Internet of Things (IoT)-based remote monitoring and irrigation system for Red Onion Plants via Telegram

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ABSTRACT

Red onion (Allium cepa L.) is an important horticultural commodity in Indonesia that is vulnerable to air pollutants, especially dust and dew that can disrupt the photosynthesis process and trigger diseases such as fusarium wilt. This research aims to design a remote monitoring and watering system based on Internet of Things (IoT) using ESP32-CAM. The system automatically takes images of red onion leaves every morning and sends them to the farmer's Telegram, allowing farmers to analyze leaf conditions and activate remote watering if necessary. This system not only improves monitoring efficiency and decision-making but also reduces excessive pesticide use due to delayed handling. Thus, this system is expected to be an innovative and sustainable solution in supporting smart farming practices for red onions in highland areas.

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1. INTRODUCTION

Red onions (Allium cepa L.) are widely cultivated horticultural crops in Indonesia [1]. These plants are vulnerable to air pollutants, particularly dust that adheres to leaf surfaces. According to research by Anisa [2], accumulated dust can damage the epidermal layer, which plays a crucial role in plant transpiration and photosynthesis. When photosynthesis is disrupted, red onion growth becomes inhibited. Nagari Sungai Nanam in Lembah Gumanti District, Solok Regency, is a significant red onion-producing region in Indonesia. Located in highlands frequently shrouded in fog, this area experiences increased air humidity. Purnowo [3] notes that under humid conditions, dust adheres more easily to red onion leaves, increasing the risk of growth disruption. Additionally, high humidity supports microbial growth, including fungi. Cahyaningrum's study [4] found that fungal infestations on leaves can cause Fusarium wilt (Moler Disease), characterized by elongated pseudostems and curved leaves. Based on interviews with a local red onion farmer in Nagari Sungai Nanam, WP (45 years old), farmers must visit their fields every morning to monitor the condition of red onion leaves. When leaves have morning dew and feel rough due to accumulated dust, irrigation is performed to clean them. However, this method is time and labor-intensive, especially for farmers with extensive fields located at considerable distances.

Red onion cultivation practices in the highlands of Indonesia, particularly in West Sumatra, remain heavily dependent on traditional methods that rely on direct observation. [5] emphasizes that regular monitoring of leaf physical conditions is a crucial factor in irrigation management and pest control. Dew and dust accumulation on leaf surfaces not only inhibit plant metabolism but also potentially create ideal conditions for the proliferation of pathogens that reduce productivity. Efficiency challenges among farmers in Nagari Sungai Nanam were revealed in a study by [6], which showed that most red onion farmers in Indonesian highland regions still rely on conventional approaches to plant care. [7] confirmed these findings by highlighting the relationship between excessive leaf moisture and increased incidence of red onion diseases. The research also noted that the majority of farming communities in major production centers continue to perform morning inspection routines and leaf cleaning, a method that becomes increasingly inefficient as planting areas expand and agricultural labor decreases.

The advancement of Internet of Things (IoT) technology offers an innovative solution for crop monitoring. According to Wagyana [8], IoT enables everyday objects to interact, collect, process, and transmit data in real-time through internet networks. Several previous studies have developed IoT systems for agriculture. Bagaskara et al. [9] developed an IoT system to control the growth environment of red onions using temperature and humidity sensors, sending real-time notifications to users via Telegram. Similarly, Saputra [10] created a system to monitor soil moisture and air temperature in red onion greenhouses using IoT technology. The purpose of these systems is to facilitate farmers in monitoring seedling conditions in real-time without having to physically visit the greenhouse.

Furthermore, research conducted by [11] developed an IoT-based automated irrigation system for red onions by integrating soil moisture sensors, environmental temperature monitors, and light intensity meters. This system successfully increased water use efficiency by up to 40% compared to conventional irrigation methods and reduced crop failures due to drought or excess water. Prasetyo and Widodo [12] implemented a system for monitoring pests and diseases in red onion crops using IoT-integrated cameras and artificial intelligence algorithms for early identification of pest attacks, such as armyworms, and moler disease. Their system improved the speed of problem detection, allowing farmers to take earlier interventions and minimize harvest losses by up to 30%. Recent research by Wijaya and Hermansyah (2023) also shows that the implementation of IoT systems equipped with microcontrollers and multispectral sensors in shallot cultivation can increase productivity by up to 25% through early detection of nutrient deficiencies and optimization of fertilization schedules based on real-time data, thus providing fertilizer use efficiency and reducing environmental impacts from conventional agricultural practices [13].

These studies primarily focused on environmental control and monitoring of soil temperature and moisture. However, there has not yet been an IoT system specifically designed for remote monitoring and irrigation. Therefore, this research aims to design a remote monitoring system for red onion plants, equipped with an irrigation feature accessible through Telegram when dew is detected on leaves. The system utilizes an ESP32-CAM with a 2-megapixel OV2640 camera. It captures images of red onion leaf conditions every morning and sends them to farmers via Telegram. Farmers can then analyze the photos to determine whether irrigation is necessary without physically visiting the fields, saving time and energy in monitoring their red onion crops. With this IoT-based remote monitoring and irrigation system, it is expected that excessive pesticide use resulting from unclean leaves can be reduced.

2. METHOD

2.1. Block Diagram

Block diagram is a system representation that displays the main parts or main functions of a system in the form of boxes connected by lines [14]. Block diagrams help users understand the working mechanism of the entire system. Its function is as a guide in designing and connecting components in electronic circuits. Therefore, block diagrams become an important part in the system design process.

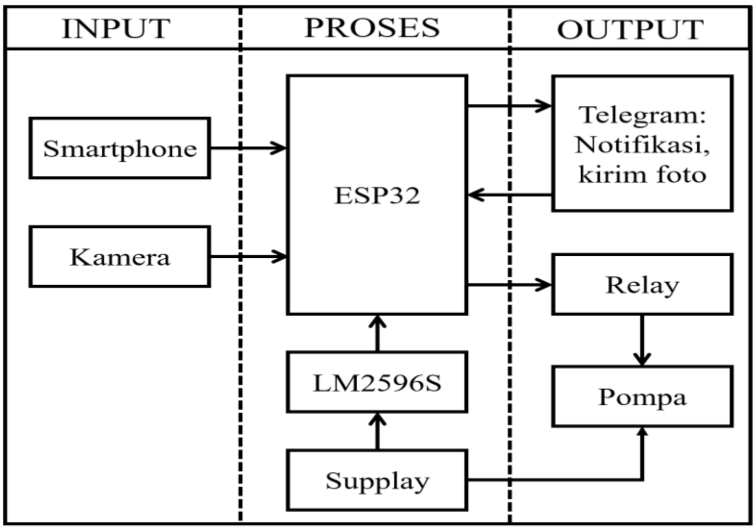

Figure 1. System block diagram.

The block diagram consists of 3 main parts, namely : 1) Input Block - The input in this block diagram consists of a smartphone and a camera. The smartphone functions as a user interface and control device that allows users to send commands or access the system. The OV2640 camera is used to take pictures and detect red onions as part of the monitoring system, 2) Processing Block - The processing section starts from the voltage supply from the battery that provides power to the entire system. This voltage is reduced by LM2596S to 5V which is suitable for ESP32. ESP32 as the main microcontroller manages the entire system by receiving data from smartphones and cameras, then processing the information to produce appropriate output, and 3) Output Block - The output of this system consists of telegram notifications and pump control. ESP32 sends notifications and photos taken by the camera via the telegram application to the user. ESP32 also controls the pump through a relay based on detected conditions or commands received from the smartphone. Circuit Scheme The circuit scheme is a visual representation that shows the relationship between various components in a system.

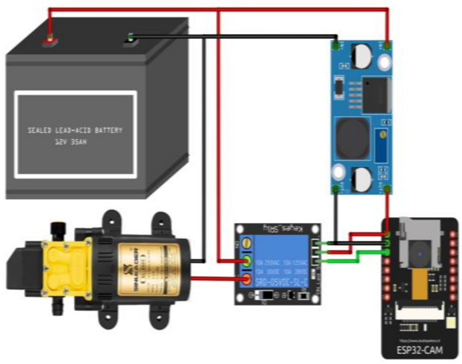

Figure. 2. Circuit scheme

2.2 Flowchart

Flowchart is a diagram or chart that represents the flow of processes or steps in a program, including the relationship between processes and statements involved [15]. Flowcharts consist of various symbols connected by lines, where each symbol has a specific meaning.

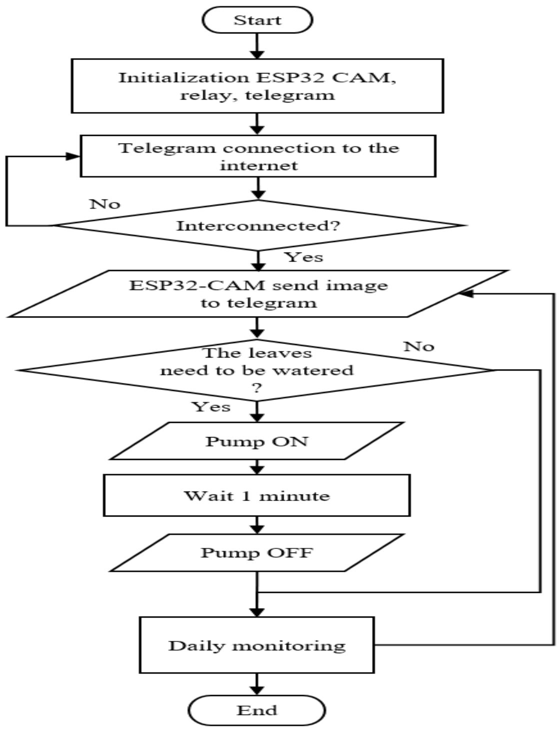

Figure 3. Flowchart

2.3 Tool Design

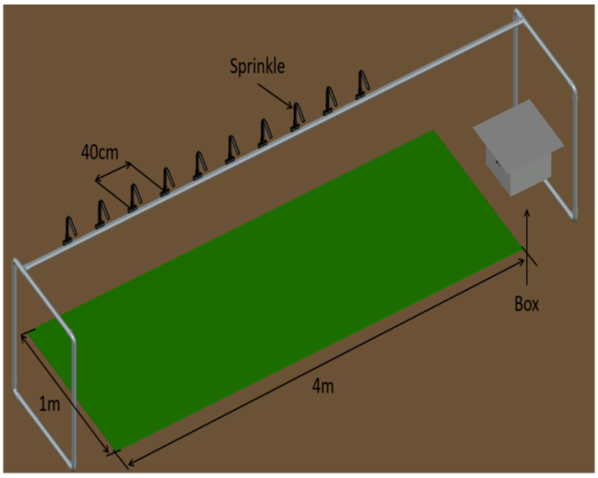

Figure 4. Overall tool design

3. RESULTS AND DISCUSSION

3.1. ESP32-CAM Testing

ESP32-CAM testing is carried out to measure the input voltage of the ESP32-CAM. This test is conducted using a digital multimeter which is connected to the 5V pin and GND pin of the ESP32. The measurement results can be seen in the image below.

Figure 5. Measurement of ESP32-CAM input voltage

The measurement results show the working voltage value of the ESP32-CAM is 5V, according to the value in the ESP32-CAM datasheet. From the measurement results, it can be concluded that the ESP32-CAM is in good condition and is able to work according to its function.

3.2. Flash LED Testing

Flash LED testing aims to determine the voltage when the LED is on or off. The flash from this LED is useful for adding lighting when taking pictures, because the pictures are taken in the morning when lighting is still insufficient. This test is carried out using a digital multimeter by connecting pin 4 to the positive probe and pin GND to the negative probe. The measurement results can be seen from the image below. To turn on the LED, it can be done by pressing /ledhidup on the message option in telegram. Meanwhile, to turn off the LED, you can first press /ledmati on the message option in telegram.

Figure 6. Measurement of LED voltage

3.3. Pump Testing

Pump testing aims to determine the pump voltage in an on or off state. Similar to LED testing, this test is carried out using a digital multimeter by connecting the relay input pin to the positive probe and the GND pin to the negative probe. In this test, one of the pump inputs is connected to the NO relay with a 12V battery source. To determine the relay input voltage of the pump when it is on, it can be done by first pressing /pompahidup on the message option in telegram. As seen in fig. 11, the pump turns on when the voltage reaches 0.1V. To determine the relay input voltage of the pump when it is off, it can be done by first pressing /pompamati on the message option in telegram. As seen in fig. 12, the pump turns off when the voltage reaches 3.4V.

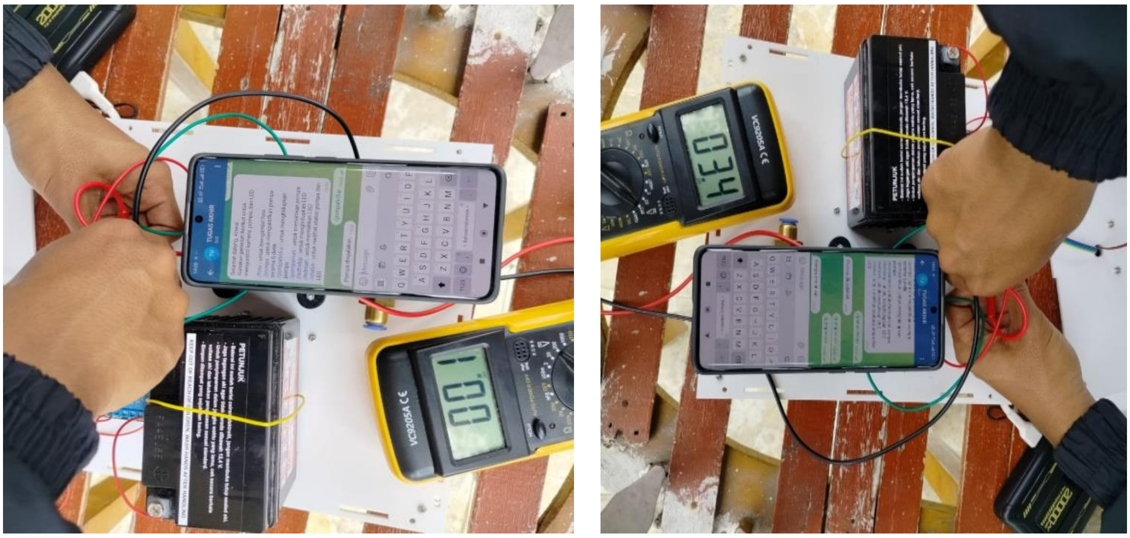

Figure 7. Measurement of pump voltage

3.4 Tool Testing

Testing of the Telegram-based remote monitoring and watering system was carried out every day at 06.00 WIB for seven consecutive days, starting from April 11 to 17, 2025. The testing was carried out in a red onion crop field with an area of 1 x 4 meters. The purpose of this test is to determine the effectiveness of the system in monitoring plant conditions and sending monitoring results in the form of images to farmers' Telegram. The image received by the farmer via telegram is analyzed to determine whether there is dew on the leaves. Based on this visual analysis, the farmer then decides whether the watering pump needs to be activated or not.

Table 1. Testing of remote monitoring and watering systems

No	Day/Date	Image	Pump
1	Friday /11/4/25		Off
2	Saturday /12/4/25		Off
3	Sunday /13/4/25		On
4	Monday /14/4/25		On
5	Tuesday /15/4/25		On
6	Wednesd Ay /16/4/25		Off
7	Thursday /17/4/25		On

The test results of the remote monitoring and watering system on red onion plants via Telegram based on IoT are shown in table 1. From testing conducted for one week, it can be seen that on Friday, Saturday, and Wednesday, the images sent show the condition of the leaves in a dry state without dew. When the condition of the leaves is like the images sent in those 3 days, the pump does not need to be turned on because the condition of the leaves is good. Testing on Sunday, Monday, Tuesday, and Thursday shows image results that indicate dew sticking to the leaves. This is a bad condition because it can become a place for the development of fungi that cause disease. Based on the images sent, the pump is turned on for watering. The images sent on Monday and Tuesday are difficult to interpret clearly when only viewing the camera transmission results, because the camera used has only a resolution of 2 megapixels which makes the image capture less than optimal. However, through direct observation, the author confirmed that dew was indeed present on the leaves during both days. This is what becomes the decision in activating the pump on these two days.

The condition of red onion leaves in Nagari Sungai Nanam, Lembah Gumanti District, Solok Regency shows significant variations from day to day. Observations show that on Friday and Saturday, the red onion leaves appear dry and clean, but experience drastic changes on Sunday to Tuesday with the appearance of dew sticking to the leaf surface. This phenomenon occurs because of the geographical characteristics of the area, which is located in the highlands with low temperatures and high humidity, creating ideal conditions for dew formation. This dew that sticks to red onion leaves not only affects plant health visually, but also has the potential to become a conducive medium for the growth and spread of pathogenic fungi that can damage plant productivity. To overcome this problem, a telegram-based remote monitoring and watering system has been created as an appropriate technological solution. This system integrates ESP32-CAM which is able to capture and send images of plant conditions and send them to farmers or land managers through the telegram platform. With this method, farmers can monitor the presence of dew on red onion plants without having to make physical visits to the fields every day, thereby increasing time and energy efficiency in plant management. The use of the telegram platform as an interface makes it easier for farmers to access information because this application is generally already familiar and easy to operate by various groups.

Implementation results show that this system successfully sends images showing the condition of dew sticking to red onion leaves. Based on the images received, farmers can perform visual analysis and make decisions to activate watering pumps selectively and in a timely manner. This decision-making process is entirely carried out by farmers based on their experience and knowledge in recognizing potential hazards from dew visible in the images. The system then allows the pump to be activated remotely via commands sent back via telegram, giving farmers full control to take preventive measures to prevent fungal growth on red onion plants. Although this system has shown promising performance, there are still limitations to the quality of the camera used, especially in conditions of less than optimal lighting or limited viewing distance. To overcome these limitations, a combination of observation through images and direct verification to the field has been applied to ensure the accuracy of decision making by farmers. Based on a series of tests that have been carried out, this method has proven effective in helping farmers manage red onion plants more efficiently. Further development can be directed at improving camera quality, integrating additional sensor data such as temperature and humidity to provide more comprehensive information, as well as refining the user interface on the Telegram platform to make it easier for farmers to analyze images and send pump activation commands.

4. CONCLUSION

After designing, observing, testing, and collecting data from each trial conducted on this remote watering device, the following conclusions can be drawn from the design of the tool in this final project: 1) The implemented system successfully monitors the condition of red onion plant leaves using ESP32-CAM which is sent to IoT-based telegram, but the quality of the images sent depends on the camera resolution. 2) The tool that has been developed can perform remote watering if needed via telegram which can be accessed via smartphone or PC.

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