

## IMPACT OF VENTILATIONS IN ELECTRONIC DEVICE SHIELD ON MICRO-CLIMATE DATA ACQUIRED IN A TROPICAL GREENHOUSE

### PENGARUH JUMLAH VENTILASI PADA PELINDUNG PERANGKAT ELEKTRONIK TERHADAP HASIL AKUISISI DATA IKLIM MIKRO DALAM RUMAH KACATROPIS

Irfan Ardiansah<sup>1)</sup>, Nurpilihan Bafdal<sup>2)</sup>, Awang Bono<sup>3)</sup>, Edy Suryadi<sup>2)</sup>, Ramadhoni Husnuzhan<sup>1)</sup>

<sup>1)</sup> Department of Agro-Industrial Technology, Faculty of Agro-Industrial Technology, Padjadjaran University / Indonesia

<sup>2)</sup> Department of Agriculture Engineering and Biosystem, Faculty of Agro-Industrial Technology, Padjadjaran University / Indonesia

<sup>3)</sup> Department of Chemical Engineering, Faculty of Engineering, Universiti Malaysia Sabah / Malaysia

Tel: +62 227798844; e-mail: irfan@unpad.ac.id

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#### ABSTRACT

The greenhouse which is a building used to manipulate the micro-climate is an essential building for plant growth. Greenhouses have one or more devices that are used to monitor their internal environments against changes in micro-climate. The problem is that some devices are metal-based devices and plastics that can be deformed, such as electronic devices, one of which is a micro-climate monitoring device, so a shield that can protect the device but does not interfere with the sensor readings is needed. The purpose of this study was to make and test a plastic-based container called Duradus Junction Box, which has six removable ventilation openings to measure the micro-climate data. This study uses five Duradus Junction Boxes with different numbers of ventilation openings, a micro-controller connected to the air temperature and relative humidity sensor, and a MicroSD module to record all micro-climate data, all devices being then tested simultaneously for 30 days. Statistically, after using One Way ANOVA, this study found that micro-climate measurements result for actual devices data can be considered similar because the *P*-value for temperature (0.886) and relative humidity (0.917) is greater than alpha level of 0.05. However, when reading the recorded data for both parameters, it can be seen that micro-climate data inside all shields are slightly higher than actual microclimate data ranging from 1 to 2°C for air temperature and 1 to 3% for air relative humidity.

#### ABSTRACT

Rumah kaca yang merupakan bangunan yang digunakan untuk mengatur iklim mikro adalah sebuah bangunan yang sangat penting untuk pertumbuhan tanaman. Pada rumah kaca umumnya terpasang satu atau lebih perangkat yang digunakan untuk memantau lingkungan internalnya terhadap perubahan iklim. Masalahnya beberapa perangkat tersebut berbahan metal atau plastik yang dapat berubah bentuk dan rusak bila terpapar air dan sinar matahari terus menerus, terutama perangkat pemantauan iklim mikro, sehingga diperlukan pelindung yang dapat melindungi perangkat dari kondisi lingkungan tanpa mengganggu pembacaan sensor. Tujuan penelitian ini adalah menguji kontainer yang disebut Duradus Junction Box, yang memiliki enam buah ventilasi yang dapat dibuka tutup. Pengujian dilakukan pada lima buah Duradus Junction Box dengan jumlah bukaan ventilasi yang berbeda yang didalamnya sudah terpasang mikrokontroler, sensor temperatur dan kelembaban relatif udara, dan modul MicroSD sebagai perekam data iklim mikro, dan semua perangkat dalam Duradus diujikan bersamaan selama 30 hari. Perhitungan dengan ANOVA Satu Arah menunjukkan bahwa hasil pengukuran dapat dikatakan serupa antara data iklim mikro aktual dan kelima perangkat yang diujikan walau jumlah bukaannya berbeda mengacu pada nilai *P* temperatur (0.886) dan kelembaban relatif (0.917) yang lebih besar dibandingkan tingkat alfa 0.05. Walaupun secara kasat mata data kedua parameter terlihat berbeda dengan data aktual, dengan perbedaan berkisar antara 1 sampai 2 °C untuk temperatur, dan 1 sampai 3 % untuk kelembaban relatif udara.

#### INTRODUCTION

In recent years, some tropical countries farmers have changed the way they manage their agriculture, from using agricultural land to indoor farming; the cause of this trend is high rainfall and humidity, which can cause crops damage and crops are more easily exposed to pests and diseases, leading to increased use of pesticides, of crops failure (Akpenpuun & Mijinyawa, 2018; Shamshiri & Ismail, 2014), with the same thing also happened in Indonesia, a tropical country in Southeast Asia.

Indoor agricultural management is usually carried out in a building called a greenhouse (*Bafdal & Ardiansah, 2020*). In the four-season country, this greenhouse is used in fall or winter, so that plants can grow even though the temperature outside the greenhouse is shallow (*Lim et al., 2020*).

Greenhouses are used to control several environmental conditions in plant growth ecosystems such as temperature, relative humidity and sunlight, which is referred to as microclimate. The reason crops are grown in this way is to extend the crop productivity period, change the cropping cycle to increase yields and crop quality, and to produce a sustainable harvest (*Sahdev et al., 2017*). In Indonesia, the temperature inside the greenhouse is always higher than the outside temperature, which can lead to spending up evapotranspiration and plant wilting (*Ardiansah et al., 2020; Bafdal et al., 2019*).

Academic Leadership Grant Universitas Padjadjaran (ALG Unpad) Greenhouse is a research greenhouse used to grow tomato plants, also has the same problem where air temperature which can reach 40°C in the dry season whereas the air temperature should be between 28°C to 32°C to optimize tomato plants growth (*Bafdal & Dwiratna, 2018*), so that the Greenhouse is now integrated with several automatic devices to monitor and manage micro-climate condition based on Arduino NANO, using air temperature and relative humidity sensor, and a misting system (*Hafiz et al., 2020*). All devices are placed inside the Greenhouse and not protected from moisture and sunlight exposure, which makes all devices vulnerable.

Devices that are expected to detect micro-climate condition accurately require a cover or shield that can protect it from direct sunlight but still have a ventilation opening capable of circulating air because poor ventilation conditions will cause the shield inside became warmer than the actual data and result in inaccurate measurements (*Buisan et al., 2015; Harrison, 2010*). A commonly used protector to cover the microclimate measurement device is called Stevenson Screen, which is made from painted white wood, although there is still a difference of 0.5 to 2.5°C between outside and inside of it (*Harrison, 2010*). The problem with the Stevenson screen is that it is large, heavy, and permanently installed, so it is not suitable for greenhouses with limited space (*Li & Song, 2017*).

The need for accurate micro-climate data measurements became an idea to seek a shield that could protect micro-climate measurement devices, could circulate air, be water-resistant and tinted white to reflect light (*Ma et al., 2019*).

## MATERIALS AND METHODS

This study was conducted for thirty days using an experimental design with a randomized design (CRD) method inside Research Greenhouse (Figure 1), a greenhouse with a size of 14.5 x 9 x 3 m<sup>3</sup> which has been built and is ready to use in the research premise with a table placed in the greenhouse centre to place all monitoring devices. Five monitoring devices were made with different numbers of ventilations ranging from two to six ventilations coded A, B, C, D, E to determine the effect of the number of ventilations on sensor data reception. A Thermo hygrometer coded (Q) is used to measure actual micro-climate data inside the Greenhouse.

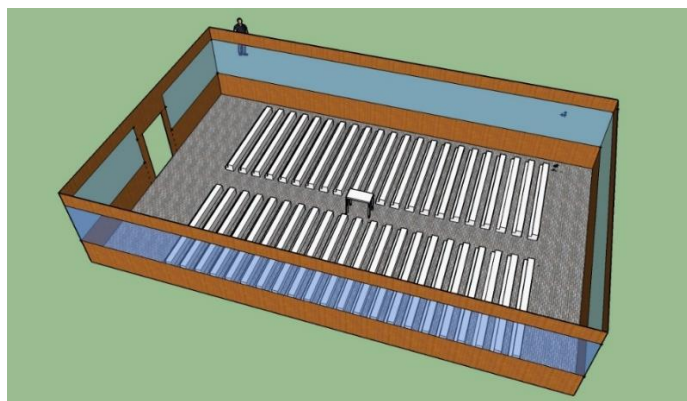


Fig. 1 - Research Greenhouse Layout

### Components Selection

These micro-climate data monitoring devices are placed on a table and positioned in the centre of the Greenhouse. The table itself has a height of 75 cm. For portability, all devices must be capable of running on batteries, capable of storing thousands of micro-climate data, and easy to move to download stored data.

Based on these specifications, Arduino Nano is selected as a processing unit, which has a size of 1.8 cm to 4.5 cm, has an operating voltage of 5V with pin current requirement of 40 mA; Arduino Nano is a variant of the Arduino micro-controller board product. The Arduino Nano is the smallest Arduino board, using the ATmega328 micro-controller for Arduino Nano version 3 and ATmega168 for the Arduino Nano version 2. This variant has the same circuit as the Arduino UNO, but with a different PCB size and design. Arduino Nano is not equipped with a power socket, but there is a pin for the external power supply or you can use the power supply from the Mini or Micro USB port. (Bt Mohd Shuib et al., 2018; Kumar et al., 2019). With specifications like this, the power supply can be fulfilled by using a 10000mAh power bank.

The MicroSD card is then connected to record measured micro-climate data; those data are retrieved from sensors every 20 minutes. The sensors used are DHT22, which have a digital output and require 1.5mA current. DHT22 detects temperature in Celsius units with a range of -40°C to 80°C and relative humidity between 0 and 100% (Bogdan, 2016; Koestor et al., 2019). These components are assembled using a breadboard and jumper cables, as shown in Figure 2a, with all sensors already tested and calibrated before use. Meanwhile, the data traffic flow starting from micro-climate detection to data recording can be seen in Figure 2b.

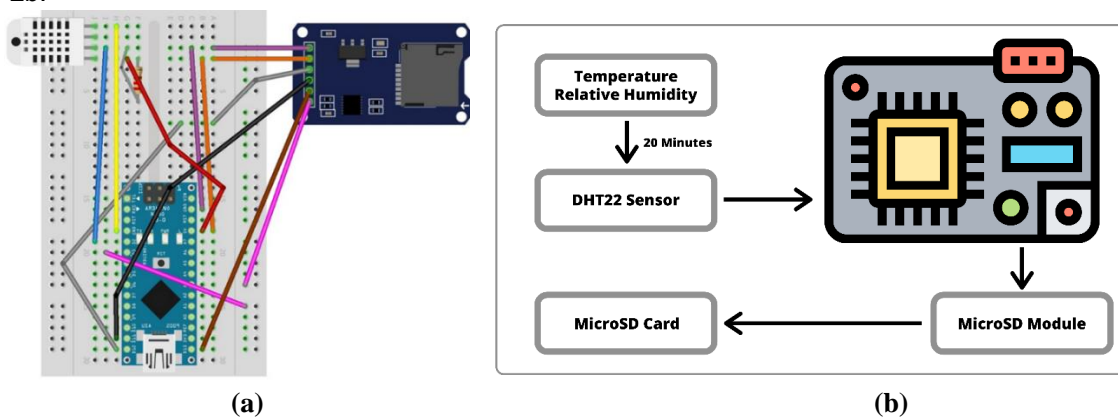


Fig. 2 - (a) Device Component Layout; (b) Device Flow Diagram

Five devices are built using the same specifications, and then those devices are inserted into the shield by positioning the sensor towards the ventilation openings (Astutik et al., 2019) to make it easier for the sensor to detect micro-climatic conditions and not degraded by the heat generated by the micro-controller. All devices are then connected to the power bank using 5 ports USB Hub (Figure 3).

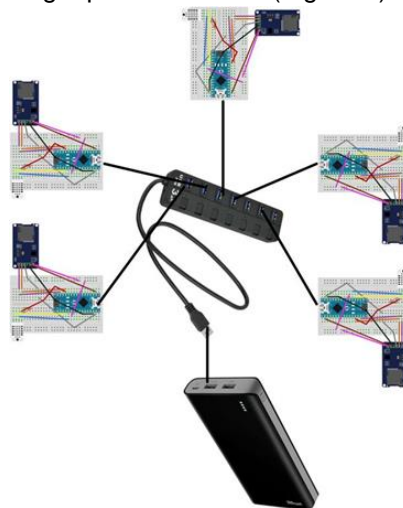


Fig. 3 - Devices Connected to Power Bank

### Shield Options

All monitoring devices must be protected from direct sunlight exposure and water droplets coming from the misting system, so it is necessary to choose a shield that is designed to be enclosed, watertight but has sufficient ventilation openings to avoid hot air caught inside the shield (Burt & de Podesta, 2020). Based on a market survey, one suitable material called Duradus Junction Box is then selected because it is made of thick white plastic, has lids that can be removed on each side with its shape, as it can be seen in Figure 4.

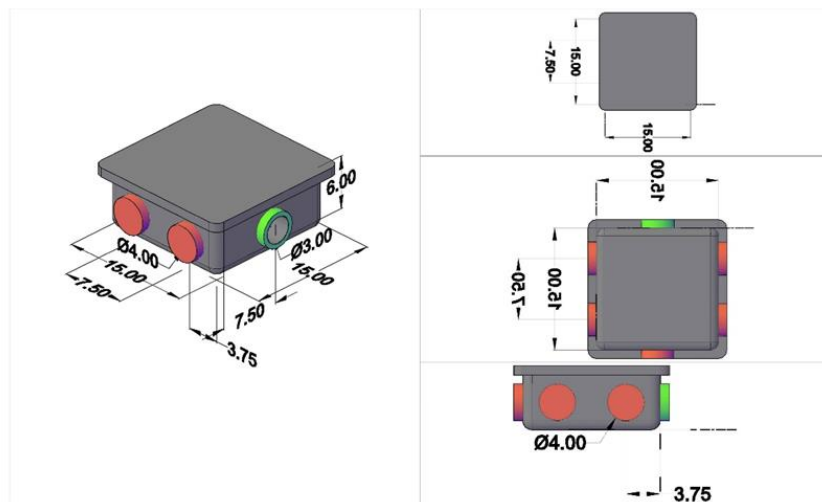


Fig. 4 - Duradus Junction Box Dimension

### Experiment Procedure

Each monitoring device is put inside the shield with a different number of ventilation openings coded Shield A (2 ventilations) to Shield E (6 ventilations) then placed on the table as in Figure 1.

Data were monitored every day from 07.00 to 17.00 and recorded every 20 minutes using Comma-Separated Values (CSV) format for more accessible data processing and were downloaded at the end of every day. The power bank is replaced every other day to avoid running out of power when collecting data. Data series collected were plotted based on mean values, variance and standard deviation using a spreadsheet application based on their average.

The research was conducted for 9 hours (540 minutes), which produced 27 data per device every day which was guided by the research conducted by (Hoover & Yao, 2018), where the researcher took data every 30 minutes, and the research carried out by (Strangeways, 2019) using the same sensor but with 10-minute intervals. The two previous researches conclude that there is no definite determination about the amount of data and the interval used for data retrieval with the DHT22 sensor; therefore, this study takes the middle value of the two studies using an interval of 20 minutes.

### RESULTS AND DISCUSSION

The study was carried out inside Research Greenhouse in December 2019 for thirty days, by measuring micro-climate data for each shield and simplifying it to 27 data. The hypothesis used in this study is that the more ventilations the shield has, the more accurate the reading of micro-climate data and closer to the actual data measurement. Shield E, which has six vents, is considered the best model for use as a shield.

The statistical analysis used is One Way Analysis of Variance (ANOVA). ANOVA is a statistical analysis that examines the mean differences between groups. The group here can mean a group or type of treatment with a test procedure similar to the t-test, but the advantage of ANOVA is that it can test the difference of over two groups. In contrast to the independent sample t-test, which can only test the mean difference between the two groups. The result of the ANOVA analysis is the P-value or F-value, if the p-value is smaller than the 5% error rate, it can be concluded that H1 is accepted and H0 is rejected, meaning that there is a significant difference in the mean in all groups. ANOVA analysis is often used in experimental research where there are several treatments and is used to test whether there are significant differences between these treatments (Wahid et al., 2018), (Pujar et al., 2020), (Hong & Hsieh, 2016).

This study will compare two groups of data, viz.:

- 1) Actual air temperature data (Q) against air temperature detected inside shields A to E using the following hypothesis:  
 $H_0: A = B = C = D = E$   
 $H_1: A \neq B \neq C \neq D \neq E$
- 2) Actual air relative humidity data (Q) against air relative humidity detected inside shields A to E using the following hypothesis:  
 $H_0: A = B = C = D = E$   
 $H_1: A \neq B \neq C \neq D \neq E$

**Air Temperature**

ANOVA calculations for temperature data Q and shield A to E can be seen in Table 1; also, this table displays all average calculation results, which show that the difference in the average temperature of each shield is only less than 1°C even though it has a different number of ventilation openings, and the actual temperature having only 1.1°C difference when compared to the average temperature of shield (A), which has the least ventilation. Table 1 also shows that the actual temperature (Q) has an average temperature value lower than all shields temperature and is more stable than shielded devices. This happens because the shielded devices have a slower response, according to the statement given by (Harrison, 2010; Li & Song, 2017; Benyezza et al., 2018).

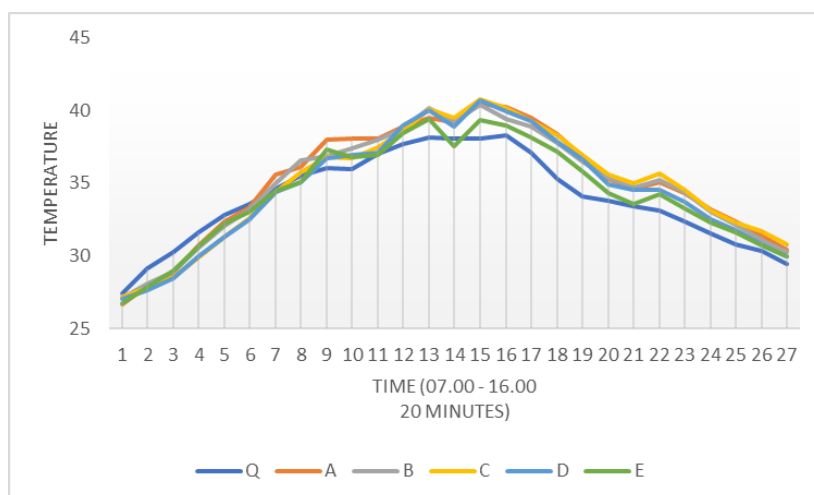
**Table 1**

One Way ANOVA for 20 Minutes Temperature using 0.05 Alpha Level						
Groups	Count	Sum	Average	Variance	STDev	
Q	27	915.5867	33.91062	9.798062	3.130186	
A	27	945.42	35.01556	15.57806	3.946905	
B	27	941.2033	34.85938	14.66141	3.829022	
C	27	940.9633	34.85049	15.62036	3.95226	
D	27	932.2267	34.52691	15.89865	3.987311	
E	27	925.02	34.26	13.02072	3.608424	

ANOVA						
Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	24.12934	5	4.825869	0.342352	0.886531	2.272137
Within Groups	2199.009	156	14.09621			
Total	2223.138	161				

Based on the P-value listed in Table 1, it can be concluded that H0 is accepted, and H1 is rejected for 27 gained data; this means that the results of measuring the actual temperature Q and the temperature inside shield A to E can be said to be the same based on ANOVA, although visually, in Figure 5, it can be seen that the line temperature values for shields A to E only approach the temperature Q and rarely touch the Q line.



**Fig. 5 - Comparison of Devices Temperature Values every 20 Minutes**

Figure 5 also noted that the actual temperature value (Q) is lower than the temperature value inside all shields for the average data; this happens because the air inside all shields does not completely circulate (Benyezza et al., 2018).

**Air Relative Humidity**

ANOVA calculations for air relative humidity data Q and shield A to E can be seen in Table 2; it also displays the average calculation results similar to air temperature, which show that the difference in the average relative humidity of each shield is only less than 3% even though it has a different number of ventilation openings, as well as the actual relative humidity which has only 3% difference when compared to the average relative humidity of shield (A) which has the least ventilation. This means that the actual relative humidity (Q) average also has a slightly lower value, which shows that the air in all shields has more water, which can happen because of minimal air exchange (*Acquah et al., 2018*).

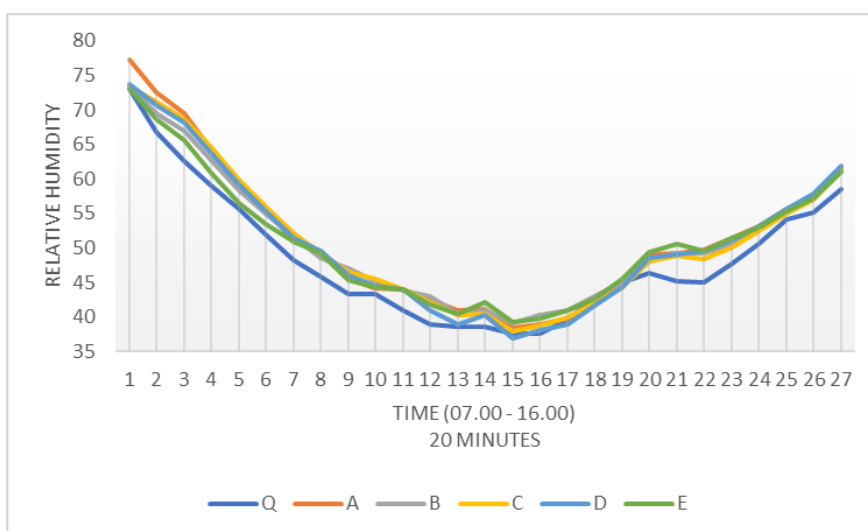
**Table 1**

One Way ANOVA for 20 Minutes Relative Humidity using 0.05 Alpha Level						
Groups	Count	Sum	Average	Variance	STDev	
Q	27	1311.867	48.58765	87.93454	9.377342	
A	27	1387.9	51.4037	110.6763	10.52028	
B	27	1378.947	51.0721	89.23243	9.446292	
C	27	1378.187	51.04395	102.284	10.11356	
D	27	1373.033	50.85309	106.7055	10.32983	
E	27	1372.127	50.81951	83.40752	9.132772	

ANOVA						
Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	141.0016	5	28.20031	0.291607	0.917056	2.272137
Within Groups	15086.25	156	96.70671			
Total	15227.25	161				

Like the ANOVA test for temperature, the P-value for air relative humidity in Table 2 also has a value higher than 0.05; this result indicated that hypothesis H0 is accepted, and H1 is rejected for the total 27 data, and actual relative humidity (Q) data has the same value as data that comes from Shield A to E.



**Fig. 6 - Comparison of Devices Relative Humidity Values every 20 Minutes**

In contrast to the ANOVA calculation results, Figure 6 above shows that the actual relative humidity value (Q) is lower than that of shield A to E. This shows that shield humidity is slightly higher than relative humidity inside the greenhouse, this happens because more vapour is trapped inside shields (*Benyezza et al., 2018*).

## CONCLUSIONS

In the course of developing greenhouse automation device using Arduino UNO, DHT22 sensor and MicroSD module, it is discovered that the instruments used have material that rusts easily, so it is important to utilize a piece of equipment that can protect all instruments from water and sunlight exposure. Duradus Junction Box made of plastic is one option to protect those instruments, especially because Duradus has six removable ventilation openings that can be used as means for air circulation. The study was conducted by developing five microclimate monitoring devices with the same specifications and placed in five Duradus Junction Boxes with different numbers of ventilation openings, then placed in the same place inside the greenhouse. Sensor acquired data then stored them in the form of a CSV file which is then processed statistically.

Based on statistical value, there was no significant difference between the real microclimate data (Q) and those measured in shield A to E because One Way ANOVA gave results that  $H_0$  was accepted and  $H_1$  was rejected after comparing the P-value to an alpha level of 5%. Also, based on collected data, it can be seen that the air temperature data in shields A to E is slightly higher than the real temperature, with a difference of 1.1°C, The same thing happens in shields A to E air relative humidity data, which was also higher than the real (Q) data although the difference is less than 3%. These results showed that the Duradus Junction Box could be a shield for micro-climate monitoring devices in tropical greenhouses while considering that the differences in recorded data, although minimal, may affect plant growth.

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