Implementation of an IoT-Based Automated Watering System for Melon Cultivation

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Abstract. Agriculture and plantations are vital for sustaining a significant portion of Indonesia's population. However, the agricultural sector faces considerable challenges, particularly due to its dependence on weather conditions, leading to fluctuations in production and market volatility. Effective water management is crucial for plant growth, and the specific water requirements of various crops, including melon plants, necessitate careful irrigation. The advancement of Internet of Things (IoT) technology presents substantial benefits for agriculture by optimizing plant growth, deterring pests, and enhancing irrigation systems. This research focuses on developing an automatic irrigation system specifically for melon farming, utilizing IoT technology. A capillary irrigation system controlled by water level sensors is implemented to ensure precise water management, reducing waste while improving plant health and yield. By enhancing agricultural productivity and promoting water sustainability, this system offers an efficient and reliable solution for automating irrigation, making it a suitable option for both household gardens and small-scale melon farms. The success of similar agricultural technologies, such as hydroponics and aquaponics, as demonstrated by Studio Tani Kalisuci in Gunung Kidul, highlights the potential of innovative farming practices in overcoming challenging environmental conditions.

1 Introduction

Agriculture and plantations are crucial for the sustenance of a substantial proportion of Indonesia's people, forming the foundation of the country's food supply chain. Despite its crucial importance, the agricultural industry encounters significant obstacles due to its extensive dependence on weather conditions for crop cultivation, leading to substantial

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fluctuations in production and volatility in the market. During the dry season, the lack of rainfall negatively impacts production, resulting in a substantial increase in costs due to inadequate supply to match the demand. In contrast, the rainy season frequently results in an oversupply of crops, which spoils rapidly and causes significant economic losses for farmers.

The cyclicality of agricultural production gives rise to a fluctuating market environment, which has an impact on price and economic stability in rural communities. In times of drought, farmers need to allocate resources towards manual irrigation, resulting in increased expenses and physical exertion in order to sustain the fertility of their crops. It is essential to tackle these problems by adopting contemporary agricultural methods and technologies, such as effective irrigation systems and enhanced storage and distribution networks. Implementing these steps has the potential to stabilize production, reduce losses, and strengthen the economic resilience of farmers, contributing to the overall stability of Indonesia's agricultural industry.

Water is essential for plant growth, and the water requirements for each plant vary based on the plant species. Due to this dependency on adequate soil moisture, farmers must meticulously manage the timing and quantity of water supplied to each plant [1]. Every plant has unique water requirements; hence farmers must carefully consider the timing and quantity of water for each plant. The advancement of the Internet of Things (IoT) in agriculture offers significant benefits for the maintenance and optimization of plant growth. IoT technology has become a valuable tool for global agriculture by acting as a controller for plant growth [2][3][4][5], a deterrent for pests [4][6][7][8][9], and a means of regulating watering systems [10][11][12][13][14].

The proliferation of Internet of Things (IoT) technology has led to the creation of diverse iterations of automated irrigation systems, tailored to the specific requirements of different plant species and soil compositions. In plants grown in a limited amount of growing medium, it is necessary to optimize water usage by considering the ratio between the amount of growing medium and the water requirements of the plants. Nevertheless, the utilization of restricted planting media, such as containers, proves to be quite advantageous for farmers with limited acreage. Using pot medium for planting perennial plants like melons is highly beneficial due to the limited space available for melon growth [15][16].

Studio Tani Kalisuci, an agricultural studio established and managed by Mr. Wiyono in Tambakrejo, Semanu, Gunung Kidul, serves as a prime example of successful agricultural innovation in a region known for its arid and infertile terrain. Despite the environmental challenges that typically hinder agricultural productivity in Gunung Kidul, Studio Tani Kalisuci has demonstrated resilience and adaptability by employing a variety of advanced farming technologies. These include hydroponic and aquaponic systems, which enable soilless cultivation, as well as mulching techniques that control weed growth and enhance water conservation in paddy fields.

In addition to these innovations, Studio Tani Kalisuci has incorporated precision irrigation systems to support melon farming. Utilizing capillary irrigation technology, controlled by water level sensors, the studio ensures that the melon plants receive the optimal amount of water. This approach minimizes water waste, improves plant health, and maximizes the limited land and water resources available in the region. The successful integration of these methods highlights the potential for sustainable and efficient agriculture, even in challenging environmental conditions. Studio Tani Kalisuci's achievements in melon cultivation not only increase crop yields but also offer a replicable model for other farmers facing similar climatic and resource constraints. This demonstrates that with the adoption of innovative technologies, high-value crops like melons can be cultivated effectively, contributing to food security and agricultural sustainability in arid regions.

This research aims to develop an automatic irrigation system specifically designed for melon farming in environments with limited access to resources by leveraging Internet of

Things (IoT) technology. The system facilitates the optimization of water requirements for melon plants through the use of a capillary irrigation system. The primary objective is to address the specific water needs of each melon plant by continuously monitoring and regulating the water levels in individual pots or fields, controlled by water level sensors. By integrating IoT technology, this system enables precise and efficient water management, ensuring that the melon plants receive the optimal amount of water needed for healthy growth. This not only reduces water waste but also enhances plant health and productivity. The implementation of such a system offers significant benefits for melon farming, especially in regions facing water scarcity, and presents a sustainable solution for improving agricultural efficiency.

2 Methodology

This research on Automatic Plant Watering systems based on Internet of Things Innovation is carried out through several stages, as seen in Figure 1. The first stage is observation, tool design, testing, and training on using tools in the field, analysis of performance and success, and implementation of tools in melon fruit crops.

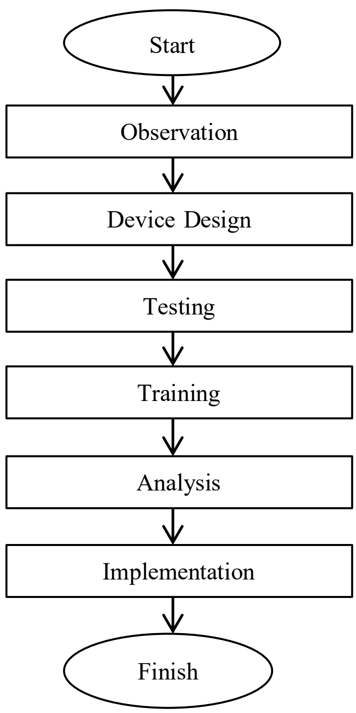

Fig. 1. Research Design

2.1 Observation

The automatic plant watering system developed in this research is specifically designed for melon cultivation at Studio Tani Kalisuci, located in Semanu Village, Gunung Kidul. As an initial phase of the project, the research team will conduct an on-site evaluation of the farmland to identify existing challenges and assess the specific conditions of the soil. This preliminary investigation is essential for designing an irrigation system that meets the unique requirements of the melon crop and the environmental conditions of the land. Effective soil investigation is a critical component of modern agriculture, particularly for crops like melons that demand specific soil conditions for optimal growth. Fertile, well-balanced soil plays a vital role in improving crop yields, as melons are sensitive to both nutrient content and soil structure. In the Semanu area of Gunung Kidul, where soil quality and composition can vary significantly, this investigation will provide crucial insights into the soil parameters that directly influence melon growth. The data gathered will guide the development of the irrigation system, ensuring it is tailored to the needs of the land and capable of delivering water efficiently. This targeted approach not only enhances the productivity and health of the melon crops but also promotes sustainable water usage, a key concern in regions with limited agricultural resources.

2.2 Device Design

Figure 2 illustrates the integration of various Internet of Things (IoT)-based electronic components utilized in the design and implementation of the automatic plant watering system specifically developed for melon cultivation in this study. The system is tailored to meet the precise water requirements of melon plants, ensuring efficient water management that promotes optimal growth and productivity.

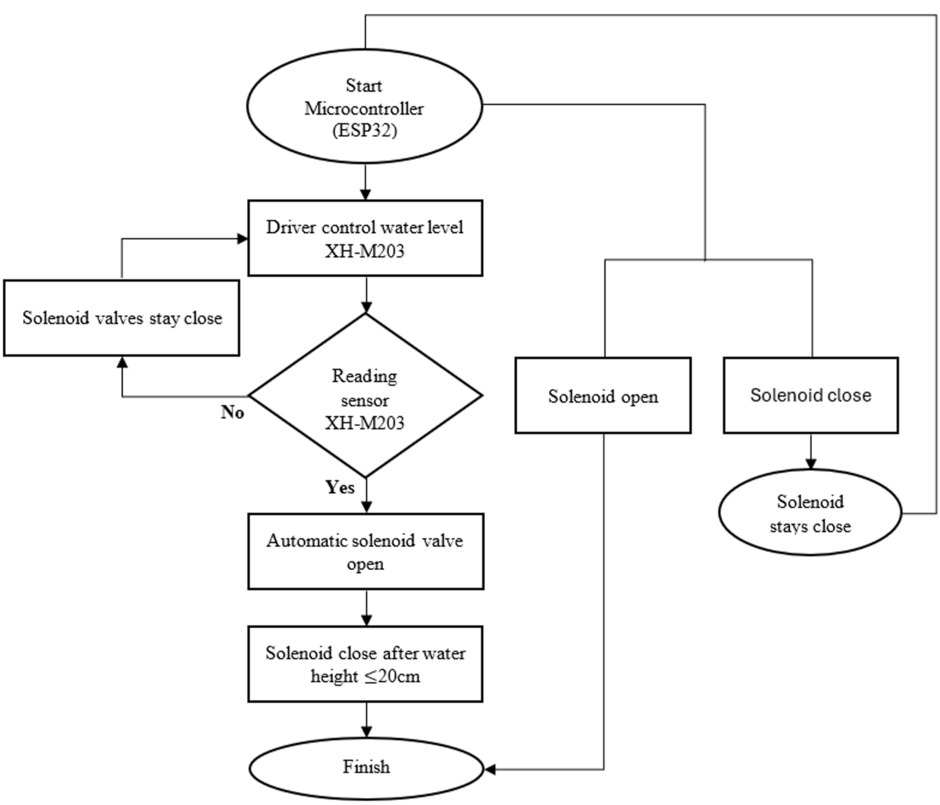

Fig. 2. Device design of automated plant watering

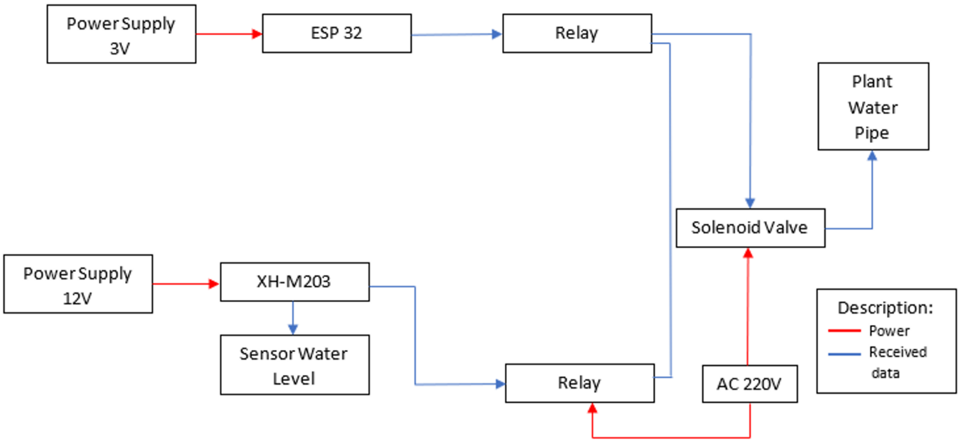

Fig. 3. Automatic Plant Watering Tool System Diagram

The first step taken in the research of IoT-based automatic plant watering is that researchers must do careful planning. Starting with making a system design, determining hardware components (sensors, pumps, controllers) and software (watering algorithms, IoT platforms). Choosing the type of sensor to be used is one of the things that needs to be considered, such as water level sensors, temperature sensors, or weather sensors. After planning, the researcher prepares the tools and materials to be designed, the following are the tools and materials used in this research as presented in Figure 3:

1. Microcontroller (ESP 32)
2. Relay (XH-M203)
3. Solenoid valve
4. Water pump
5. Water pipe
6. Water hose
7. Water tube
8. Wi-Fi
9. Smartphone
10. Sensor Water Level

Figure 3 shows the wiring diagram of Automatic Plant Watering Tool. Design of the IoT-based automatic plant watering device using ESP32 and XH-M230 relay starts by identifying the main components needed, namely ESP32 as a microcontroller and a link to the internet, XH-M230 relay to control the water pump, water level sensor to detect the moisture level, and water pump to water the plants. The ESP32 will serve as the system's brain, reading data from the water level sensor and controlling the relays based on that data while sending the data to the IoT platform for remote monitoring and control.

First, a water level sensor is installed near the plant roots, and the water level is measured regularly. This sensor is connected to an analog pin on the ESP32 to allow reading of the moisture value. The ESP32 is programmed to read this moisture value and compare it to a predefined threshold. If the water level drops below the threshold, the ESP32 will send a signal to the XH-M230 relay via the connected digital pin, activating the relay and starting the water pump to water the plants. The water pump is connected to the Relay, with one pump terminal connecting to the resource through the Relay and the other terminal to the ground. When the Relay is activated, the circuit is closed, and the water pump starts operating, irrigating the plant for the duration programmed in ESP32. After irrigation, ESP32 turns off the Relay, stops the electricity flow to the pump, and stops irrigation.

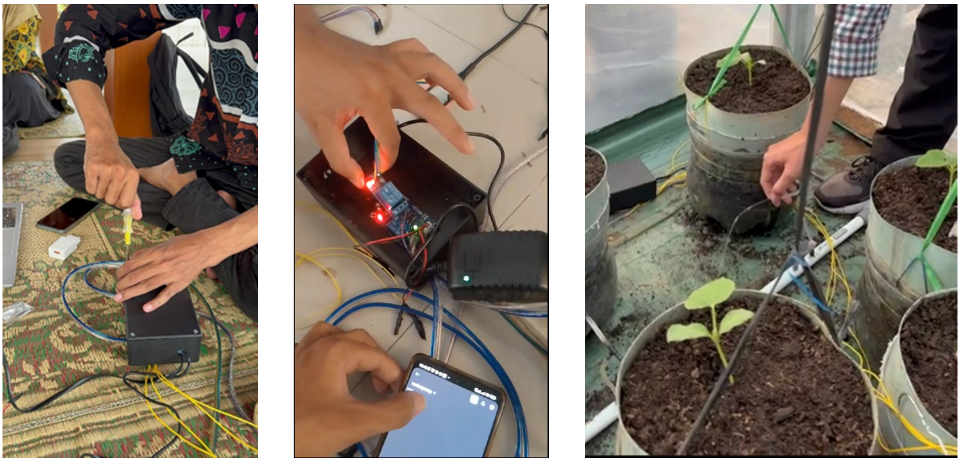

Fig. 4. Wiring, programming, and system testing of automated plant watering

In addition, ESP32 is connected to a Wi-Fi network, enabling the system to send water level and irrigation status data to the IoT platform. Users can monitor the plant condition and control the irrigating system through the application or web dashboard integrated with this IoT Platform. For example, users can view water level data in real-time, receive notifications if the soil is too dry, and manually trigger irrigations through the app.

This design ensures that the irrigation of plants is carried out automatically based on actual water level conditions, optimising water use and plant health and providing additional flexibility and control through IoT connectivity. All components are assembled on a breadboard or PCB to ensure a stable and organised connection. The system can be powered by appropriate external resources to support the operation of the water pump and the ESP32 microcontroller. Complete wiring, programming, and system testing documentation is carried out to ensure optimal performance before full implementation in the actual environment, as shown in Figure 4.

3 Results and Discussion

The implemented program involved the installation of automatic plant watering devices specifically designed for melon cultivation. These tools were installed to optimize the watering process for melon crops, ensuring precise and efficient irrigation throughout the growth cycle.

3.1 Testing

It is essential to conduct field testing of the developed tools before their final deployment to ensure they are appropriately adapted to the specific conditions of the target area. This testing allows for necessary adjustments to be made, ensuring the tools are suited to the unique environmental and agricultural requirements. Such modifications are crucial for optimizing the system's performance in real-world conditions. The implemented program involves the installation of an automated plant-watering system specifically designed for melon cultivation. The device is configured to meet the irrigation needs of melon plants, ensuring efficient and precise water management throughout their growth cycle.

3.2 Training and Implementation

The results of the testing and implementation of the IoT-based automatic melon fruit plant watering device using the ESP32 microcontroller, XH-M230 relay, pump, and other tools show satisfactory and efficient performance. During the trial period, the system successfully maintained the water level within the optimal range for plant growth. Data collected from the water level sensor showed a fast and accurate response to changing soil conditions, with the ESP32 activating the water pump automatically when the sensor water level dropped below a predetermined threshold. This automatic watering not only saves time but also optimizes water usage, reducing water wastage significantly.

The implementation of IoT connectivity enables remote monitoring and control, which proved very useful. Through the IoT platform used, water level data can be accessed in real time, and users can receive notifications when the soil requires irrigation. In addition, users can manually control irrigations through the application, providing additional flexibility. During testing, this feature makes it easy to monitor the plant condition remotely, especially during periods of absence.

Table 1. Monitoring Data Result

Plant Age (day)	Frequency of Water Filling	Water Volume Used (liter/day)	Plant Absorption Time (WIB)
1-10	1 time	0,4	14:00
11-15	1 time	0,5	15:30
16-20	1 times/ 3 day	0,8 - 1	16:00
21-25	1 times / 2 day	1 - 2	16:30
26-30	1 times/ day	1,5 - 2, 5	15:40
31-35	1 times/day	2,5 - 3	16:20
36-40	1 times/day	3 - 4	16:00
41-45	1 times/day	3,5 - 4	16:45

Table 1 outlines the results from the monitoring instruments used on melon plants over a 45-day period, from day 1 to day 45. The installation and monitoring processes were carried out during the dry season to minimize the impact of potential weather fluctuations. This approach was chosen to ensure that environmental factors did not interfere with the monitoring outcomes, allowing for more controlled and consistent data collection. The instrument used for monitoring water levels operated within a range of 2 to 9 liters for the water volume parameter. When the water level fell below the minimum threshold, the sensor system was triggered to automatically restore the water to the required level. This automated process ensured a stable and sufficient water supply for the plants throughout the monitoring period.

According to Table 1, the device starts the first filling process on day 10, and the second filling process on day 15. During days 16-20, filling takes place every 3 days, whereas on days 21 to 25, filling happens every 2 days. From day 26 until day 45, filling occurs daily. During the first 15 days, the amount of water given ranges from 0.4 to 0.5 liters, and this is the least volume observed during monitoring. The water replenishment gradually increased each day from day 16 to 45 in response to the growth of the plants. The plants reached maximum filling at an age of 36-45 days. Plants begin to experience water deficiency in the afternoon, which is when water replenishment takes place. It is evident that the automatic watering device operates effectively in accordance with the requirements of the plant. According to the plant's age, the instrument is capable of draining water when the water volume is minimal to maximal, and it functions in accordance with the plant's requirements.

4 Conclusions

Based on the research conducted, it can be concluded that the automatic irrigation system is reliable and highly beneficial for melon farming, particularly in households and small-scale melon plantations. However, key challenges include maintaining stable Wi-Fi connections in remote farming areas and ensuring a consistent power supply for the water pump. Despite these challenges, the system has shown considerable promise in automating the watering process for melon plants in controlled environments such as greenhouses. This innovative approach not only enhances agricultural productivity but also promotes sustainable water usage, which is especially critical in regions with limited water resources. The device has been optimized for durability and energy efficiency, ensuring that it operates effectively in accordance with the specific water requirements of melon plants. As the plants grow, the system adjusts its water distribution, providing the necessary amount of water based on the plants' age and stage of development, maintaining optimal water levels from minimal to maximal thresholds. This ensures that the irrigation system meets the precise needs of melon crops, promoting healthier growth and higher yields.

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