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Implementation of a Water Nutrient Monitoring System for Integrated IoT-Based Hydroponics at CV Tirta Fertindo

Ananda Pandu Candra Purnomo[1], **Annas Faiz Assariy**[2] **, Galih Prastiawan**[3] **, Zaenal Arifin***[4]
Electrical Engineering Faculty of Engineering, Universitas Dian Nuswantoro
E-mail : xzaenal@dsn.dinus.ac.id
***Corresponding Author**

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Abstract - CV Tirta Fertindo Pratama is an agribusiness company specializing in hydroponics in Semarang. The company manages hydroponic farms for various vegetables and fruits but faces challenges in manually measuring Potential of Hydrogen (pH), electrical conductivity (EC), and Total Dissolved Solids (TDS), which affect product quality. To address this issue, an Internet of Things (IoT)-based hydroponic plant monitoring system was developed using temperature, pH, and TDS sensors connected to an ESP32 microcontroller. This system enables remote automated measurement and control, displaying data via an LCD. The implementation of this IoT system enhances efficiency and consistency in plant management by enabling real-time monitoring and more precise control, reducing the risk of manual errors, and improving hydroponic crop production.

Keywords - hydroponics; IoT; pH; EC; TDS; microcontroller

1. INTRODUCTION

CV Tirta Fertindo Pratama is an agribusiness company focused on hydroponics. The company manages several hydroponic farming lands in Semarang, cultivating various types of vegetables and fruits such as lettuce, spinach, tomatoes, melons, watermelons, and papayas. The production process at CV Tirta Fertindo Pratama begins with seedling, plant nursery, and planting in hydroponic media. Subsequently, the plants are maintained by manually controlling the nutrient levels in the water using measuring tools.

AB Mix fertilizer is applied daily, with the dosage adjusted based on pH and EC measurements. To maintain plant quality, the AB Mix fertilizer dosage must be precise; if the nutrient level in the water is below 1.4, 100 ml of AB Mix is added to increase the concentration by 0.1. Conversely, if the nutrient level exceeds the limit, water is added to reduce the excess nutrients. pH adjustment is done by adding fertilizer C to lower the pH if it is too high, or plain water to raise the pH if it is too low. CV Tirta Fertindo Pratama faces significant challenges in manually measuring pH, EC, and TDS, which impact quality consistency [1], [2]. These parameters are crucial for determining optimal nutrient dosing in hydroponic systems [3], [4]. The use of pH meters, EC meters, and TDS meters, which require regular calibration and cleaning, as well as reliance on employee skills for fertilizer application and temperature regulation, results in product quality instability and inconsistent quality standards.

Figure 1. Hydroponic Proses in CV Fertindo Pratama

To address this issue, a solution is proposed in the form of an Internet of Things (IoT)-based hydroponic monitoring system. This system uses temperature, pH, and TDS sensors to automatically measure water conditions. Data from the sensors will be controlled by an ESP32 microcontroller to automatically regulate water temperature and fertilization, and will be displayed on an LCD screen and a website. With the ESP32, this system enables remote monitoring and control, thereby improving efficiency and consistency in hydroponic management and optimizing production outcomes.

2. RESEARCH METHOD

This research aims to develop an Internet of Things (IoT)-based hydroponic plant monitoring system to address challenges in measuring and controlling pH, EC, TDS, and temperature at CV Tirta Fertindo Pratama. Below is the research methodology employed:

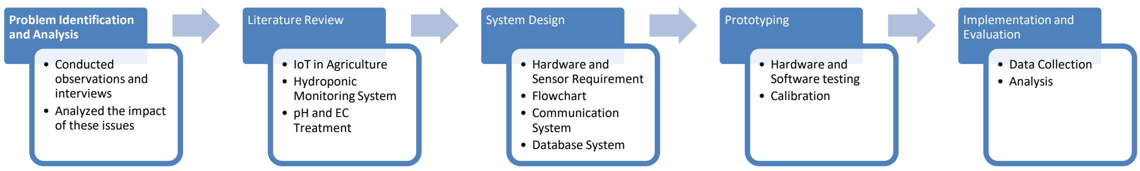


Figure 2. Research Method Diagram

2.1. Problem Identification and Analysis

The research methodology begins with a problem identification study. In this stage, the issues faced by CV Tirta Fertindo Pratama, such as inaccuracies in pH, EC, and TDS measurements, as well as temperature control relying on manual methods, are identified to determine the necessary solutions. Following this, a literature review analysis is conducted to explore information related to hydroponic monitoring technologies and IoT to understand the fundamental principles and relevant technologies. The measurement and control process is conducted on a fixed schedule, at 08:00, 12:00, 13:00, and 16:00, to ensure that the pH and EC remain within the desired range. The ideal pH is between 6.4–6.8, while the EC (nutrient content) should be in the range of 1.4–2. The greenhouse temperature must also be maintained at a cool temperature of around 28°C using cooling boxes or shade nets to stabilize the temperature [1].

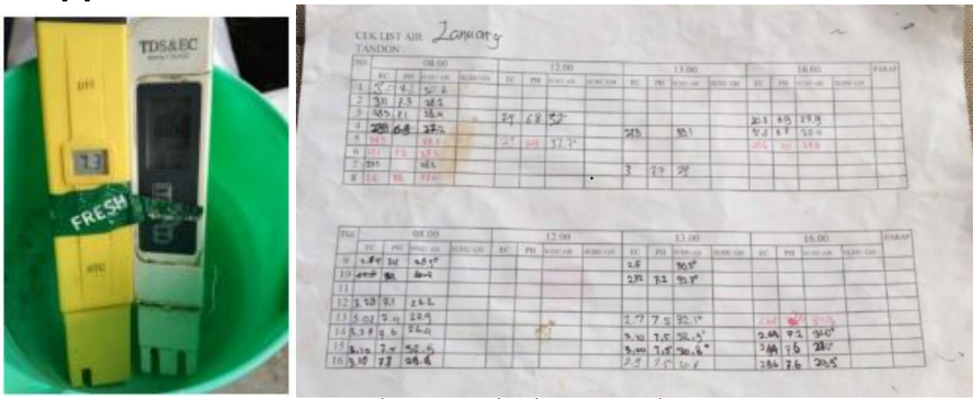


Figure 3. Daily Report Checking pH and EC

2.2. Literature Review

a. Internet of Things (IoT) in Agriculture

The Internet of Things (IoT) has been widely applied in the agricultural sector to enhance efficiency and effectiveness in production processes. IoT enables the automation of various processes, including real-time monitoring of environmental conditions, irrigation, and nutrient delivery to plants. The use of IoT in agricultural systems can reduce reliance on manual labor and improve the accuracy of decision-making related to farmland management. IoT-based hydroponic systems utilize various sensors to detect environmental parameters such as temperature, humidity, pH, and EC [5], [6]. ESP32 microcontrollers are widely adopted due to their connectivity and computing capabilities [7], [8]. Additionally, microcontrollers such as the ESP32 are commonly used in these systems due to their Wi-Fi connectivity and sufficient processing capabilities to handle data from multiple sensors.

b. The Influence of pH and EC on Hydroponic Plant Growth

pH and EC are critical factors in plant health; imbalance may result in deficiencies or toxicities that reduce yield [3], [4], [9]. The optimal pH range for most hydroponic plants is between 5.5 and 6.8, while the ideal EC value depends on the type of plant being cultivated. Imbalances in these parameters can lead to nutrient deficiencies or toxicities, negatively impacting plant growth and yield. The use of automated systems for fertilization and temperature control in hydroponics has been proven to enhance the stability of plant growth environments. IoT-based automated fertilization systems can increase crop production by 20-30% compared to manual methods [6]. Furthermore, temperature control using automated cooling systems also helps maintain ideal conditions within greenhouses [7].

2.3. System Design

In the system design phase, appropriate temperature, pH, and TDS sensors are selected based on the monitoring requirements. These sensors are chosen for their accuracy and precision in measuring hydroponic plant parameters. The ESP32 is selected as the microcontroller due to its capability to process data from the sensors and control the system automatically.

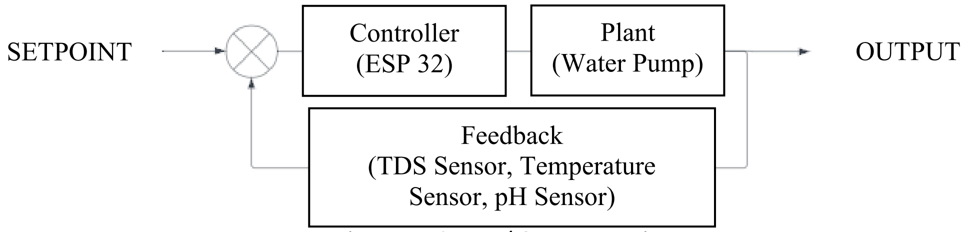


Figure 4. Control System Design

The control system design includes the development of algorithms to regulate water temperature and fertilization based on sensor data. The system will also be equipped with an LCD screen to display data locally, as well as integration with an IoT platform to enable remote monitoring and control through a website [7].

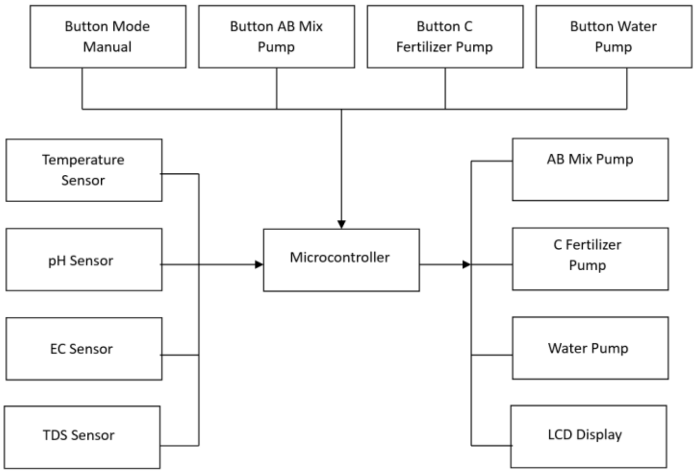


Figure 5. Design Diagram Control

The next stage is prototype development, which involves assembling hardware components such as sensors and the ESP32, as well as developing the necessary software. The software will include programs for reading sensor data, controlling devices, and transmitting data to the IoT platform. Integration of the LCD screen and website is also carried out to display information directly on-site. Once the prototype is assembled, testing and calibration are conducted. Sensor functionality tests are performed to ensure data accuracy, followed by system calibration to guarantee measurement consistency. Field testing is conducted by implementing the system in the hydroponic fields of CV Tirta Fertindo Pratama to evaluate the system's performance under real-world conditions and make necessary adjustments.

After the system is implemented, the performance evaluation phase begins. Data is collected to assess the extent to which the IoT system improves the efficiency of plant management, with a focus on product quality and consistency. The results are analyzed to measure the system's impact on pH, EC, and temperature control compared to the previous manual methods. Finally, documentation and reporting are carried out to record the entire development, implementation, and evaluation process of the system. System analysis is required to present the methodology, results, analysis, and recommendations for further development or application of the system in other locations. This methodology is designed to provide an effective and efficient solution to the challenges faced by CV Tirta Fertindo Pratama in hydroponic plant management, ensuring that the developed IoT system enhances overall product quality and consistency.

3. RESULTS AND DISCUSSION

The design of the device consists of several parts with different functions. The visualization provided by this design is expected to simplify the device fabrication process. The device includes:

1. Three XLR Chassis Mounts: Used to house the temperature sensor, pH sensor, and TDS sensor.
2. Three Peristaltic Pumps:
   The first pump functions as the AB Mix fertilizer supplier.
   The second pump functions as the fertilizer C supplier.
   The third pump functions as the water supplier.
3. LCD Screen: Displays sensor data in real-time.
4. Power Socket and Power Button: Supplies electricity and controls the device's power (on/off).

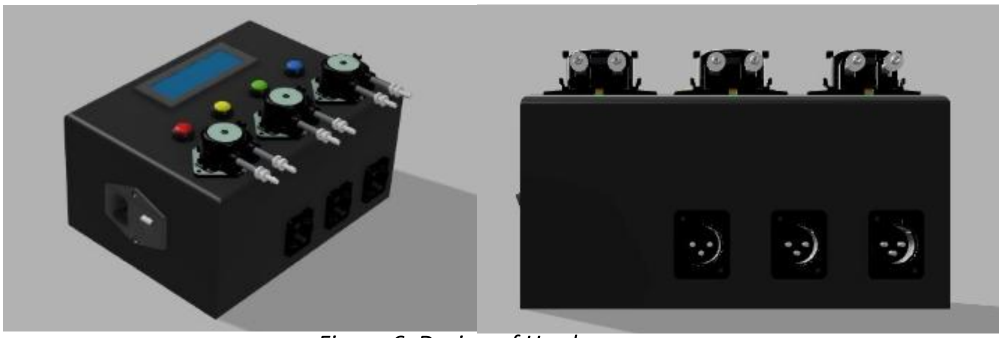
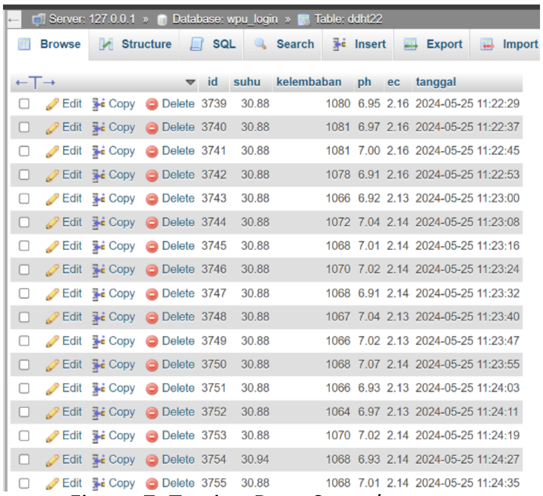


Figure 6. Design of Hardware

3.1 Water pH Control System

The DS18B20 sensor and DFRobot pH sensor calibration confirmed accurate readings aligned with manual devices [10]. The system automatically adjusted EC levels through conversion of TDS data, enabling real-time water nutrient control [11]. Testing of the pH V1 Dfrobot sensor was conducted to evaluate its performance. The pH V1 Dfrobot sensor is connected to a pump and sends data to the microcontroller to activate the pump when the water pH falls below the predetermined set point. The testing was carried out at the partner's location by inserting the pH V1 Dfrobot probe into a water tank. The water pH was measured using a conventional pH meter and compared with the data obtained by the pH V1 Dfrobot sensor connected to the microcontroller, with the results displayed on the LCD. The NodeMCU ESP32 microcontroller sends data to a MySQL database using the HTTP POST method, which is then displayed on the website user interface. Unlike HTTP GET, HTTP POST transmits data in the request body, making it more secure and capable of handling larger volumes of data. Testing was conducted by sending sensor data from the ESP32 to a web server. The received data is stored in the sensor_data table in the MySQL database. Below is an example of successfully stored data.


Server: 127.0.0.1 » Database: wpu_login » Table: ddht22

Browse Structure SQL Search Insert Export Import

				id	suhu	kelembaban	ph	ec	tanggal
☐	Edit	Copy	Delete	3739	30.88	1080	6.95	2.16	2024-05-25 11:22:29
☐	Edit	Copy	Delete	3740	30.88	1081	6.97	2.16	2024-05-25 11:22:37
☐	Edit	Copy	Delete	3741	30.88	1081	7.00	2.16	2024-05-25 11:22:45
☐	Edit	Copy	Delete	3742	30.88	1078	6.91	2.16	2024-05-25 11:22:53
☐	Edit	Copy	Delete	3743	30.88	1066	6.92	2.13	2024-05-25 11:23:00
☐	Edit	Copy	Delete	3744	30.88	1072	7.04	2.14	2024-05-25 11:23:08
☐	Edit	Copy	Delete	3745	30.88	1068	7.01	2.14	2024-05-25 11:23:16
☐	Edit	Copy	Delete	3746	30.88	1070	7.02	2.14	2024-05-25 11:23:24
☐	Edit	Copy	Delete	3747	30.88	1068	6.91	2.14	2024-05-25 11:23:32
☐	Edit	Copy	Delete	3748	30.88	1067	7.04	2.13	2024-05-25 11:23:40
☐	Edit	Copy	Delete	3749	30.88	1066	7.02	2.13	2024-05-25 11:23:47
☐	Edit	Copy	Delete	3750	30.88	1068	7.07	2.14	2024-05-25 11:23:55
☐	Edit	Copy	Delete	3751	30.88	1066	6.93	2.13	2024-05-25 11:24:03
☐	Edit	Copy	Delete	3752	30.88	1064	6.97	2.13	2024-05-25 11:24:11
☐	Edit	Copy	Delete	3753	30.88	1070	7.02	2.14	2024-05-25 11:24:19
☐	Edit	Copy	Delete	3754	30.94	1068	6.93	2.14	2024-05-25 11:24:27
☐	Edit	Copy	Delete	3755	30.88	1068	7.01	2.14	2024-05-25 11:24:35

Figure 7. Testing Data Stored

3.2 Testing and Implementation

The testing procedure begins with individual sensor testing. The pH V1 Dfrobot sensor is tested by comparing its readings with a pH meter. Sensor calibration is performed to obtain data or results that closely approximate actual values. The test is conducted by collecting data 20 times. The Analog TDS Sensor is tested to evaluate its performance in measuring TDS. The obtained TDS values are converted into EC values using the Hanna method, as the partner uses an EC meter as the standard for measuring nutrient concentration in water. The Analog TDS Sensor transmits data to the ESP32 microcontroller, which processes it into EC values. The DS18B20 temperature sensor is tested by comparing its readings with a hygrometer. Sensor calibration is performed to obtain data or results that closely approximate actual values. The sensor test results can be seen in the following table:

Table 1. Testing TDS Sensor

Testing Number	Result and Calibration		
	TDS Measurement	TDS Sensor Dfrobot	Error Percentage (%)
1	1164	1170	0.513%
2	1169	1170	0.085%
3	1170	1170	0.000%
4	1172	1172	0.000%
5	1171	1171	0.000%
6	1171	1171	0.000%
7	1172	1171	0.085%
8	1172	1171	0.085%
9	1171	1171	0.000%
10	1171	1170	0.085%
11	1164	1170	0.513%
12	1169	1170	0.085%
13	1170	1172	0.171%
14	1172	1171	0.085%
15	1171	1171	0.000%
16	1171	1171	0.000%
17	1172	1171	0.085%
18	1172	1171	0.085%
19	1171	1171	0.000%
20	1171	1171	0.000%
Average Error Percentage			0.094%

Figure 8. Comparation Testing pH Sensor

The "SIHITER" system is designed to maintain hydroponic environmental conditions by monitoring water temperature, pH, and EC in real-time using sensors installed in the water reservoir. Testing of this system has shown that the AB mix nutrient pump, pH up pump, and pH down pump function effectively in regulating nutrient dosage and adjusting the solution's pH within the required range for plant growth.

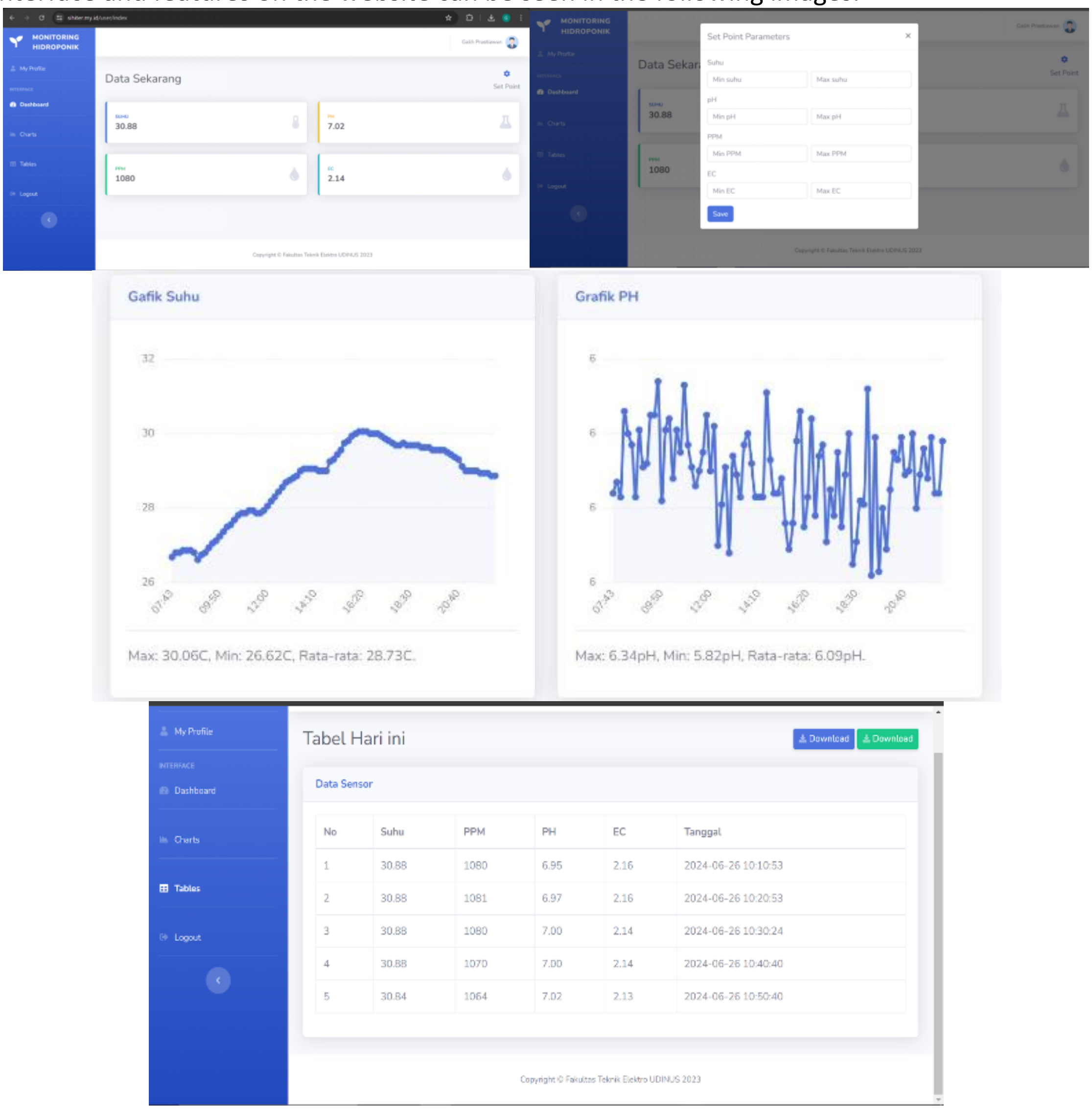
Table 2. Testing and Calibration Thermal Sensor

Testing Number	Thermal Measurement	Thermal Sensor DS18B20	Error Percentage (%)
1	29	29.06	0.0021
2	29	29.08	0.0028
3	29	29.14	0.0048
4	30	30.1	0.0033
5	30	30.12	0.0040
6	31	30.88	0.0039
7	31	30.95	0.0016
8	30	30.12	0.0040
9	30	30.12	0.0040
10	29	29.08	0.0028
Average Error			**0.0033**

The "SIHITER" system operates in two modes: automatic and intervention. In automatic mode, the microcontroller effectively regulates nutrient dosage and pH adjustments based on setpoints configured through the website. This feature allows users to remotely control and monitor plant conditions without direct manual interaction with the system. Conversely, the intervention mode enables manual adjustments via the device menu, providing additional flexibility for plant maintenance according to specific needs.

Figure 9. Implementation SIHITER on Field

During testing with lettuce plants, which require an optimal pH range of 6.4 - 6.8 and an EC range of 2.1 - 2.3, the system successfully maintained pH and EC within the optimal limits. The pumps operated automatically to adjust pH and EC levels as needed, which could be configured using the setpoint feature on the website. The website interface supports remote monitoring and provides access to historical data for analysis and troubleshooting [12]. The interface and features on the website can be seen in the following images:



No	Suhu	PPM	PH	EC	Tanggal
1	30.88	1080	6.95	2.16	2024-06-26 10:10:53
2	30.88	1081	6.97	2.16	2024-06-26 10:20:53
3	30.88	1080	7.00	2.14	2024-06-26 10:30:24
4	30.88	1070	7.00	2.14	2024-06-26 10:40:40
5	30.84	1064	7.02	2.13	2024-06-26 10:50:40

Figure 10. Main Page and Set Point View

The website connected to "SIHITER" functions to provide real-time data on temperature, pH, and EC, as well as enabling users to access graphs, daily reports, and warning notifications if environmental conditions fall outside the desired range. The provided graphs facilitate the monitoring of changes in hydroponic environmental conditions, while daily reports assist in analyzing AB mix nutrient consumption and optimizing further system management.
During testing, the consumption of nutrients A and B in a system with 5 planting holes was recorded at approximately 20 ml over a four-day period. This data provides a reliable estimate for nutrient consumption in larger systems, such as those with 500 planting holes at the partner's site. After implementation at the partner's location, the "SIHITER" system functioned according to the initial design and demonstrated good performance. However, some aspects require further evaluation to ensure optimal performance on a larger scale, which will be discussed in more detail in the following chapter.

Overall, the "SIHITER" system has demonstrated its ability to manage hydroponic environments automatically and efficiently. Testing and implementation on a larger scale confirm that the system is reliable in maintaining pH, temperature, and EC conditions according to plant requirements. Further evaluation and improvements will be carried out to ensure the system continues to function optimally in broader applications.

4. CONCLUSION

The implementation of an IoT-based hydroponic plant monitoring system has brought significant changes to the management and monitoring of plants at CV. Fertindo Pratama. Prior to this system, monitoring was done manually or with simple, non-automated devices, resulting in limited information and time-consuming data collection. However, with the installation of the IoT system, the monitoring process has become more automated and integrated, enabling real-time supervision of water temperature, pH, EC, and other conditions remotely through the website.

This system not only simplifies tasks for partners such as farmers or greenhouse managers by providing quick access to critical information about plant conditions but also enhances decision-making efficiency regarding plant care and nutrient management. Furthermore, the ability to control critical factors such as water temperature, pH, and EC with greater precision helps improve overall hydroponic plant production. By consistently providing the right nutrients, the system reduces the risk of plant stress and optimizes growth.

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