BIS INFORMATION TECHNOLOGY AND COMPUTER SCIENCE

Volume 2 2025 | DOI: 10.31603/bistycs.180
6th Borobudur International Symposium on Science and Technology (BIS-STE) 2024

UNIMMA PRESS
Universitas Muhammadiyah Magelang

IoT-based soil condition monitoring for efficient pakcoy watering system

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Abstract

Pakcoy is one of the most popular vegetables in Indonesia due to its nutritional value and its wider stems and leaves compared to regular mustard greens. However, the growing demand for pakcoy has not been effectively met due to declining soil fertility, excessive use of chemical fertilizers, and suboptimal farming techniques. This research proposes a solution to overcome these problems by developing an IoT-based soil condition monitoring system for watering and fertilization. The Rapid Application Development (RAD) method consisting of Requirements Phase, Design Workshop, and Implementation is used to design and implement the system. The system uses an Arduino ESP8266 microcontroller integrated with a soil moisture sensor, DHT11 temperature sensor, and pH sensor to monitor plant conditions. Data is collected and sent to the server every 10 seconds and displayed to the monitoring system. The system automatically regulates watering and fertilization to ensure optimal soil moisture and pH levels. Field testing in a greenhouse by comparing pak coy plants with the traditional way and with the IoT-based system. The results showed significant improvements in plant health, reduced susceptibility to pests, and increased leaf width, with an average increase from 1.8 cm (traditional) to 2.4 cm (IoT-based). This research demonstrates the potential of IoT technology to improve pakcoy farming efficiency, yield quality, and sustainability.

Keywords

Pakcoy, Monitoring system, IoT-based, Rapid application development, Greenhouse

Published:
April 28, 2025

Selection and Peer-review under the responsibility of the 6th BIS-STE 2024 Committee

Introduction

Nowadays, people consume several types of mustard greens, including green mustard greens, chicory greens, Japanese mustard greens, and pakcoy greens. One of the most popular types of mustard is pakcoy mustard, as its stems and leaves are wider than those of regular green mustard. Therefore, farmers prefer to grow this type of mustard. Pakcoy mustard farmers can see quite bright business prospects from this [1]. According to BPS data, mustard production increased in 2022 to 760,608 tons from the previous year, which was 727,467 but decreased in 2023 to 686,876 tons [2].

Less intensive cultivation techniques, unfavorable climate, and declining soil fertility are some of the factors that cause pakcoy mustard production to decline. Excessive use of chemical fertilizers is one of the factors that cause soil fertility to decline [1]. The type of soil suitable for pakcoy plants is soil that contains a lot of humus, loose, fertile, and has good drainage. Optimal pakcoy growth is at soil acidity (pH) between pH 6 - 7 [3].

In pakcoy cultivation requires quite a lot of water for cultivation. Water is needed to support the growth of pakcoy, therefore the appropriate soil moisture standards for mustard plants are those that have 50% - 70% moisture [4] and for optimal temperatures in pakcoy plant growth ranging from 15^0 - 30^0 C [5].

Research on planting and maintenance models to increase pakcoy yields include the hydroponic model [6] [7] [8] [9]. With the hydroponic planting model, the soil growing medium is replaced with flowing water. Fertilization is done by dissolving it in a water reservoir which will later be flowed into all water channels. Another planting method is to use a greenhouse with soil planting media but inside a house that uses UV transparent plastic [10]. To maintain the condition of the greenhouse, automatic control through the Internet of Things (IoT) is also added [11] [12].

To maintain soil moisture and pH conditions in tomato plants, one of them is a monitoring system using IoT [13]. The results of this study were able to maintain soil conditions in the range of 30-80% for soil moisture, and 5.5 - 7.2 for pH. The greenhouse principle and automatic watering and fertilization make this system better and more precise. One effective way to support agricultural growth is by implementing a planting system using the greenhouse principle, this principle is very environmentally friendly and can minimize global warming [13].

Improper conditions can cause pakcoy plants to not grow well such as growing tall with small leaves, yellowing leaves or curling leaves (Figure 1). To solve this problem, IoT-based Soil Condition Monitoring System for Automatic Watering and Fertilization of Pakcoy. By using this system, watering and fertilizing the soil for pakcoy plants will be evenly distributed and according to their needs.

Figure 1. Pakcoy plants are not growing well

Method

This research produces an IoT-based Soil Condition Monitoring System for Automatic Watering and Fertilization of Pakcoy. The RAD method (Figure 2) in this research is to build a system in the form of Requirement Planning steps, Design Workshop, to Implementation in the greenhouse (4x6 m) as presented in Figure 3. The final test compared pakcoy plants raised in a greenhouse with traditional treatments and by using the proposed system.

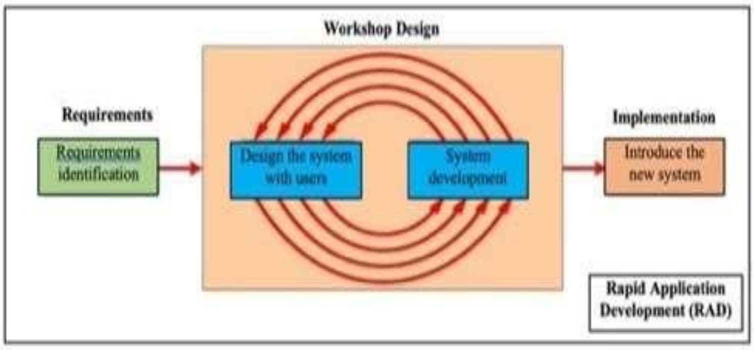

Figure 2. Rapid Application Development (RAD) method

Figure 3. Greenhouse with a size of 4 x 6 m

IoT Based Soil Condition Monitoring System consists of Automatic Watering & Fertilization System, IoT Server & Soil Condition Monitoring System (Figure 4).

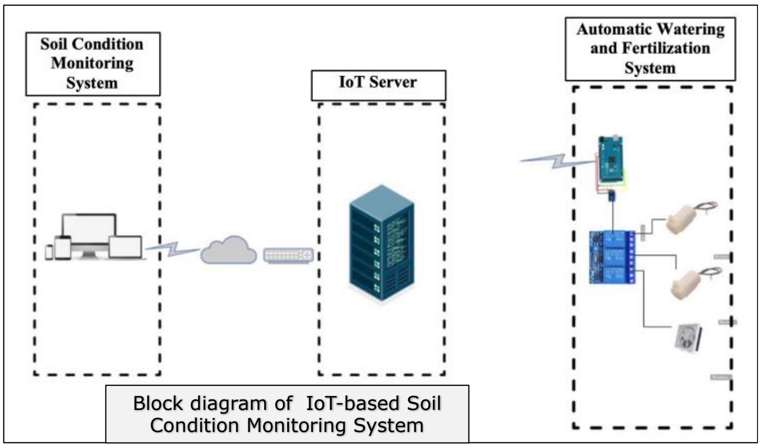

Figure 4. Block diagram of IoT-based Soil Condition Monitoring System

The Automatic Watering & Fertilization System is placed in a greenhouse consisting of NodeMCU ESP8266, LCD, 3-channel relay, 2 water pumps for watering & fertilizing, exhaust blower and also a series of sensors such as Soil Moisture, pH and DHT11. How the Automatic Watering and Fertilization System works in a greenhouse is presented in the form of a flow diagram in Figure 5.

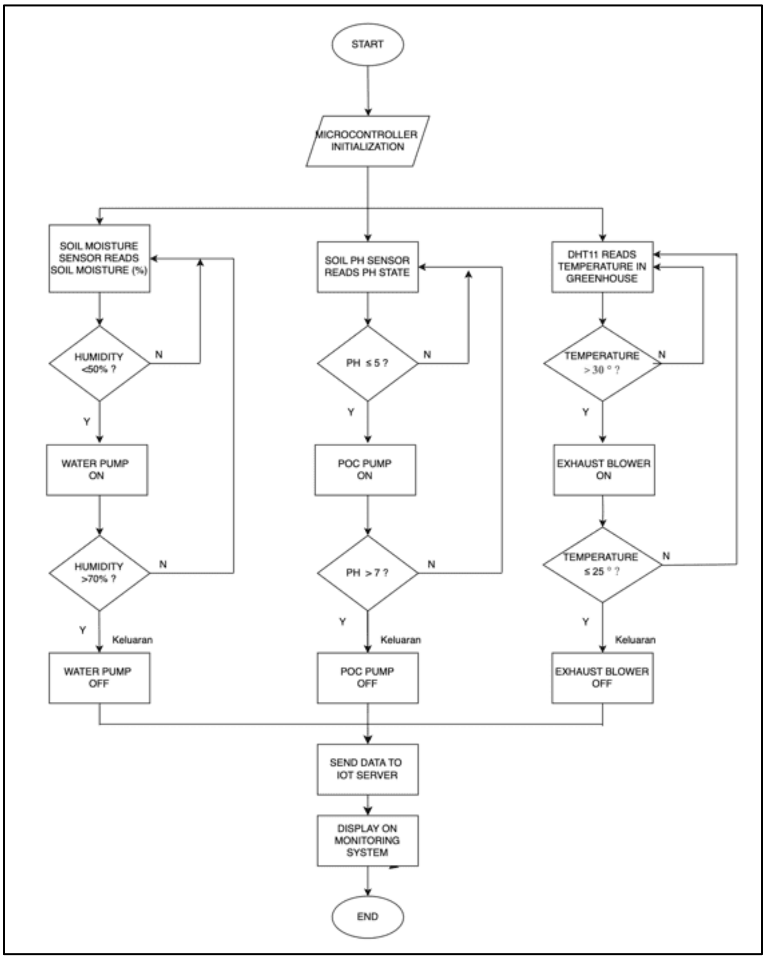

Figure 5. Flowchart of IoT-based Soil Condition Monitoring System

Humidity data will be read by the Soil Moisture sensor. If the humidity value is <50%, the NodeMCU ESP8266 will turn on the water pump to flow water through the Drip watering system, and will turn off if the humidity is >70%. If the pH sensor shows a value of <5, the NodeMCU ESP8266 will turn on the POC pump for fertilization and the pump will turn off if the pH value is >7. The DHT-11 sensor is used to read the greenhouse room temperature. If the temperature is >30° C, the exhaust blower will be turned on until the temperature is <25° C. Data changes from the sensor will appear on the LCD monitoring display (Figure 6).

The watering and fertilization system with a drip irrigation system model was chosen because it only requires a water pump. With this system, watering and fertilization are more evenly distributed throughout the greenhouse area. The growth of pakcoy plants is relatively uniform and the width of the leaves is almost the same throughout the greenhouse.

Data from the sensors are used by ESP8266 to control the water pump for watering and fertilizing and the exhaust blower to maintain the air temperature. The data is displayed on the LCD and sent to the IoT Server in real time so that it can be displayed directly on the soil condition monitoring system (Figure 7).

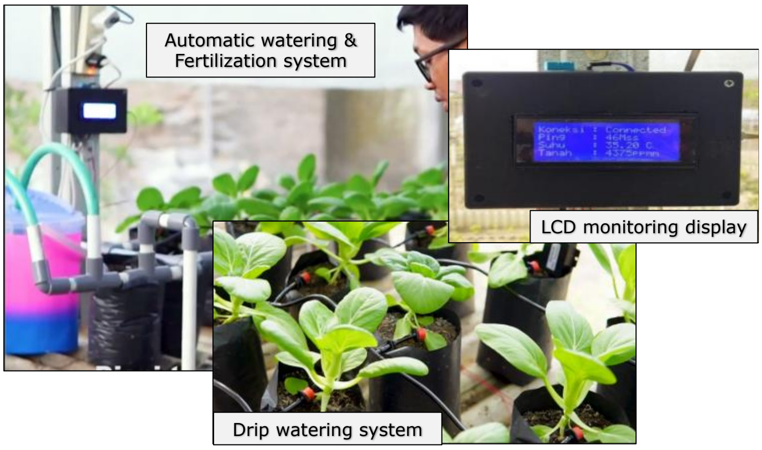

Figure 6. Implementation of IoT-based Soil Condition Monitoring System

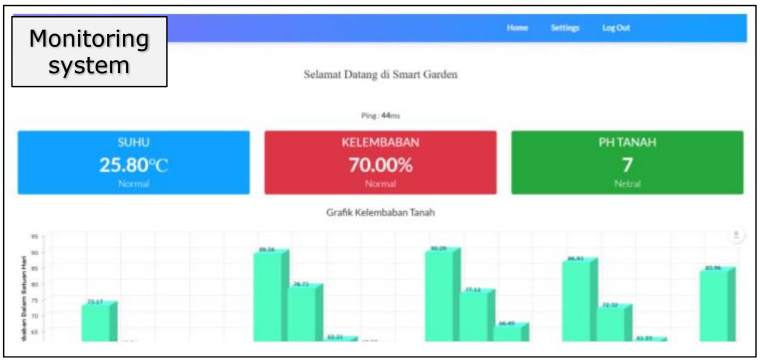

Figure 7. Dashboard of the soil condition monitoring system

This monitoring system, in addition to being able to display real-time soil condition data, also has a default value setting feature for automatic watering & fertilization systems. This system can ensure that the soil condition is always maintained with the appropriate conditions for optimal plant growth. Watering and fertilization are also always in accordance with the needs of the plant. Furthermore, the monitoring system has a feature to set the desired soil conditions at any time, so that users can adjust to the development of their plants.

With these features, this system can be used not only for pakcoy but also for plants, especially other vegetables that use temperature, humidity, and pH parameters for their plants treatment.

Result and Discussion

The IoT-based Soil Condition Monitoring System works based on data from sensors received by the ESP8266 which is used to turn on watering pumps, fertilizer pumps, or exhaust blowers and will turn off when the soil conditions meet the standards (humidity: 50%-70%, temperature: 15-300C, PH: 6-7). This system is installed on 25 polybags of pakcoy plants in a 4 x 6 m greenhouse with a maximum capacity of 300 polybags (scale 1:12). For implementation in larger areas, it is necessary to adjust the number and type of pumps for watering and fertilizing as well as blowers to regulate greenhouse temperature. This system is only designed for plant care systems that use a drip system for watering and fertilizing. If using another system, the control system must be adjusted or replaced.

Pakcoy can be harvested after 30-40 days from planting, so this system has been installed in the greenhouse for 15 days at the beginning of the planting period. The system can work according to plan and send it in real time to the IoT server. The monitoring system is able to display data in real time via the internet network on a laptop or smartphone screen.

Further testing was carried out by measuring the leaf width of pakcoy plants treated with the system compared to pakcoy plants treated with traditional treatment every 5 days (Figure 8). The selection of plants measured randomly was taken from the smallest and widest.

Figure 8. Pakcoy leaf width measurement process

Comparison of the results of measuring the width of pakcoy leaves that are cared for traditionally and with an automatic irrigation and fertilization system is presented in Table 1. The results are an average increase in leaf width of 2.4 cm for those cared for with the system and 1.8 cm for those cared for traditionally.

Table 1. Comparison of the results of measuring the width of pakcoy leaves

No	Testing date	by System treatments (cm)			by Traditional treatments (cm)		
		min	max	avg	min	max	avg
1	29/07/2024	2.1	2.8	2.45	1.8	2.5	2.15
2	03/08/2024	4	5	4.5	3.3	4	3.65
3	08/08/2024	6.5	8	7.25	5.5	6	5.75

Initial measurements showed that the comparison results were not very significant. However, as the pakcoy plants aged, a significant difference was seen between the pakcoy plants treated using the system compared to the pakcoy plants treated traditionally significant comparison results as shown in Figure 9.

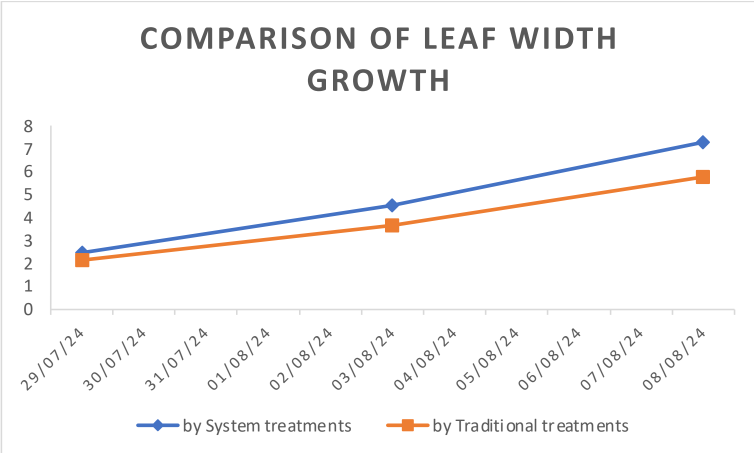

Figure 9. Comparison chart of pakcoy leaf width growth

The results showed significant improvements in plant health, reduced susceptibility to pests, and increased leaf width better than traditional treatments, which is an average of 2.4 cm every 5 days. This study shows the potential of IoT technology to improve pakcoy farming efficiency, crop quality, and sustainability.

Conclusion

The IoT-based Soil Condition Monitoring System can always maintain soil conditions with standard temperature, humidity, and PH that support optimal pakcoy growth by automatically controlling watering and fertilizing pumps. This is proven by the growth of pakcoy leaf width better with system care compared to traditional care, with an average increase of 2.4 cm every 5 days.

Acknowledgement

This research received funding from LPPM Universitas Muhammadiyah Magelang. Our gratitude goes to the laboratory assistants in the Informatics Engineering laboratory of the Universitas Muhammadiyah Magelang, who helped prepare system and its supporting devices.

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