Design of IoT Based Indoor Planting Media Quality Monitoring System

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***Abstract*— Indoor plants have become a popular choice for many people in urban environments with limited space for gardening. However, proper care of indoor plants often requires careful monitoring and control of environmental factors such as temperature, humidity, lighting, and watering. In an effort to address these challenges, this study aims to design and build an Internet of Things (IoT)-based indoor plant control system using the Telegram application as the user interface. The system is designed to automatically monitor and control the environmental conditions around indoor plants. IoT sensors connected to the system hardware measure these environmental parameters and send the data to a server. Users can then access and control the system through the Telegram application on their mobile devices or computers. The system also notifies users if there are changes in conditions that require action. The results of this study include the development of an efficient IoT control system, a customized Telegram application, and complete technical documentation. The study identifies security and privacy issues related to the use of the Telegram application in this context and proposes appropriate solutions. Overall, this system combines IoT technology with popular applications to provide practical benefits to indoor plant owners with a remote plant monitoring and care system that can make their work easier. system shows its effectiveness in optimizing indoor plant growth and improving the quality of life with healthy and fertile plants.**

Keywords*— *IoT Sensors, IoT System, Monitoring System, Planting Media, Telegram.

I. INTRODUCTION

The escalating pace of urbanization has significantly reduced available agricultural land in cities, prompting a growing interest in alternative cultivation methods such as indoor farming [1]. Among leafy vegetables, Lactuca sativa L. (lettuce) stands out due to its nutritional value and adaptability to controlled environments [2]. Optimal lettuce growth requires specific environmental conditions, notably ambient temperatures between 25°C and 28°C and soil moisture levels ranging from 65% to 78% [3]. Traditional outdoor cultivation in tropical regions like Indonesia is often hindered by seasonal variability, particularly reliance on rainfall, which leads to inconsistent yields and market price volatility [4].

To mitigate land constraints and climate dependency, indoor plant rooms equipped with real-time monitoring systems have emerged as a viable solution [5]. These systems leverage advancements in Internet of Things (IoT) technology to automate the regulation of critical growth parameters—temperature, humidity, lighting, and irrigation—thereby ensuring stable and efficient crop production regardless of external conditions [6]. IoT-enabled agriculture not only enhances productivity but also reduces labor intensity, making it especially suitable for urban dwellers with limited time or gardening expertise [7].

Remote monitoring and control capabilities are central to modern smart farming. Messaging platforms such as Telegram offer a user-friendly interface for interacting with IoT systems without requiring specialized applications [8]. This integration allows plant owners to receive real-time alerts, view sensor data, and issue commands directly from their smartphones [9]. For instance, when the temperature exceeds 28°C, a cooling fan can be automatically activated via a DS18B20 sensor; similarly, a YL-69 soil moisture sensor can trigger a solenoid valve to irrigate when moisture drops below 65% [10].

Moreover, artificial lighting—typically in the form of LED grow strips—substitutes natural sunlight in indoor setups, supporting photosynthesis during periods of insufficient daylight [11]. Complementing these features, embedded vision systems like the ESP32-CAM enable visual monitoring of plant development, offering users a comprehensive view of their indoor garden's health [12]. The use of microcontrollers such as Arduino Uno, interfaced with environmental sensors and actuators, forms the backbone of such automated systems [13].

Recent studies underscore the effectiveness of IoT in precision agriculture, demonstrating up to 30% water savings and improved crop uniformity through automated feedback control [14]. In the Indonesian context, where smallholder farmers face challenges related to climate unpredictability and post-harvest losses, smart indoor farming presents a scalable and sustainable alternative [15]. By integrating real-time data acquisition, automated actuation, and user-centric communication via Telegram, the proposed system aims to deliver a robust, low-cost solution for urban lettuce cultivation that aligns with Industry 4.0 principles [16].

II. METHOD

A. System Design (Hardware, Software, and Applications)

This stage contains the preparation of planning tools, systems and software and formulating information needs based on observations and literature studies in reference journals, articles or theses that are being worked on. Tool design is the

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creation of a framework to place the plants, electronics and actuators needed. While circuit design is the design of electronics for reading, decision making and to move the actuators needed. System design contains software design in microcontroller ic and telegram bot to display and manage a system.

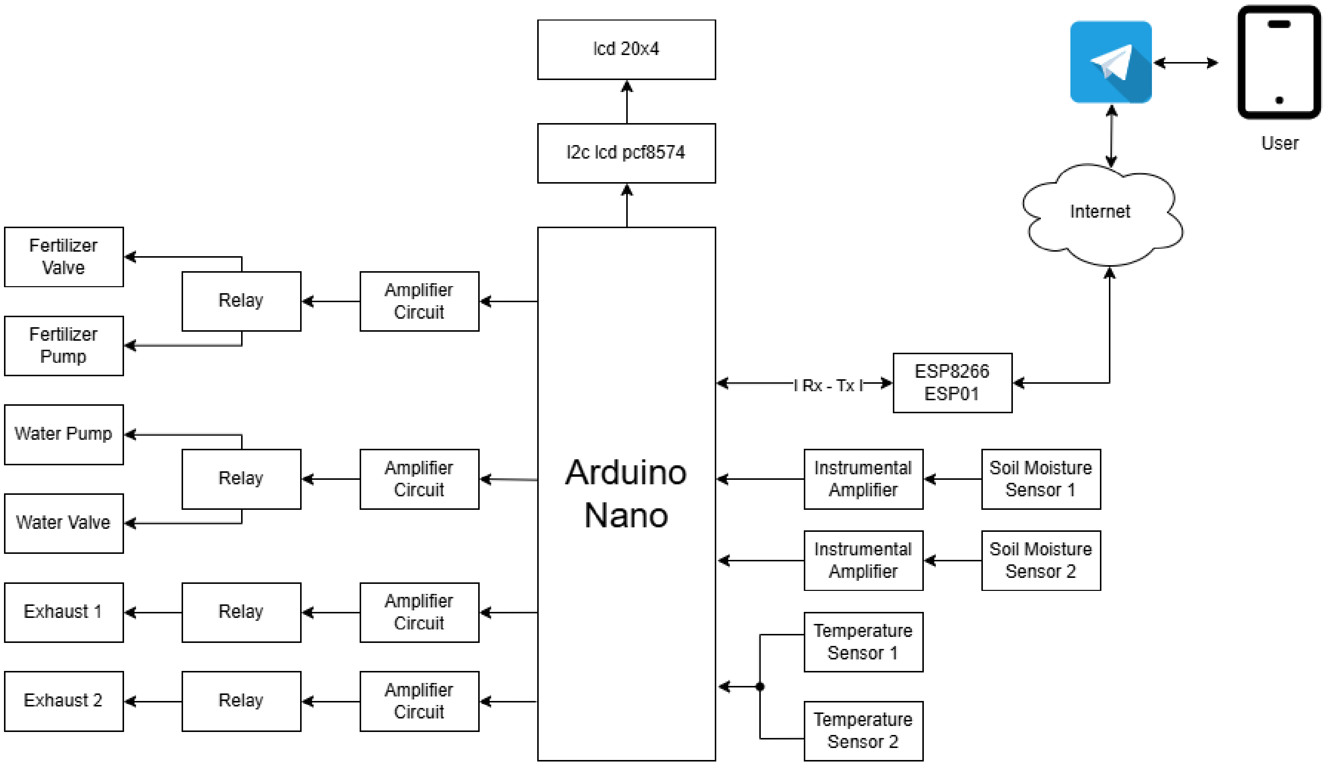

Figure 1. Block diagram

Based on the block diagram in Fig.1, each system block has the following functions:
Arduino nano functions as a signal reader from the DS18B20 temperature sensor and soil moisture sensor. The soil moisture sensor requires an instrumentation amplifier using LM393, known on the market as YL-69. Arduino nano also controls and performs actions using relays connected to actuators and displays on the LCD using I2C communication. ESP8266 or ESP01 is used to connect devices to the internet which users can then access via Telegram. The communication used to connect the Arduino nano and the ESP01 is serial communication with a baud rate of 9600 bps.

B. Flowchart System

The main program that needs to be prepared is the library used, defining names with constant values, and initializing variables. The libraries used are OneWire.h, DallasTemperature.h, Wire.h, and LiquidCrystal_I2C.h. The program body in the Arduino nano void setup contains determining the baud rate for serial communication, determining the Arduino leg using pin Mode, preparing the DS18B20 temperature sensor, displaying the initial LCD display, display Wi-Fi connection and enter initial variables for temperature set points and soil moisture set points.

Retrieval of temperature sensor data uses request temperature and looping for to retrieve data from both sensors, while soil moisture takes analog values using the analog Read syntax and is calculated using a formula. The data obtained is updated to the ESP01 every 2 seconds and displayed on the LCD every 0.5 seconds. Fig.2 shows the Arduino nano void setup flowchart.

C. Flowchart Application

The second diagram shows the flow of how the application work application side which is run on the smartphone Fig.3 shows the flowchart.

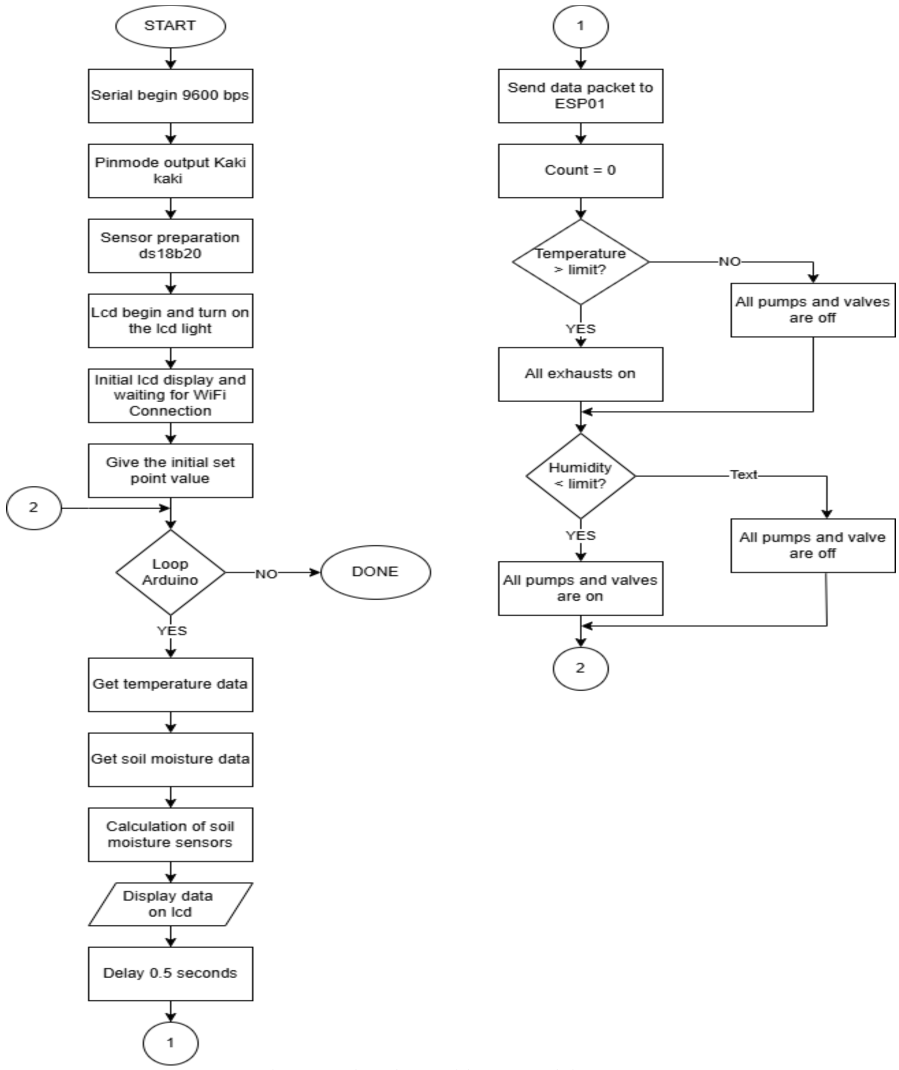

Figure 2. Flowchart void setup Arduino nano

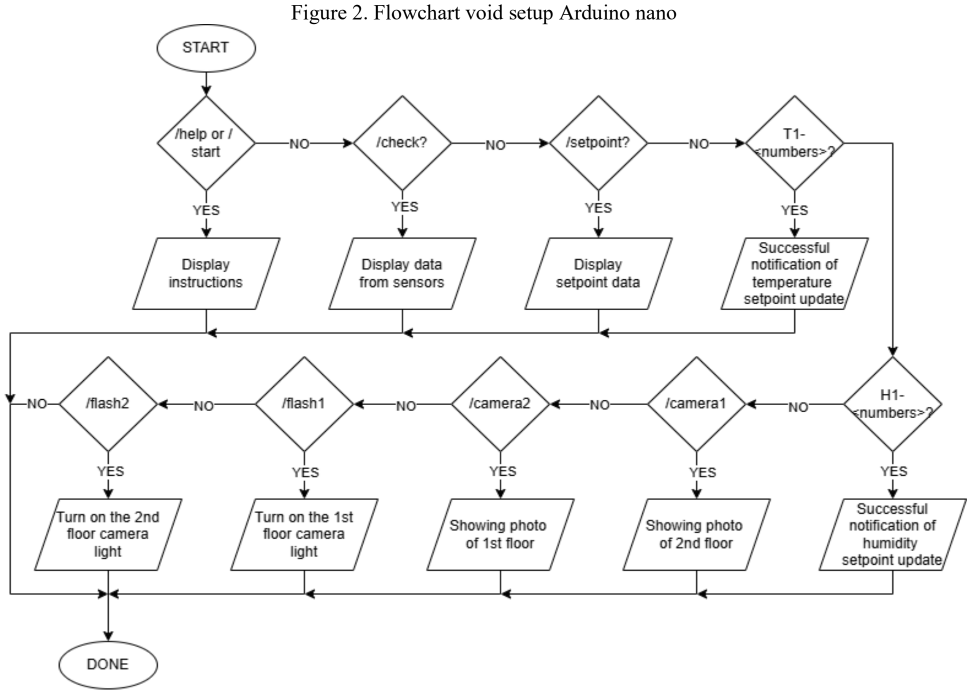

Figure 3. Flowchart application BOT Telegram

III. RESULTS AND DISCUSSION

The results of the system design are divided into two plans, namely hardware and software planning.

A. Hardware Design Results

The results of the hardware design include the components in the box consisting of Nozzle, Temperature Sensor, ESP32 CAM, Exhaust fan.

Figure 4. Tool set display

TABLE I
OUTPUT COMPONENT FUNCTIONS

Component	Function
Fertilize valve	Mechanical actuator, functions to open and close the flow of fertilizer liquid
Water valve	As a mechanical actuator that opens and closes the flow of water for the soil
Water pump	Mechanical actuator, in charge pf pumping water for plants
Exhaust 1	Mechanical actuator that removes heat from the 1st floor
Exhaust 2	Mechanical actuator that disposal on the 2nd floor
Relay	As an electronic actuator that runs mechanical actuator, valves, pump motors and exhaust motors
Amplifier network	Displays with 16 columns and 2 rows
LCD 16x2	Display with 16 columns and 2 rows
PCF857	A functional i2c module connects THE LCD with the Arduino nano

TABLE II
INPUT COMPONENT FUNCTIONS

Component	Function
Temperature Sensor 1	Sensors to measure the temperature on the 1st floor using DS18B20
Temperature Sensor 2	Sensors to measure temperature on the 2ns floor using DS18B20
Soil Moisture Sensor 1	In the form of electrodes to measure soil moisture on the 1st floor
Soil Moisture Sensor 2	In the form of electrodes to measure soil moisture on the 2nd floor
Instrumentation Booster	Humidity sensor range using LM292 IC opamp

B. Software Design Results

Create a telegram bot that will be used via the telegram ID @BotFather, this telegram ID profile can be seen in Fig.5. The next step is to send "/start", then send "/newbot". After receiving a reply and further commands from @BotFather, create the desired telegram ID, if successful, you will receive a token reply to access the HTTP API. This token is used to be entered into the software on the ESP01 Wi-Fi module. Fig.5 shows the Botfather telegram ID profile.

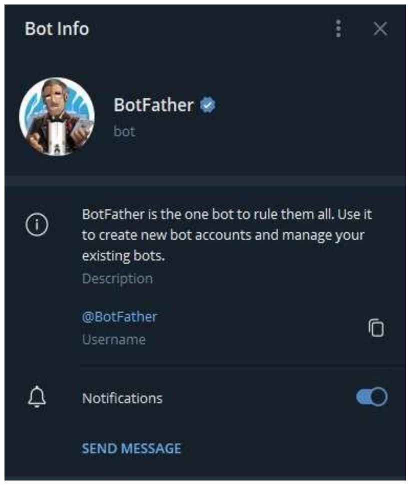

Figure 5. BotFather telegram ID profile

A step that is no less important is getting an ID number. This ID number is important and is obtained from a Telegram account with ID @IDBot. This account can be seen in Fig.6. Send "/getid" to get the ID number.

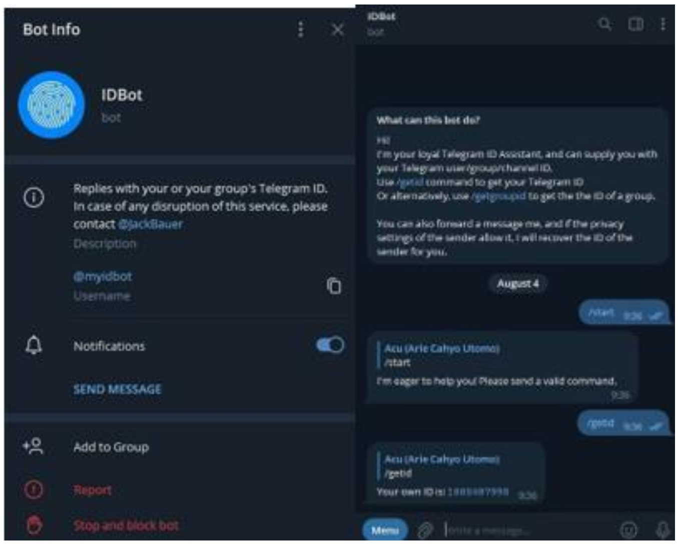

Figure 6. Telegram account to get ID number

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C. Testing All Features

1) Transistor Base Resistor Calculation Results: It is known that the relay voltage required is 5V, while the maximum Collector Emitter voltage is 1V. When the source voltage is 6V, the mini360 is set to reduce the voltage from 12V to 6V. The equation used is Equation (1).

$$V_{Source} = V_{Relay} + V_{CE} \quad (1)$$
$$V_{Source} = 5V + 1V$$
$$V_{Source} = 6V$$

Search for the base current value of the 2N2222 transistor using Equation (2). However, it is necessary to find the value of the current through the collector to the emitter. The calculation is below:

$$I_C = I_{Relay} + I_{LCD} \quad (2)$$
$$I_C = 89{,}3mA + 10mA$$
$$I_C = 99{,}3mA \approx 0{,}933A$$

The I_c value above is a reference for determining the I_Cmax value, the value is obtained from the datasheet of 150mA and 50 times amplification, then calculate the base current value that will be given to the transistor using Equation (3):

$$l_B = \frac{l_{cmax}}{hfe} \quad (3)$$
$$l_B = \frac{150mA}{50}$$
$$l_B = 3mA$$

This I_B value is far below the maximum value that can be provided by the Arduino nano output leg of 20mA, then the resistor value is obtained using Equation 3.4 and specific calculations as follows:

$$R_B = \frac{V_{ard} - V_{BE}}{l_B} \quad (4)$$
$$R_B = \frac{5V - 0.6V}{0.003A}$$
$$R_B = \frac{4.4V}{0.003A}$$
$$R_B = 1466\Omega \approx 1500\Omega = 1k5\Omega$$

2) Actuator Test Result: The electronic circuit that has been designed is shown in Fig.7 below, and the results obtained in actuator testing can be seen in Table III after Fig.7. When the valve is on or given a HIGH signal, the valve is open, while when the signal is LOW the valve is closed. This valve applies to water and fertilizer valves.

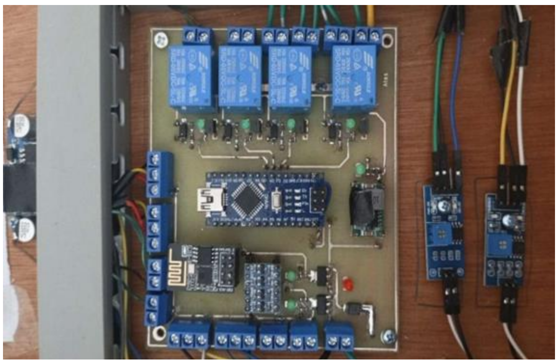

Figure 7. Electronic circuits in the form of PCBs and modules

TABLE III
ACTUATOR TEST RESULTS

Arduino Battery	Actuator	Signal Testing	Result
D2	Fertilizer pumps and valves	HIGH	Turn on
		LOW	Die
D3	Pure water pumps and valves	HIGH	Turn on
		LOW	Die
D4	Exhaust 2nd floor	HIGH	Turn on
		LOW	Die
D5	Exhaust 1st floor	HIGH	Turn on
		LOW	Die

3) LCD Test Results: Each LCD display mode is made in the form of a procedure. So, the programmer simply calls the name of the procedure and can save time and writing the program syntax. The results obtained were successful as can be seen in Fig.8 to Fig.12.

Figure 8. LCD Initial display mode

Figure 9. WiFi connecting display mode

Figure 10. Wi-Fi status display mode is successful

Figure 11. Wi-Fi status display mode failed

Figure 12. Sensor and display mode

4) Temperature Sensor Test Results: The DS18B20 temperature sensor succeeded in measuring temperature, this can be seen from the comparison of digital thermometers in Fig.13 and Fig.14.

Figure 13. Comparison of DS18B20 temperature sensors on floor

The comparison between the DS18B20 sensor and the comparison sensor for the 1[st] floor has an error of 3.8°C.

Figure 14. Comparison of 2[nd] floor DS18B20 temperature sensors

While the DS18B20 sensor and the comparison sensor for the 2[nd] floor has an error of 1.9°C.

Figure 15. Location of the DS18B20 comparison sesnor

The location of the comparison sensor is placed next to the DS18B20 sensor as shown in Fig.15 above.

5) Soil Moisture Sensor Test Results: The soil moisture sensor uses the Arduino analog leg to read. The formula is shown below. The measurement results can be seen in Table IV below. From Table IV, a fixed soil mass of 400 grams was used, and water was provided with varying amounts. It can be seen that the sensor measurement value is directly proportional to the amount of water applied to the soil.

$$Humidity\,\% = 100 - \left(\frac{adc}{1023} \times 100\right) \tag{5}$$

Information:

- Humidity = soil moisture value in % units
- Adc = analog value from Arduino reading

TABLE IV
TEST RESULTS OF YL-69 SOIL MOISTURE SENSOR

Soil mass (gram)	Lots of water (ml)	Measurement results (%)
400	50	72
400	100	73
400	150	74
400	200	75
400	250	77

6) Telegram Bot Test Results: When the /start command is sent, you will get a reply with a choice of commands, this condition can be seen in Fig.18. Next, select the /newbot command, then create the desired telegram ID name. Succeed with the name @Agro_User_Bot, and get a token as shown in Fig.16 and Fig.17.

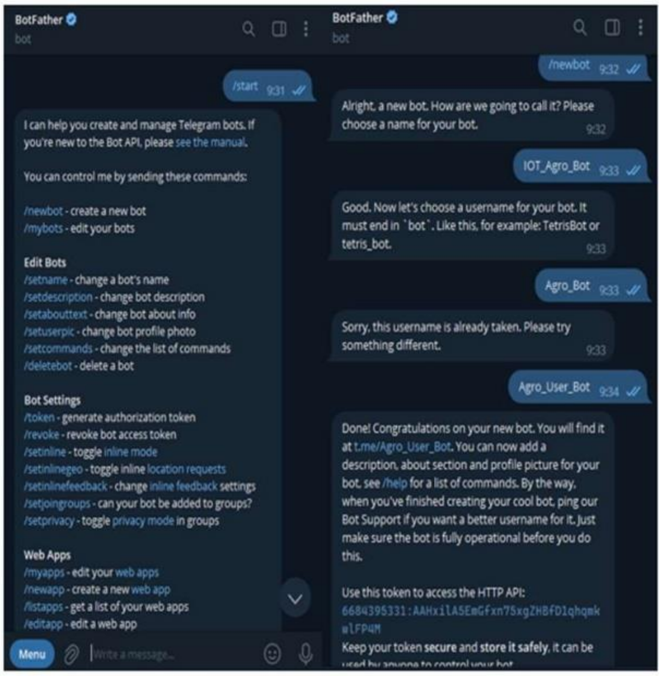

Figure 16. Screenshot of creating a telegram token ID

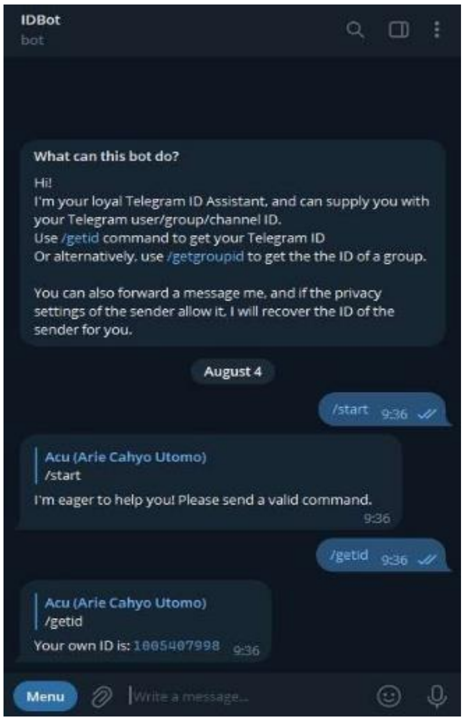

Figure 17. Screenshot of getting the telegram ID number

Figure 18. Answer to the / help and / start commands

The first test is testing the /help and /start commands, then instructions for use will appear as shown in Fig.18 above. Next, the second test is the /check command to see the temperature values for floor 1 and floor 2 as well as soil humidity for floor 1 and floor 2, the results are successful and the same as the LCD displayed. A screen shot of the telegram command /check can be seen in Fig.19.

Figure 19. Screen of the answer to the / check telegram command

The third test is to send or update the desired temperature and humidity setpoint, the temperature setpoint is 27.3 and the soil moisture set is 75. The temperature commands are t1-27.3 and h1-75, the results can be seen in Fig. 20.

Figure 20. Temperature and humidity set point update command

7) Controller Test Results: In controller testing, the soil temperature and humidity used is the soil temperature and humidity at the time of the test. What is changed is the temperature setpoint below and above the temperature measurement, as well as soil moisture, which is done in the same way as the temperature testing pattern. The results have worked as targeted, this can be seen in Table V.

TABLE V
CONTROLLER AND ACTUATOR TEST RESULTS

Floor	Sensor		Set Point		Actuator	
	Temperature °C	Soil Moisture (%)	Temperature	Moisture Land (%)	Exhaust	Fertilizer and water
1	28.5	72	30	80	Turn on	Not flowing
	28.5	71	25	80	Die	Not flowing
	28.5	72	25	50	Die	Flow
	28.5	72	25	75	Die	Not flowing
2	28.5	72	30	80	Turn on	Not flowing
	28.5	71	25	80	Die	Not flowing
	28.5	72	25	50	Die	Flow
	28.5	72	25	75	Die	Not flowing

8) Camera Test Results: The shelf 1 camera test was successful in taking photos and shelf 2 was also successful in taking photos. This can be seen in Fig.21 for shelf 1 and shelf 2, shown in Fig.22. Both images show that the photos do not have good pixels because they are broken, and the resulting color is also not good.


Figure 21. Photo of shelf 1


Figure 22. Photo of shelf 2

9) Results of Light Intensity Testing on Lettuce Plants: Measurement of light intensity in the plant room was carried out three times in 10 minutes with the aim of determining the effect of light intensity on the growth of lettuce (Lactuca sativa Lettuce), namely at 07.00-08.00 WIB, 12.00-13.00 WIB and 16.00-17.00 WIB with using a lux meter.

TABLE VI
LUX METER TEST IN THE MORNING, AFTERNOON, AND EVENING

Hour	Minute	Temperature	Measuring Tool	Measurement Result (LUX)
07.42	10	24°	Lux Meter	4754 lux
12.17	10	27°	Lux Meter	5442 lux
16.26	10	25°	Lux Meter	5335 lux

In the full spectrum purple LED treatment, the lettuce received sufficient light intensity and the light color was a combination of red and blue which caused the lettuce plants to grow better compared to the white light treatment. Blue and red light is good for plant growth because chlorophyll absorbs blue and red light so that photo- synthesis runs optimally compared to other light [5]. Blue light is used by plants in the vegetative phase and red light is used by plants in the generative phase.

10) Test Results Growing Lettuce Plants: The results of the test using plants at box levels 1 and 2 can be seen as 3 weeks old lettuce growing with a stem height of 2 cm as shown in Fig. 23. Clear pictures were taken using a smartphone camera and are shown in Fig. 24.

Figure 23. Lettuce aged 3 weeks, stem height 2cm, with esp 32 cam

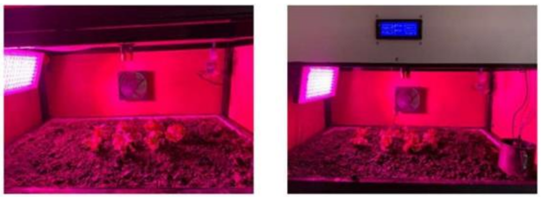

Figure 24. 3 weeks old lettuce, stem height 2cm, with smartphone camera

Figure 25. Lettuce is ready to harvest at 30 days with ESP 32 cam

Fig. 25. taken using an ESP32 cam camera. Meanwhile, Fig. 26. is the result of taking a picture using a smartphone camera. It can be seen that the overall results of the tests that have been carried out are successful.

IV. CONCLUSION

From the test results and discussion, the conclusions are obtained, namely: This system optimizes indoor plant care by monitoring and controlling environmental parameters such as optimal temperature in the air range of 25°C to 28°C, soil humidity of 65% to 78%, lighting measured using a lux meter, and automatic watering. This helps plant owners to care for their plants more efficiently and without having to be physically near the plants. The implementation of IoT on salad plants is going well, this can be proven through notifications and control using the Telegram application.

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