The Novel Design for Cooling System of Greenhouse

by Amelia Sugondo

The Novel Design for Cooling System of Greenhouse

Amelia Sugondo [1,a)] and Ekadewi A. Handoyo [1], Guntar Henjaya [1]

Author Affiliations
[1,2,3]*Mechanical Engineering Department, Petra Christian University, Siwalankerto 121-131, Surabaya, Indonesia*

Author Emails
[a)] Corresponding author: amelia@petra.ac.id

Abstract. Recently, the use of greenhouse is developing. Farming the fruits and vegetables using a greenhouse can overcome the unpredictable climate. The plants that need specific air temperature and humidity could grow well inside a greenhouse. As a preliminary study, the effect of circulating water as a thin film at the outer surface of greenhouse is observed. The water film is intended to cool the greenhouse. In this experiment, there are three models used. The first is a greenhouse (called GH1) with cooling water flowing at the outer surface of greenhouse periodically. The second is a greenhouse (called GH2) without cooling system and the third is in the open space or natural farming. A water sprayer is installed in each model to water the plants. It sprays periodically. In each greenhouse, three temperature and humidity loggers are installed to measure the air temperature and humidity. The loggers are installed in the middle of the greenhouses with different height from the plants. From the experimental results, the air temperature inside the greenhouse G1 decreased by 1.5-2°C that compared to GH 2. The average air temperature above the plant GH1, GH2 and natural farm decreased by 5°C and 3°C at greenhouse GH1 and natural farm compared to surrounding. However, the air temperature it increased by 10°C at greenhouse GH2. The average relative humidity is 72%, 68% and 47% at GH 1, GH 2 and natural farm (N).

INTRODUCTION

A greenhouse is one of useful cultivation plant system to get the fresh and good quality fruits or vegetables for all seasons. The building structure can be made of glass or plastic. A greenhouse is used to grow and protect the plants from the tough to unpredictable climate and some insect pest. The different vegetables or fruit need a specific environment to grow [AJ. Both; Telambanua 2014; Zulfahmi 2019]. The air temperature and humidity are two important factors to get the plants grow well. The ventilation is commonly used to control the air condition inside a greenhouse. It is an inexpensive way to decrease the inside air temperature. It controls the requirements naturally. The hot air will be replaced by the fresh air. The difference of density causes the air movement or the wind and the thermal buoyancy effect [Ganguly 2011]. [Akrami 2019] studied that the capability to reduce air temperature is influenced by location, number, and size of ventilation. The air humidity and temperature will increase in location where there is no circulation. Akrami stated that no ventilator could meet the requirement of air temperature and humidity inside a greenhouse right now. According to Ganguly 2011, there are two types of ventilation i.e., natural ventilation and fan induced ventilation. Natural ventilation become ineffective when the ambient temperature is high enough. It need a fan induced ventilation. The exchange air rate depends on the wind velocity and the total area ventilator [Ganguly 2011].

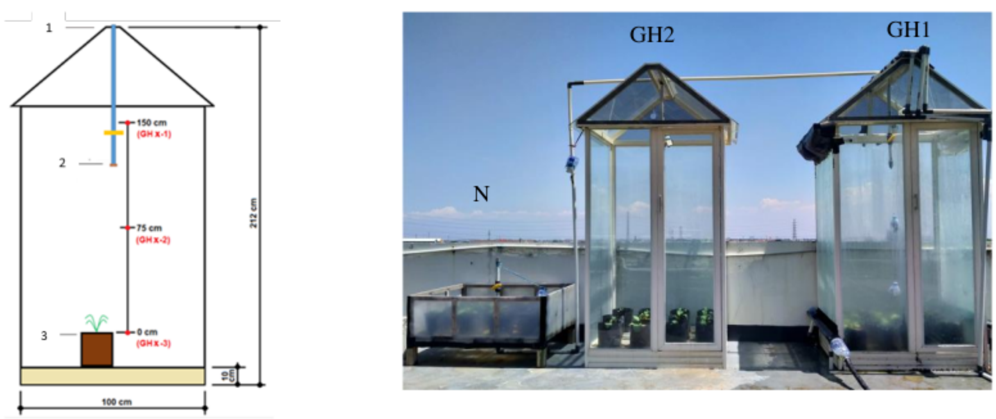
Other way to reduce the air temperature inside the greenhouse is using a cooling system, such as an evaporative cooling and a fan-pad evaporative cooling [Ganguly 2011] and an aquifier water that studied by [Senthi 2006]. The evaporative cooling systems are based on the sensible and latent heat of the evaporated water. This method can decrease the air temperature and increase the air humidity [Ganguly 2011]. However, increasing the air humidity should become other concern because it can easily promote some microorganism to grow [Senthi 2006, Ganguly 2011]. On a fan-pad evaporative cooling system, a draught fan is installed on one side of greenhouse and the cooling pad on the opposite wall. This method can reduce 4-5°C of the inside temperature greenhouse [Ganguly 2011]. Other cooling system used in a greenhouse is fogging and misting system. This system employs the evaporative cooling system, but the system uses small droplet size or mist. This method can reduce the inside air temperature of the green house until 5°C at the sunny day and increase its relative humidity until 20% [Ganguly 2011]. It needs lower initial cost than pad-fan systems [Toida 2006]. The other method for cooling is the roof evaporation cooling where it uses a water film when the water is circulated on the roof. The temperature inside of the greenhouse decreases until 4-5°C analytically [Sutar 1995].

In this research, the new cooling system is proposed. The greenhouse is usually being cooled inside. But this paper will discuss the result of cooling the greenhouse on the outside surface of the roof and the walls. Two small greenhouses and an open space or natural farming were built in the same location. Thus, the plants will live in same surrounding. The new model of cooling system of the greenhouse is observed. The cooling system is applied to reduce the air temperature and increase the relative humidity in the greenhouse. The outside roof and walls of the first greenhouse (called GH 1) is surrounded with a thin water flowing on them. The other greenhouse (called GH 2) was set without any water flowing outside of it. Then, the comparison on those two greenhouses and the open space or natural plant (called N) are studied. The air temperature and relative humidity inside the greenhouse are parameters studied and compared to the natural plant system refer to the surrounding.

METHODS

Greenhouse Model Design

The greenhouse GH 1 and GH 2 are made of glass for the surfaces and aluminum for the frame. The size of greenhouses is 100 cm x 80 cm x 210 cm as shown in Figure 1 (a). There is a small opening (1) on the top of each greenhouse for ventilation. The air trapped inside the greenhouse could move out the greenhouse from this opening. A water pump is used to supply the water through a half-inch pipe. Figure 1 (b) shows the piping system that brings water to the sprinklers (2) and water flowing on the outside of the roof and walls of the GH1 except the front side. No water flowing on the front side wall because there is a door in there. The GH2 is just a greenhouse with no water cooling on the outside surface. The pipe also brings water to the plant (3) through the sprinkle. The sprinkler will produce droplet to water the plants. So, it is installed over the plants in each greenhouse and on the open space farm.



(a) greenhouse model

(b) the GH1, GH2, and open space farm (N)

FIGURE 1. The experimental apparatus used

The logger to measure the air temperature and humidity are installed in three points as shown in Fig 1 (a). For logger installed in GH at top point is defined GHx-1, at middle point as GHx-2, and over the plants as GHx-3. Three loggers are installed in three points in both the GH1 and GH2, one logger is installed on the open space farm (N) and one is placed at surrounding to measure surrounding air temperature (TS) and humidity (Rh-S).

Experiment Set Up

This experiment will be used for preliminary study to the new cooling system of the greenhouse. The method uses a water film that flows on the three outsides of wall surface and the roof side of the greenhouse. The ventilation used in GH1 and GH2 is a passive ventilation through the opening on the roof side of the greenhouse. The experiments were conducted during summer season 2021 on the balcony at fifth floor of the building in urban area in Surabaya, Indonesia.

This paper describes the data that were measured and recorded for four days in the end of August 2021. The data were the air temperature and relative humidity inside the greenhouse, on the natural farm and in the surrounding. The cooling water on the outside surface could be considered as a water film. The water was given periodically, i.e., it is ongoing in an hour and quarter, then stopped for fifteen minutes. But this cooling water was performed 24 hours a day. To water the plants, a sprinkler was used in GH1, GH2 and over plant in natural farm, N. The sprinklers in the GH1, GH2, and N were spraying water for one minute every three hours in a day.

Figure 1 (a) shows the position of the air temperature and relative humidity. There are eight units of logger Elitech RC-4HC to record the air temperature and humidity. Three loggers were used for each greenhouse. They were installed vertically in the center of greenhouse with different height, i.e. 0 cm, 75 cm, and 150 cm from the plant bags/boxes. The loggers installed in GH1 will be called as GH1-1, GH1-2, GH1-3 when it was located in 150 cm, 75 cm, and 0 cm from the plants bags, respectively. The logger used on the natural farm will be installed parallel with the plant box. Data will be recorded from 7 am to 7 pm every 30 minutes.

RESULTS AND DISCUSSION

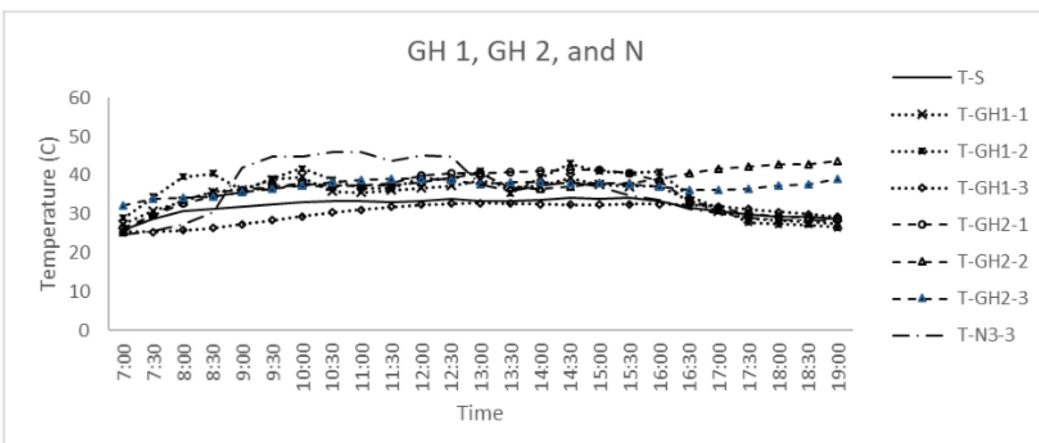


FIGURE 2. The Air temperature inside of greenhouses, on natural farm, and its surrounding

Figure 2 shows the air temperature inside GH1 and GH2, on the natural farm (N) and the surrounding (TS). The air temperature inside greenhouse was increasing from 7 a.m. to 10 a.m. and tend to be constant in the evening. The trend followed the surrounding's temperature (T-S). After 5 p.m., the air temperature inside GH1 was decreasing at point 1 (T GH1-1) and 2 (T GH1-2) even lowered than the surrounding (T-S). The average air temperature at point 1 which is close to ventilation was lower than at point 2 for both GH1 and GH2. In GH1, the average air temperature at point 1 was 8% lower than at point 2. In GH2, it was 5% lower. The air temperature inside GH2 tend to increase after 5 p.m. While air in GH1 was 3 – 4% cooler than in GH2, because there was has cooling water on the outside surface of GH1. The cooling water on the outside could lower the air temperature that was trapped in a greenhouse.

Point 3 is the lowest location that is right above the plants. The air temperature at this point inside the cooled greenhouse, GH1 (called T-GH1-3) was the lowest among other points, i.e., point 1 and 2. It was even lower than the surrounding in the morning and through daytime. After 4 p.m., it is slightly higher than the surrounding. The maximum temperature of air near the plants in GH 1 was 33°C and it was 39°C and 46°C in GH2 and Natural farm (N), respectively. The air temperature near the plants is much lower in GH1than in GH2 or natural farm. The graph shows that the air temperature inside greenhouses is almost constant. The deviation of air temperature in GH1 and GH2 was only 2.5°C and 1.8°C, respectively. The temperature at point 3 is almost constant because the air is trapped inside the greenhouse and its locations is far from opening compared to point 1 or 2. The air temperature at the same position (right above the plants) in the natural farm was increasing until 46°C when the surrounding was only 33°C. The same sprinkler was used to spray the same amount of water to the plants in GH1, GH2, and N. Yet, the temperature near the plants in open space (N) was the highest, especially in the morning or daytime. It is even hotter than the surrounding. It could be because (1) the open space farm (N) got the sunshine directly and (2) the ground where the plants grow in absorb more solar energy and increase its temperature. The surrounding and air temperature at point 3 inside GH1, GH2, and the N was decreasing as the sun radiation was decreasing i.e., from 1 p.m. But the air temperature at point 3 inside GH2 was found to be quite high compared to the open space farm (N) because the solar radiation received in GH2 was kept inside and the opening for ventilation is far above of point 3. This founding fits with Akrami [Akrami 2019]. The cooling water that flows outside the GH1 is found to be effective to lower the air inside GH1, especially the temperature near the plants. Thus, the plants could be kept inside a greenhouse to meet the required air conditions and be cooled on the outside to reduce the solar radiation transmitting to the greenhouse. It could be a great opportunity to do urban farming in the cities using a greenhouse.

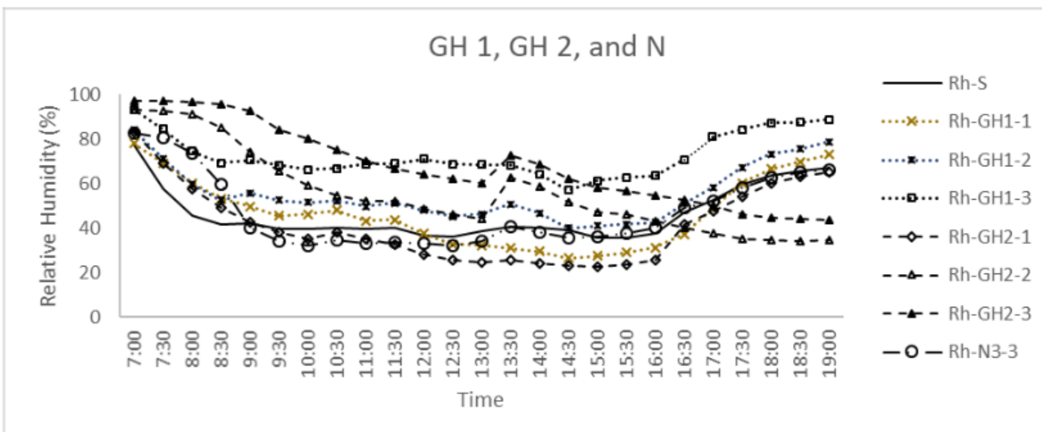


FIGURE 3. The air relative humidity inside of the greenhouses, on natural farm, and its surrounding

The air relative humidity (RH) inside GH1 and GH2, on natural farm and its surrounding are shown in Figure 3. In the morning 7 a.m. the RH is the highest in all greenhouses and surrounding. It was 80 – 90%. In the afternoon after 4 p.m. the RH was increasing gradually until 65 – 80%. As the air temperature increased, the RH decreased. The air RH at point 1 inside both greenhouses was lower than at point 2, because it is near to the opening which served as passive ventilation. The air RH at point 2 is higher because it is near to sprinkler that sprayed the water to the plants.

The relative humidity of air inside the greenhouses at point 3 (RH-GH1-3 and RH-GH2-3) is higher than the air above the plants on the natural farm (RH-N3-3) or the air at the surrounding (RH-S). In the morning, 7 a.m. the relative humidity of air in all apparatus was the highest. Then, the relative humidity decreased gradually with time. From the graph, it was found that the relative humidity of air at point 3 inside GH1 was the most stable among other apparatus. The deviation of RH in GH1 was only 9%, while in GH2 and N was 18% dan 16%, respectively. The average RH at point 3 inside GH1, GH3, and natural farm (N) was 73%, 68% dan 47%, respectively. When the humidity is more than 90%, microorganism could grow, but if the humidity is too low than the plants cannot grow well. Thus, a greenhouse with water cooling on the outside surface could increase the humidity that is necessary to grow plants in it.

CONCLUSION

From the experiment conducted during summer, the air temperature inside greenhouse GH1 and GH2 at point 1 and 2 is higher than the surrounding temperature, but the air temperature at point 3 (right above the plants) inside the greenhouse GH1 is 1°C less than in N and 7°C less than in GH2. The relative humidity of the air inside GH1 at point 3 is almost stable at 80% compared to GH2 or N. The relative humidity at point 2 was not much different in all the apparatus. The average relative humidity of air above the plants RH at point 3 inside GH1, GH3, and natural farm (N) was 73%, 68% dan 47%, respectively. The cooling water given on the outside surface of the roof and three walls is proven to cool the air and increase its relative humidity near to the plants inside the greenhouse. It could be a great opportunity to do urban farming in cities using greenhouse.

ACKNOWLEDGMENTS

The authors are grateful for getting the research grant from Petra Christian University.

REFERENCES

1. M. Telaumbanua, B. Purwantana, L. Sutiarso, “Design of Actuator of Micro Climate Control in Green House for Mustard (Brassica var rapa. Parachinensis L.)”, Agritech, Vol. 34, No. 2, (Mei 2014).
2. H. Zulfahmi and N. E. Suminarti, “Effect of Amount and Frequency of Distribution of Water on Plant Growth and Yield of Potato (Solanum tuberosum L.) Granola Varieties”, Jurnal Produksi Tanaman, Vol. 7 No. 9, September 2019: 1653–1659
3. A.J. Both, “Greenhouse Temperature Management”
4. A. Ganguly and S. Ghosh, “A Review of Ventilation and Cooling Technologies in Agricultural Greenhouse Application”, Iranica Journal of Energy & Environment 2 (1): 32-46 (2011).
5. M. Akrami, A. A. Javadi, M. Hassanein, R. Farmani, G. Tabor, A. Negm, H. E. S. Fath, “Analysing Greenhouse Ventilation Using Computational Fluid Dynamics”, UKACM Conference City, University of London (2019).
6. V.P. Sethi, S.K. Sharma, “Experimental and Economic Study of A Greenhouse Thermal Control System Using Aquifer Water”, Energy Conversion and Management 48 (2007), pp. 306–319.
7. R. F. Sutar and G.N. Tiwari, “Analytical and Numerical Study of A Controlled-Environment Agricultural System For Hot and Dry Climatic Conditions”, Energy and Buildings 23 (1995), pp. 9-18.
8. H. Toida, K. Ohyama, T. Kozai, Handarto, M. Hayashi, “A Method for Measuring Dry-bulb Temperatures during the Operation of a Fog System for Greenhouse Cooling”, Biosystems Engineering (2006) 93 (3), pp. 347–351
9. A. Perdigones, J.L. Garcia , A. Romero , A. Rodriguez , L. Luna , C. Raposo , S. de la Plaza, “Cooling Strategies for Greenhouses In Summer: Control of Fogging by Pulse Width Modulation”, https://oa.upm.es/2563/1/INVE_MEM_2008_56916.pdf

The Novel Design for Cooling System of Greenhouse

ORIGINALITY REPORT

6%	2%	5%	0%
SIMILARITY INDEX	INTERNET SOURCES	PUBLICATIONS	STUDENT PAPERS

PRIMARY SOURCES

1	Lecture Notes in Electrical Engineering, 2014. Publication	1%
2	repository.petra.ac.id Internet Source	1%
3	Hesham A. Ahemd, Abdulelah A. Al-Faraj, Ahmed M. Abdel-Ghany. "Shading greenhouses to improve the microclimate, energy and water saving in hot regions: A review", Scientia Horticulturae, 2016 Publication	1%
4	Róisín Griffin, Kasey Miller, Aleona Swegen, Mark Baker, Geoffry De Iuliis, Robert John Aitken, Zamira Gibb. "Measuring Oxidative DNA Damage in Stallions Susceptible to Heat Stress", Animal Reproduction Science, 2020 Publication	1%
5	Almuhanna, Emad A.. "Evaluation of Single Slop Solar Still Integrated With Evaporative Cooling System for Brackish Water Desalination", Journal of Agricultural Science, 2013.	<1%

Publication

6	Kumar, K.S.. "Design and technology for greenhouse cooling in tropical and subtropical regions: A review", Energy & Buildings, 200912 Publication	<1 %
7	V.P. Sethi, S.K. Sharma. "Experimental and economic study of a greenhouse thermal control system using aquifer water", Energy Conversion and Management, 2007 Publication	<1 %
8	Sethi, V.P.. "Optimal space utilization of a greenhouse using multi-rack tray system: Thermal modeling and experimental validation", Energy Conversion and Management, 200810 Publication	<1 %
9	Submitted to Universitas Kristen Petra Student Paper	<1 %
10	almondfurniture.co.uk Internet Source	<1 %
11	cigrjournal.org Internet Source	<1 %
12	Toida, H.. "A Method for measuring Dry-bulb Temperatures during the Operation of a Fog System for Greenhouse Cooling", Biosystems Engineering, 200603 Publication	<1 %

13	A. Perdigones, J.L. García, A. Romero, A. Rodríguez, L. Luna, C. Raposo, S. de la Plaza. "Cooling strategies for greenhouses in summer: Control of fogging by pulse width modulation", Biosystems Engineering, 2008 Publication	<1 %

Exclude quotes	On	Exclude matches	< 5 words
Exclude bibliography	On		