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Website Based Greenhouse Microclimate Control Automation System Design

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ABSTRACT

Microclimate control is very important for plants cultivation in a greenhouse, two of microclimate variables are temperature and humidity, this variable can be controlled using several methods, one option is to use the misting cooling system, but this process is still done manually. This study aims to create a greenhouse microclimate control system that can be automatically displayed and controlled via a website. This research uses engineering design methods. The results show that the system can automatically turn on the misting cooling system when temperatures are above 30 °C and RH below 80%. Greenhouse microclimate data can be displayed and controlled via a website. The UV index greatly influences the performance of the misting cooling system on temperature and RH conditions in the greenhouse, while the UV index rises to 12 the temperature cannot be lowered and RH cannot be increased, but when the UV index falls from 12 the temperature can be reduced by ± 3 °C and RH can be increased by ± 12%.

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1. INTRODUCTION

A greenhouse is a building used to cultivate plants, and this building is composed of a translucent material such as glass or plastic to form a microclimate inside a greenhouse that is different from the surrounding climate. A microclimate is a special environmental condition in a limited area, the occurrence of microclimate in the greenhouse is caused by changes in sunlight entering the greenhouse into longwave radiation and trapped inside the greenhouse, this radiation will heat plants, the soil inside, and the air around the soil that makes the temperature inside the greenhouse becomes higher than the temperature of the surrounding environment.[1].

The formation of microclimate inside a greenhouse makes the environment adequate for plant growth. Still, for some cases in wet tropical countries such as Indonesia, the temperature and humidity of the air inside the greenhouse are sometimes too high, which triggers stress on plants and stimulates the growth of fungi that brings disease in plants[2].

North Pedca Greenhouse UNPAD also experienced this, the temperature of North Pedca greenhouse once reached 44 °C and RH 30%, the climatic conditions are not ideal for the growth of tomato plants because the maximum temperature for tomato according to the stage of growth of tomatoes is 34 °C which can be seen in Table 1 [3]. Greenhouse temperatures are very far above the maximum temperature limit, thus inhibiting the growth and formation of tomatoes that are cultivating inside the greenhouse [4], even damaging pollen and eggs if they occur for 5 to 10 days. Also, temperatures between 10°C and 30°C make the tomato diameter grow 5 µm larger [5].

Table 1. Stage of development tomato

No.	Stages	Temperature (°C)		
		Minimum	Suitable	Maximum
1.	Seed Germination	11	16 – 29	34
2.	Seedling Growth	18	21-24	32
3.	Fertilization (Afternoon)	10	15-17	30
	(Night)	18	20-24	30
4.	Color Development	18	20-24	30

The room inside of a greenhouse has a different treatment from the outside environment, and several parameters need to be engineered properly according to the plant's needs for optimal growth, these parameters are but not limited to temperature, humidity, and light intensity [6]. These microclimate control can be done with a cooling system. A cooling system is a device that is installed in a greenhouse to reduce air temperature and increase the humidity inside, one of the cooling systems that can be used for greenhouses is misting cooling system [7]. Misting cooling system is a cooling system that uses water as its cooling subject, the water is released through a nozzle with a high-pressure pump and forms a smooth splash of water (dew), it can be done manually but the tool needs to be controlled by an operator for 24 hours. This condition requires an automatic control system for the tool to run by itself without having to be controlled intensively.

The entire automatic control system will be controlled by Raspberry Pi as the center, commands from Raspberry Pi will be forwarded to the website to make data reading and controlling task easier. Raspberry Pi is a small computer and can also be called a microcomputer, and this device can work as an ordinary desktop computer [8]. Raspberry Pi has the advantage of a wired or wireless network connection, having a Linux-based operating system benefits Rasberry Pi to have large storage capacity and lots of applications which functions as a mini server for websites. The GPIO pin contained on this device serving Raspberry Pi to work as a micro-controller. [9].

The sensors used in this study are the SHT11 sensor, the GUVA-S12SD sensor, and the relay. The function of the SHT11 sensor detects the temperature and humidity of the micro-greenhouse climate. The study [10] shows that the SHT11 sensor has the best performance at a temperature of 25° C with a tolerance level of ± 0.5° C and RH (20-80)% with a tolerance level of ± 3%. GUVA-S12SD sensor functions to detect the intensity of light in a greenhouse in UV index units. The study [11] shows that the GUVA-S12SD sensor can function to automate smart home lights. The relay functions as a switch that will turn on and off the device according to the instructions of the Raspberry Pi. The relay has two main parts, namely the electromagnet (coil) and the mechanics (switch). The relay uses the electromagnetic principle to move the switch contacts so that a small electric current run through the device and conduct higher-voltage electricity [12].

This research will create an automatic greenhouse microclimate control device to help maintain the microclimate conditions that remain stable for tomato plants cultivated by control via the website. In its implementation, this tool will record greenhouse microclimate data every minute for each day, and the maximum and minimum microclimate can be flexibly changed via the web to cater to a wide range of plant variety in the future. The method used in this research is engineering design method, this method is a series of activities consisting of planning, designing, constructing, and applicating which in its application will produce new modifications in the form of processes or products. [13].

2. METHOD

The method used in this research is the engineering design method, which creates an automatic control system to engineers the microclimate in the greenhouse. In order to objectify this automatic control system, this research uses the Python programming language and integration into the website using the HTML, MySQL, and PHP programming languages.

This research was conducted from February 4, 2020, to March 3, 2020. The design of the equipment was carried out at the Computer Laboratory of Agro-Industrial Technology Study Program, Faculty of Agro-Industrial Technology, Padjadjaran University. The process of installing and testing the equipment was carried out in the North Pedca greenhouse UNPAD. The research phase consists of the initial stage, tool design, and the final stage, which can be seen in Figure 1.

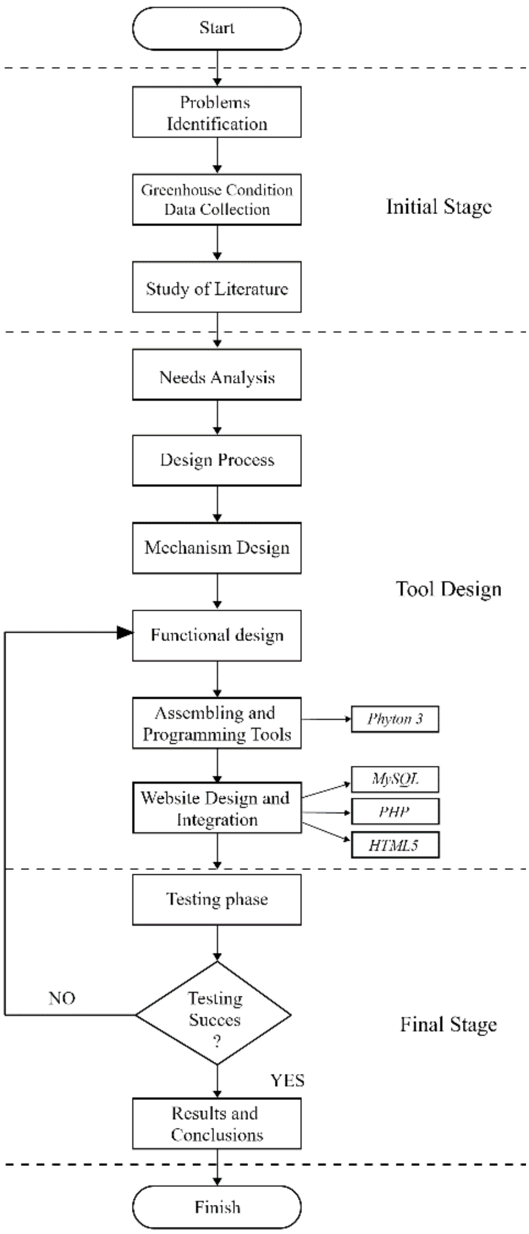


Figure 1. Research phase

2.1. Problems identification

Before making the tools, identify problems that occur in the greenhouse by monitoring the condition of the greenhouse and interviewing the owner of the greenhouse about the shortcomings or problems that still exist in the location.

2.2. Greenhouse condition data collection

The next stage is to collect data about the greenhouse utilizing field observations to determine plant varieties planted, the condition of the original microclimate, the dimensions of the greenhouse dimensions, handling when the microclimate is not suitable for plants, and the tools that are available in the greenhouse can potentially support tool making.

2.3. Study of literature

This stage is carried out to gather references sourced from books, journals, theses, and websites that are relevant to the subject of research to be a comparison and reference for developing tools to be built.

2.4. Needs analysis

This stage is carried out to analyze every need that supports the manufacture of tools, hardware, and software for tool making, which can be seen in Table 2 and Table 3.

Table 2. Automatic microclimate control hardware

No	Name	Function	Amount
1	6x4mm PVC Hose	Water Hose to the Nozzle	30m
2	8x11mm PVC Hose	Inlet Water Hose	2m
3	Breadboard	The Connector of Electronic Devices	1
4	Connector L	Hose to Hose Connection	1
5	Connector T	Hose to Hose Connection	1
6	DC Water Pump	Pumping Water For Misting Cooling System	1
7	Duradus	Automation Tool Protective Cover	1
8	GUVA-S12SD Sensor	Measuring UV INDEX Sunlight	1
9	Jumper Cable	Sensor Connection Cable to Raspberry Pi	24
10	Laptop	Accessing Raspberry Pi	1
11	Nozzle 0,3mm	Breakwater Water Into Dew	18
12	Quick Connector	Hose and Water Pump Connector	2
13	*Raspberry Pi 3b+*	Automation Control Center	1
14	SD Card (16gb)	Raspberry Pi memory	1
15	SHT11 Sensor	Measuring Temperature and Humidity	1
16	Terminal	Water Pump Plugs and Automation Tools	2
17	Wooden Box	Water Pump Protector	1

Table 3. Automatic microclimate control software

No	Name	Function
1	Advanced IP Scanner	IP Address Finder
2	Balena Etcher	Bootable OS Raspberry Pi
3	Bootstrap 4.4	HTML Framework
4	HTML 5	Web Programming Language
5	MySQL	Web and database programming language
6	PHP	Web Programming Language
7	Putty	SSH
8	Python 3.0	The Raspberry Pi Programming Language
9	Raspbian	Raspberry Pi Operating System
10	Windows 10	Laptop Operating System

2.5. Design process

Making a design is the initial activity in realizing the manufacture of tools, by doing design blueprint, the shape of the tool will be visualized in as much detail as possible to clarify the placement of the components needed when assembling tools. Following is the schematic design and placement design of the misting cooling system, which can be seen in Figure 2 and Figure 3.

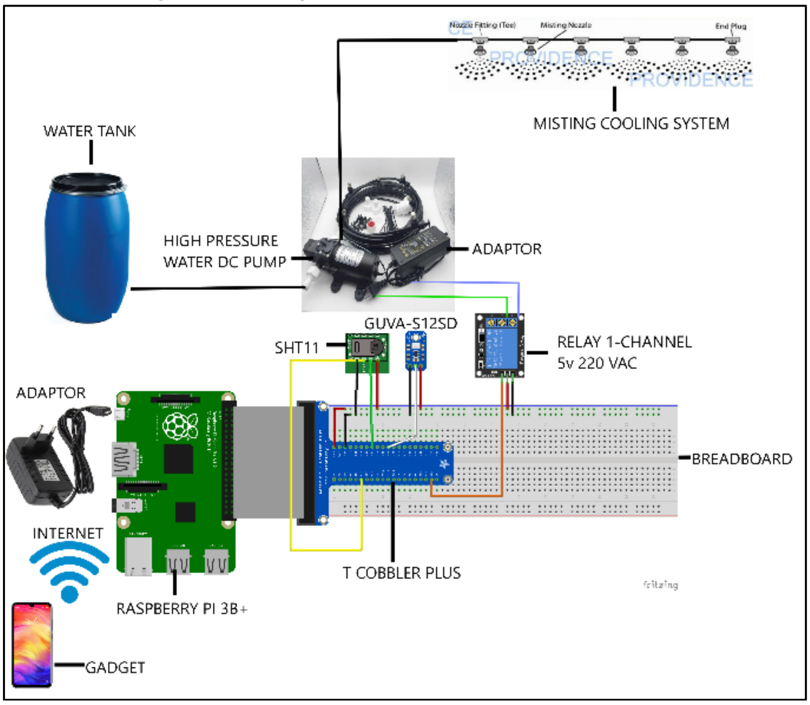


Figure 2. Schematic design of automatic microclimate control

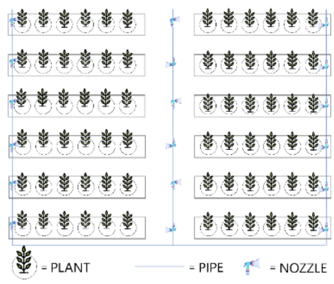


Figure 3. Misting cooling system placement design

2.6. Mechanism design

Before entering the tool manufacturing stage, the mechanism design is carried out in advance so that an appropriate workflow can be found for the tools manufacturing, and the automatic control system mechanism is divided into two different environments namely the information environment and the technical environment, the technical environment is the place where the system processes microclimate data and executing commands that will be sent to the device, while the information environment is a place where the system displays information on the microclimate and determines temperature or humidity in the greenhouse, the flow of the automatic control system mechanism can be seen in Figure 4.

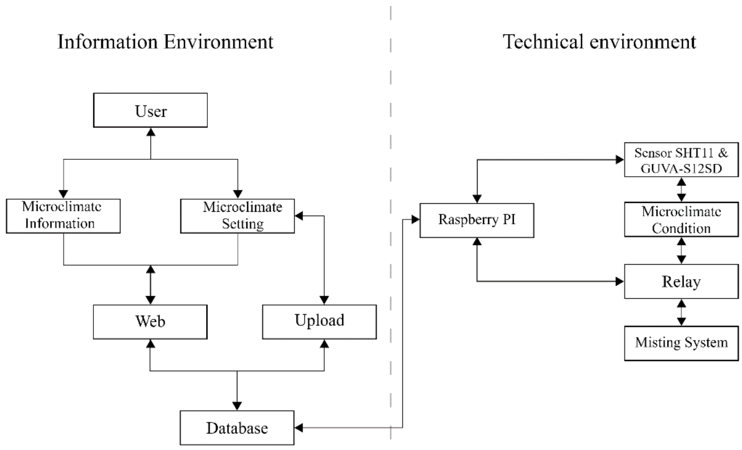


Figure 4. The flow mechanism of automatic microclimate control

2.7. Functional design

The functional design is carried out to elaborate each component of the greenhouse automation system so that each component function is known and reasoning its use in the system. The function of the components system can be seen in Table 2 and Table 3.

2.8. Assembling and programming tools

The phase of tool assembling and programming is done by referring to the planning that has been done in the previous stages. Each component will be assembled to become a tool that functions automatically. Programming is done using Python and Raspberry Pi with access to a laptop with the Putty application.

The running time of the misting cooling system is determined by psychometric calculations. This begins by finding the temperature of the wet-bulb with the following equation [14].

$$Tw = T \text{ atan } [0{,}15197 \cdot (RH\% + 8{,}313659)\text{\^{}}(1/2)\ ] + \text{atan } (T + RH\%) - \text{atan } (RH\% - 1{,}676331) + 0{,}00391838 \cdot (RH\%)\text{\^{}}(3/2) \cdot \text{atan } (0{,}023101\ \cdot RH\%) - 4{,}686035$$

Information:

T_w = Wet bulb temperature (°C);
T = Dry bulb temperature (°C);
RH = Relative humidity (%).

This next equation is used to calculate the pressure of the saturated water vapor temperature of a wet-bulb in a greenhouse [15].

$$T_{wi} = T_w + 273.15$$

$$e_{stwi} = (-5{,}8002206) \cdot (1000/T_{wi}) + 1{,}3914993 + (-4{,}8640239/100) \cdot T_{wi} + 4{,}1764768/100000\ \cdot\ {T_{wi}}^2 + (-1{,}4452093/100000000 \cdot)\, {T_{wi}}^3 + 6{,}5459673 \cdot \log T_{wi}$$

$$e_{stwi} = \exp(e_{stwi}/100)$$

Information:
T_{wi} = Wet bulb temperature (K);
e_{stwi} = Water vapor pressure saturates the temperature of a wet-bulb in a greenhouse (kPa).

The next equation is used to calculate the pressure of water vapor in the greenhouse [16].

$$e_i = e_{stwi} - 0{,}000662 \cdot P_o \cdot (T - T_w)$$

Information:
e_i = Water vapor pressure in the greenhouse (kPa);
P_o = Atmospheric pressure (kPa).

The next equation is used to calculate absolute humidity in a greenhouse.

$$X_i = (\varepsilon \cdot e_i)/(P_o - e_i)$$

Information:
X_i = Absolute humidity in a greenhouse (kg.kguk^{-1});
ε = The ratio of water molecular weight to air molecules (0.6222).

The next equation is used to calculate the water flow to be sprayed by the misting cooling system.

$$m_f = V \cdot A \cdot \left[\left((RH_{it}/100) \cdot X_{si}\right) - X_i\right]/R$$

$m_f = V \cdot A \cdot [((RH_{it}/100) \cdot X_{si}) - X_i]/R$

Information:
m_f = Discharge of water to be sprayed (kg.s^{-1});
V = Mass-based ventilation rate (kg.m^2.s^{-1});
A = Surface area of the greenhouse (m^2);
X_{si} = Saturated absolute humidity (kg.kguk^{-1});
RH_{it} = Expected greenhouse RH (%);
R = Ratio of evaporated masses to water (0 – 1).

The next equation is used to calculate the duration of the misting cooling system.

$$t_f = t_{fs} \cdot \left(m_f/m_r\right)$$

Information:
t_f = On time water pump duration (s);
t_{fs} = Cycle time (s);
m_r = Nozzle discharge (kg.s^{-1}).

2.9. Website design and integration

This stage is done as a refinement of tools that have been assembled in the previous stages so that the tool can be monitored and controlled through the website. The programming languages used are HTML, MySQL, and PHP. For this stage, the tool will be connected to the internet to obtain information gathered by the tool and displays it on the website. Tool settings can be done through the website. Website design is done first as a reference to visualize the appearance of the website when it has finished, and the following website layout design can be seen in Figure 5.

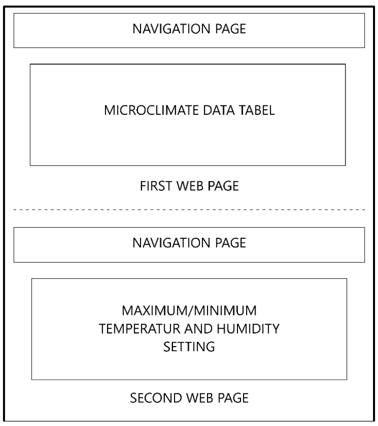


Figure 5. Website layout design

2.10. Testing phase

The testing phase is carried out to see whether the automation tool is working by the function and whether the variable under study has been controlled optimally. This stage will be carried out for several days to find out the stability of the tool because it will be used in the long run.

2.11. Results and conclusions

The test results will be analyzed and concluded whether the automatic microclimate controller can be used to monitor and control the microclimate climate through the website and reduce the temperature and increase the humidity of the greenhouse automatically.

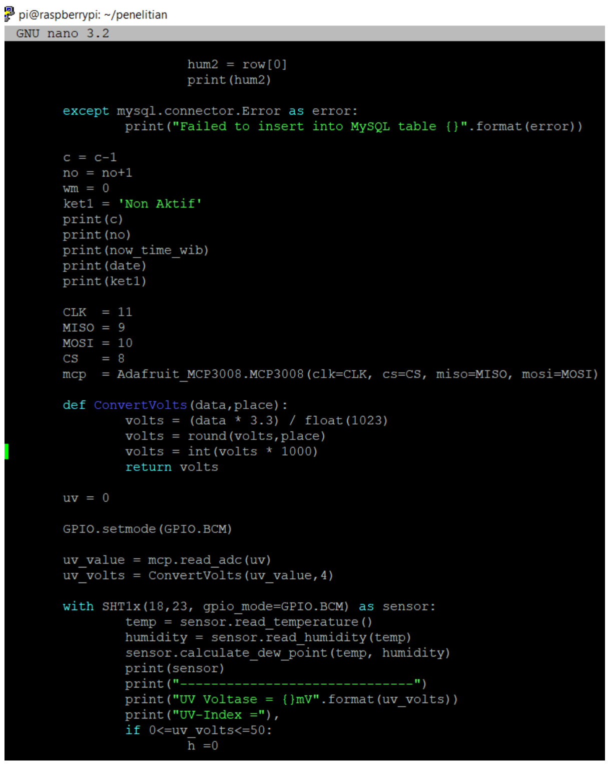
3. RESULTS AND DISCUSSION

The results and discussion will be divided into 3 sub-chapters, namely the results of the programming of the Raspberry Pi, the results of the greenhouse microclimate website, and the analysis of microclimate conditions of the greenhouse to UV index, temperature, and RH.

3.1. Programming result of raspberry pi

Programming the automatic microclimate control device is done using the Python programming language, the microclimate control process is changing temperature and RH in the greenhouse by activating the misting cooling system pump which aims to reduce temperature and increase RH in the greenhouse and the process periodic monitoring every 1 minute of the microclimate in the greenhouse. Programming begins with taking the maximum temperature, and minimum RH data contained in the greenhouse website database, the purpose of this data collection is so that the tool knows the temperature limits and the RH, which activates the misting cooling system pump. The maximum temperature and RH of the minimum greenhouse in this study are 30 °C and 80%.

The pump ignition process uses AND logic, where the pump will start when the condition of the greenhouse temperature is above the maximum temperature (30 °C), and RH is below the minimum RH (80%), if one of these conditions is not met then the pump will not light up. This programming also uses looping logic that is WHILE, where the results of reading the data by the SHT11 and GUVA-S12SD sensors will be displayed on the website every 1 minute in the form of a greenhouse microclimate table. In addition to this programming, the calculation of the duration of the misting pump cooling system is also calculated using a psychometric formula, following the Raspberry Pi programming snippet, which can be seen in Figure 6.

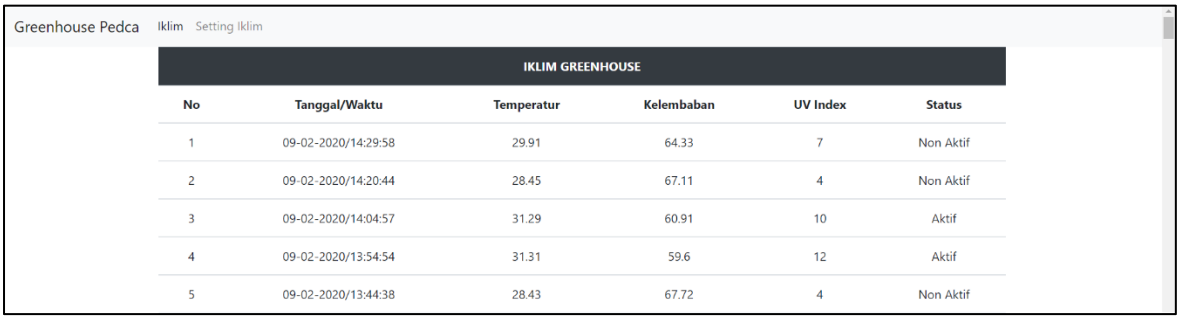


```
pi@raspberrypi: ~/penelitian
GNU nano 3.2

                        hum2 = row[0]
                        print(hum2)

        except mysql.connector.Error as error:
                print("Failed to insert into MySQL table {}".format(error))

        c = c-1
        no = no+1
        wm = 0
        ket1 = 'Non Aktif'
        print(c)
        print(no)
        print(now_time_wib)
        print(date)
        print(ket1)

        CLK  = 11
        MISO = 9
        MOSI = 10
        CS   = 8
        mcp  = Adafruit_MCP3008.MCP3008(clk=CLK, cs=CS, miso=MISO, mosi=MOSI)

        def ConvertVolts(data,place):
                volts = (data * 3.3) / float(1023)
                volts = round(volts,place)
                volts = int(volts * 1000)
                return volts

        uv = 0

        GPIO.setmode(GPIO.BCM)

        uv_value = mcp.read_adc(uv)
        uv_volts = ConvertVolts(uv_value,4)

        with SHT1x(18,23, gpio_mode=GPIO.BCM) as sensor:
                temp = sensor.read_temperature()
                humidity = sensor.read_humidity(temp)
                sensor.calculate_dew_point(temp, humidity)
                print(sensor)
                print("------------------------------")
                print("UV Voltase = {}mV".format(uv_volts))
                print("UV-Index ="),
                if 0<=uv_volts<=50:
                        h =0
```

Figure 6. Python programming on raspberry pi

3.2. Website programming results

Data obtained from the Raspberry Pi will be stored into a database. After that, the data will be displayed on the website using the programming language HTML, MySQL, and PHP. The website contains two pages, the first page will display microclimate data in the form of a table that contains a date, time, temperature, RH, UV index, and the status of the pump, this microclimate data will be sorted by the latest date and time using descending query in MySQL so that the greenhouse operators do not have to scroll to see the latest conditions, while on the second page there is a form used to determine the maximum/minimum temperature and RH, the data displayed on this page is taken from the database, and when changes occur in maximum/minimum temperature and RH then the data will be sent back to the database and then taken back by Raspberry Pi as maximum temperature and minimum RH reference data. Website views can be seen in Figure 7 and Figure 8.


Greenhouse Pedca Iklim Setting Iklim

IKLIM GREENHOUSE

No	Tanggal/Waktu	Temperatur	Kelembaban	UV Index	Status
1	09-02-2020/14:29:58	29.91	64.33	7	Non Aktif
2	09-02-2020/14:20:44	28.45	67.11	4	Non Aktif
3	09-02-2020/14:04:57	31.29	60.91	10	Aktif
4	09-02-2020/13:54:54	31.31	59.6	12	Aktif
5	09-02-2020/13:44:38	28.43	67.72	4	Non Aktif

Figure 7. First-page display of the website

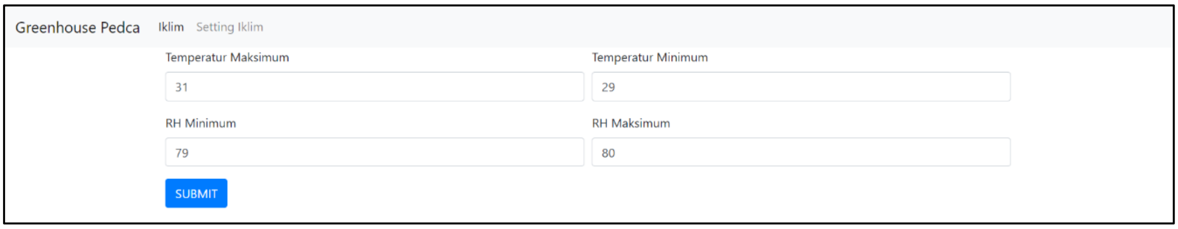


Figure 8. Second-page display of the website

3.3. Analysis of the greenhouse microclimate conditions

The data analyzed is when the micro-climate conditions of the greenhouse are not ideal or when the misting cooling system pump is working, this condition usually occurs at 09:00 - 14:00, with UV index conditions between 8-12. UV index, pump status, temperature, and RH data can be seen in Figure 9.

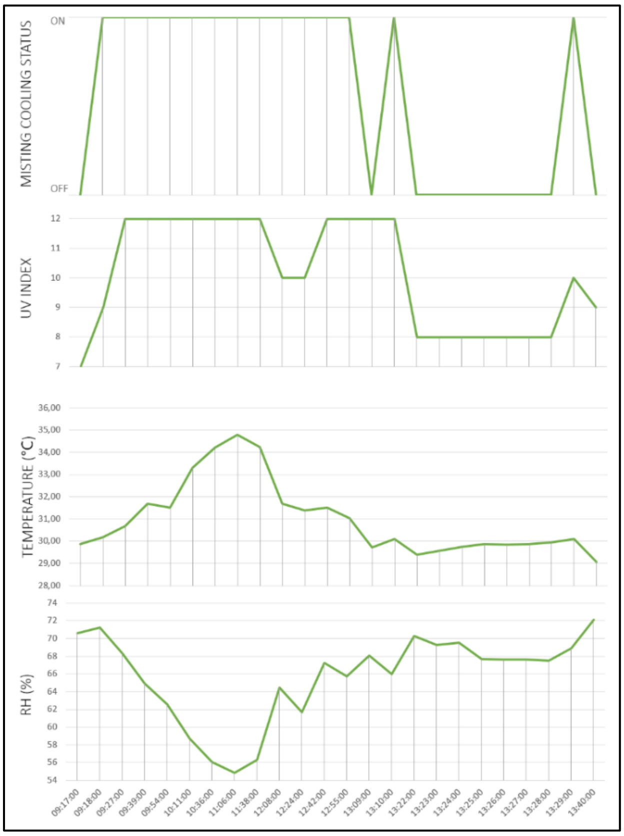


Figure 9. UV index graph, pump status, temperature and humidity of the greenhouse

Figure 9 above shows the duration of the pump running longer than the duration of the pump not running, this is because the UV index conditions tend to be in the numbers 10-12, where the UV index conditions between 8-10 are very high, and UV index> 11 is included extreme category, so the sunlight in these conditions is very hot. The temperature and RH conditions on the graph also show that this automatic controller works correctly, where the misting cooling system pump only works when the temperature is above its maximum temperature of 30 ℃, and the RH is below the minimum RH of 80% which can be seen at 09:18 with temperatures and RH respectively 30.17 and 71.27%, at 13:22 the micro-climate conditions of the greenhouse began to stabilize with temperatures and RH respectively 29.38 ℃ and 70.28%, these conditions make the tool stop working because the use of AND logic in programming controls if one of the temperatures and RH enters in an ideal condition that is the temperature below the maximum temperature or RH above the minimum RH then the tool will stop working.

The graph in Figure 9 also shows that when the UV index tends to rise and stabilize at 12 then the temperature tends to rise and RH tends to decrease even though the microclimate control device is actively working which can be seen at 09:17 - 11:06, the greenhouse temperature is always up to 34.79 ℃ as well as RH which always drops to 54.85%, but when the UV index tends to fall from 12 microclimate controllers can lower the temperature and increase the RH it can be seen at 11:06 - 12:42, the temperature always goes down to reach 31.51 ℃ as well as RH which always goes up to reach 67.25% which means the temperature drops ± 3 ℃ and RH rises ± 12%. This condition can be seen more clearly in Figure 10 below.

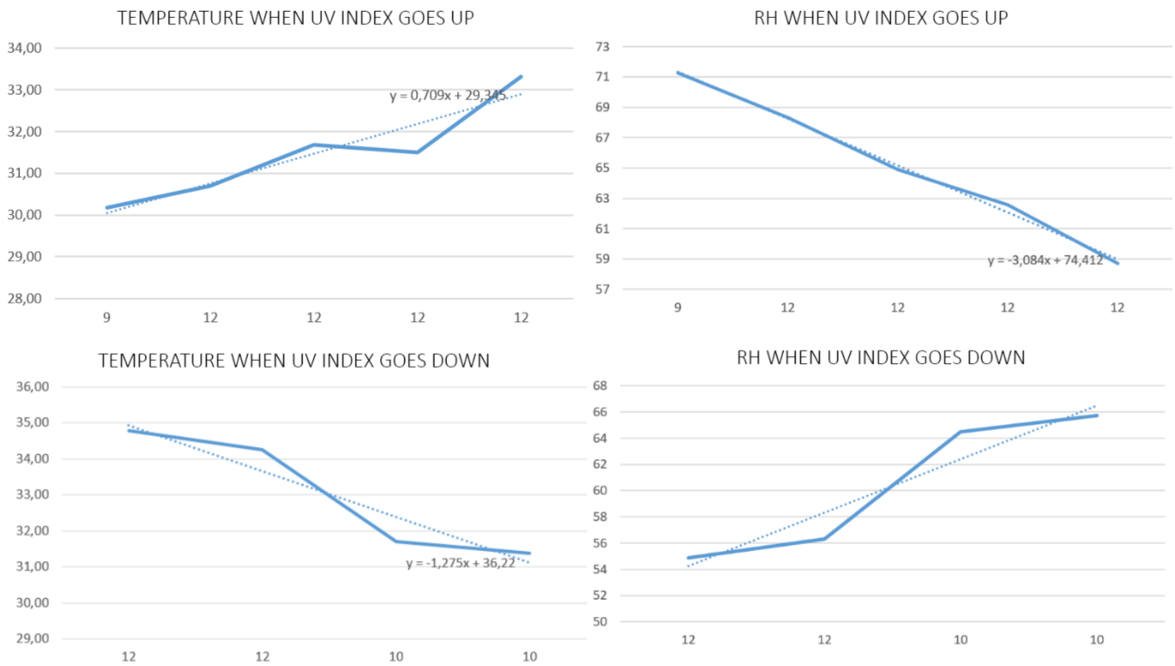


Figure 10. Chart comparison of UV index against temperature and RH

This condition occurs due to the absence of paranet nets installed inside the greenhouse, so that very hot sunlight at UV index above 11 freely enters the glass without any retaining of the sun's rays and traps heat carried by sunlight into the greenhouse.

4. CONCLUSION

Based on the results of research that have been conducted on the greenhouse, greenhouse microclimate control devices can automatically trigger the misting pump of the cooling system when the temperature is greater than the maximum temperature (30 ℃), and RH is smaller than the minimum RH (80%). The website displays microclimate data in a table form, shows the setting for temperature and RH maximum/minimum, when UV index rise and stabilize at number 12 microclimate control devices cannot decrease temperature and increase RH but when UV index falls from number 12 temperature can be decreased by ± 3 ℃ and RH can be increased by ± 12%.

This system is quite effective for stabilizing greenhouse temperature automatically so it can advantage many that need a cooling system without having to continuously adjust the temperature throughout the day and investing time for manual microclimate surveillance. Usability wise, it can also be applied to a wide range of plant varieties because the maximum and minimum microclimate can change according to the type of desired plants

Some suggestions for further development is the need to install paranet at the top of the greenhouse to control the intensity of incoming sunlight so the misting cooling system can perform more effectively. According to the temperature sensor, statistics show in the afternoon phase, and the sun is at its peak, the UV index jump above 10, this leads to misting cooling system decreasing in performance since currently there is not any layer of protective elements around the greenhouse to avoid overheating.

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