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Monitoring and Control System for Organic Vegetable Crops using Aeroponic Methods Based on the Internet of Things

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ABSTRACT

Organic farming offers environmental and health benefits but faces challenges in controlling nutrients, pH, temperature, and humidity. This study develops an IoT-based aeroponic monitoring and control system for organic vegetable cultivation. Environmental parameters—pH, nutrients, temperature, and humidity—are measured in real time using sensors connected to an ESP32 NodeMCU. Data is transmitted to Firebase and displayed on an Android application. The system features automatic water spraying based on temperature and humidity, as well as manual pump control via the app. Results show high measurement accuracy (error: pH 0.15%, TDS 3.68%, temperature 1.83%, humidity 0.31%, water temperature 0.5%). The Android app allows easy monitoring and control, supporting sustainable and efficient organic farming.

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INTRODUCTION

Organic farming has been a topic of concern in recent decades due to its important role in achieving environmental sustainability and public health [1]. However, based on surveys conducted in the garden, farmers face obstacles in conventional vegetable cultivation, namely: Difficulties in optimizing plant nutrients, difficulties in maintaining soil pH balance, difficulties in monitoring the temperature and humidity of the surrounding environment, and weed disturbances that can reduce the quality of crop yields. To overcome this, organic vegetable cultivation can be applied using the aeroponic method.

The aeroponic method is a method of farming using air. In their application, plants are placed in a hanging position and given mist-shaped nutrients, offering the advantages of ease of harvesting, efficient land use and nutrient control. However, conventional monitoring of plant growth support parameters takes time, the use of IoT technology is a solution to overcome this.

The integration of IoT technology allows real-time monitoring of environmental parameters such as pH, nutrients, temperature, and humidity, as well as automatic control of watering. With IoT, changes in plant growth support parameters can be monitored using pH sensors, TDS sensors and DHT22 sensors. The monitoring data is sent to the firebase, then the data is displayed through a smartphone. The data is expected to be used as a basis for farmers to improve the quality of the crops produced.

The research aims to: apply aeroponics to organic vegetable cultivation on limited land, develop IoT systems to monitor pH, nutrients, temperature, and humidity in real-time, and integrate the two methods to create sustainable precision farming systems. This solution is expected to answer the challenges of farmers in optimizing plant growth, as identified in Mr. Buono's garden, Magetan, where the absence of environmental monitoring leads to a decline in crop quality.

THEORETICAL REVIEW

Organic Farming

According to Siregar, organic farming has been a topic of concern in recent decades due to its important role in achieving environmental sustainability and public health (Siregar, 2023)

Aeroponics

According to Candranata, the aeroponic method is a method of farming by utilizing air. In their application, plants are placed in a hanging position and given mist-shaped nutrients, offering the advantages of being easy to harvest, efficient in land use and nutrient control (Candranata et al., 2024)

Internet of Things

Internet of Things (IoT)-*based agricultural automation* can transform the agricultural sector from static and conventional to dynamic and intelligent, leading to increased production with reduced human effort (Shafi et al., 2019)

Android

Android is a mobile operating system that runs on Linux and comes with apps, middleware, and an operating system. Android gives developers a free platform on which to build their apps. When it came to developing software for smartphones or mobile phones, Google Inc. was a pioneer. The Open Handset Alliance, a group of 34 telecom, software, and hardware companies, was later established to create Android. According to Ditha et al. (2023), these companies included Google, HTC, Intel, Motorola, Qualcomm, T-Mobile, and Nvidia.

Flutter

Developers can design mobile applications for iOS and Android using the Flutter framework. The fact that Flutter is a multiplatform framework created by a Google team sets it apart from other frameworks. Compilation is accelerated since every code is compiled in its native code (Android NDK, LLVM, AOT compiled) without the use of an interpreter. Widgets, which can range from decorative elements to components that are merely containers for additional widgets, are used to implement code. Flutter's ability to run on both the iOS and Android platforms with a single code run using the Dart programming language is one of its benefits. Google developed the programming language Dart to take the place of JavaScript. Dart offers a high-performance implementation, is simple to use, and may be used prior to compilation in the construction of contemporary applications (Rahmawati & Sari, 2024).

Firebase

Google owns the Firebase service, which facilitates the development of applications for developers. Google offers Firebase, a backend-as-a-service and cloud service provider, as a way to make it easier for developers to create websites and apps. App developers may concentrate on creating their apps with Firebase instead of having to start from scratch with backend features and infrastructure, which allows them to create larger applications (Ditha et al., 2023).

METHODOLOGY

This research method is designed by involving hardware and software as the main components. The tools and materials needed are outlined in Table 1.

Table. 1 List of Tools and Materials

	Tools and Materials	**Information**
	NodeMCU ESP32	It functions as a brain that reads data from sensors, processes it and sends data to the firebase via a Wi-Fi connection. The ESP32 is also used to control the on-and-off of the relay.

	Sensor DHT22	The DHT22 sensor is used to measure ambient temperature and humidity.
	Sensor TDS	TDS sensors are used to measure the level of nutrients dissolved in water.
	Sensor pH Meter	The pH Meter sensor is used to measure the acidity level of the water.
	Relay Module	The relay module is used to control the start and off of the pump.
	Jumper Cable	Serves as a link between components.
	12V 5A Adapter	Serves as a pump power source by converting AC voltage to DC.
	DC12V Pump	Used to suck water on water reservoirs.
	Jack Female DC	Used as a connector to connect the pump with the relay.
	Mist Nozzle 0.4mm	It is used to convert water into mist by utilizing the water pressure at the pump.
	Styrofoam Box	Used as a water reservoir and pump.
	Custom Rack	Used as a tool for arranging styrofoam boxes.
	Netpot 7cm	Used as a container to place plants in styrofoam boxes.

The method used in the development of this system is the prototyping method because it supports testing the system while ensuring that the needs of the user are met. The prototyping method has stages ranging from identifying needs, design processes, building prototypes, evaluation and improvement. Here's the development flow:

1. Identification of needs is carried out to understand the needs of the developed system.
2. The design process is carried out so that the process of running the system can be understood before the start of the manufacture of the tool.
3. Building the prototype begins with identifying hardware needs, programming the ESP32 microcontroller to ensure data can be sent to the

firebase and developing a mobile application using the flutter framework.

4. Evaluation and improvement are carried out to ensure that the system can function as expected.

Here is the design of the monitoring and control system for organic vegetable crops:

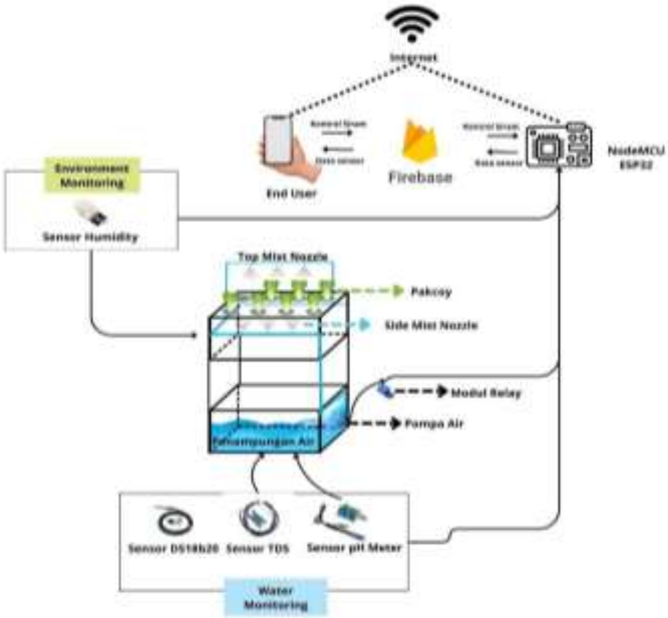

Figure. 1 System design

Based on the system design in Figure 1, the system uses various sensors (humidity, DS18B20, TDS, and pH meters) to measure the temperature and humidity of the environment, water temperature, nutrient content, and pH level. Data from the sensor is processed by the ESP32 NodeMCU, which connects to Firebase to transmit information to the user in real-time via the android app. Based on the data, the system automatically controls the water pump and mist nozzles to water the plants, with the option of manual control by the user through the app. The output is in the form of automatic watering and sensor data monitoring.

The schematic of the network on the monitoring and control system for organic vegetable crops is shown in Figure 2. This schematic shows the path of the components used on this system.

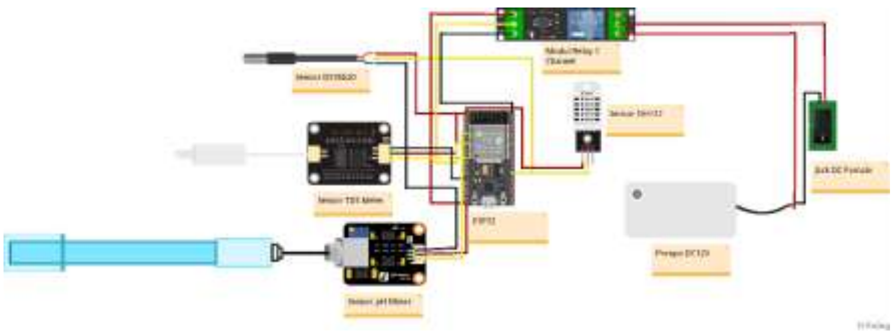

Figure. 2 Schematic design

Figure 2. is a schematic diagram visualization consisting of the ESP32 Microcontroller, pH Meter sensor, TDS sensor, and DHT22 sensor. The DHT22 sensor is connected to the ESP32 via pin 19 to read the air temperature and humidity, while the TDS sensor and pH sensor are connected to analog pins 35 and 34 respectively to measure the content of dissolved nutrients in the water and the acidity level of the water. The water temperature sensor DS18B20 connected to pin 4 with an additional pull-up resistor to detect the water temperature. All sensors get power supply from 3V pins and GND ESP32 except for the 1-channel relay module using 5V power. In addition, the 1-channel relay module is connected to pin 26 and is controlled by the ESP32 to power the 12V DC pump, with external power supply via the female DC jack. The flowchart of the monitoring system is shown in Figure 4.

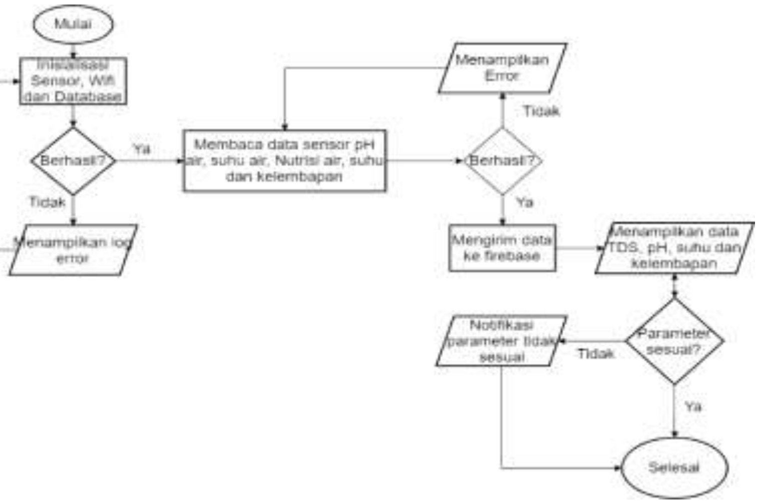

Figure. 3 Flowchart monitoring system

Based on figure 3. The above is a Flowchart of environmental parameter monitoring systems for organic vegetable crops. In the early stages, initialize the sensors, Wi-Fi, and databases. If successful, the sensor reads the water pH data, water temperature, water nutrients, temperature, and humidity. The data is then validated, and if it is invalid, the system displays an error. If valid, the data is sent to Firebase to be stored and displayed on the android app, including TDS, pH, temperature, and humidity parameters. The system evaluates whether the parameters are appropriate; otherwise, the system sends a notification that the parameters do not match. The process is complete if all parameters are within the appropriate limits. The flowchart of the automatic spraying system is shown in Figure 5.

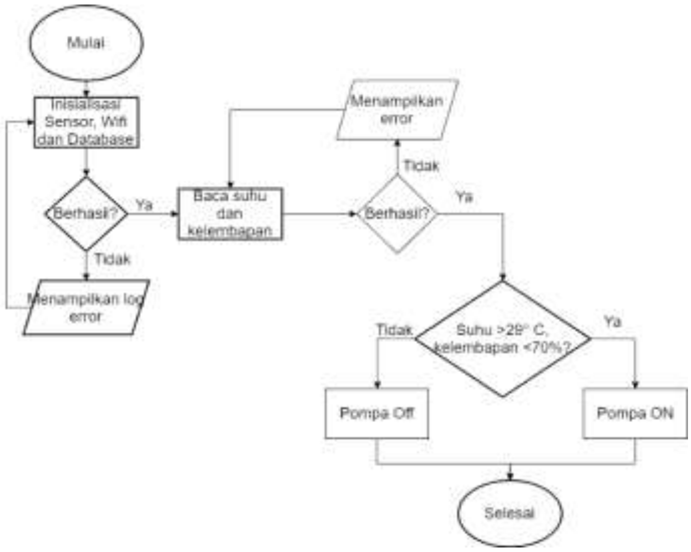

Figure. 4 Flowchart automatic spraying system

Figure 4. Above is a Flowchart automatic spraying control system for organic vegetable plants. In the initial stage, namely initialization of sensors, Wi-Fi, and databases. If successful, the system reads the temperature and humidity data, and then validates the data. Spraying can be done automatically by checking whether the temperature is > 29°C and the humidity is < 70%; If the conditions are met, the pump will turn on, otherwise, the pump will remain off. The flowchart of the manual spraying system is shown in Figure 6.

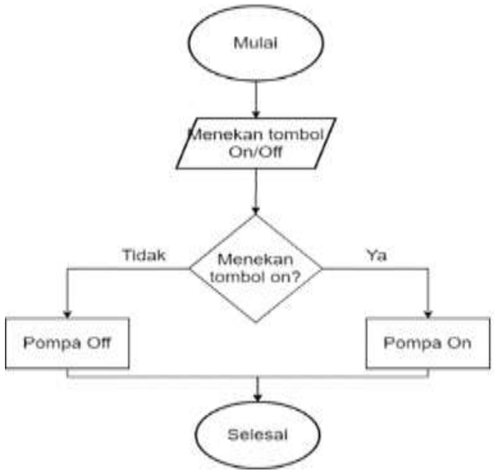

Figure. 5 Flowchart manual spraying system

Figure 5. above is a flowchart of manual spraying control systems for organic vegetable plants. The process begins with the user pressing the On/Off button to control the pump, the pump will be turned on or off (Off) as per the button command.

RESULTS

In the results of the research, the stages that will be discussed are the design of the tool to be made, analysis of system testing and application display. The following are the results of the implementation of the prototype design of a monitoring and control system for organic vegetable crops. The prototype is designed in such a way as shown in Figure 6.

Figure. 6 Tool results

Monitoring and Control System for Organic Vegetable Crops Using Internet of Things Based Aeroponic Method is designed with ESP32 as a microcontroller to retrieve data values from sensors. In this system, a DHT22 sensor is used to measure temperature and humidity, a TDS sensor is used to measure the nutrient content in the water, a pH sensor is used to measure the pH level in the water, a sensor DS18B20 is used to measure the water temperature to support the calculation of the ppm value, and a 1-channel relay is used to control the start and off of the pump. The ESP32 collects data from the sensors and then sends it to the firebase via WiFi. Then the application will retrieve the data in the Realtime database to be displayed on the Monitoring page.

In the application, there is also a feature to turn on the pump manually by turning off the automatic control mode and pressing the button to turn on the pump, if successful, the system will send a message "the pump has been turned on successfully". Values from the sensors will be sent every 15 minutes unless the nutrient levels and pH are outside the normal range, then the data will be sent every 5 minutes. Then the data will be saved to firestore and displayed on the log page and also the chart view.

Table. 2 The Sensor Accuracy

Yes	Component	Sensor Value	Comparative Value	Percentage Error
1	Sensor DHT22	Temperature = 27.80, humidity = 71.78%	Temperature = 27.30, humidity = 72%	Temperature = 1.83%, humidity = 0.31%
2	Sensor TDS	473 ppm	492 ppm	3.68%

3	Sensor pH Meter	6.67	6.68	0.15%
4	Sensor DS18B20	25.37	25.5	0.5%

In Table II. The accuracy of the sensor is calculated using the formula **Error Percentage= ((Sensor Value-Comparative Value)/(Comparative Value))×100%).** Sensor calibration is carried out using the manufacturer's standard comparator.

The following is a view of the application of the monitoring and control system for organic vegetable crops using IoT-based aeroponic methods shown in Figure 7.

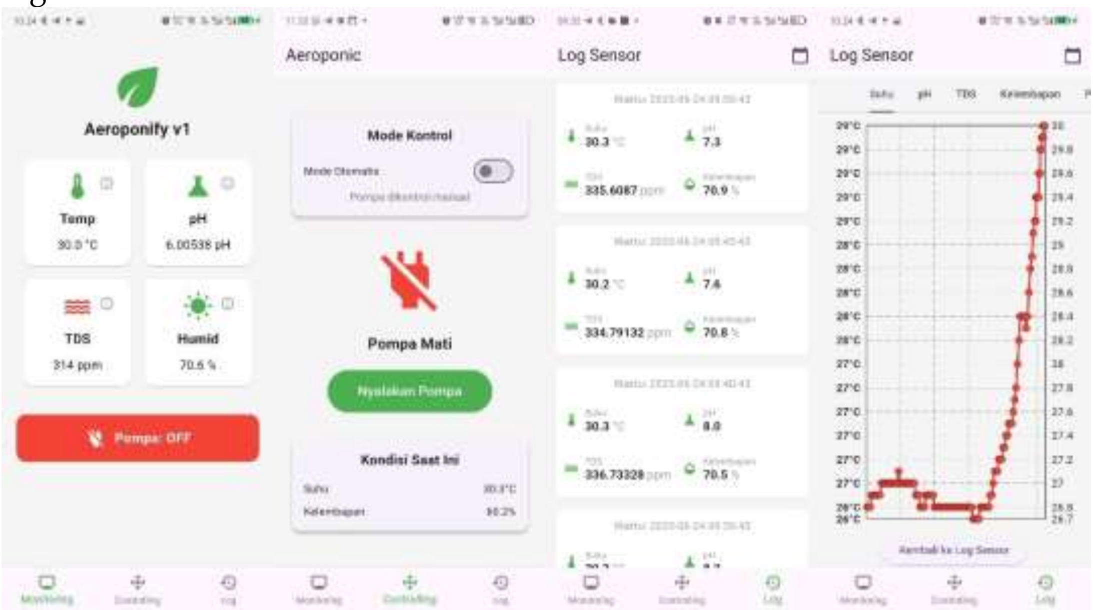

Figure. 7 App view

Figure 7. Above are the monitoring, controlling, logs and charts pages. The Monitoring page is the starting page that will be displayed when they first open the app, where users can monitor temperature, humidity, nutrient levels, and pH in real-time, with parameters that have red icons indicating values outside the normal range (as seen in Figure 4.4). Meanwhile, the Controlling Page is used to control the start and off of the pump automatically or manually, the Log Page displays parameters such as temperature, humidity, TDS, and pH at a given time, and the Chart View presents historical data in the form of graphs of temperature, humidity, TDS, and pH.

In order to determine whether the plants will grow successfully, testing is done during the seeding procedure. The duration of this examination is thirty days.

Table. 3 Table of Sowing Procedures

Number	Date	Height(cm)	Number of Leaves	Leaf Width(cm)
1	5 MAY 2025	SPROUT	-	-
2	6 MAY 2025	SPROUT	-	-
3	7 MAY 2025	0,8	2	0,2
4	8 MAY 2025	1,3	2	0,3
5	9 MAY 2025	2	2	0,3
6	10 MAY 2025	2,2	2	0,5
7	11 MAY 2025	2,5	3	0,5
8	12 MAY 2025	2,6	3	0,6
9	13 MAY 2025	2,6	3	0,8
10	14 MAY 2025	2,6	4	0,8
11	15 MAY 2025	3	4	0,9
12	16 MAY 2025	3,5	4	0,9
13	17 MAY 2025	3,7	5	1
14	18 MAY 2025	4	5	1

The aeroponic system's 30-day plant growth time test is shown in Table 4. Bok choy plants with IoT exhibited more optimal development than those without. In contrast to plants without IoT, which only grew to 3.9 cm with 5-6 leaves and a leaf width of 0.9 cm, plants with the IoT system attained a height of 7.7 cm with 6-7 leaves and a leaf width of 2 cm. Plants with IoT grew on average by 0.15 cm in height per day between the 21st and the 30th day, while plants without IoT only increased by 0.13 cm.

Table. 4 Table of Aeroponic Plant Growth Period

Number	Date	Day	IoT			Without IoT		
			Height(cm)	Number of Leaves	Leaf Width(cm)	Height(cm)	Number of Leaves	Leaf Width(cm)
1	25 MAY 2025	21	6,2	6	1,7	2,6	5	0,9
2	26 MAY 2025	22	7	6	1,8	2,8	5	0,9
3	27 MAY	23	7,1	7	1,9	3,5	5	0,9

Number	Date	Day	IoT			Without IoT		
			Height(cm)	Number of Leaves	Leaf Width(cm)	Height(cm)	Number of Leaves	Leaf Width(cm)
	2025							
4	28 MAY 2025	24	7,3	7	2	3,5	5	0,9
5	29 MAY 2025	25	7,4	7	2,1	3,5	5	0,9
6	30 MAY 2025	26	7,5	7	2,1	3,6	6	0,9
7	31 MAY 2025	27	7,6	7	2	3,6	6	0,9
8	1 JUNI 2025	28	7,6	7	2	3,7	6	0,9
9	2 JUNI 2025	29	7,7	6	2	3,8	6	0,9
10	3 JUNI 2025	30	7,7	6	2	3,9	6	0,9

DISCUSSION

The Effect of IoT-based Aeroponic Cultivation on the Seeding Period of Organic Vegetables

Based on the sowing period test carried out for 14 days, pakcoy plants showed significant development from the *sprout phase* to reach a height of 4 cm with an increase in the number of leaves from 2 leaves to 5 leaves, as well as an increase in leaf width from 0.2 cm to 1 cm.

The Effect of IoT-based Aeroponic Cultivation on the Growth Period of Organic Vegetables

Based on the testing of the plant growth period using an aeroponic system was carried out for 30 days. With IoT, pakcoy plants show more optimal development compared to without IoT. Plants with IoT systems reach a height of 7.7 cm with 6-7 leaves and a leaf width of 2 cm, while plants without IoT only grow up to 3.9 cm with 5-6 leaves and a leaf width of 0.9 cm. Growth on days 21 to 30 with an average height increase of 0.15 cm per day in plants with IoT, compared to only 0.13 cm in plants without IoT.

CONCLUSIONS AND RECOMMENDATIONS

Based on the test results on "Monitoring and Control System for Organic Vegetable Crops Using the Internet of Things-Based Aeroponic Method", it can be concluded that the aeroponic method has been successfully applied to vegetable cultivation. IoT implementation allows real-time monitoring of environmental parameters using TDS sensors with an error of 3.68%, pH meters with an error of 0.15%, DHT22 with a temperature error of 1.83% and a humidity error of 0.31%, and DS18B20 with an error of 0.5%, with data sent to Firebase and displayed on the Android app, making it easy to monitor and control automatic spraying based on environmental conditions. Overall, the system has proven to be effective as an innovative solution for sustainable organic farming, combining the advantages of aeroponics and IoT in monitoring and optimizing the growing environment in real-time.

FURTHER STUDY

The high outdoor temperature during the day results in the appliance not functioning optimally. Therefore, it is recommended to place the appliance indoors to ensure that the automatic watering system based on temperature and humidity parameters can work optimally.

Currently the tool is only equipped with 11 netpots for planting. To increase production capacity, it is necessary to add streforoam boxes and Misting Nozzles so that the number of cultivated plants is more.

Since the appliance is placed indoors, the use of growlight is required to ensure that the plant continues to receive adequate light intensity to support the process of photosynthesis and optimal growth.

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REFERENCES

Chandranata, A., Kurniadi, D., & Aryananda, F. (2024). Design and Development of a PPM Control System for Aeroponic Lettuce Plant Nutrient Based on Microcontrollers and Internet of Things. *Journal of Social Research*, *3*(2). https://doi.org/10.55324/josr.v3i2.193

M. A. R. Siregar, "PERAN PERTANIAN ORGANIK DALAM MEWUJUDKAN KEBERLANJUTAN LINGKUNGAN DAN KESEHATAN MASYARAKAT," May 29, 2023, *Open Science Framework*. doi: 10.31219/osf.io/mfwz2.

A. Safrimawan, "Sistem Kontrol Pemberian Nutrisi pada Budi Daya Tanaman Aeroponik Berbasis Fuzzy Logic," *JAEE*, vol. 3, no. 1, pp. 19–23, June 2019, doi: 10.30871/jaee.v3i1.1397.

A. N. Iman and S. Widiono, "PERANCANGAN APLIKASI SMART GREENHOUSE BERBASIS IOT UNTUK OPTIMALISASI PERTUMBUHAN SAYURAN," Jurnal Informatika, vol. 7, no. 2, 2024.

Ditha, R. L., Faulina, S. T., No, J. A. Y., & Baturaja, A. (2023). RANCANG BANGUN APLIKASI LAYANAN PENGADUAN PADA DINAS PENDIDIKAN KABUPATEN OKU BERBASIS ANDROID MENGGUNAKAN ANDROID STUDIO. 14.

Rahmawati, I., & Sari, D. P. (2024). APLIKASI BERBASIS ANDROID MENGGUNAKAN FLUTTER FRAMEWORK UNTUK KEPERLUAN PERIZINAN TUGAS KELUAR PADA PT. XYZ. *JIPI (Jurnal Ilmiah Penelitian dan Pembelajaran Informatika)*, *9*(2), 979–993. https://doi.org/10.29100/jipi.v9i2.5489