) and Stationery. The results of observation, among others: Temperature, Humidity, Wind Speed, soil temperature and soil pH.
2. Literature Studies
This method is used to obtain data related to Greenhouse and other data that support this research by searching the literature from journal, proceedings, books (libraries), internet (e-book), and other sources.
2.4. *Data Processing Technique and Data Analysis*

1. Data Processing

Data processing aims to check again the respondent's answer (information) on each question points that have been submitted during the interview to confirm to the rules that have been determined.

2. Data Analysis

In this study, the first step is find the problems behind the emergence of initial ideas. The next step is to analyze the problem with qualitativa descriptive analysis method. So that will be found the main problems and other problems behind the main problem. The data in the analysis include temperature, humidity and wind speed obtained from the measuring instrument. Data is measured 24 hours per day with 30 day measurements and measurement intervals every 30 minutes. The results of the measurements were recapitulated after it was distinguished between the UV plastic roofhouse and the plastic roofhouse of the used plastic bottle roof. While the measurement of soil conditions in greenhouse only to know the difference of soil temperature and humidity from both greenhouse.

2.5. *Flow Chart of Research*

Flow chart of research is shown in Figure 2:

![Flow Chart of Research](image-url)

**Figure 2.** Flow Chart of Research

3. **RESULT AND DISCUSSION**

3.1. *Greenhouse Design Results*

From the results of the study and discussion group obtained the size of the greenhouse is 24 m$^2$ (6m x 4m). This measure is agreed upon by considering the roof frame material to be used, while the roof frame used is a PVC pipe with a diameter of 1 inch. However, the roof frame stands on a 100 cm high wooden frame, which aims to make the greenhouse much higher than that of a PVC roof frame with no wooden skeleton underneath. Initial consideration with a higher greenhouse certainly thermal conditions in it much better. However, with the higher greenhouse wind load received much higher as
well. The height of greenhouse that is made is 310 cm with high calculation of wooden frame 100 cm and height of roof frame 210 cm.

![Figure 3. Greenhouse Plan](image)

![Figure 4. Rear view of Greenhouse](image)

The structure of the greenhouse made using a wooden frame for the bottom and for the roof using a PVC pipe framework. The wood frame is used as a reinforcement under construction of the greenhouse, this construction must be strong because it supports the load of the roof frame and roof cover, the retained load is the load from the roof frame and roof cover, wind and rain load. While the roof frame using PVC pipe, the use of this material due to the form of Quonset greenhouse/curved roof, PVC material is quite easily formed / arched. Construction of greenhouse 1 (use paranet roof and UV plastic) as in general greenhouse. While construction of greenhouse 2 (use paranetroof and bottle used) roof covering material that is different from the greenhouse 1. The bottle used is arranged lengthwise along the 7 m, in the middle of the bottle is reinforced with a diameter of 8 mm. Actually to assemble this used bottle can use cheaper materials such as bamboo or wooden slats, but frame of iron choosed because this research requires speed in the manufacture.

![Figure 5. Greenhouse Quonset type](image)
Figure 6. Bottle Roof Cover Design

Layers of plastic bottles

The bottom of plastic bottles perforated then arranged horizontally

Reinforcement Ø 10

mineral water bottle 1500 L

rope

bottle arrangement

board as a bottle case

bottle preparation
Figure 7. Roof assembly with used bottle material (a. collection of plastic bottles; b. assembling of plastic bottles; c. installation of plastic bottle device)

Figure 8. Construction of UV Paranet and Plastic Pallet roofed greenhouse

In this research, 2 types of greenhouse are made: 1) existing greenhouse with paranet roof then covered with UV plastic, 2) greenhouse with roof using used material (mineral water bottle used). The purpose of making these two types is to know the thermal differences that exist in it and reuse of waste materials (waste) as a useful material, in addition to using waste, the environment would be maintained.
3.2. Thermal Measurement Results

Measurements were made to determine the difference of thermal conditions between the two Greenhouses, the measured thermal conditions include: Temperature, Humidity, and Wind Speed. While soil measurement (Soil Test), among others: Soil Temperature and soil pH as additional data. Measuring tool used is Weather Station (temperature, humidity and wind speed), and Soil Test (soil temperature and soil pH). Measurements were made for 31 (Thirty-One) days, in a day measured for 24 hours with a 30-minute measurement interval. The placement of the measuring instrument is at the center of the greenhouse. With measuring height for Weather Station about 160 cm, while for soil test measured place on the ground.

![Construction of Bottle Plastic roofed greenhouse](image)

**Figure 9.** Construction of Bottle Plastic roofed greenhouse

Calculations each day are shown in the figure 11 to 13 below.

![Laying of Measurement and Thermal Measurements](image)

**Figure 10.** Laying of Measurement and Thermal Measurements

![Differences indoor temperature](image)

**Figure 11.** Differences indoor temperature
From the measurement results obtained the temperature of greenhouse 2 (paranet roof material and used bottle) is lower than greenhouse 1 (paranet roof material and UV Plastic) the difference between greenhouse 2 with greenhouse 1 are 2.5°C for temperature, humidity 10% while for wind speed difference 0.4 m/s. The recordable thermal measurements within the greenhouse can be seen in table 1.

**Table 1.** Thermal measurements within the Greenhouse

| No | Greenhouse                        | Temperature (°C) | Humidity (%) | Wind speed (m/s) |
|----|-----------------------------------|------------------|--------------|------------------|
| 1. | Greenhouse 1 (Paranet roof + UV plastic) | 28.7             | 70.4         | 0.5              |
| 2. | Greenhouse 2 (Paranet roof + used bottle) | 26.2             | 66.4         | 0.9              |
For additional data, the average soil temperature in greenhouse 1 and greenhouse 2 is equal to 27°C whereas average soil pH for greenhouse 1 7.0 and average soil pH for greenhouse 2 6.5 with pH difference between greenhouse 1 and greenhouse 2 is 0.5.

3.3. Finding results
The findings of this study include; materials and structures. The existing material in Merauke district is still very limited, for example is UV Plastics in Merauke small category size, for large size does not exist yet. As for the structure in greenhouse 1 (paranet roof material + plastic UV) PVC pipe becomes curved due to the sun's heat.

![Figure 14. Finding results](image)

4. Conclusion
The greenhouse with paranet + UV plastic roof has an average temperature of 28.7 °C, 70.4% humidity and 0.5 m/s wind speed, while the greenhouse with paranet + plastic bottle roof has an average temperature of 26.2 °C, humidity 66.4% and wind speed 0.9 m/s. The difference in measurement between the two greenhouses is; temperature 2.5 °C, humidity 4% and wind speed 0.4 m/s. Greenhouse with paranet + plastic bottle roof more thermally comfortable than greenhouse with paranet + UV plastic roof.

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