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Automation of Air Humidity Monitoring and Control for Orchid Plants Using BME280 Sensor Based on IoT

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Air humidity is one of the important indicators in supporting the growth and development of plants. Mismatched humidity levels with plant needs can hinder their growth and cause root and stem rot. One type of plant that requires a certain humidity level is the Cymbidium orchid, which ideally needs air humidity between 60% and 80%. However, the fulfillment of this humidity requirement is generally still done manually, requiring time and human labor. To address this issue, an air humidity automation system is needed that can be monitored remotely to ensure the needs of the plants are met optimally. This study aims to design an Internet of Things (IoT) based air humidity automation system using the NodeMCU ESP32 microcontroller as the main control unit programmed through Arduino IDE software. This system has a BME280 sensor as a humidity detector and a mist maker as an actuator that produces cool mist to maintain humidity in the Cymbidium orchid planting space. The system monitoring is done remotely via the Blynk IoT application on smartphones. The research results show that this system successfully implemented the BME280 sensor in air humidity automation, with an average precision value of 98.91%, an accuracy of 98.98%, and an error rate of 0.076%.

Keywords: *Automation of Air Humidity, Blynk, BME280 sensor, Internet of Things, WiFI NodeMcu ESP32*

1. INTRODUCTION

The BME280 sensor is a small digital sensor that has various functions, one of which is to measure air humidity. This sensor can be utilised in various systems such as smart garden, smart home, weather monitoring, and navigation both indoors and outdoors (Suprihanto et al., 2023) . Therefore, the BME280 sensor is very suitable to be applied in orchid cultivation, which requires air humidity within a certain range-not too humid and not too dry (Gerry et al., 2020).

One type of orchid that is commonly cultivated is the Cymbidium soil orchid. These plants require air humidity in the range of 60%-80%, with 60% being the critical limit between wet and dry conditions (Marni et al., 2022). If air humidity is not maintained as needed, orchid growth can be disrupted and potentially cause rotting of the roots and stems (Gerry et al., 2020).

The problem in orchid cultivation today is that it is still done manually, which requires a lot of time and energy. To overcome this, technology is needed that can monitor and control air humidity automatically and remotely. The technology is the Internet of Things (IoT) (Aminah et al., 2022).

IoT is a technology that enables automation of various devices, and has been widely applied in agriculture and plantations as a modern solution for farmers. This technology is not only able to monitor diseases, pests, and soil fertility, but can also control micro weather such as air humidity, as well as remotely manage fertilisation, spraying, and watering automatically (Heru and Fatma 2023).

There are several studies related to the use of BME280 sensors with IoT technology. One of them is a study entitled 'Design of Smart Mini Greenhouse Based on Internet of Things'. The study

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shows that the performance of the BME280 sensor in detecting air humidity in the growing room is quite good, with an average error of 4.964% (Yuandri et al., 2021).

Another study entitled 'Comparison of Quality Between Air Humidity Sensors Using Arduino Uno' compared the performance of four air humidity sensors: DHT11, DHT21, DHT22, and BME280. As a result, the BME280 sensor showed the best performance with the highest level of accuracy and the lowest average error of 3.78% (Utama et al., 2017).

Based on these two studies, the author chose the BME280 sensor as the main sensor to detect air humidity in Cymbidium orchid cultivation. The author develops an air humidity automation system by combining concepts from both studies. The designed tool uses a BME280 sensor to detect humidity, a mist maker as an actuator to increase humidity by producing cold dew, and a DC fan to drain the dew from the water reservoir to the Cymbidium orchid growing room.

The whole system is controlled by NodeMCU ESP32, which functions as the brain of the device and is in charge of sending humidity data to the Blynk IoT application via WiFi connection. NodeMCU ESP32 also performs user identification through checking the IP address and internet connection. The detected humidity data is displayed in real-time through the IoT server and also offline through the I2C LCD. Thus, monitoring of air humidity in orchid plants can be done automatically and remotely through the Blynk IoT application.

2. METHOD

2.1 Design of Air Humidity Automation System

The air humidity automation system in the Cymbidium orchid growing room consists of two main components, namely hardware and software design. The hardware is designed using a BME280 sensor as the main sensor to detect air humidity. The NodeMCU ESP32 microcontroller acts as the main control unit that runs the automation system based on the programme that has been programmed into the microcontroller board. As an actuator, a mist maker is used to produce cold dew that serves to increase air humidity in the Cymbidium orchid growing room.On the software side, Arduino IDE software is used as a programming platform to upload the code to the NodeMCU ESP32 microcontroller. In addition, the Blynk application is used as an interface to monitor real-time air humidity conditions remotely via the internet network. The hardware system design of the air humidity automation tool is shown in Figure 1 below.

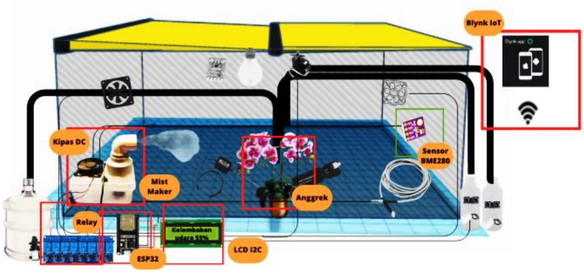

Figure 1. Hardware Design of Air Humidity Automation System

Figure 1 shows the hardware design of the air humidity automation system, which consists of a BME280 sensor as an air humidity detector and a NodeMCU ESP32 microcontroller as the main control unit. This microcontroller functions to read data from the BME280 sensor and control other components such as relays and mist makers according to the logic of the programme that has been implemented.

Orchid plants, especially Cymbidium species, require air humidity in the range of 60%-80% (Bestgrow, 2018). If the air humidity detected by the BME280 sensor is below 60%, which indicates the condition of the growing room is too dry, the relay will be active (ON) and turn on the mist maker to produce dew and raise the air humidity to reach the upper limit of 80%. Conversely, if the air humidity has reached or exceeded 80%, the system will automatically switch off the relay and mist maker so that the humidity does not exceed the optimal threshold, so that the environmental conditions remain ideal for orchid growth. To enable the system to be controlled and monitored remotely through the Internet of Things (IoT)-based Blynk application, all components are assembled according to the scheme shown in Figure 2.

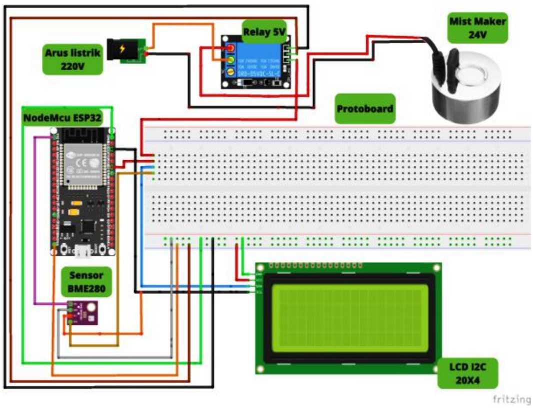

Figure 2. Schematic of air humidity automation circuit

2.2 Air Humidity Automation System Design (Software)

The workflow of the air humidity automation system is designed by utilising the WiFi connectivity feature on the NodeMCU ESP32 microcontroller. System programming is done using Arduino IDE software as a development platform to upload code to the microcontroller. For real-time remote monitoring purposes, the Blynk application is used as a user interface that displays air humidity data detected by the BME280 sensor.

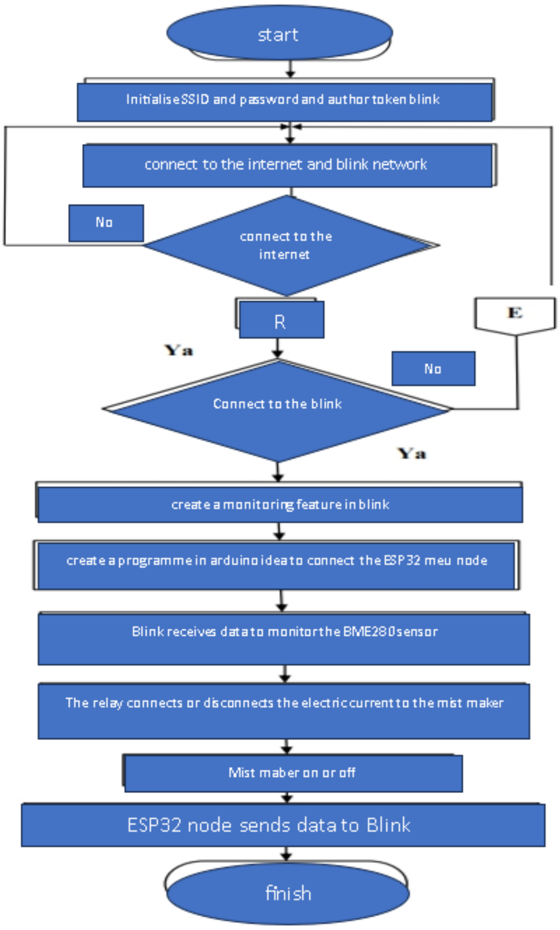

Figure 3. Software Flow Chart

Figure 3 shows the flow chart of the software system on the humidity automation tool. The initial stage in this process is to initialise the SSID and password of the WiFi network used, as well as the authentication token from Blynk which can be accessed through a template on the official Blynk website. Next, the system connects to the internet network and Blynk server. If the connection is successful, then the process continues with activating the monitoring feature on the Blynk application. If the internet connection is lost, the system will attempt to reconnect to the network until successful.

After the monitoring feature is successfully configured in the Blynk application, the next step is to develop a programme using the Arduino IDE software. This programme aims to integrate the NodeMCU ESP32 microcontroller with the Blynk application, so that the BME280 sensor reading data can be sent and displayed in real-time.

If the NodeMCU ESP32 has been connected to the Blynk server, the air humidity data from the BME280 sensor will be sent periodically. If the detected air humidity is below 60% (indicating dry air conditions), then the relay will activate and flow current to the mist maker, so that the device turns on and increases the air humidity. Conversely, if the humidity value exceeds 80% (air conditions are too humid), the relay will cut off the electric current, causing the mist maker to turn off automatically. In addition, the Blynk app can also send notifications to the user's device when the mist maker is active, as an indicator that the air humidity in the grow room is below the ideal threshold.

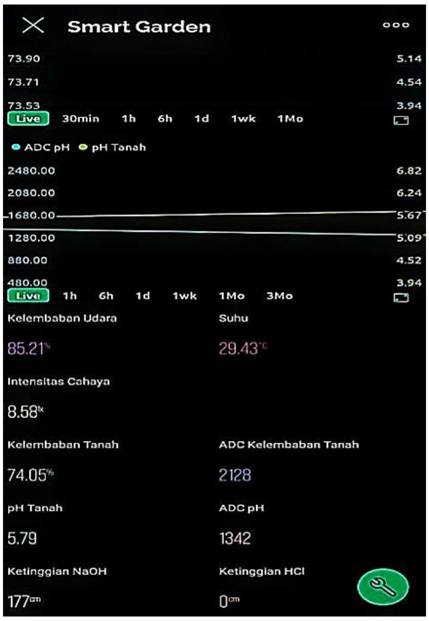

Figure 4. Air humidity output display in the blynk app

Figure 5. Air humidity output display on blynk website

2.3 Design of Blynk Monitoring Features

In the air humidity automation system, the Blynk application acts as a platform for monitoring the air humidity data of Cymbidium orchid plants. This system utilises the same WiFi connectivity between the NodeMCU ESP32 microcontroller and the Blynk application, and uses the authentication token generated by Blynk to secure the connection between devices. The database used in this system is in the form of air humidity data from the BME280 sensor reading. The data is stored and displayed through the Datastream feature on Blynk IoT. To create a monitoring feature, users can access the Web Dashboard menu, then add Chart elements, give display names (labels), and select the Datastream that matches the air humidity parameters to be displayed. The output display of air humidity monitoring on the Blynk application can be seen in Figure 4, while the monitoring interface through the Blynk website is shown in Figure 5.

2.4 Combination of Air Humidity Automation System Components

Before all components of the device are assembled into one system, the process of testing and verifying the function of each component is carried out to ensure that all devices work properly and according to specifications. After all components are declared to be functioning properly, the air humidity automation system assembly process can be carried out as a whole.

System circuit assembly includes integration between sensors, actuators, microcontrollers, and communication modules used in the air humidity automation system. Details of the connections between component pins can be seen in Table 1 below.

Table 1. List of Interconnected Pins in the Air Humidity Automation Circuit.

NodeMcu ESP32	**Sensor BME280**	***Relay***	**LCD I2C 20 x 4**
Vin (5 Volt)	**-**	**VCC**	**VCC**
3V3	Vin	-	-
Ground	*Ground*	*Ground*	*Ground*
D21	SDA	-	SDA
D22	SCL	-	SCL
D23	-	IN6	-

Table 1 lists the pin connections between the components used in the humidity automation system. After all components are assembled according to the pin configuration listed in the table, the next step is to connect the mist maker actuator to the relay module and 24V voltage adapter.

After the tool assembly process is complete, the air humidity automation system is implemented in a specially designed block-shaped Cymbidium orchid growing room. This growing room is made using acrylic material with a thickness of 3 mm and has dimensions of 100 cm × 80 cm × 80 cm. The base of the growing room uses a plywood board with a thickness of 5 mm, while the roof is designed as a sliding roof made of 3 mm thick plywood.

Figure 6. The result of designing an air humidity automation device.

3. RESULTS AND DISCUSSION

The main components used in the air humidity automation system include BME280 sensor, mist maker, DC fan, relay module, 20×4 I2C LCD, 24V adapter for mist maker, and NodeMCU ESP32 microcontroller. The complete circuit of the air humidity automation system is shown in Figure 6.

Before the system is implemented to monitor and control the air humidity in the growing room, a series of tests are conducted to ensure the performance of the system is optimal. The tests carried out include: WiFi NodeMCU ESP32 Range Testing, aims to evaluate the stability of network connectivity used in remote monitoring systems. Testing the BME280 Sensor Response to the Mist Maker Actuator, aims to see the relationship between the humidity reading by the sensor and the activation of the mist maker in maintaining the humidity of the planting room. BME280 Sensor Characteristic Testing, conducted to assess the accuracy of the sensor in detecting air humidity, by comparing it to a standard measuring instrument (Krisbow DT895B). Output Data Validation Testing, which includes verifying the suitability of humidity data displayed on the I2C LCD, serial monitor, and Blynk platform. The results of the design and implementation of the air humidity automation system are shown in Figure 6.

3.1 Communication Distance Testing of Smartphone Hotspot to WiFi NodeMCU ESP32

Testing the communication distance between the smartphone hotspot and the NodeMCU ESP32 WiFi module was carried out to evaluate the delay in sending the BME280 sensor reading data to the Blynk platform and the display on the Arduino IDE serial monitor. This trial aims to determine the effective range of wireless communication using a personal hotspot network in stable signal conditions.

Data collection was conducted indoors with variations in the distance between the NodeMCU ESP32 and the smartphone hotspot source, starting from 0 metres to 50 metres. Observations focused on response delay and data connection stability during the monitoring process.

The results of the communication distance test between the smartphone hotspot and the WiFi NodeMCU ESP32 are presented in Table 2 below.

Table 2. Communication Distance Testing Results of Smartphone Hotspot to WiFi NodeMCU ESP32

No	Distance of WiFi from Device (meters)	Time of Sending Data to Blynk	Time of Sending Data to Serial Monitor	Delay (s)
1	0	09:24:15	09:24:17	2
2	5	09:28:02	09:28:02	2
3	10	09:31:49	09:31:51	2
4	15	09:35:36	09:35:38	2
5	20	Connection Lost	Connection Lost	-
6	50	Connection Lost	Connection Lost	-

Table 2 presents the results of testing the communication distance between the smartphone hotspot and the NodeMCU ESP32 WiFi module. Based on the data, it can be seen that the time of sending data to the Blynk platform is faster than sending data to the serial monitor. This is due to the initialisation sequence in the program, where the connection to Blynk is done first before the initialisation to the serial monitor.

At a distance of 20 metres, the connection between the NodeMCU ESP32 and the smartphone hotspot was lost, so the measurement data could not be sent or displayed on the Blynk platform or the serial monitor. This condition shows that the quality and range of network sources greatly affect the stability of the connection and the ability to store data online (Anto et al., 2021).

Tests show that within a distance of 0-15 metres, the system is still able to transmit data consistently with a delay of ±2 seconds. However, at a distance of 20-50 metres, there was no more data transmission, indicating that the effective range of the hotspot network was limited to 15 metres in this test condition.

The conclusion of this test is that the humidity automation system has a stable WiFi communication range of up to 15 metres with an average delay of 2 seconds. The quality and range of the smartphone hotspot network proved to play an important role in determining the stability of data transmission from the BME280 sensor to the IoT-based monitoring device.

3.2 Testing the BME280 Sensor Value on Mist Maker Performance

Testing the value of the BME280 sensor on the performance of the mist maker is carried out to evaluate the extent of the mist maker's response to changes in air humidity values detected by the sensor. This test is carried out indoors with controlled environmental conditions to ensure measurement stability.

During the test, the system is monitored directly to observe when the mist maker is on (ON) and off (OFF) based on predetermined humidity thresholds, which are <60% for dry air conditions and >80% for humid air conditions.

The test results show that the mist maker switches on automatically when the air humidity value is below 60%, and stops working when the humidity value reaches or exceeds 80%. This shows that the air humidity automation system responds well to the BME280 sensor output in controlling humidity according to the needs of Cymbidium orchid plants. The test result data is presented in Table 3 below.

Table 3. Testing Results of BME280 Sensor Value against Mist Maker Performance

No	Date	Time	RH (%)	Mist Maker Status	Remark
1	12/24/2023	09:51:00	98,628	Off	Successful
2	12/24/2023	10:09:00	82,641	Off	Successful
3	12/24/2023	10:32:00	58,436	On	Successful
4	12/24/2023	10:33:00	56,156	On	Successful
5	12/24/2023	10:34:00	57,565	On	Successful
6	12/24/2023	10:36:00	59,833	On	Successful
7	12/24/2023	10:56:00	69,723	Off	Successful
8	12/24/2023	11:02:00	78,813	Off	Successful
9	12/24/2023	11:42:00	80,817	Off	Successful
10	12/24/2023	13:04:00	83,266	Off	Successful

Table 3 shows the test results of the BME280 sensor value on the performance of the mist maker in the air humidity automation system. Orchid plants require optimal air humidity in the range of 60%-80%. Air humidity below 60% is considered a critical threshold that can negatively affect the health of orchid plant roots, stems, and buds (Marni et al., 2022).

To prevent such conditions, the programme has been configured as shown in Figure 7, i.e. the mist maker will automatically switch on (ON) when the air humidity detected by the BME280 sensor is below 60%, and will switch off (OFF) when the air humidity reaches or exceeds 80%.

Based on the data in Table 3, it can be concluded that the system responds well to the sensor output. The mist maker activates when the humidity is <60% and stops working when the humidity is >80%, according to the predefined limits. This indicates that the performance of the mist maker is effective in maintaining air humidity in the Cymbidium orchid growing room, thus preventing potential damage to plant tissues.

```
if (humidity < 60) {
    digitalWrite(RELAY_MIST_MAKER, LOW); // Turn relay 6 on
  Serial.println("mist maker hidup");
  Blynk.logEvent("mist_maker");
  }
  else if (humidity > 80) {
    digitalWrite(RELAY_MIST_MAKER, HIGH);  // Turn relay 6 off
     Serial.println("mist maker mati");
```

Figure 7. Program Arduino IDE

3.3 Testing BME280 Sensor Characteristics

Testing the characteristics of the BME280 sensor is carried out to evaluate the level of accuracy, precision, and error of the sensor in measuring air humidity. This test is carried out by comparing the measurement results of the BME280 sensor against the reference value obtained from the comparison tool, namely Krisbow DT895B.

Data collection was carried out 10 times to ensure consistency of results and increase data reliability. The measurement data obtained through the Blynk application was downloaded in CSV format, then analysed using Microsoft Excel software. Calculations were performed to determine the mean error, absolute error, and percentage error to quantitatively assess the characteristics of the BME280 sensor. The results of testing the characteristics of the BME280 sensor against the Krisbow DT895B are presented in Table 4 below.

Table 4. presents the test results of the BME280 sensor characteristics

Krisbow DT895B	Average Sensor Value (BME280)	Bias	Standard Deviation	Accuracy (%)	Precision (%)	Error (%)
57,00	57,069	0,069	0,352	98,026	98,149	0,121
66,40	66,409	0,009	0,869	96,060	96,074	0,014
73,10	73,200	0,100	0,333	98,497	98,635	0,137
75,60	75,537	0,063	0,211	99,079	99,161	0,083
79,30	79,200	0,100	0,134	99,367	99,493	0,126
81,90	81,823	0,077	0,048	99,731	99,825	0,094
84,10	84,154	0,054	0,132	99,467	99,531	0,064
85,50	85,540	0,040	0,119	99,535	99,582	0,047
86,40	86,422	0,022	0,080	99,698	99,723	0,025
94,60	94,647	0,047	0,088	99,671	99,720	0,050

Table 4 presents the test results of the BME280 sensor characteristics. Based on these results, the BME280 sensor shows excellent performance in terms of bias, standard deviation, accuracy, precision, and error rate.

The analysis results show that the BME280 sensor has an average accuracy of 98.91%, an average precision of 98.98%, and an average error of 0.076%. The standard deviation of the measurement results is also below 2%, which indicates high data consistency. Referring to existing standards, good accuracy and precision are above 95%, while the acceptable error for air humidity sensors is less than 5% (Riyanto, 2014). Thus, the BME280 sensor can be categorised as a reliable and feasible sensor for use in air humidity monitoring systems.

The performance of this sensor that is close to the actual value is supported by capacitive technology based on silicon semiconductor materials that are able to respond to changes in air humidity through changes in the dielectric constant of the material (Hengko, 2025). Therefore, the BME280 sensor is very suitable for use in monitoring and controlling air humidity systems in Cymbidium orchid growing rooms.

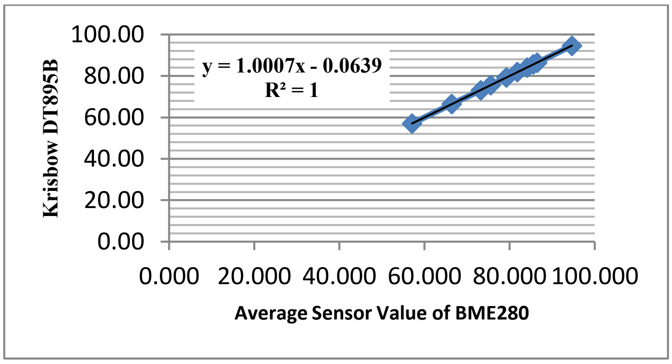

Figure 8. Graph of the relationship between the Krisbow DT895B value and the BME280 sensor.

The coefficient of determination $R^2 = 1$ indicates a very strong correlation between the results of air humidity measurements using the Krisbow DT895B comparison tool and the BME280 sensor. This $R^2 \approx 1$ value fulfils the criteria for correlation feasibility and is statistically acceptable (Sugito and Marliyana 2021).

Based on the graph in Figure 8, it can be seen that the relationship between the readings from the Krisbow DT895B and the BME280 sensor shows a very strong positive correlation. This is evidenced by the value of the correlation coefficient (r) and the coefficient of determination (R^2), both of which reach the maximum value of 1. This perfect correlation indicates a very high level of precision of the BME280 sensor in representing the air humidity value compared to the standard comparison tool, thus strengthening the validity of using the BME280 sensor in the air humidity monitoring automation system.

3.4 Data Validation Testing on I2C LCD, Serial Monitor and Blynk

Data validation testing is carried out on I2C LCD, serial monitor and blynk to verify whether the data displayed by the three devices is identical. Suppose the output results displayed on the I2C LCD, serial monitor and blynk are the same. In that case, it can be concluded that the program that has been uploaded to the NodeMcu ESP32 microcontroller using the Arduino IDE software is successful. Details of the results of the data validation test can be seen in table 5 below.

Table 5. Data Validation Test Results on I2C LCD, Serial Monitor and Blynk

No	LCD I2C	*Serial Monitor*	Blynk	Remark
	RH (%)	RH (%)	RH (%)	
1	91,38	91,38	91,378	Valid
2	91,18	91,18	91,184	Valid
3	91,08	91,08	91,075	Valid
4	90,94	90,94	90,942	Valid
5	90,78	90,78	90,781	Valid

Table 5 presents the results of data validation tests displayed on the I2C LCD, Serial Monitor, and Blynk application. The output produced by the three media shows similar values. The only difference that appears lies in the rounding of numbers on the data display on the I2C LCD and Serial Monitor when compared to the data display in the Blynk application. Thus, it can be concluded that the program embedded in the NodeMCU ESP32 microcontroller through the Arduino IDE software has run according to the designed instructions, and is able to display data in real-time. The conformity of the data between the I2C LCD, Serial Monitor, and Blynk is shown in Figure 9, Figure 10 and Figure 11.

Figure 9. Results of air humidity measurements displayed on the I2C LCD.

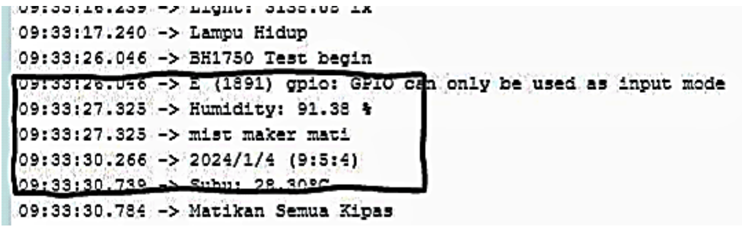

Figure 10. Results of air humidity measurements displayed on the serial monitor.

2771	1/4/2024 9:35	
2772	1/4/2024 9:35	91,184
2773	1/4/2024 9:35	
2774	1/4/2024 9:35	
2775	1/4/2024 9:35	
2776	1/4/2024 9:33	
2777	1/4/2024 9:33	
2778	1/4/2024 9:33	91,378
2779	1/4/2024 9:33	

Figure 11. Results of air humidity measurements displayed in Blynk

4. CONCLUSION

The design of software, hardware, and testing of the tool's working system have been successfully carried out. Based on the results of the mist maker performance test, it is proven that the tool operates according to the instructions of the designed program. There is a delay in sending data to the Blynk and Serial Monitor applications for 2 seconds, and the system can send data stably up to a distance of 15 meters.

In testing the characteristics of the device, the BME280 sensor showed very effective performance in measuring air humidity in the Cymbidium orchid planting room. This is evidenced by an average accuracy rate of 98.81%, an average precision rate of 98.98%, and an average error rate of only 0.076%. In addition, the linearity graph shows a coefficient of determination of 1, which indicates very good quality measurement results. The output displayed via the I2C LCD, Serial Monitor, and Blynk application shows the consistency of air humidity values at the same time, strengthening evidence that the device is functioning optimally.

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