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IoT Prototype System Design for Monitoring Green Mustard Microgreen Cultivation at Sayur Mini Microgreen Jakarta

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Abstract — Microgreen cultivation has become an increasingly important component of urban agriculture, offering a practical solution for food production in land-limited environments. This study aims to develop and evaluate an Internet of Things (IoT)-based monitoring prototype for green mustard microgreens (Brassica juncea L.) cultivated in Jakarta. The system integrates soil moisture, DHT22 (temperature and humidity), TDS (Total Dissolved Solids), and NPK sensors into an ESP32 platform connected to Blynk for automated, real-time monitoring. Prototype validation was conducted through unit, integration, and functional testing to assess sensor accuracy and system responsiveness. The results demonstrate improved water-use efficiency of up to 35% and enhanced plant growth, with microgreens reaching an average height of 7.2 cm significantly higher than the manual control group (5.8 cm). These findings highlight the system's potential to support precision agriculture in urban settings and provide a scalable digital solution for improving microgreen cultivation efficiency and sustainability.

Keywords – Microgreen, green mustard, Internet of Things, urban farming.

I. INTRODUCTION

Urban agriculture has emerged as a strategic solution to address food security challenges in metropolitan areas with limited land availability. One increasingly popular method is microgreen cultivation, a high-nutrient miniature vegetable crop harvested within 7 to 21 days. Green mustard (*Brassica juncea L.*) is among the most favored microgreen varieties due to its high nutritional content and short harvesting period, making it suitable for urban farming practices [1], particularly in Jakarta, where land scarcity contrasts with high consumption demands. However, the success of microgreen cultivation is highly dependent on the stability of environmental parameters such as temperature, soil moisture, and water quality. Irregular monitoring of these factors often leads to reduced yield and lower plant quality [2].

Although Internet of Things (IoT) technology has been increasingly adopted in agricultural systems, research on IoT-based monitoring for microgreen cultivation—particularly in Indonesia—remains limited. Existing studies predominantly focus on hydroponics, general horticulture, or single-parameter monitoring systems, often using basic sensors such as DHT11 or simple soil moisture detectors [3][4]. These systems frequently lack multi-sensor integration, do not include nutrient-level monitoring (TDS/NPK), or rely on scheduled automation rather than real-time, condition-based responses. Furthermore, prior research in Indonesia rarely incorporates comprehensive monitoring combining temperature–humidity (DHT22), soil moisture, water nutrient concentration (TDS), and macro-nutrient measurement (NPK) in a unified IoT platform. This gap is critical, as microgreens particularly green mustard require tight environmental control due to their sensitivity and rapid growth cycle.

To address these limitations, this study aims to design and evaluate an integrated IoT prototype capable of performing real-time environmental monitoring specifically tailored for green mustard microgreen cultivation in urban settings. By combining multiple sensors (soil moisture, DHT22, TDS, and NPK soil analyzer) into an ESP32-based system connected to the Blynk platform, the prototype seeks to demonstrate how comprehensive IoT monitoring can improve plant performance and resource efficiency. The expected contribution of this research is to provide a more holistic, data-driven solution for microgreen cultivation in Indonesia and offer a practical technological reference for urban farmers, SMEs, and agricultural startups seeking sustainable production methods.

II. METHODOLOGY

This study employs the Prototype method as the system development approach. This method is selected because it enables a faster design [5] and evaluation process through the creation of an initial model (prototype) that can be directly tested by users. Through this approach, developers can obtain early feedback to refine the system before the final implementation stage.

The development stages using the Prototype method for the IoT monitoring system in green mustard microgreen cultivation consist of five main steps [6]:

a) Quick Plan – Identifying user needs and expectations, as well as determining the objectives of the system to be developed. This stage serves as the foundation for understanding the issues addressed and the solutions to be proposed.
b) Modeling / Quick Design – Designing the initial representation of the system, including the user interface, data flow, and overall system structure. This stage provides an early visualization of the system's form and functions.
c) Construction of Prototype – Developing an initial system model that can be tested to evaluate its functionality and alignment with user requirements. In this study, the system is developed using an ESP32 microcontroller connected to IoT sensors to monitor soil moisture, temperature, and environmental conditions of the plants.
d) Deployment, Delivery & Feedback – Conducting prototype testing with users to gather input on the system's functions, interface, and performance. The feedback obtained is used as a reference for improvements and the development of subsequent versions.
e) Communication – Evaluating the testing outcomes and refining the system based on user feedback. Continuous communication between developers and users is essential to the success of this method.

The overall architecture of the proposed IoT-based microgreen monitoring system is illustrated in Figure 1. This architecture describes the interaction between sensors, the ESP32 microcontroller, cloud services, and the mobile dashboard, forming a complete automated monitoring and control ecosystem for microgreen cultivation.

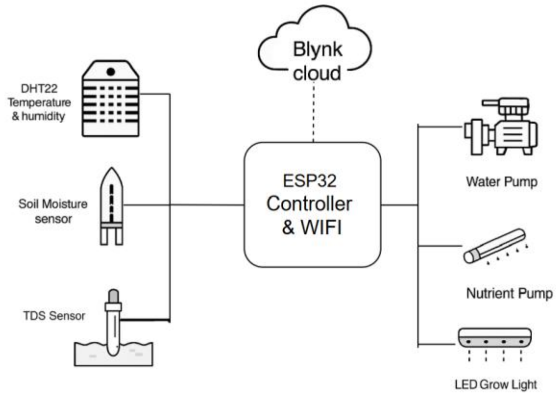

Fig.1. IoT Architecture.

Figure 1 explains the IoT architecture developed in this study is designed to enable automated and real-time monitoring of green mustard microgreen cultivation. The system consists of three primary layers: the sensor layer, the processing and control layer, and the cloud–user interface layer. Each layer plays a distinct role in capturing environmental data, executing control logic, and delivering information to users.

A. Sensor Layer (Data Acquisition Layer)

This layer collects all environmental parameters required for optimal microgreen growth. The sensors integrated into the system include:

a) DHT22: measures ambient temperature and humidity,
b) Soil Moisture Sensor: measures planting media moisture percentage,
c) TDS Sensor: measures nutrient concentration in the water solution,
d) NPK Soil Analyzer: detects the levels of nitrogen (N), phosphorus (P), and potassium (K) in the growing medium.

These sensors interface with the ESP32 microcontroller through ADC, UART, or I2C communication channels. The ESP32 retrieves sensor readings every 5 seconds, forming the basis for automated decision-making.

B. Processing & Control Layer (ESP32 Microcontroller)

The ESP32 functions as the central processing unit responsible for:

a) receiving and filtering sensor data,
b) executing automated control logic using predefined thresholds,
c) activating actuators through relay modules.

The actuators controlled by the ESP32 include:

a) Water pump for automatic irrigation,
b) Nutrient pump for automatic nutrient dosing based on TDS values,

c) LED grow light to support photosynthesis when temperature drops below the threshold.

C. Cloud Layer (Blynk Cloud Platform)

The ESP32 transmits sensor data to the Blynk Cloud using Wi-Fi via MQTT/HTTP protocols.
The cloud platform provides:

a) real-time telemetry storage,
b) historical graphing and logging,
c) encoded communication between device and user interface,
d) rule-based notification and alerting,
e) remote control capabilities.

This architecture ensures that monitoring and control can occur from any location with an internet connection.

D. System Workflow (Data and Control Flow)

The complete operational workflow of the system is as follows:

a) Sensors measure temperature, humidity, soil moisture, TDS, and NPK values every 5 seconds.
b) ESP32 processes the data and evaluates conditions based on predefined thresholds.
c) If necessary, the ESP32 activates actuators (water pump, nutrient pump, LED grow light).
d) Sensor data and actuator states are sent to the Blynk Cloud.
e) Users access the mobile dashboard (through the cloud) to monitor conditions and manage the system.

III. RESULTS AND DISCUSSION

The research was conducted at Sayur Mini Microgreen, located in Mampang Prapatan Raya, Duren Tiga, Pancoran District, South Jakarta. It is known that water temperature and nutrient levels must be maintained according to the established standards for green mustard microgreen cultivation. The ideal water temperature for green mustard ranges from 20 to 26°C, while the nutrient concentration should be between 800 and 1200 ppm. Maintaining the quality of nutrients in the water or fertilizer is essential, as it serves as the primary source of nourishment for the green mustard plants.

Hardware and software specifications are essential in developing an IoT system for monitoring green mustard microgreen cultivation. The tools and components required are as follows:

A. Hardware Specifications for the IoT Monitoring System of Green Mustard Microgreens

a) ESP32-WROOM Microcontroller

Table 1. Specifications of the ESP32-WROOM Microcontroller

No.	Specification	Description
1.	SPIFlash	default 32Mbi
2.	Bluetooth-compatible	Bluetooth-compatible 4.2 BR/EDR and BLE standards
3.	WiFi	802.11
4.	*Module interfaces*	UART, SPI, SDIO, I2C, PWM, I2S, IR, ADC, DAC
5.	*Power supply range*	Micro USB power supply: 5V Vin
6.	Seri	CH9102

b) Total Dissolved Solids Sensor

Table 2. Specifications of the Total Dissolved Solids (TDS) Sensor

No	Specification	Description
1.	Module voltage	3.3 V – 5.5 V
2.	Module dimensions	42 mm × 32 mm
3.	Accuracy	±10% F.S. (25 °C)
4.	Operating temperature	0 – 60 °C

c) DHT22 Sensor

Table 3. Specifications of the DHT22 Sensor

No	Specification	Description
1.	Module voltage	3.3 V – 5 V
2.	Module dimensions	28 mm × 12 mm × 10 mm
3.	Measurement range	Humidity: ±2% RH (0–100% RH)

d) Soil Moisture Sensor

Table 4. Specifications of the Soil Moisture Sensor

No	Specification	Description
1.	Module voltage	3.3 V – 5 V
2.	Module dimensions	60 mm × 20 mm
3.	Measurement range	0 – 100% moisture
4.	Operating temperature	10 – 60°C

e) NPK Soil Analyzer Sensor

Table 5. Specifications of the NPK Soil Analyzer

No	Specification	Description
1.	Module voltage	9 V – 24 V DC
2.	Module dimensions	70 mm × 45 mm
3.	Measurement range	N: 0–1999 mg/kg

B. Software Specifications for the IoT Monitoring System for Green Mustard Microgreens

Table 6. Software Specifications of the IoT System

No	Name	Specification
1.	Arduino IDE	Used for writing and uploading code to the Arduino/ESP32.
2.	Blynk	Used as an interface platform for the IoT hydroponic system.
3.	Android Studio	Used as a text editor for Android application development.

To ensure that the IoT monitoring system for green mustard microgreen cultivation operates properly and meets the specified requirements, several testing stages were conducted, including unit testing, integration testing, and comprehensive system functionality testing.

C. *Unit Testing*

Unit testing aims to evaluate the performance of each sensor and actuator component independently. The following methods were used during the testing process:

a) DHT22 Sensor (Temperature and Humidity): Tested using a hair dryer to simulate rapid changes in temperature and humidity.
b) Soil Moisture Sensor: Tested under three soil moisture conditions: fully wet, moderately moist, and dry.
c) TDS Sensor: Calibrated using a 1000 ppm standard solution and tested at a temperature of 25°C.
d) NPK Soil Analyzer Sensor: Tested using cocopeat media supplemented with organic fertilizer, with readings taken across three moisture cycles.
e) Pump and Relay Actuators: Tested under both automatic and manual commands via Blynk, with ON/OFF states monitored using a multimeter.

The results of the unit testing are presented as follows

a) DHT22 Sensor, as shown in Figure 2, responded accurately to changes in temperature and humidity, with a deviation of less than ±2%.

Fig 2. DHT Sensor in the IoT Microgreen System

Table 7. DHT22 Sensor Testing

No	Temp. (°C)	Humidity (%)	LED Status	Description
1	26	65	OFF	Temperature and humidity are ideal; LED remains inactive
2	24	60	ON	Temperature is low; LED activates to stabilize temperature
3	22	58	ON	Temperature decreases further; LED remains active
4	28	70	OFF	Temperature is high; no additional lighting is required

b) Soil Moisture Sensor, as shown in Figure 3, provided stable output with a deviation of less than 5% when tested across three moisture levels.

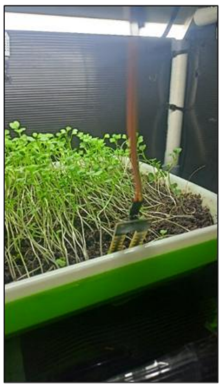

Fig 3. Soil Moisture Sensor in the IoT Microgreen System

Table 8. Soil Moisture Sensor Testing

No	Growing Media Condition	Moisture Percentage (%)	Description
1	Wet	80	Very moist
2	Moist	55	Normal
3	Dry	25	Requires watering

c) TDS Sensor, as shown in Figure 4, produced stable readings between 987 and 1012 ppm (for a 1000 ppm solution), indicating a deviation of ±1.5%.

Fig 4. TDS Sensor in the IoT Microgreen System

Table 9. TDS Sensor Testing

No	Testing Condition	Calib. Value	Reading	Dev. (ppm)	Desc.
1	Temp. (25°C)	1000	1002	+2	Good
2	Temp (30°C)	1000	1006	+6	Good
3	Temp.	1000	998	–2	Good

No	Testing Condition	Calib. Value	Reading	Dev. (ppm)	Desc.
	(20°C)				

d) NPK Sensor, as shown in Figure 5, detected N: 850 mg/kg, P: 780 mg/kg, and K: 910 mg/kg in moist cocopeat media, indicating good functional accuracy.

Based on the NPK sensor readings obtained from the cocopeat growing medium, the nitrogen (N) content measured was 825 mg/kg, phosphorus (P) was 715 mg/kg, and potassium (K) was 900 mg/kg under moist conditions. These values indicate that the macronutrients are available in sufficient quantities to support the growth of green mustard microgreens, although the P value is slightly below the recommended range in commercial hydroponic formulations.

In line with the study conducted by Tulaseket et al. (2023), the application of inorganic NPK fertilizer has been shown to significantly influence the height of mustard plants [7]. The availability of NPK nutrients also affects the number of leaves, leaf width, and fresh biomass. Optimal nitrogen supplementation enhances plant growth by increasing protein synthesis and chlorophyll formation, which contributes to deeper green leaf coloration and an improved shoot-to-root ratio [8].

Fig 5. NPK Sensor in the IoT Microgreen System

A study by Syamsinar et al. (2022) reported that the application of AB Mix nutrients containing macronutrient levels equivalent to NPK 16:16:16 at concentrations of 1000–1200 ppm significantly affects plant height and leaf count in green mustard [9]. Consistent nutrient provision within this optimal concentration range has been shown to promote rapid and uniform vegetative growth.

Thus, it can be concluded that the IoT-based NPK monitoring system developed in this study successfully provides relevant and accurate nutrient data. This information can serve as a reference for farmers in determining precise fertilization actions, thereby enhancing microgreen productivity efficiently and sustainably.

Table 10. NPK Soil Analyzer Sensor Testing

No	Moisture Condition	Nitrogen (mg/kg)	Phosphorus (mg/kg)	Potassium (mg/kg)
1	Wet	1024	1280	1536
2	Moist	825	715	900
3	Dry	1	1	1

Table 11. Soil Analyzer NPK Sensor Testing – Ratio and Description

No	N:P:K Ratio (%)	Description
1	34.1 : 29.4 : 36.5	Optimal
2	33.8 : 29.3 : 36.9	Adequate
3	33.6 : 28.9 : 37.4	Insufficient

e) Relay and Actuators: All relays functioned properly according to digital logic triggers (HIGH/LOW), and the pump operated in response to system signals.

D. Integration Testing

Integration testing was conducted to ensure that all sensor and actuator components could communicate synergistically within a unified, integrated system. The following methods were used during the integration testing process:

a) Each sensor was tested simultaneously within an integrated ESP32-based system.
b) Test scenarios included: low moisture, high temperature, and TDS levels dropping below the threshold to trigger the pump, grow light LED, and alarm.

The results of the integration testing are presented as follows:

a) The system successfully activated the water pump when moisture levels fell below 30%.
b) The grow light LED turned on when temperature dropped below 26°C to support photosynthesis.
c) The nutrient pump activated when TDS levels were below 900 ppm, according to the control logic.
d) Data were displayed in real time on the Blynk application, updating every 5 seconds.

E. System Functionality Testing

The following methods were used during the system functionality testing process:

a) Two treatments were compared: manual control and the automated IoT system under identical growing conditions for 20 days.
b) The measured growth parameters included plant height, leaf color, and root strength.

The results of the system functionality testing are presented as follows:

a) The IoT-based samples achieved an average plant height of 7.2 cm, higher than the manual control group (5.8 cm).
b) Leaf color was greener, and root strength was superior in the IoT-treated plants.
c) Daily monitoring showed that the IoT system reduced the frequency of manual intervention by 80%.

F. Comparison and Advantages of the IoT System Over Previous Systems and Related Studies.

The previous system used at Sayur Mini Microgreen relied solely on manual notifications from an application without automatic triggering based on sensor data. There was no temperature actuator (LED grow light) and no direct monitoring of NPK levels. The new system integrates full automation, real-time data acquisition, and responsive control of environmental parameters, resulting in improved efficiency and more consistent crop growth.

The advantages of this system are evident not only when compared to the prior manual system but also when evaluated alongside existing studies. By integrating multiple sensors—DHT22, soil moisture, TDS, and an NPK soil analyzer—into a unified framework and connecting them to a real-time digital platform such as Blynk, the system is capable of performing automated monitoring and control based on actual environmental data. The following table presents a comparison of this system's performance with related research.

Table 12. Comparison and Advantages of the IoT System Compared to Related Studies

Sensor	**Current Study**	**Related Research**	**Comparison and Advantages**
DHT22 (Temperature & Humidity)	Detects temperature and humidity with <2% deviation. LED automatically turns on when temperature < 26°C.	Safitrah et al. (2024): Temperature automation for red radish microgreens. [10[Saputra et al. (2022): Used DHT11, system activated based on time schedules. [3]	DHT22 offers higher accuracy compared to DHT11. The system operates based on actual temperature rather than preset time intervals, making it more efficient and adaptive to environmental changes.
Soil Moisture	<5% deviation. Pump automatically activates when moisture < 30%.	Laksana et al. (2023): Capacitive sensor for automatic watering control.	The threshold used (30%) is more realistic for microgreen cultivation. Testing across wet, moist, and dry conditions provides more detailed validation of sensor reliability
TDS (Total Dissolved Solids)	Stable at 987–1012 ppm when calibrated at 1000 ppm. Nutrient pump automatically activates when TDS < 900 ppm.	Syahputra (2024): Manual and semi-automatic control. [11] Fuada et al. (2023): Ideal TDS range 560–840 ppm. [12]	Provides automated action based on real-time sensor values. Offers high accuracy close to calibration standards, enabling more precise nutrient management.
Soil Analyzer NPK	Detects NPK at three moisture levels (wet–dry) with N: 850–860 mg/kg, P: 680–740 mg/kg, K: 880–920 mg/kg.	Sari & Hidayat (2023): IoT NPK improves fertilizer efficiency. Setiawan et al. (2023): Wireless NPK sensor with fuzzy logic.	Integrated with Blynk in real time using a simpler, non-fuzzy system while maintaining effectiveness for NPK monitoring in urban farming applications.

IV. CONCLUSION

Based on the design and implementation of the IoT prototype system for monitoring green mustard microgreen cultivation, several conclusions can be drawn. First, the system was successfully developed by integrating soil moisture, DHT22, TDS, and NPK sensors controlled through an ESP32 microcontroller and monitored via the Blynk platform, enabling automated and real-time environmental monitoring. Second, the IoT system demonstrated measurable improvements in plant performance, achieving an average height of 7.2 cm—higher than the manual control group (5.8 cm)—alongside enhanced leaf greenness, stronger roots, and a 35% increase in water-use efficiency. Third, despite issues related to sensor calibration, power stability, and internet connectivity, the system reduced manual intervention by up to 80%, offering practical benefits for urban farmers.

This study is subject to several limitations, including the use of a single plant type, limited cultivation scale, and dependence on stable internet connectivity, which may affect system responsiveness. Further research is recommended to expand sensor integration, validate the system across larger and more diverse cultivation environments, and assess long-term reliability under varying environmental conditions. Future work may also explore machine-learning-based decision support, energy-independent configurations using renewable power sources, and full commercial-scale deployment within vertical farming or controlled-environment agriculture systems.

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