Control and Monitoring System of IOT-Based Orchid Culvivation

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***Abstract*—This study focuses on orchid plants, specifically the *Phalaenopsis* species, commonly known as the moth orchid, which is popular in Indonesia due to its beauty and stable flower prices. Orchid cultivation requires special attention to environmental factors such as light intensity, temperature, air humidity, and soil moisture. To enhance the efficiency of plant care, this research designs *an Internet of Things* (*IoT*)-based control and monitoring system. The system utilizes DHT22 sensors to monitor temperature and air humidity, BH1750 sensors to measure light intensity, and *soil moisture* sensors to measure *soil moisture*. The data collected by these sensors are transmitted in *real-time* to a NodeMCU ESP32 connected to the *Firebase platform*. Users can monitor and control plant conditions through an Android application linked to *Firebase*. Testing indicates that the sensors used provide accurate results in monitoring soil moisture. The water pump control system based on soil moisture and air humidity has proven effective, with consistent responses to environmental changes. This system is expected to assist cultivators in improving water usage efficiency and plant condition monitoring. The implementation of *IoT* technology in orchid cultivation can be an innovative solution to enhance the quality and quantity of ornamental plant production in the future.**

Keywords—Moon Orchid, *Internet of Things* (*IoT*), ESP32, DHT22 Sensor, Android *Mobile*.

I. INTRODUCTION

Orchids are a type of ornamental plant in the Orchidaceae family. Orchids are found throughout the world, including Indonesia. These flowers and plants are very popular so many people cultivate these plants. Phalaenopsis orchids or moon orchids are the type most in demand by people not only because the flowers are beautiful but also because the price is relatively stable. Orchids are a type of beautiful ornamental plant and have many unique features, such as various flower shapes and patterns that are beautiful to the eye. Orchids can live in the highlands, lowlands, jungles and deserts. Orchids are often found in tropical areas, this is because orchid plants are very suitable for tropical climates. There are many types of orchid plants, such as moon orchids, mustache slipper orchids, kebutan orchids, star moon orchids and others. Each type of orchid plant has its own characteristics and charm. In Indonesia, orchid plants are now increasingly rare.

Orchids are a type of plant with relatively slow growth. The growth rate of orchid plants varies, depending on how they are cared for and maintained. Several factors, both internal and external, can influence orchid growth. External factors include light intensity, temperature, humidity, water requirements, fertilizer, as well as pest and disease attacks. Therefore, in cultivation techniques it is important to provide optimal care so that orchid growth can improve its quality and quantity.

The local moon orchid (Phalaenopsis amabilis) is a type of orchid known for its beautiful flowers, pure white with yellow tongues and long flower stalks. Usually, when this orchid flowers, the number of flowers that bloom ranges from 15 to 20 flowers [1]. It is called the local moon orchid because it is often found on the island of Java. Moon orchids require temperatures between 21-29°C, with ideal humidity between 60% - 80% and sunlight intensity ranging between 30% - 60% [2]. This plant does not like conditions that are too humid or too dry. Because it is a natural orchid, its care must adapt to the original environmental conditions to maintain its survival and speed up the flowering process.

Even though orchids are parasitic plants, their selling value is quite high. Prices for local orchid plants start from IDR 75,000, while imported orchids have higher prices, ranging from IDR 150,000 to IDR 300,000 [3]. According to data from the Central Statistics Agency (BPS), orchid production reached 11.68 million stalks in 2020, which shows a decrease of 37.22% compared to production in 2019 which reached 18.61 million stalks. During the period 2016 to 2020, orchid production experienced a fluctuating trend. In 2016, orchid production was recorded at 19.98 million stalks, then increased by 0.35% in 2017, and again rose 23.3% in 2018 with production reaching 24.72 million stalks [4].

Considering that the price of orchids is currently still relatively high, more intensive care is needed for orchid plants. Many people still care for orchids manually, such as watering them with a bucket without paying attention to temperature and humidity. However, with the rapid development of technology, this manual method has become ineffective and time consuming. Therefore, technological tools are needed that can monitor the condition of orchid plants while simultaneously watering them automatically to make maintenance easier.

In this research, the author used several references from previous research, for comparison and reference material to complete this research. [5] has conducted research entitled "Automatic Watering Model for Moon Orchid Plants and Monitoring Temperature Conditions and Light Intensity (Lombok orchid case study)", the method used in this research is by collecting literature studies, system requirements analysis, system work design, hardware and software design, implementation, system testing and evaluation, system documentation. The results of the research are that the system can water when the humidity value of the planting medium is below 60% and record the time. This system can provide notifications when the light intensity is above 40%, the temperature is above 27°C and the air humidity is below 60% in the greenhouse. This research shows that the IoT-based automatic monitoring and watering system functions as expected. The system is not only capable of automatic watering based on soil moisture, but is also capable of providing real-time notifications and monitoring of environmental conditions in the greenhouse via the website and all components function properly. The advantage of the research is that it can carry out automatic watering according to needs, monitor greenhouse environmental conditions in real-time via the website, and can provide notifications when environmental conditions do not comply with specified parameters. Meanwhile, the drawback of the research is that it requires good technical understanding in designing and implementing an IoT-based system, the system relies on an internet connection to send data to the website.

From the description above, the author plans to design a tool model that can control and monitor by paying attention to soil moisture, temperature, air humidity and light intensity. The sensors used are the DHT22 sensor, BH1750 sensor and soil moisture sensor, where the soil moisture sensor is used to measure soil moisture in dry and wet soil conditions, while the DHT22 sensor is used to monitor air temperature and control air humidity. around the object as well as the BH1750 sensor for monitoring the intensity of light around it. The results from the sensor are sent to ESP32. If the soil moisture control system shows less than 60% then the relay will be active and the soil pump will flush and if the soil humidity is more than 60% the relay will turn off and the soil pump will turn off, as well as air humidity. if the sensor shows a value of less than 60% then the relay will be active and the air pump will flush and if the air humidity is more than 60% then the relay will turn off and the air pump will stop. The BH1750 and DHT22 sensors are used for monitoring. On the BH1750 sensor the data is taken on light intensity, while on the DHT22 sensor the data taken for monitoring is temperature in Celsius units. Data from the ESP32 will be sent to the Android mobile or application for monitoring and control of the tools that have been created, applications that have been created in the watering control system using 2 methods, namely automatic watering via data from sensors and manual watering. By making this tool, it is hoped that it can help cultivators and the public in monitoring moon orchid plants.

II. Design and Implementation

A. System Overview

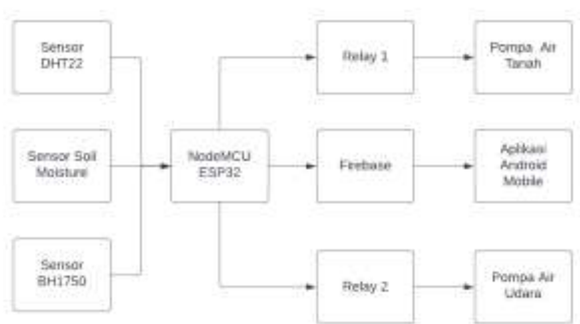

Fig. 1. Block Diagram

The DHT22 sensor, soil moisture sensor, and BH1750 sensor are connected to the NodeMCU ESP32. The DHT22 sensor is placed outside the system box to detect air temperature and humidity, the soil moisture sensor is inserted into the soil of the orchid plant to detect soil moisture, while the BH1750 sensor is placed outside the box to detect light, The data obtained from the sensors will be processed and sent to Firebase via an internet connection. Data that has been sent to Firebase will be accessed or read by the Android application that is installed on the user's smartphone via an internet connection. In this way, users can monitor and control via the Android application.

If the data from the soil moisture sensor shows that the moisture level has reached the minimum limit set in the program, then the relay connected to the NodeMCU ESP32 will be activated to turn on the ground water pump and the application shows information that the ground water pump is ON or on. Next, the ESP32 will receive data from the DHT22 sensor, namely temperature and humidity. If the air humidity data from the DHT22 sensor shows a value below that which has been determined, then the relay connected to the ESP32 will turn on the air water pump and the application shows information that the air water pump is ON or on, while the temperature data on the DHT22 sensor will be sent to the ESP32 and this data is used for monitoring those that are connected to the application. After the levels of soil moisture and air humidity reach the maximum limits set in the program, the pump will automatically and on the application a statement will appear that the pump is OFF. Apart from that, the pump in the application can be manually set for ON or OFF use. And the ESP32 will receive data from the BH1750 sensor, where the data will be sent to the connected Android application as data for monitoring light intensity.

B. System Planning

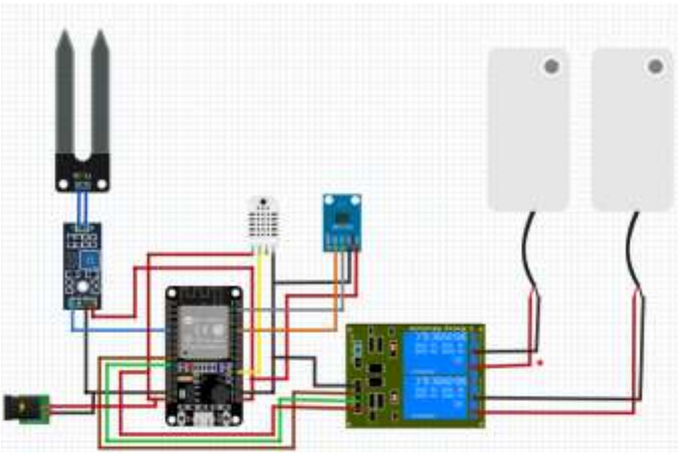

Fig. 2. System planning

In designing this system, ESP32 is used as a tool that can control all activities that occur. This system uses three sensors, namely the soil moisture sensor, the DHT22 sensor, and the BH1750 sensor. The soil moisture sensor is used to detect soil moisture and the DHT22 sensor is used to detect air temperature and humidity, where the two sensors are connected to a relay to optimize and obtain good values for air humidity and soil moisture. The soil moisture sensor is plugged into fertilizer or soil containing moon orchid plants. Apart from that, there is a BH1750 sensor which is used to detect light intensity. This system uses a 2 channel relay connected to a mini water pump, soil moisture sensor, and DHT22 sensor. This system uses an input voltage of 5 volts. The hardware design can be seen in the picture.

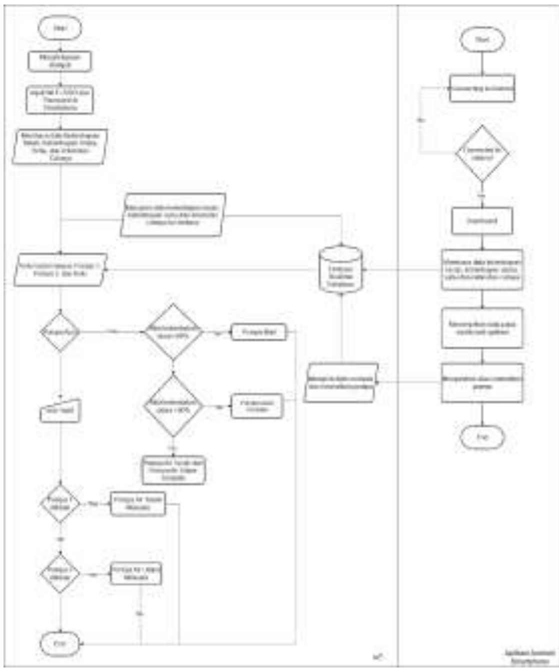

Fig. 3. Flowchart

The picture shows a flowchart of the entire system which starts by connecting to the internet, then continues by reading data from sensors and sending it to Firebase. After that, if the pump mode in the automatic application (auto) is OFF, then the ground water pump and air water pump can be operated manually. However, if the pump mode in the application is ON, the ground water pump and air water pump will turn on automatically based on a predetermined and programmed set point. Thus, this system allows flexible control both manually and automatically, ensuring that plant watering needs are met according to the conditions that have been set and programmed.

If the soil moisture sensor data shows a value of less than 60%, the groundwater pump will turn ON. Conversely, if the sensor value is more than 60%, the pump will turn off (OFF). The DHT22 sensor is responsible for detecting air temperature and humidity. If the air humidity sensor data shows a value of less than 60%, the air water pump will turn on (ON), while the temperature data on the DHT22 sensor is used to monitor the condition of the orchid plant. The BH1750 sensor is tasked with detecting the light intensity that occurs on orchid plants. The Android application will read data from Firebase to monitor conditions and control the pump. This data will be displayed on the application's main screen (homescreen), allowing users to easily monitor and control the watering system in real-time.

Fig. 4. Android User Interface

The design of the Android application aims to make the smartphone the main control tool for watering plants and as an interface for monitoring sensor data. In the application display plan that will be developed, there will be several features displayed on the screen. These features include real-time monitoring of temperature and light intensity, as well as controls for turning on and off the ground water pump (soil moisture) and air water pump (air humidity). With this design, the Android application will function as a control and monitoring center that provides convenience and efficiency for users. Based on The display design in the Android application, there are several features that will be displayed, such as monitoring soil moisture, air humidity, temperature and light intensity. Also, for the control system features used to turn on and off the water pump, there are several features such as ground water pumps, air water pumps and auto pumps.

C. System Implementation

The outer circuit consists of a sensor, pump, misting sprayer nozzle. There are 3 types of sensors on the outside, in the picture number 1 shows the BH1750 sensor, number 2 the soil moisture sensor, number 3 the DHT22 sensor. At number 4, there is a ground water pump, at number 5 an air water pump and at number 6 a misting sprayer nozzle. This sensor has the function of detecting air temperature and humidity. On the outside there is a pump that is connected to soil moisture and air humidity data.

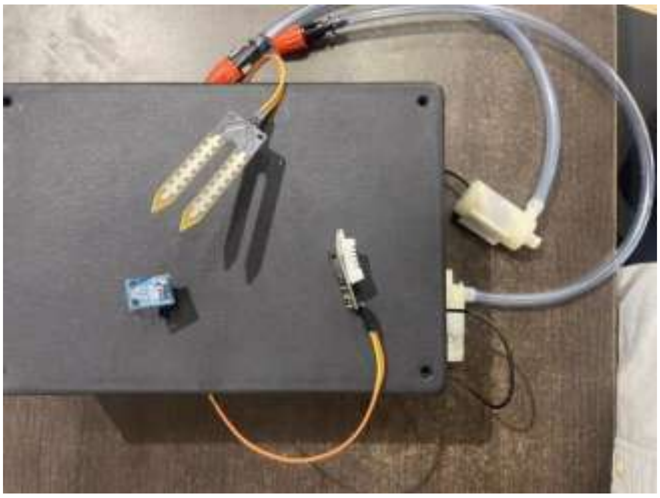

Fig. 5. External System

In the internal network consisting of 2 relays to regulate the ground water pump and the air water pump. On the internal system there is an ESP 32 as a sensor data receiver. And there is a 5V input to run the entire system using a usb adapter.

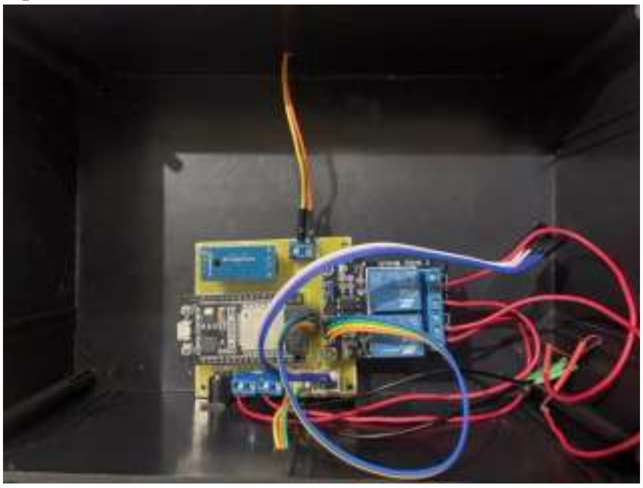

Fig. 6. Internal System

III. Testing

A. Sensor Testing

The soil moisture sensor test aims to determine whether the performance of the soil moisture sensor is running well as expected or not on moon orchid plants. In sensor testing, a comparison is made between the measurement results from the soil moisture sensor and a soil analyzer. The sensor test results can be seen in Table I.

TABLE I. *Soil Moisture Sensor Testing*

No	Soil Analyzer	Sensor Soil Moisture	Difference
	Soil Moisture (%)	Soil Moisture (%)	
1	61	55	6
2	64	61	3
3	66	64	2
4	53	49	4
5	59	54	5
6	67	63	4
7	70	68	2
8	62	56	6
9	65	58	7
10	67	59	8
11	65	63	2
12	62	66	4
13	60	61	1
14	57	54	3
15	61	59	2
Average			3.93
Standard Deviation			2.09

Based on Table I from the results of 15 tests, the average difference between the two measurements is 3.93%. Standard deviation of soil analyzer and sensor measurement results *soil moisture* is 2.09%.

Testing on the BH1750 sensor aims to ensure accuracy in measuring light intensity. In testing the BH1750 sensor, a comparison is made between the measurement results from the BH1750 sensor and the lux meter. The test results can be seen in Table II.

TABLE II. *BH1750 Sensor Testing*

No	Lux Meter	Sensor BH1750	Difference
	Light Intensity (lux)	Light Intensity (lux)	
1	993	1040	47
2	1001	1039	38
3	997	1026	29
4	1107	948	159
5	1085	1025	60
6	1064	1010	54
7	1070	1003	67
8	1060	998	62
9	1055	960	95
10	1038	945	93
11	1028	935	93
12	975	1020	45
13	982	1025	43
14	1002	970	32
15	1007	987	20
Average			62.47
Standard Deviation			35.57

Based on Table II from the results of 15 tests, the average difference between the lux meter measurements and the BH1750 sensor is 62.47 lux. The standard deviation of the difference between the lux meter and the BH1750 sensor is 35.57 lux.

The aim of testing the DHT22 sensor is to determine the response and performance of the sensor in determining the parameters for measuring temperature and air humidity in cultivating moon orchids. This test is to ensure that the DHT22 sensor provides accurate results in various environmental conditions around the moon orchid plant with variations in temperature and humidity by responding to these changes. The DHT22 sensor measurement results are then compared with a hygrometer which functions as a comparison tool. The DHT22 sensor test results are presented in tables III and IV.

TABLE III. *DHT22 Air Humadity Sensor Testing*

No	hygrometer	Sensor DHT22	Difference
	Air humidity (%)	Air humidity (%)	
1	72	77	5
2	72	79	7
3	73	78	5
4	72	80	8

5	73	81	8
6	69	79	10
7	73	79	6
8	73	80	7
9	75	77	2
10	70	78	8
11	76	81	5
12	77	81	4
13	75	79	4
14	79	80	1
15	80	82	2
Average			5.47
Standard Deviation			2.59

TABLE IV. *DHT22 TEMPERATURE SENSOR TESTING*

No	hygrometer	Sensor DHT22	Difference
	Temperature (°C)	Temperature (°C)	
1	31	32	1
2	31	33	2
3	31	32	1
4	32	32	0
5	32	32	0
6	32	31	1
7	32	34	2
8	31	33	2
9	32	32	0
10	31	32	1
11	31	32	1
12	32	32	0
13	31	32	2
14	32	32	0
15	31	31	0
Average			0.87
Standard Deviation			0.83

Based on Tables III and IV from the test results 15 times. In Table III the average difference between the results of air humidity measurements carried out by a hygrometer and the DHT22 sensor is 5.47% with a standard deviation of 2.59%. In Table IV the difference between the results of temperature measurements by the hygrometer and the DHT22 sensor varies from 0°C to 2°C. The average difference is 0.87°C with a standard deviation of 0.83°C.

B. Pump Testing

In testing pump 1, the aim is to determine whether the pump's performance can water or not according to the threshold limit of less than 60% based on soil moisture. In testing, the number 0 indicates that the pump is not active or does not flush with a value of more than 60%, while the number 1 indicates that the pump is active or does not flush with a value of less than 60%.

TABLE V. *PUMP 1 TESTING*

No	Soil Moisture (%)	Pump 1	Information
1	56	1	Watering
2	64	0	Not Watering
3	41	1	Watering
4	47	1	Watering
5	61	0	Not Watering
6	48	1	Watering
7	52	1	Watering
8	55	1	Watering
9	62	0	Not Watering
10	64	0	Not Watering
11	51	1	Watering
12	56	1	Watering
13	61	0	Not Watering
14	57	1	Watering
15	63	0	Not Watering

Based on Table V, the results of testing 15 times. In this test, pump 1 or several groundwater pumps tested according to the specified parameter value of less than 60%, the pump is actively watering according to the parameter value by showing number 1 according to the table and when the parameter value is more than 60%, the groundwater pump will turn off or not watering by showing the number 0.

In testing pump 2, the aim is to determine the performance of the pump, whether the pump can flush or not according to the threshold limit of less than 60% based on air humidity. In testing, the number 0 indicates that the pump is not active or does not flush with a value of more than 60%, while the number 1 indicates that the pump is active or does not flush at less than 60%.

TABLE VI. *PUMP 2 TESTING*

No	Air Humidity	Pump 2	Information
1	71	0	Not Watering
2	70	0	Not Watering
3	68	0	Not Watering
4	65	0	Not Watering
5	63	0	Not Watering
6	58	1	Watering
7	62	0	Not Watering
8	62	0	Not Watering
9	59	1	Watering
10	64	0	Not Watering
11	61	0	Not Watering
12	57	1	Watering
13	63	0	Not Watering
14	66	0	Not Watering
15	69	0	Not Watering

Based on Table VI, from the results of 15 tests containing pump 2 on air humidity, the test shows that the pump is not actively watering at air humidity of more than 60% by showing the number 1. Meanwhile, when the value shows less than 60%, the air water pump will actively water according to the specified parameter values

C. Whole System Testing

Testing the entire system aims to ensure that all system components (pump, soil moisture sensor, light intensity sensor, temperature sensor and air humidity sensor) function properly and as desired. The set point that has been determined is when the soil moisture is less than 60%, the groundwater pump will water when the pump is automatically ON, when the soil moisture value is more than 60%, the groundwater pump will turn off. Meanwhile, if the air humidity value is less than 60%, the air water pump will spray the water sprayer, and when the air humidity value is more than 60%, the air water pump will turn off.

TABLE VII. *OVERALL SYSTEM RESULTS*

No	Soil Moisture (%)	Light Intensity (lux)	Temperature (°C)	Air Humidity (%)	Pump 1	Pump 2	Car Pump	Information
1	45	600	32	76	1	0	0	Succeed
2	48	709	31	77	1	0	0	Succeed
3	35	590	30	73	1	0	0	Succeed
4	59	707	32	79	0	1	0	Succeed
5	37	670	30	79	0	1	0	Succeed
6	51	644	29	76	0	1	0	Succeed
7	38	805	33	75	1	0	1	Succeed
8	34	773	34	71	1	0	1	Succeed
9	56	814	32	68	1	0	1	Succeed
10	57	812	31	65	1	0	1	Succeed
11	49	635	33	59	1	1	1	Succeed
12	55	497	33	63	1	0	1	Succeed
13	62	699	34	64	0	0	1	Succeed
14	69	728	33	61	0	0	1	Succeed
15	68	732	33	57	0	1	1	Succeed
16	67	729	33	62	0	0	1	Succeed
17	48	799	33	65	1	0	1	Succeed
18	51	772	32	69	1	0	1	Succeed
19	56	779	33	71	1	0	1	Succeed
20	72	808	33	72	0	0	1	Succeed

Based on Table 7 from 20 tests, the system as a whole functions as expected, where the pump will be activated based on the air humidity and soil moisture detected by the sensor. The automatic system works well to maintain optimal soil conditions and air humidity conditions for moon orchid plants.

IV. RESULT AND CONCLUSIONS

In this research, an IoT-based monitoring and control system for orchid cultivation was designed using a soil moisture sensor to detect soil moisture, a DHT22 sensor to detect air temperature and humidity, and also a BH1750 sensor to detect light intensity. Sensor data is connected to the ESP32 and the data obtained will be processed and sent to Firebase via an internet connection. After the data is successfully sent to Firebase, the data will be accessed or read by the Android application that is installed on the user's internet-connected smartphone. In this way, users can monitor and control directly via the Android application.

Apart from that, the control system in designing this tool is for reading data from the soil moisture sensor when it shows a soil moisture value of less than 60% which has been set in the program, then the relay connected to the ESP32 will be activated to turn on the ground water pump and the application shows information that groundwater pump ON. Next, the ESP32 will receive air humidity data. When the data shows a value of less than 60%, the relay connected to the ESP32 will turn on the air water pump and the application shows information that the air water pump is ON. Once the value of air humidity and soil humidity has reached the value set in the program of more than 60%, the relay and pump will automatically turn off (OFF). In the Android application the pump control system can be adjusted manually (OFF) or automatically (ON). Meanwhile, the monitoring system of this design uses data on light intensity, soil humidity, air humidity and temperature. This data can be monitored via an Android application in real time according to sensor readings.

Several tests were carried out on the system, testing the soil moisture sensor using two different tools, namely a soil analyzer and a soil moisture sensor. From the soil moisture sensor test data, the average difference between the soil analyzer and the soil moisture sensor is 3.93%. This shows that the two measuring instruments have fairly consistent results, although there are slight differences. The standard deviation of the two tools is 2.09%, which shows that the difference in measurements does not deviate too much from the average and indicates quite good results. Based on soil moisture sensor measurements, it provides quite consistent and accurate results compared to soil analyzers. The relatively small average difference and low standard deviation indicate that the sensor is reliable for use in monitoring soil moisture in various conditions. Testing the BH1750, there is a difference between the light intensity measured by the lux meter and the BH1750 sensor. The average difference between the lux meter and the BH1750 sensor is 62.47 lux which shows a consistent difference between the two measuring devices. The standard deviation is 35.57 lux which shows that there is quite significant variation in the differences between the measurements of the two tools which are inconsistent and varied. Differences in measurement results are caused by various factors such as tool calibration, environmental conditions during measurement or sensor characteristics of each tool. To get more accurate and consistent measurement results, it is recommended to calibrate both measuring instruments. DHT22 testing, from the results of air humidity measurements carried out by a hygrometer and DHT22 sensor, the difference between the two tools varies from 1% to 10%. The average difference is 5.47% with a standard deviation of 2.59%. This shows that the DHT22 sensor tends to produce higher air humidity values compared to the hygrometer. The average difference in temperature measurements is 0.87°C with a standard deviation of 0.83°C, this shows that the DHT22 sensor tends to be accurate in measuring temperature with a relatively small difference compared to hygrometer measurements. Overall, the DHT22 sensor shows good results in temperature measurements, there is a need to evaluate and recalibrate the sensor for air humidity measurements to obtain more accurate and consistent results.

Further testing on pump 1 and pump 2 is based on soil moisture and air humidity parameters. In the pump 1 active watering test, when the soil moisture was less than 60% and not actively watering more than 60%, this showed consistent performance in accordance with the specified parameters and showed that the soil moisture control set on pump 1 was working well. In testing pump 2, pump 2 is active for watering plants when the humidity is less than 60% and when the value is more than 60% the pump will be inactive for watering, this is in accordance with the set point that has been determined. Overall tool testing, this testing is based on predetermined parameters. This system controls three types of pumps, pump 1, pump 2 and pump auto. The system is quite effective in activating the pump based on soil moisture and air humidity, from the overall test data the soil moisture pump system is active when it is less than 60%, showing that the system responds according to the parameters with the pump being automatically ON, as well as the air humidity data when the sensor reads a value less from 60% active air humidity pump flushes with auto ON pump. The use of sensors to measure soil moisture and air humidity is quite accurate in triggering pump activation. Environmental conditions with temperature monitoring range from 29°C to 34.

The performance of the sensor used has been tested and shows that the sensor is quite accurate in monitoring the environmental conditions of orchid plants. As with the DHT22 sensor, it can measure temperature with good accuracy, although there is a slight difference in measuring air humidity compared to other measuring instruments. The soil moisture sensor functions according to the parameters determined by the conditions for moon orchid plants. The BH1750 sensor also functions to monitor the lighting conditions required by moon orchid plants.

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