Design of Watering and Ambient Temperature Control of Pakcoy Aeroponic Plants with IoT-Based Telegram Notification

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Plant cultivation with hydroponic techniques involves using water or nutrient-rich solutions without soil, focusing on meeting plants' nutritional needs efficiently. Among various hydroponic methods, aeroponics stands out by growing plants in air and providing nutrients via water mist. This method minimizes resource use and enhances plant growth. This research aimed to develop an IoT-based control system for watering and temperature management of pakcoy aeroponic plants, with real-time monitoring via Telegram notifications. The system uses an ESP32 microcontroller to manage watering schedules through an NTP server and regulate temperature with a DS18B20 sensor and a DC fan. The integration of IoT allows farmers to monitor and control the system remotely. Results demonstrated the system's effectiveness in maintaining optimal conditions for pakcoy growth, ensuring efficient resource use, and providing reliable notifications. The proposed system offers a practical solution for optimizing aeroponic cultivation, potentially enhancing productivity and resource management for urban agriculture.

Keywords: Aeroponic, NTPServer, Ds18b20.

I. INTRODUCTION

Plant cultivation with hydroponic technique is a plant cultivation technique by utilizing water or nutritious mineral solutions without soil by concentrating more on meeting nutritional needs[1]. This hydroponic method has many variations of methods that have been developed and over time, the use of planting techniques with hydroponic techniques began to be recognized by the public, because land utilization is quite efficient and can even be made in places with minimal land. The types of plants that the majority of people grow using hydroponic methods are domestic or foreign vegetables that can be consumed daily such as lettuce, kale, mustard greens, spinach, pakcoy and various other types of vegetables. The hydroponic planting technique has many types of planting methods, one of which is the aeroponic system.

In this hydroponic method with an aeroponic system, the planting process is carried out without using soil media for growth and development, but rather growing using air as the main medium and using nutrient water condensed through a water sprayer which has an output in the form of water with small particles which will later hit the roots of the plant so that the plant is able to grow. This aeroponic method is done in such a way that the roots of the plant are suspended in the air and supported by styrofoam[2]. The aeroponic technique minimizes the use of water and nutrients by delivering nutrient solutions to the plant roots in a measured manner. This not only saves resources, but also improves plant growth and quality.

In aeroponic plant care, there are several things that need to be considered, such as providing nutrients to the roots of the plant and conditioning the temperature in the grow box or 2 aeroponic growing room. Watering nutrient water is done by spraying water droplets in the form of dew particles that have been mixed with nutrients directly to the roots of plants that hang in the air. The process of condensation of the plant roots is carried out in a continuous manner, but if you have to stop, it should not be more than 15 minutes so that the plants can absorb nutrients properly[3]. An example of a vegetable crop that can be grown using this aeroponic technique is pakcoy vegetables

Pakcoy is one type of vegetable crop that is widely consumed by the community. However, from BPS data in 2020, it is stated that pakcoy production from 2017-2019 has decreased, this is due to the limitations of growing media and the diversity of commodities in a n

arrow area which results in the growth of this plant being less than optimal and not sustainable. [4]. The growth of pakcoy itself has a harvest period of up to 45 days, and the temperature required for its growth is vulnerable to 15 degrees to 30 degrees with 60%-80% humidity [5], as well as with the treatment of watering plants in aeroponic techniques carried out approximately 15 seconds with a pause every 15 minutes every watering [6].

The use of modern technology such as the internet today can be one solution to help support and develop aeroponic plant care systems, such as the application of the Internet of Things, the Internet of Things, also known by the abbreviation IoT, is a concept that has the aim of expanding the utilization of internet connectivity that is connected intensely which makes it possible to connect with machines, equipment, and other physical objects with network sensors and actuators to obtain data and manage their own performance. [7]. Therefore, the use of IoT is expected to develop the optimization of aeroponic planting systems.

From the existing problems regarding aeroponic plant care such as the duration of plant watering and air temperature conditioning in the aeroponic plant growing room and the utilization of the Internet of Things, there are previous studies that examine these systems such as research conducted by Muhammad Fadhil, et al in 2015 with the title "Designing a prototype of Automatic Watering Tool with RTC DS1307 Timer System Based on Atmega16 Microcontroller on Aeroponic Plants" in this study researchers made a design tool for watering aeroponic plants using the RTC DS1307 timer module. [8]

The second research is research by Rohadi, E, et al in 2019 with the title "Aeroponic Vegetable Plant Watering System Based on Iot-Based Temperature and Humidity Using Fuzzy Methods" in this study conducted on pakcoy plants by setting the duration of the RTC timer for watering using the fuzzy mamdani method with temperature and humidity inputs. [6].

The third research was conducted by Safitri, L., & Prasetyo, G in 2022 with the title "Design of a Pump Control Tool and Monitoring the Minimum Limit of Nutrient Solution in the Aeroponic Method Using the Esp32 Microcontroller" in this study the researcher made a design of an aeroponic plant watering pump controller for mustard plants with an RTC timer that can be timed via a smartphone and is able to monitor the minimum limit of nutrient solution via email notification. [9].

From the existing research, there are some similarities, namely the use of the RTC timer as a scheduler for scheduling the length of time the pump does watering, but for the use of RTC makes us add the timer module as an additional device, and must be recalibrated in some time so that the time can be more accurate again. Based on this, the author intends to apply the Network Time Protocol (NTP) server as a synchronizer for scheduling the watering time of aeroponic plants on pakcoy vegetables based on the ESP32 microcontroller. The process of watering aeroponic plants can be integrated with the Network Time Protocol (NTP) server to ensure that the watering schedule is always synchronized with a more accurate time in order to further optimize the aeroponic plant watering system. NTP server is an internet protocol used to synchronize time on internet networks connected within a few milliseconds of universal time coordinated (UTC). [10].

The use of this NTP server has been applied in research conducted by ibnu aulia aza, et al in 2023 with the title "Drip Irrigation System Using YL-69 Soil Moisture Sensor Based on Internet of Things (iot)" where in the study the researchers made an irrigation system that can be monitored remotely, the system uses Network Time Protocol (NTP) for scheduling the pump to turn on the watering automatically. [11].

From the background description, the researcher plans to integrate IoT technology in the control system for watering aeroponic plants and also control for environmental temperature in the aeroponic growing room with internet of things-based telegram notifications in order to help optimize technology that can help farmers in cultivating pakcoy vegetable plants in aeroponic systems. The system will later implement an NTP server for watering scheduling, as well as using a DS18B20 sensor and a DC fan to control the temperature of the growing room so that the temperature in the growing room matches the temperature conditions for pakcoy plant growth, this system will also be able to provide information on the success of watering and temperature conditions in the growing room through telegram application notifications so that farmers can monitor it from anywhere.

II. METHODS

Design System

System design is the stage of making a prototype. In this stage there is a block diagram of the flow of the system as well as Hardware design and Software Design.

1. Block diagram

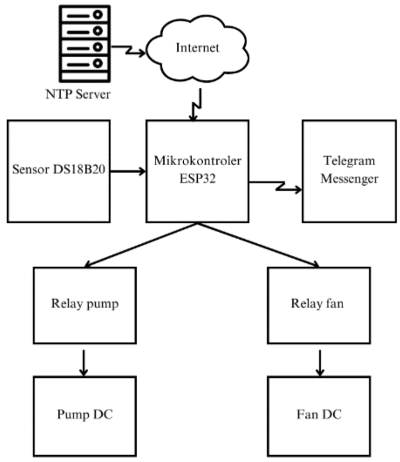

Figure 1. Block diagram

According to the Figure 1 The ESP32 microcontroller functions as the main controller that processes all data, from the microcontroller we program to request a specific timezone to the NTP server which then the NTP Server will respond by providing time data in the form of UTC timestamp format which can then be processed by the microcontroller as a scheduling time for the on and off relays to turn on and off the pump that waters the plants, The microcontroller is also a data processor from the DS18B20 temperature sensor which provides the temperature value of the aeroponic plant room which will control the relay to turn on the DC fan if the temperature is more than predetermined, the data obtained in the form of watering success and sensor sensing data will be sent to telegram so that it can be used as monitoring by users.

2. Hardware Design

Hardware design is carried out with the aim of forming an interconnected circuit system and understanding the function of each component used. The circuit system design for this research is shown in Figure 2.

You can notice in Figure 2 that number 1 is the power supply used to convert the source voltage, namely AC to DC. Then number 2 is the stepdown module used to reduce the DC voltage. Then number 3 is the ESP32 which is a microcontroller that is used as a data processor for the entire system. Then number 4 is the relay module that functions as a switch in controlling the DC pump and DC fan. Then number 5 DC 12V water pump acts as a nutrient water pump from the nurition water reservoir to the roots of aeroponic plants. Then number 6 DS18B20 sensor functions as a sensing of room temperature in the aeroponic plant. Then number 7 DC fan functions as a room temperature controller in the aeroponic plant. Then number 8 is

Telegram which functions as a medium to display the results of monitoring watering and room temperature of the aeroponic plant. Then nor 9 is the NTP server which functions as a reference for synchronising plant watering scheduling. And the last is the Aeroponic plant acts as a place for aeroponic plants to grow.

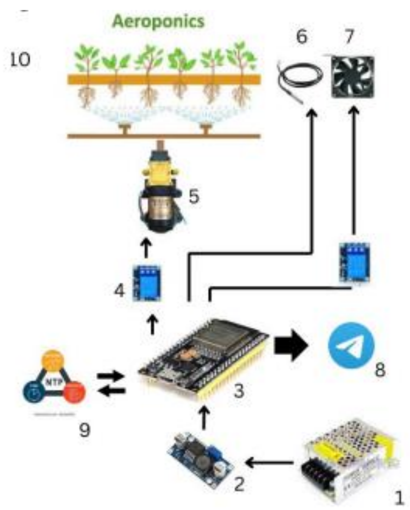

Figure 2. Hardware Design

3. Software Design

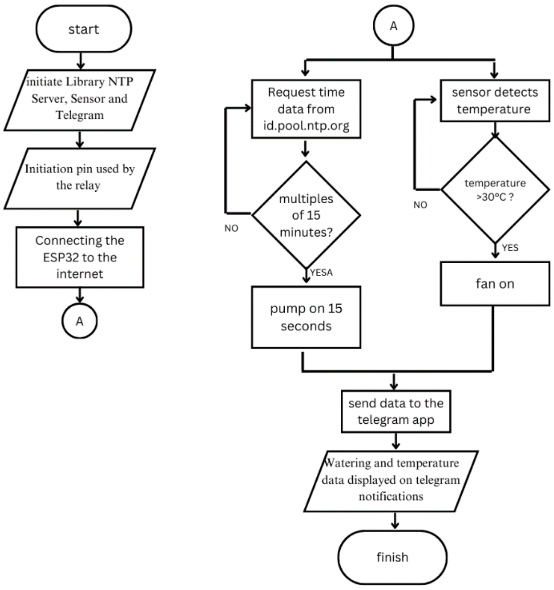

Figure 3. System Flowchart

From the system flow diagram in figure 3 above, the parameters for the pump to water the plants are that every 15 minutes interval the pump will turn on to water the plants for 15 seconds, while for temperature control can be seen in table 1.

No.	Kontrol suhu	
	Suhu	Kondisi kipas
1	Suhu < 30°C	Mati
2	Suhu > 30°C	Hidup

Table 1. Growing room temperature control table

Implementation

After the design stage is complete, what needs to be done is the implementation of the system design that has been made, at this stage the researcher builds the system into a concrete form of watering control, planting room temperature control system, and telegram notifications.

System Test

In this phase, thorough testing of the sensors, NTP server and all components used in the system design, including hardware and software, is carried out. The goal is to evaluate the final results of the system design and ensure that the system can operate according to the specified achievement indicators.

Analysis

Analysis is carried out after the trial phase of all systems has been completed, if readjustment is still needed, it will be followed up to adjust the system made until it is as expected.

III. RESULT AND DISCUSSION

Hardware Design Results

In the design made regarding the control of watering and temperature of the aroponic plant growing room with IoT-based telegram notifications, there is a hardware design that has been designed in the previous chapter, starting from the source of the electrical voltage to the electrical load used by the system, the voltage source in the system made is derived from a 12V power supply, then the voltage is lowered using the lm2596 dc-dc step down module to provide a voltage source according to the needs of the components used. From these two systems using one main microcontroller, namely ESP32, from this microcontroller, the hardware design is then divided into two parts of the hardware design, the first as a watering controller for pakcoy aeroponic plants, then the second as a temperature controller for the pakcoy aeroponic plant growing room.

a. Watering control

In this design, ESP32 is used for the main data processor for watering control where the GPIO 26 pin is integrated with a 2- channel 5V optocoupler relay module on the IN 1 relay pin used to turn on and turn off the DC pump to water the plants according to the data program in the ESP32 microcontroller.

b. Control the temperature of the growing room.

In this design, ESP32 is used as the main data processor of the system where GPIO pin 32 is integrated with the ds18b20 sensor as a temperature sensing in the planting room, the ESP32 microcontroller on GPIO pin 27 is integrated with a 2-channel 5V optocoupler relay module on relay pin IN 2 which is used to turn on and off the DC fan according to the program processed in the microcontroller.

(a) (b)

Figure 4. Hardware design results

For an overall picture of the hardware design can be seen in Figure 4(a) for the hardware design in the box and Figure 4(b) for the hardware design when installed with the growbox.

Software Design Results

Researchers designed and implemented software to create a design system for watering and temperature control of the planting room with IoT-based telegram notifications using the Arduino IDE version 2.3.3 software installed on a laptop device, with the ESP32 microcontroller as the main data processor for this system. There are two software designs used, including

a. Watering control

The software design for watering control with telegram notification begins with initializing the NTP server library, telegram bot and WiFi. then connect the microcontroller to internet access so that the NTP server gets the time data through the id.pool.ntp.org server which will be managed to control the DC pump with the provisions of the watering interval is 15 minutes. For watering intervals, time data from the NTP server is used to be able to turn on the pump every 15 minutes, with watering time carried out at minute 00, minute 15, minute 30 and minute 45 from the server. if it is still in the watering interval, the relay for the DC pump will turn off while when the watering states, the DC pump will turn on. Furthermore, telegram notifications are made with the provision that when the program is just running and can access WiFi, it will display a "bot started" notification, then when the pump turns on to do watering, the telegram will display a notification "memulai penyiraman", then when watering is complete, the telegram will display a notification "penyiraman selesai". For the results of the watering control software design can be seen in Figure 5.

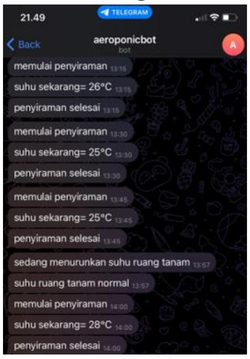

Figure 5. Output of the watering control software design

b. Control the temperature of the growing room.

The software design for temperature control of the growing room with telegram notification begins with the initiation of the ds18b20 sensor library, WiFi, and telegram bot, then the process of reading the room temperature with the ds18b20 sensor which has been calibrated with existing temperature measuring instruments. Then control is carried out for the relay module which controls the on and off of the DC fan according to the sensor sensing with the provisions of the DC fan according to table 1. The telegram will later provide a "bot started" notification when the program starts running. Then the telegram will provide a telegram notification with the notification "sedang menurunkan suhu ruang tanam" if the DC fan turns on when the temperature is more than the provisions, namely temperature> 30 degrees,dc fan has lowered the temperature to a temperature <= 30 degrees it will provide a notification "suhu ruang tanam normal" the notification will also appear by displaying the temperature 36 when finished watering with the display "suhu sekarang = (current temperature) °C". For a picture of the results of the temperature control software. For a picture of the results of the temperature control software design can be seen in Figure 6.

Figure 6. Design of temperature control software

System Testing

After the implementation stage of the hardware design and software design has been successfully carried out, the next stage is to carry out the test phase on the ds18b20 sensor and NTP server for calibration and determine the accuracy of the sensor and NTP server with measuring instruments and real time references.

a. Ds18b20 Sensor Trial

The test on the ds18b20 sensor was carried out to determine the accuracy of the ds18b20 sensor to changes in room temperature used for aeroponic plants. Trials were conducted in the planting room during the day and at night because of the two temperature differences between day and night.

(a) (b)

Figure 7. Sensor testing with measuring instruments.

In Figure 7(a) looks inside the growbox where there is a thermometer iron tip and an iron tip from the ds18b20 sensor that reads the sensor value in the growing room. Then for Figure 7(b) looks outside the growbox. Trials were also carried out comparing the results of the ds18b20 temperature sensor measurements with a thermometer that was able to read the temperature value in centigrade units. then the author experimented 10 times to get the average reading with a pause in taking the experiment was 15 minutes, the results of the experiment can be seen in Table 2 below:

From the table 2 you can notice that the average value of the measuring instrument during the day is 31.1 ° C, and at night is 25.3 ° C, while for the average sensor results during the day is 31.7 ° C and at night is 25.2 ° C, then for the error value with the results of the error value during the day.2) with the results of the error value during the day is 1.85% and at night is 0.4%, then for the accuracy the results during the day is 98.15% and when tried at night at 99.62%. So it can be concluded that the accuracy value of the sensor is very good to be used as a sensing of changes in the temperature of the planting room.

Table 2. Testing table of ds18b20 temperature sensor

No.	Hours	Temperature(°C)		Error Value (%)	Accuracy Value
		Tool	Sensor		
1	08.00	30	30	0	98,15%
2	08.15	30	30	0	
3	08.30	30	30	0	
4	08.45	30	30	0	
5	09.00	30	30	0	
6	09.15	31	32	3,22	
7	09.30	32	32	0	
8	09.45	33	34	3,03	
9	10.00	33	35	6,06	
10	11.15	32	34	6,25	
Average		31,1° C	31,7° C	1,85%	

No.	Hours	Temperature (°C)		Error Value (%)	Accuracy Value
		Tool	Sensor		
1	18.15	25	25	0	99,62%
2	18.30	25	25	0	
3	18.45	25	25	0	
4	19.00	25	25	0	
5	19.15	25	25	0	
6	19.30	25	25	0	
7	19.45	25	25	0	
8	20.00	26	25	3,8	
9	20.15	26	26	0	
10	20.30	26	26	0	
Average		25,3 ° C	25,2° C	0,38%	

b. NTP server test run

for testing the NTP server time data is done by experimenting to turn on the 12V relay module programmed with the NTP server within 15 minutes once, namely at 15 minutes, 30 minutes, 45 minutes and 00 minutes, a total of 10 trials, as for the results for testing can be seen in Table 3 below:

Table 3. NTP server test experiment table

No.	Parameter	Real time	Relay turn-on time	Time lag (minutes)
1	Relay on every 15 minutes	17.00	17.00	0
2		17.15	17.15	0
3		17.30	17.30	0
4		17.45	17.45	0
5		18.00	18.00	0
6		18.15	18.15	0
7		18.30	18.30	0
8		18.45	18.45	0
9		19.00	19.00	0
10		19.15	19.15	0
	Average			0

In Table 3, it is obtained from testing the NTP server which is implemented to turn on the 12V optocoupler relay module which is compared with the real time at that time ,which results in accurate results where the relay programmed with the NTP server will turn on according to the specified time, namely at minute 00, minute 15, minute 30, minute 45, with an average lag between real time and the time from the NTP server to turn on the relay is 0 minutes. So it can be concluded that the NTP server can be used as a watering scheduler later, because the running time is accurate to turn on the relay.

Data Retrieval

a. watering control

Table 4. Day 1 watering control data collection table

No.	Watering Schedule	Watering success time	Pause Time (Minute)	Notifications Telegram
1	13.00	13.00	0	receive
2	13.15	13.15	0	receive
3	13.30	13.30	0	receive
4	13.45	13.45	0	receive
5	14.00	14.00	0	receive
6	14.15	No Watering	0	Not receive
7	14.30	14.30	0	receive
8	14.45	14.45	0	receive
9	15.00	15.00	0	receive
10	15.15	15.15	0	receive
11	15.30	15.30	0	receive
12	15.45	No Watering	-	Not receive
13	16.00	16.00	0	receive
14	16.15	16.15	0	receive
15	16.30	16.30	0	receive
16	16.45	16.45	0	receive
17	17.00	17.00	0	receive
18	17.15	17.15	0	receive
19	17.30	17.30	0	receive
20	17.45	17.45	0	receive
21	18.00	18.00	0	receive
22	18.15	18.15	0	receive
23	18.30	18.30	0	receive
24	18.45	18.45	0	receive
25	19.00	19.00	0	receive
26	19.15	19.15	0	receive
27	19.30	19.30	0	receive

No.	Watering Schedule	Watering success time	Pause Time (Minute)	Notifications Telegram
28	19.45	19.45	0	receive
29	20.00	20.00	0	receive
30	20.15	20.15	0	receive
31	20.30	20.30	0	receive
32	20.45	20.45	0	receive

Data collection is carried out on the results of the watering control design by recording the scheduled watering time and the time to start watering by the DC pump and the receipt of the "start watering" notification sent via telegram notification and compared with the real time when data collection takes place. Data collection is carried out for 3 days in order to determine the reliability of the system that has been made

Table 5. Day 2 watering control data collection table

No.	Watering Schedule	Watering success time	Pause Time (Minute)	Notifications Telegram
1	13.00	13.00	0	receive
2	13.15	13.15	0	receive
3	13.30	13.30	0	receive
4	13.45	13.45	0	receive
5	14.00	14.00	0	receive
6	14.15	14.15	0	receive
7	14.30	14.30	0	receive
8	14.45	14.45	0	receive
9	15.00	15.00	0	receive
10	15.15	15.15	0	receive
11	15.30	15.30	0	receive
12	15.45	15.45	0	receive
13	16.00	16.00	0	receive
14	16.15	16.15	0	receive
15	16.30	16.30	0	receive
16	16.45	16.45	0	receive
17	17.00	17.00	0	receive
18	17.15	17.15	0	receive
19	17.30	17.30	0	receive
20	17.45	17.45	0	receive
21	18.00	18.00	0	receive
22	18.15	18.15	0	receive
23	18.30	18.30	0	receive
24	18.45	18.45	0	receive
25	19.00	19.00	0	receive
26	19.15	19.15	0	receive
27	19.30	19.30	0	receive
28	19.45	19.45	0	receive
29	20.00	20.00	0	receive
30	20.15	20.15	0	receive
31	20.30	20.30	0	receive
32	20.45	20.45	0	receive

The results of Table 5 data collection on the second day, it was found that of the 32 experimental samples conducted when the watering control system was active, 32 of them successfully watered and successfully sent a "start watering" notification when the plant watering began in all 32 trials it was found that all delivery pauses were 0 minutes.

Table 6. Day 3 watering control data collection table

No.	Watering Schedule	Watering success time	Pause Time (Minute)	Notifications Telegram
1	13.00	13.00	0	Accepted
2	13.15	13.15	0	receive
3	13.30	13.30	0	receive
4	13.45	13.45	0	receive
5	14.00	14.00	0	receive
6	14.15	14.15	0	receive
7	14.30	14.30	0	receive
8	14.45	14.45	0	receive
9	15.00	15.00	0	receive
10	15.15	15.15	0	receive
11	15.30	15.30	0	receive
12	15.45	15.45	0	receive
13	16.00	16.00	0	receive
14	16.15	16.15	0	receive
15	16.30	16.30	0	receive
16	16.45	16.45	0	receive
17	17.00	17.00	0	receive
18	17.15	17.15	0	receive
19	17.30	17.30	0	receive
20	17.45	17.45	0	receive
21	18.00	18.00	0	receive
22	18.15	18.15	0	receive
23	18.30	18.30	0	receive
24	18.45	18.45	0	receive
25	19.00	19.00	0	receive
26	19.15	19.15	0	receive
27	19.30	19.30	0	receive
28	19.45	19.45	0	receive
29	20.00	20.00	0	receive
30	20.15	20.15	0	receive

No.	Watering Schedule	Watering success time	Pause Time (Minute)	Notifications Telegram
31	20.30	20.30	0	receive
32	20.45	20.45	0	receive

The results from Table 4 above of the first day of data collection show that the scheduled watering of plants took place every 15 minutes from 13:00 to 20:45. Each row in the table records the scheduled watering time, the actual time when the watering was successfully carried out, the time lag between the schedule and the watering execution in minutes, as well as the status of the notification received on Telegram. This table shows that most of the watering was carried out on time according to the specified schedule, with the execution time exactly the same as the scheduled time, and a time lag of 0 minutes. The Telegram notifications for watering that were successfully received show that the system is working well and on time. However, there were some exceptions, namely in entries number 6 and 12, where watering was not carried out according to the set 43 schedule. In entry number 6, the watering scheduled for 2:15pm did not take place, and the Telegram notification was not received. The same thing happened with entry number 12, where the watering scheduled for 15:45 did not take place, and the Telegram notification was also not received.

The results of Table 6 data collection on the third day, it was found that of the 32 experimental samples conducted when the watering control system was active, 32 of them successfully watered and successfully sent a "start watering" notification when watering the plants began. all 32 trials it was found that all delivery pauses were 0 minutes.

It was found from the three days of trial data collection that the first day there were two trials of watering and sending notifications are failed, then on the second day the watering was successful to turn on and provide notifications, on the third day the same was able to water and provide notifications, on the there was a failure of watering and sending notifications, this is because the internet was cut off, so the microcontroller could not run the program that should have been running, but from the whole experiment it can be concluded that the watering and notification system has run well and properly.

b. temperature control of the growing room

Then data collection for planting room temperature control with telegram notifications, data collection is carried out within a period of three days.

Table 7. Planting chamber temperature control data table day 1

No.	Temperature > 30°C			Temperature < 30°C			Fan On (Minutes)
	Time	Fan	Notifications	Time	fan	Notifications	
1	10.35	On	receive	10.37	Off	receive	2
2	10.50	On	receive	10.55	Off	receive	5
3	11.17	On	receive	11.22	Off	receive	5
4	11.24	On	receive	11.30	Off	receive	6
5	11.42	On	receive	11.45	Off	receive	3
6	12.06	On	receive	12.12	Off	receive	6
7	12.20	On	receive	12.26	Off	receive	6
8	12.49	On	receive	12.55	Off	receive	6
9	13.09	On	receive	13.15	Off	receive	6
10	13.38	On	receive	13.39	Off	receive	1
11	14.10	On	receive	14.13	Off	receive	3
12	14.57	On	receive	15.00	Off	receive	3
Average Time to Lower Temperature to <30°C							4.3

From Table 7, it is obtained from taking data from the air temperature control system, the sensor detects the initial temperature of >30 ° C at 10.35, and ends reading the temperature at >30 ° C at 14.57, namely 12 times the fan turns on. and the results of the reliability of air temperature control efficiency in the planting room using a DC fan requires a temperature drop time of 4.3 minutes, but at some times such as in data 4,5,9, and 12 the temperature drop is helped after watering is done. Then for the reliability of sending notifications the success rate is 100%.

Table 8. Planting chamber temperature control data table day 2

No.	Temperature > 30°C			Temperature < 30°C			Fan On (Minutes)
	Time	Fan	Notifications	Time	Fan	Notifications	
1	10.12	On	receive	10.13	Off	receive	1
2	10.25	On	receive	10.27	Off	receive	2
3	11.09	On	receive	11.10	Off	receive	1
4	11.39	On	receive	11.41	Off	receive	2
5	12.11	On	receive	12.13	Off	receive	2
6	12.42	On	receive	12.43	Off	receive	1
Average Time to Lower Temperature to <30°C							1.5

From Table 8, it is obtained from data collection from the air temperature control system, the sensor detects the initial temperature of> 30 ° C at 10.12, and ends reading the temperature at> 30 ° C at 12.42, which is 6 times the fan turns on, this is because the ambient temperature conditions are cloudy and the planting room is not exposed to sunlight. The results of the reliability of air temperature control efficiency in the planting room using a DC fan requires a temperature drop time of 1.5 minutes, for the reliability of sending notifications the success rate is 100%.

Table 9. Planting chamber temperature control data table day 3

No.	Temperature > 30°C			Temperature < 30°C			Fan On (minutes)
	Time	Fan	Notifications	Time	Fan	Notifications	
1	09.20	On	receive	09.25	Off	receive	5
2	10.12	On	receive	10.13	Off	receive	1
3	10.51	On	receive	10.53	Off	receive	2
4	11.13	On	receive	11.15	Off	receive	2
Average Time to Lower Temperature to <30°C							2.5

From Table 9, it is obtained from data collection from the air temperature control system, the sensor detects the initial temperature of >30 ° C at 09.20, and ends reading the temperature at >30 ° C at 11.13, which is 4 times the fan turns on, this is because the ambient temperature conditions are cloudy and the planting room is not exposed to sunlight. Furthermore, the results of the reliability of the efficiency of controlling the air temperature in the planting room using a DC fan requires a temperature reduction time of 2.5 minutes, for the reliability of sending notifications the success rate is 100%.

Of the three days of experiments to collect data on the temperature control of the planting room, each day has a difference where the first day has the most frequent number of fans to turn on, namely 12 times while the third day has the least number of times to turn on the fan, namely 4 times. This is due to differences in temperature influenced by weather from the outside environment of the growing room. But it can be concluded from the whole experiment that temperature control and notification can run well.

IV. CONCLUCION

The IoT-based pakcoy aeroponic plant watering control system with Telegram notifications was successfully developed, using an NTP server for managing watering intervals, and notifications were sent successfully. The temperature control system for the pakcoy aeroponic growing room was also effectively designed using a DS18B20 sensor to detect temperature changes and a DC fan to reduce temperature. Watering control and Telegram notifications functioned well, with accurate watering times and notifications processed by the ESP32 microcontroller, despite minor issues due to unstable internet on the first day. Overall, the system operated smoothly.

The temperature control and Telegram notifications were reliable, with the DC fan's operation varying based on external weather conditions and effective Telegram notifications ensuring all data transmissions were successfully received, maintaining temperatures below 30°C.

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