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Smart Greenhouse Monitoring With Soil Temperature and Humidity Control on Internet of Things (IoT) Based Orchid Plants

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Abstract

Research on monitoring systems with control has been developed with several different inputs and outputs. This research has realized a smart greenhouse monitoring tool with temperature and soil moisture control on orchid plants based on the Internet of Things (IoT). This study aims to create a monitoring tool for temperature, air humidity, soil moisture, and water level. In the system, the microcontroller used is Wemos D1 R1, with inputs in the form of a DHT-11 sensor to measure air temperature and humidity, a soil moisture sensor to measure soil moisture, and an ultrasonic sensor to measure the water level in the containers. The resulting system output is in the form of pump and fan control. Based on the results of sensor testing, the accuracy of the DHT-11 sensor is 99.97%, the error is 0.03%, the soil moisture sensor is 98.63% accurate, the error is 1.37%, and the ultrasonic sensor is 97, 61% with an error of 2.89%. Based on the research results, the system can run well, as shown by Thingspeak, and the website smartgreenhouseanggrek.weebly.com can receive the results of monitoring sensor data using an internet connection. The tool will carry out the process of watering plants when the soil moisture value read by the sensor is 20% and will stop watering when the sensor reads the soil moisture value reaches ≥50%. In contrast, the air temperature control is done by turning on the fan if the temperature reaches 30° C.

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Abstrak

Penelitian sistem monitoring disertai pengontrolan telah banyak dikembangkan dengan beberapa input dan output yang berbeda. Penelitian ini telah merealisasikan alat monitoring smart greenhouse dengan kontrol suhu dan kelembaban tanah pada tanaman anggrek berbasis *Internet of Things (IoT).* Penelitian ini bertujuan untuk membuat alat monitoring pada suhu, kelembaban udara, kelembaban tanah, dan ketinggian air. Pada sistem, mikrokontroler yang digunakan yaitu *Wemos D1 R1,* dengan input berupa sensor *DHT-11* untuk mengukur suhu dan kelembaban udara*, sensor soil moisture* untuk mengukur kelembaban tanah, dan sensor ultrasonik untuk mengukur ketinggian air dalam wadah. Output sistem yang dihasilkan berupa pengontrolan pompa dan kipas. Berdasarkan hasil pengujian sensor diperoleh akurasi sensor DHT-11 sebesar 99,97%, error 0,03%, sensor *soil moisture* diperoleh akurasi sebesar 98,63%, error sebesar 1,37%, dan sensor ultrasonik diperoleh akurasi sebesar 97,61% dengan error sebesar 2,89%. Berdasarkan hasil penelitian, sistem dapat berjalan dengan baik ditunjukkan dengan *platform Thingspeak* dan website *smartgreenhouseanggrek.weebly.com* dapat menerima hasil monitoring data sensor menggunakan koneksi internet. Alat akan melakukan proses penyiraman tanaman ketika nilai kelembaban tanah yang terbaca oleh sensor sebesar ≤20% dan berhenti melakukan penyiraman ketika sensor membaca nilai kelembaban tanah mencapai ≥50%, sedangkan untuk proses pengontrolan suhu udara dilakukan dengan menyalakan kipas jika suhu mencapai ≥30°C.

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1. Introduction

Orchid plants are ornamental plants with 25,000 to 30,000 species worldwide (Kasutjianingati & Irawan, 2013). Indonesia is one of the countries with the world's largest orchid germplasm, which is around 6000 species of orchid plants (Fandani et al., 2018). Based on data from the Central Statistics Agency in 2018, it is known that the production of orchids in Indonesia reached 24 million stalks and became one of the ornamental plants with the highest production in Indonesia. However, in 2019 there was a decline in the production of orchid plants to 18 million stalks (Statistics, 2019). The sustainability of orchid plants is starting to be threatened due to illegal logging and climate change (Heriswanto, 2009), as well as the development of the industrial and service sectors, which causes the scarcity of land resources. Greenhouse technology is one solution to control microclimate conditions in plants (Tando, 2019). Besides that, greenhouses for plant cultivation can provide an environment close to optimum conditions for plant growth and increase plant productivity (Kurniawan & Witanti, 2021).

According to Government Regulation Number 39 of 2006, monitoring or monitoring is an activity to observe the progress of the implementation of the plan and identify and anticipate problems that arise and or will arise so that action or control can be taken. One of the efforts to control automatically and controlled is the use of Internet of Things (IoT) technology which helps assist in the care and monitoring of plants in greenhouses. (Prakoso et al., 2017) .

Regarding the cultivation of orchids (Najikh et al., 2018) researched monitoring orchid plants. The ideal temperature for orchid plants was obtained at daytime temperatures between 27-30°C and night temperatures between 21-24°C, while ideal air humidity ranges from 60-80%. However, the monitoring results are not stored and only display sensor readings at that time. Therefore, in this research, Internet of Things-based monitoring uses Thingspeak as a medium for storing and retrieving data from various sensors or devices using the Hypertext Transfer Protocol (Chwalisz, 2019). In addition to using Thingspeak, the monitoring process can also be done by accessing the website that will be created. The website can make it easier for other users to access monitoring results without logging into Thingspeak.

Based on the explanation above, this study will create a monitoring system based on the Internet of Things (IoT) with sensor inputs consisting of a DHT-11 sensor to measure temperature and humidity in the greenhouse, a soil moisture sensor to measure soil moisture, and an ultrasonic sensor to measure water levels. Sensor readings can be stored in Thingspeak media and accessed using the website in real-time. Wemos D1 R1 is also used as a microcontroller with an esp8266 module embedded so that no additional modules are needed and that it is easier to connect to the monitoring system (Protosupplies, 2021). In addition to the monitoring system in this study, soil moisture control is also carried out by looking at the soil moisture sensor value that affects the pump work in the process of watering plants, and the temperature value affects the fan in lowering the temperature in the greenhouse.

2. Research methods

The tools and materials used in this research are Wemos D1 R1, Sensor DHT-11, Soil Moisture Sensor, Ultrasonic Sensor HCSR 04, LCD I2C, AC water pump, AC fan, LED (Light Emitting Diode), Relay, Resistor, Jumper, and 9V DC Adapter.

2.1. Overall Design of the Tool

The monitoring tool design consists of 3 parts: input, processor, and output. The input section contains a DHT-11 sensor to measure air temperature and humidity, a soil moisture sensor to measure soil moisture, an ultrasonic sensor to measure water level, and a power supply or adapter as a voltage source. In the processing section, there is Wemos D1 R1 as an input data processor, which produces output in the form of a relay to activate the pump and fan, a 20X4 LCD as a data display on the monitoring tool, and the data obtained is sent to Thingspeak as a server that stores are monitoring results. The system planning block diagram can be seen in **Figure 1.**

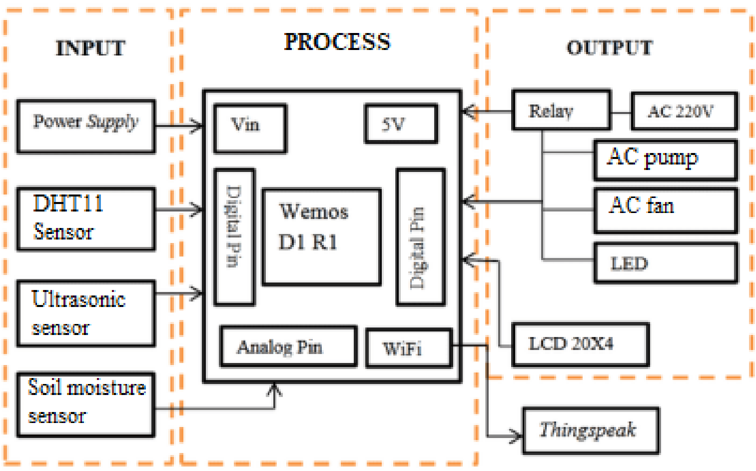


Figure 1. Block diagram system planning

The working principle of this research is to build an automatic monitoring and control system with a data acquisition mechanism. This system's monitoring and control parameters include monitoring the conditions of temperature, air humidity, soil moisture, and water level in the reservoir. The sensor detection data is then sent to the Wemos D1 R1 microcontroller via a cable to be read and the value conversion process. The temperature control process is based on the set point value of the DHT-11 sensor. Namely, the relay will activate the fan when the measured temperature reaches 30°C. Soil moisture control is based on the measured soil moisture sensor value reaching 20%. Then the relay will activate the pump to perform the watering process and stop when the soil moisture sensor measures soil moisture reaching 50%. The output of this system is the monitoring data sent to Thingspeak in real-time using the internet network. In addition, the monitoring results can be visualized in graphic form on the Thingspeak server and the website that has been created, namely smartgreenhouseanggrek.weebly.com. In general, a series of monitoring tools is shown in **Figure 2.**

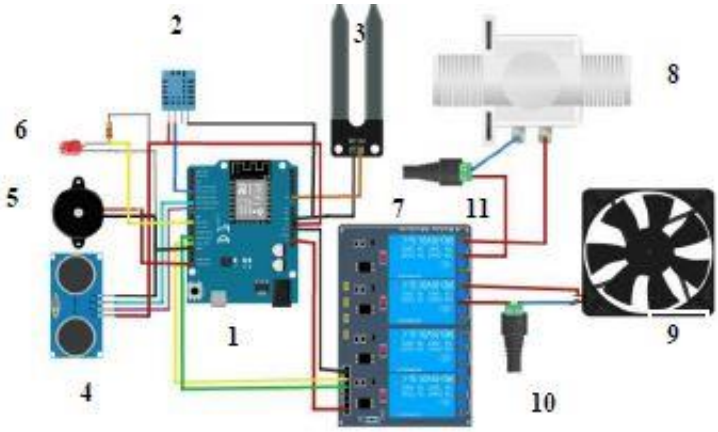


Figure 2. Schematic circuit of the tool

Information:
1. Wemos D1 R1
2. DHT 11 Humidity Sensor
3. Soil moisture sensor
4. Ultrasonic Sensor HCSR-04
5. Resistor
6. Light Emitting Diode (LED)
7. Relay 4 channel 5V
8. AC Pump
9. AC fan

Based on the series of tools in **Figure 2**, Wemos D1 R1 is used as a microcontroller using nine digital pins, one analog pin, a VCC pin, and a GND pin. The soil moisture sensor connects pins A0, VCC, and GND. The DHT-11 sensor is connected to pins D2, VCC, and GND. The ultrasonic sensor is connected to echo on pin D6 and triggers on pin D7, VCC, and GND. For LCD, I2C connected SCL on pin D3 and SDA on pin D4. For the relay used, four channels are connected, namely input 1 (fan) connected to pin D12, input 2 (pump) on pin D13, input 3 (green LED) on pin D8, and input 4 (orange LED) on pin D9. Design draft smart greenhouse monitoring tools are shown in **Figure 3.**

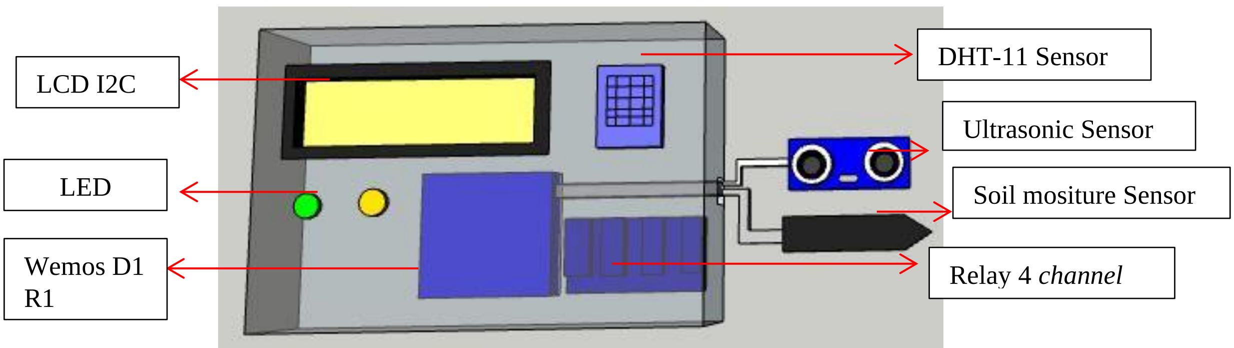


Figure 3. Monitoring tool design

Based on **Figure 3**, the box used with plastic material is 18 cm long and 13 cm wide. On the front of the box is an I2C 20X4 LCD, which displays monitoring results, an LED indicator of sufficient or depleted water conditions, and a DHT-11 sensor to measure air temperature and humidity. On the outside of the box, an ultrasonic sensor is connected to measure water level and humidity. s oil moisture sensor to measure soil moisture. Inside the box is Wemos D1 as a microcontroller with a WiFi module embedded, and there is a four-channel relay as an automatic switch on the pump and fan.

3. Results and Discussion

3.1 System Design Implementation

The instrumentation system for monitoring temperature, air humidity, soil moisture, and water levels accompanied by the Internet of Things (IoT) based soil temperature and humidity control has been realized with the results shown in **Figure 4.** This tool uses a plastic-based box with 18 x 13 x 5 cm dimensions. Before this tool is realized in a smart greenhouse, it is necessary to characterize the DHT -11 sensor, soil moisture sensor, and an ultrasonic sensor to ensure the sensor can work and has good sensor accuracy and precision.

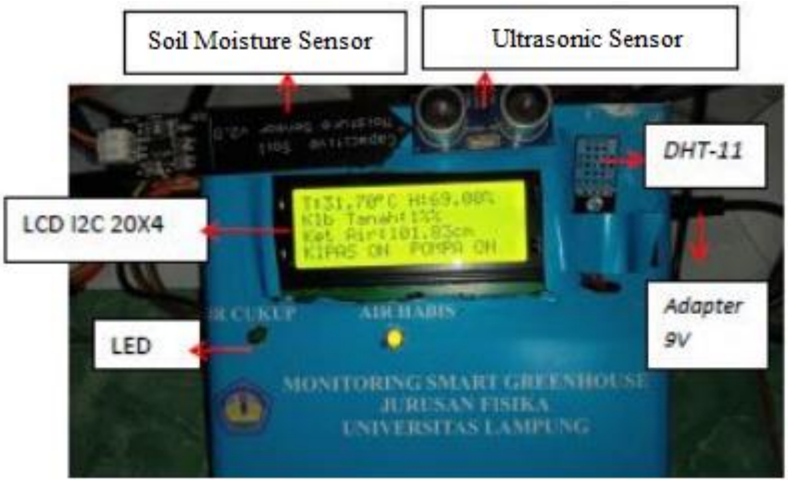


Figure 4. A series of monitoring tools

In **Figure 4,** there are several components in the design of IoT-based monitoring tools, such as an I2C LCD to display monitoring results such as temperature, air humidity, soil moisture, the water level in the storage container, and the status of the fan and pump actuators being active or not. For the soil temperature and humidity control system, the system diagram is shown in **Figure 5.**

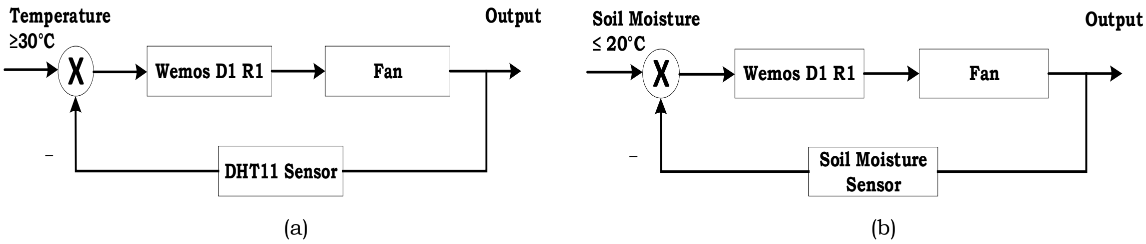


Figure 5. Loop system, (a) Temperature Control, (b) Soil Moisture Control

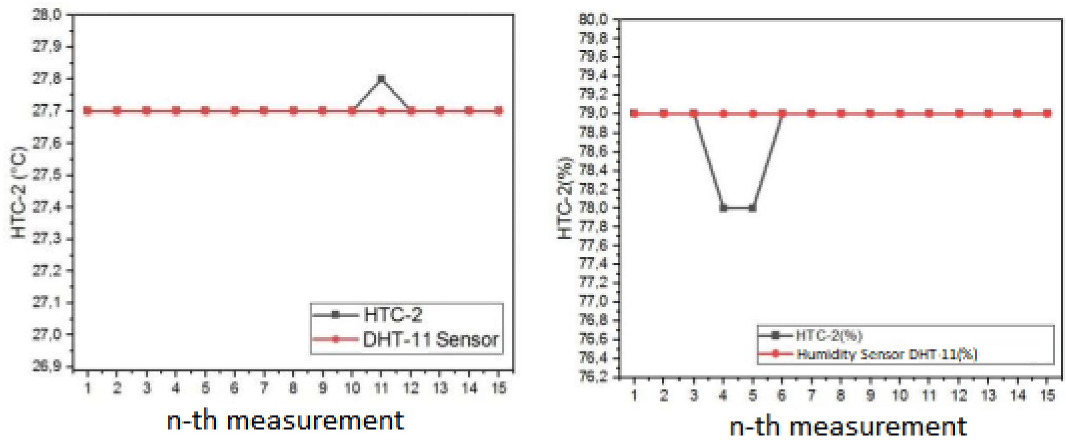
In a closed loop system, there are two controls: pump control and fan control. **Figure 5** (a) shows an input temperature value of 30°C. Wemos D1 R1 as a microcontroller will activate the fan as a plant to carry out control actions with feedback, namely the DHT-11 sensor. Taking the initial or set point value is based on the growth of orchid plants at optimal conditions at a temperature of 21°C to 30°C (Najikh et al., 2018). While **Figure 5** (b) has an input of 20% soil moisture value, the pump as a plant will carry out the watering process with feedback, namely the soil moisture sensor.

3.2 DHT-11 Sensor Testing

DHT-11 sensor testing is done by comparing the sensor with the HTC-2 measuring instrument. This tool can measure indoor and outdoor temperatures with a temperature range of 10-50°C and a humidity measurement range of 10-99%. The test was carried out three times with an average value of temperature (temp) and humidity (hum), indicating that the temperature conditions at the time of testing ranged from 27.7 °C - 27.8 °C and air humidity conditions ranging from 78.0 % - 79.0%. The results of testing the temperature and humidity of the DHT-11 sensor against HTC-2 can be seen in **Table 2,** and the graph for testing the DHT-11 sensor against HTC-2 is shown in **Figure 6.**

Table 2. DHT-11 sensor test against HTC-2 measuring instrument

HTC-2		DHT-11		Temp Accuracy (%)	Hum Accuracy (%)
Temp (°C)	Hum (%)	Temp (°C)	Hum (%)		
27.7	79	27.7	79	100	100
27.7	79	27.7	79	100	100
27.7	79	27.7	79	100	100
27.7	78	27.7	79	100	98.7
27.7	78	27.7	79	100	98.7
27.7	79	27.7	79	100	100
27.7	79	27.7	79	100	100
27.7	79	27.7	79	100	100
27.7	79	27.7	79	100	100
27.7	79	27.7	79	100	100
27.8	79	27.7	79	99.6	100
27.7	79	27.7	79	100	100
27.7	79	27.7	79	100	100
27.7	79	27.7	79	100	100
27.7	79	27.7	79	100	100



(a) (b)
Figure 6. Test graph (a) Temperature (b) Humidity

Based on **Figure 6** (a), the temperature value of the DHT-11 sensor by the HTC-2 measuring instrument is in the range of 27.70 °C**, so** the accuracy value of the DHT-11 sensor for air temperature is 99.97%. While in **Figure 6** (b) for air humidity, the relative humidity value is obtained, which is 79%. So that the accuracy of the DHT-11 sensor for air humidity is 99.82%.

3.3 Soil Moisture Sensor Test

Soil moisture sensor testing aims to measure soil moisture using the sensor. Humidity sensor calibration is done by looking at the sensor ADC value against Three-way digital tool soil meters. In the standard soil meter, the soil moisture value is divided into three parts: DRY or dry conditions with a range of 0%-30%, NOR or normal conditions with a range of 40%-60%, and WET or wet conditions with a range of 70%-100%. The results of testing the ADC value of the soil moisture sensor with standard tools are in **Table 3.**

Table 3. Testing the ADC value of the soil moisture sensor with a soil meter

No	Standard tools *Soil Meters* (%)		*Soil Moisture* sensor ADC value
1	0	DRY	783
2	10	DRY	746
3	20	DRY	680
4	30	DRY	634
5	40	NOR	597
6	50	NOR	562
7	60	NOR	526
8	70	WET	464
9	80	WET	412
10	90	WET	385
11	100	WET	366

This test is used to obtain the equation of soil moisture value in percent form. The graph of testing the ADC value against the soil meter can be seen in **Figure 7.**

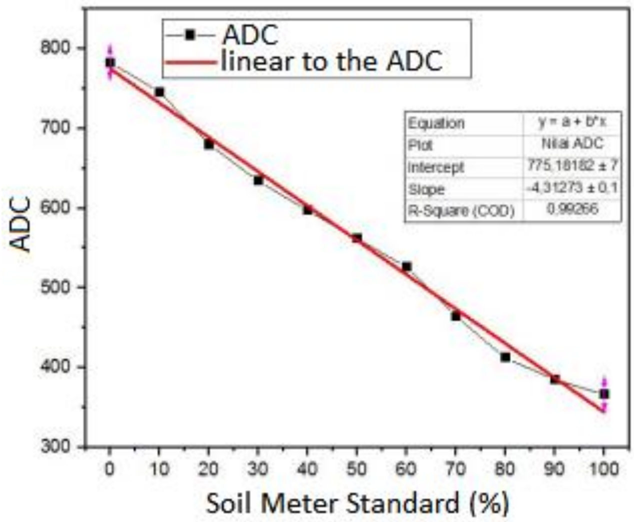


Figure 7. Testing the ADC value of the soil moisture sensor on the soil meter measuring instrument

Based on the test results, a linear graph of the ADC sensor value against the soil meter tool produces **Equation 1.**

$$y = -4,3127x + 775,1818 \tag{1}$$

Equality 1 is used to calibrate the soil moisture sensor then the linear equation is converted into **Equation 2:**

$$SM\,(\%) = \frac{Nilai\ ADC - 775,18}{-4,3127} \tag{2}$$

with *SM* is the soil moisture percent. This calibration is done by entering the equation into the program on the Arduino *software* IDEA.

```
int soilMoistureValue = 0;
int soilmoisturepercent = 0;
void setup()
{}
void loop()
{
ADC value = analogRead(soilPin);
Serial.println(ADC Value);
Soilmoisturepercent = (ADC Value - 775,818) / -4.3127 ;
Serial.print("Soil Moisture : ");
Serial.print(soilmoisturepercent);
Serial.println("%");
}
```

After calibration using the Arduino IDE program, the results obtained after testing the sensor can be seen in **Table 4.** Calculating the percentage value of the sensor's accuracy, error, and precision uses **Equations 3-5.**

$$error = \left|\frac{Y - X_n}{Y}\right| \text{X } 100\% \tag{3}$$

$$Akurasi = \left[1 - \left|\frac{Y - X_n}{Y}\right|\right] \text{X } 100\% \tag{4}$$

$$\text{Presisi} = \left[1 - \left|\frac{X_n - \overline{X}_n}{\overline{X}_n}\right|\right] \text{X } 100\% \tag{5}$$

After the data is obtained from the test results, then calculate the value of the percentage error, accuracy, and precision of the sensor using **Equation 3**, **Equation 4,** and **Equation 5** where : Y = reference parameter value, X_n = nth measured parameter value, $\overline{X}_n$ = nth measured parameter value average.

Table 4. The results of testing the soil moisture sensor on the soil meter measuring instrument

No	Soil meter (%)	Soil Moisture Sensor (%)			Average (%)	Error (%)	Accuracy (%)	Precision (%)
		1	2	3				
1	0	2	3	2	2.34	2.33	97.67	80.86
2	10	9	10	10	9.67	2.33	96.67	95.39
3	20	21	19	21	20.33	5	95	95.60
4	30	32	30	30	30.67	2.33	97.67	97.13
5	40	41	42	42	41.67	4.33	95.67	98.94
6	50	51	50	49	50	1.33	98.67	98.66
7	60	61	60	60	60.33	0.67	99.33	99.27
8	70	70	70	71	70.33	0.67	99.33	99.46
9	80	80	79	81	80	1.33	98.67	99.16
10	90	89	90	91	90	1.33	98.67	99.26
11	100	100	99	100	99.67	1.33	99.67	96.53
Average						**1.37**	**98.63**	**96.38**

This test was repeated three times. The graph of testing the soil moisture sensor on the soil meter measuring instrument is shown in **Figure 8.**

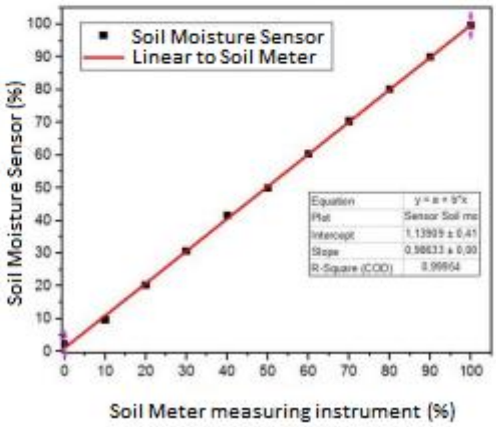


Figure 8. Graphics testing soil moisture sensor to soil meter

The soil moisture sensor test results against the standard soil meter show that the coefficient of determination R^2 is 0.99954. Based on the calculation results, the average error value or error is 1.37%, so the sensor accuracy value is 98.63%, and the sensor precision is 96.38%.

3.4 Ultrasonic Sensor Test

HCSR-04. Ultrasonic sensor measuring object distances from 2cm – 4m with an accuracy of 3mm (Junaidi & Prabowo, 2018). This test is done by comparing the distance detected by the sensor with the actual distance measuring instrument. The results of measuring the distance of the sensor to the surface of the water to the ruler measuring instrument in full can be seen in **Table 5.**

Table 5. Ultrasonic sensor test results on ruler measuring instruments

No	Ruler measuring tool (cm)	Ultrasonic Sensor			Average	Green LED	Orange LED
		1	2	3			
1	5	5.23	5.25	5.25	5.24	Light up	No flame
2	10	10.34	10.32	10.34	10.33	Light up	No flame
3	15	15.38	15.35	15.35	15.36	Light up	No flame
4	20	20.33	20.33	20.34	20.33	No flame	Light up
5	25	25,17	25.26	25.33	25.25	No flame	Light up

The mechanism for testing this parameter is carried out three times with an interval of 5 cm from the sensor distance to the water surface to a distance of 25 cm from the sensor to the water surface. The graph of ultrasonic sensor testing on the ruler measuring instrument is shown in **Figure 9.**

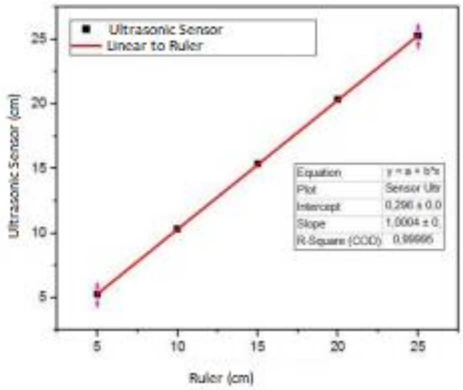


Figure 9. Graph of ultrasonic sensor testing against a ruler

The results of measuring the water level in the container using an ultrasonic sensor against a ruler measuring instrument in **Figure 9** show the coefficient of determination R ^{2} of 0.99998 with a linear regression equation. Based on the calculation results, the average error is 2.39%, the overall accuracy is 97.61%, and the sensor precision value is 99.64%.

3.5 Overall Data Analysis

The monitoring process in this study utilizes Internet of Things (IoT) technology and is displayed on the Thingspeak server. Platforms Thingspeak is an open-source tool or web server that can store sensor readings and is easy to configure (Sahuleka et al., 2018). Data on the results of greenhouse monitoring carried out for 30 days starting from September 20, 2021, to October 19, 2021, are displayed in graphic form.

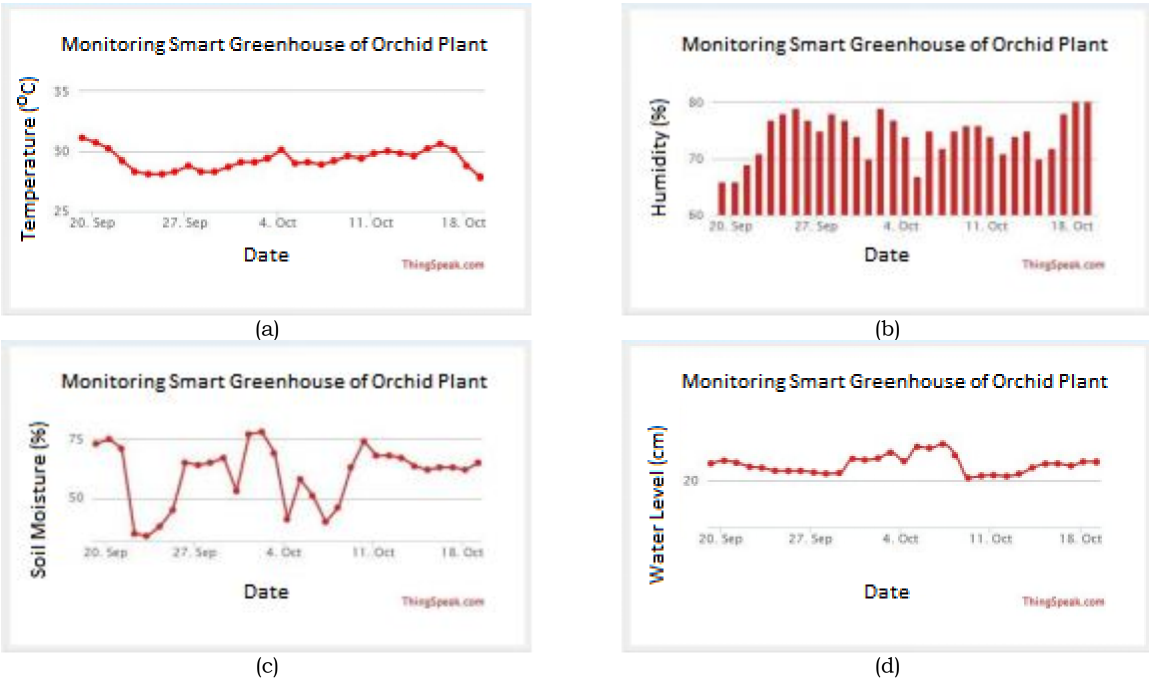


Figure 10. Monitoring results (a) Temperature (b) Air Humidity (c) Soil Moisture (d) Water Level

Based on **Figure 10**, the results of monitoring using Thingspeak media have been going well and can work if they have an internet connection. Observations can also be downloaded on Thingspeak. **Figure 10** (a **)** is the result of monitoring that has been carried out. It is found that the air temperature during monitoring is in the range of 28°C to 30°C. In **Figure 10** (b), the air humidity ranges from 67% to 80% Relative Humidity.

In contrast, **Figure 10** (c) is the result of soil moisture monitoring which has a value that varies between 15% to 80%. Using Thingspeak in the monitoring process can facilitate the user or users in observing the greenhouse system in real-time. In addition to using Thingspeak or applications, monitoring or monitoring processes can be done by accessing the smartgreenhouseanggrek.weebly.com website. The appearance of the website is shown in **Figure 11.**

Figure 11. (a) Website title (b) Website content (c) Website footer

Based on **Figure 11** is the result of making a smart greenhouse website using the weebly.com domain. **Figure 11** (a) is the title of the website that was created, in which there is an explanation of the author and the website that was created. **Figure 11** (b) is part of the monitoring results in which there are fields of temperature, air humidity, soil moisture, and water level. In addition, there is the status of controlling the fan and pump whether it is in an operational condition or not. While **Figure 11** (c) is part of the website footer, which details the location and components used in the monitoring tool that has been created. The monitoring results can be easily accessed by the user, either using a cellphone or a Personal Computer (PC), by accessing the link smartgreenhouseanggrek.weebly.com. Using this website for greenhouse monitoring can make it easier for other users to view state information without logging in to Thingspeak.

4. Conclusion

The realization of monitoring tools with the Internet of Things (IoT) based soil temperature. This monitoring tool can be used to monitor the value of soil moisture and temperature in the greenhouse in real-time and facilitates the process of watering plants automatically. Humidity control can work well, as shown by Thingspeak, and the website can receive sensor value readings in the greenhouse. Several characteristics, namely the pump does the watering process when the soil moisture sensor reaches the soil moisture value of 20% and will stop watering when the sensor reads the soil moisture value reaches 50%. The intelligent greenhouse's temperature control process can be indicated by a fan that turns on when the air temperature reaches 30°C. Based on the test results of the DHT-11 sensor, the accuracy of the air temperature is 99.97%, and the humidity is 99.82%, the soil moisture sensor has a sensor accuracy of 98.63% and a precision value of 96.38%. Moreover, the ultrasonic sensor has a sensor accuracy of 97.61%, an error of 2.39%, and a sensor precision value of 99.64%.

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