# Low-Cost Monitoring and Control for Melon Cultivation in Greenhouse using Internet of Thing and Drip Irrigation

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**Abstract:** Melons are become a popular fruit cultivating inside the greenhouse using the drip irrigations in Indonesia. The application of internet of things-based monitoring is beneficial to optimize cultivation management. Another issue on melon cultivation inside the greenhouse is automation of the water and nutrient delivery. However, currently monitoring and control is expensive and difficult to modify by farmers. The aim of this study was to develop a low-cost technology and easy to use by farmers using internet of technology. The method used in this study consisted of analysis, design and implementation. The result of this study was a system monitoring to monitor air temperature, air humidity, media humidity and solar radiation inside the greenhouse integrated with nutrient or water delivery using drip irrigation. A web-based dashboard was developed as a user interface for the farmers and users. The overall cost to develop a system monitoring and control was 358.24 USD not including the water thank and nutrient delivery system (pump and irrigations pipe). The system was deployed and tested at Agribusiness and technology park IPB University.

**Keywords:** control; drip irrigation; internet of thing; melon production; monitoring system

## INTRODUCTIONS

### Background

Melon is horticulture commodity that affected on climate condition and become a popular fruit in Indonesia. Currently, greenhouse based cultivation with automatic drip irrigation system are using to cultivate melon. Greenhouse is a set of buildings for plant production including a grow controller, intelligent fertigation, and control environmental parameter (temperature and humidity) (Bao et al., 2023). The parameters of greenhouses consisted of air temperature, nutrient density, and humidity that affected agriculture products. Greenhouse with integrated controller is implementation of controlled environment agriculture (CEA) concept on melon productions (Chen et al., 2023). In tropical regions, high humidity and elevated temperatures pose significant challenges. To mitigate these conditions, advancements in greenhouse horticulture, including automation, renewable energy integration, and soilless cultivation practices, have demonstrated improvements in resource efficiency and productivity (Koukounaras, 2021). Energy requirement is also one of the important things to consider on implementation of CEA. One of the strategies is using solar power to support cultivations process (Salih et al., 2012). Additionally, life cycle assessments have shown that melon cultivation has a notable carbon footprint, reinforcing the need for sustainable solutions (Suppen-Reynaga et al., 2024).

Implementation of monitoring system using digital technology to monitor several parameters on greenhouse-based productions. Greenhouse monitoring systems are mainly using several sensors, internet of things (IoT) and artificial intelligence (AI) to support cultivations (Mondejar et al., 2021). IoT technologies have transformed smart greenhouse farming by integrating sensors, network topologies, and intelligent decision-making platforms, optimizing critical parameters such as temperature, humidity, and CO2 levels (Rayhana et al., 2020). These systems enable real-time data collection, analysis, and precise control, automating tasks such as cooling, heating, and irrigation to achieve sustainable crop production. Advances in IoT architectures and intelligent systems have also facilitated smart greenhouse designs that dynamically adapt to changing environmental conditions (Bersani et al., 2022). For instance, IoT-based systems utilizing Petri Net models effectively monitor greenhouse environments, regulate temperature, and improve energy efficiency while maintaining optimal growing conditions (Subahi & Bouazza, 2020).

These systems employ integrated networks of sensors and communication protocols to enable precise indoor climate control, promoting resource efficiency and sustainability. Further advancements, such as hydroponic cascade systems, have significantly improved water and nutrient use efficiency within controlled environments (Naounoulis et al., 2024). IoT-based fertigation systems enhance precision agriculture by combining real-time monitoring with data-driven resource allocation and optimization models, maximizing both economic and environmental benefits (Lin et al., 2020). These systems support informed decision-making by providing accurate tools for monitoring, controlling, and predicting greenhouse conditions (Hosny et al., 2024). Fuzzy logic-based control systems further enhance greenhouse automation by addressing the complex interdependencies of climate parameters such as temperature and humidity, which are critical for maintaining optimal growing conditions while reducing energy and water consumption (Azaza et al., 2016). In digital farming applications on melon productions there are several research projects that was conducted such as production prediction using Artificial Neural Networks (Erniati et al., 2023), photosynthetic rate estimation model using Artificial Neural Networks (Erniati et al., 2024), and crop yield prediction (van Klompenburg et al., 2020). There are several important parameters for melon production affected by the rate of photosynthesis such as air temperature, sunlight intensity, and relative humidity.

Good agriculture practices and management of melon production inside the greenhouse are also important information inside the greenhouse (Li et al., 2022). Root growth, yield and fruit quality in greenhouse-based production also depend on the nutrient delivery. Nutrient deliveries are using the drip irrigation system with the cocopeat media to grow the melon. Nutrient deficiency and excess will affect the growth of melon in vegetative phase or generative phase (Sharma et al., 2014). Drip irrigation combined with film mulching has been shown to enhance soil enzyme activity, improve soil microorganism populations, and promote muskmelon root growth and fruit quality, making it a promising approach for sustainable melon production (Wang et al., 2018). Fuzzy logic-based precision fertigation systems have demonstrated efficiency in optimizing water and nutrient delivery, reducing waste, and improving plant performance (Prastono et al., 2024). Another issue on melons is the information of cultivations such as the date that starting nursery, date of planting, prediction of pollination time, and prediction of harvesting time are the main information needed in melon production. Cultivation information is mainly maintained manually by growers and farmers. Integrating environmental parameters monitoring using the internet of things and greenhouse-based melon cultivation information are beneficial to improve the management of melon cultivation. However, cost are the main issues on application of digital monitoring system of melon in greenhouse.

This research proposed a low-cost monitoring system to monitor the environmental condition inside the greenhouse and cultivation information. The system will be implemented on a web-based user interface to make it easy to access and used by farmers and growers. The benefits of implementing this technology are to achieve the sustainable production of melon for current and future generations.

### Purposes

The purposes of this research were:

1. Develop a system monitoring using internet of things technology to monitor air temperature, air humidity, media humidity and solar radiation inside the greenhouse.
2. Develop the automatic water and nutrient delivery system using drip irrigations on melon cultivation.
3. Design and deploy user interface using web-based applications to interact with users.
4. Deploy and test the system in Agribusiness and Technology Park, IPB University greenhouse for cultivating melon using drip irrigation.

## METHOD

### Schedule and Research Location

This research was conducted from January to October 2024 in melon cultivation greenhouse at Agribusiness and Technology Park and bioinformatic laboratory, Mechanical and Biosystem Engineering IPB University Indonesia. The development of low-cost sensors was conducted in Bioinformatic laboratory, mechanical and biosystem engineering department, IPB University. Then, testing and implementation was conducted at Greenhouse to cultivate melon using drip irrigation and cocopeat media.

### System Analysis

User demand on melon cultivations consisted of monitoring environmental parameters such as air temperature, media humidity, air humidity, and solar radiation. Those parameters were measured using several sensors such as air temperature, media humidity, air humidity, and solar intensity. Based on the user requirement, the system should have several sensors such as temperature, light intensity and humidity (air and media). All sensors were installed inside the greenhouse and cultivation media. Then, another information such as nutrient delivery time, nutrient timer (control), and cultivation information was gathered and transmitted to the server. The data transmission was used on the internet for technology that can be transmitted in real time transmission. The data transmission included the data from the greenhouse and user preference to the nutrient control that was installed inside the greenhouse. Then, user interfaces were designed to fulfill the user requirements to show the data such as: temperature, light intensity, humidity (media and air), nutrient control and cultivation information. The schematic diagram of the system shows in Figure 1.

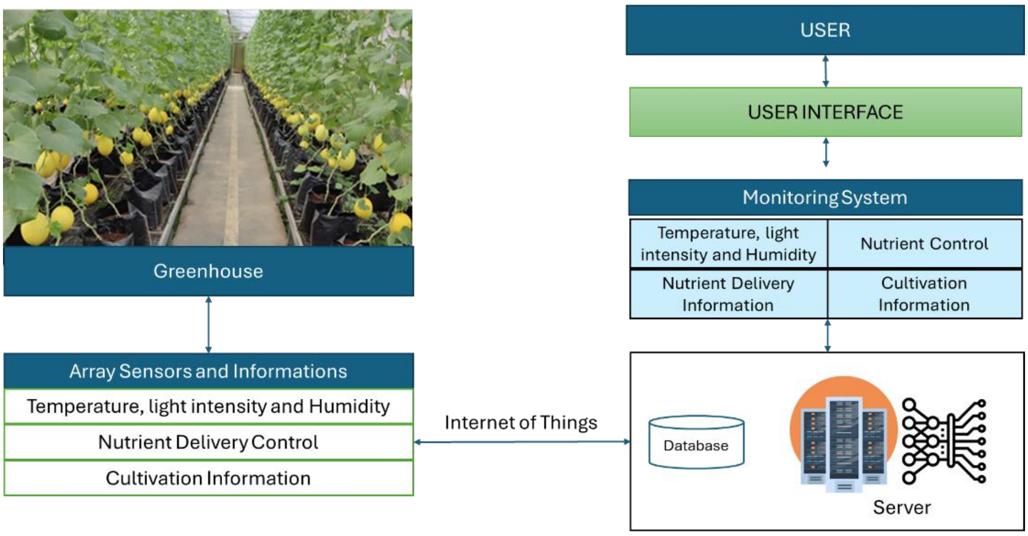


**Figure 1.** Schematic Diagram of the monitoring system using Internet of Things

## Hardware Design

### *Monitoring System*

In this step, the design of monitoring system hardware was conducted. There are two main hardware configurations such as: hardware for monitoring and hardware for controlling the nutrient delivery. First, hardware for monitoring the environment parameters consisted of NodeMcu ESP32 microcontroller, sensor DH21 (for air humidity and air temperature), sensor BH170 for solar radiation, and cultivation media humidity. All sensors were connected to NodeMcu ESP32 microcontroller to send the data through the internet. Figure 2 shows the configuration of hardware for monitoring.

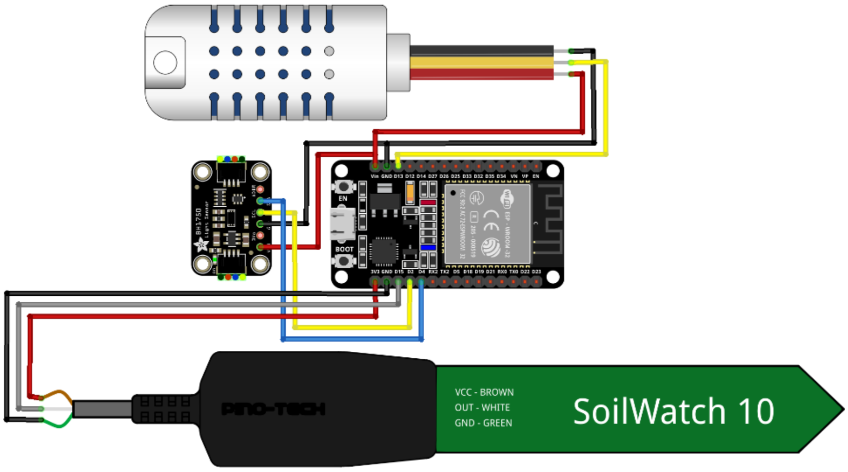


**Figure 2.** Hardware for Monitoring air temperature, air humidity, solar radiation, and cultivation media humidity

Data from sensors will be sent to the webserver using the http-post command using the representational state transfer application program interface (REST API) for sending data to databases. MySQL database was used to manage data that was collected by sensors. The code for sending data from the devices was:

```
void kirim_data(float t_udara, float rh_udara, int rh_tanah, float t_akar) {
   String postData = "t_udara=" + String(t_udara) + "&rh_udara=" +
   String(rh_udara) + "&rh_tanah=" + String(rh_tanah) + "&t_akar=" +
   String(t_akar);

   HTTPClient http;
   http.begin("https://api_sensor
   .php");
   http.addHeader("Content-Type", "application/x-www-form-urlencoded");

   int httpCode = http.POST(postData);
   if (httpCode > 0) {
   if (httpCode == HTTP_CODE_OK) {
   String payload = http.getString();
   Serial.println(payload);
   } else { Serial.println("HTTP error: " + String(httpCode));
   }} else { Serial.println("Connection failed");
   } http.end();}
```

In server side, there are code to send data to the mySQL database. Those code consisted of code to read the data that sending by devices throught internet connections then sending to the database.

```
<?php
   require_once(__DIR__ ."/db_conn.php");
   ini_set("date.timezone", "Asia/Jakarta");

   $now = new DateTime();
   if (!is_nan($t_udara) && !is_nan($rh_udara) && !is_nan($rh_tanah))
   {
        $sql = "INSERT INTO sensor_melon1 (tanggal, t_udara, rh_udara, rh_tanah) VALUES
        ('$tanggal', '$t_udara', '$rh_udara', '$rh_tanah')";
        if ($mysqli->query($sql) === true) { echo "success input data :)";
   } else { echo "ERROR: Could not execute $sql. " . $mysqli->error;
   }} else { echo "data was accepted."; }

   $mysqli->close();
} else { echo "ERROR: data not sended."; } ?>
```

### *Control System*

Second, nutrient delivery was also important to automate the melon cultivations. Nutrient was delivered using pump to 800 individuals' plant in agribusiness and technology park IPB University greenhouse. Nutrient was scheduled to deliver in the morning (8.00 am) by utilizing the pump and opening the solenoid valve of nutrient tanks. Nutrient delivery and volume were defined depending on the stages of melon cultivation. Then, there are five intervals of water delivery, such as 10.00 am, 12.00 pm, 14.00 pm, 15.00 pm, and 17.00 pm. Water volume will be delivered depending on the soil humidity captured by sensor.

The hardware used on this system was NodeMcu ESP32 microcontroller, SSR relay (three unit), contactor, cable, solenoid valve for nutrients, solenoid valve for water, water tank, nutrition tank, water delivery pump, and lateral pipe to deliver water or nutrient to the melon media. Figure 3 shows the hardware configuration of nutrient control and delivery.

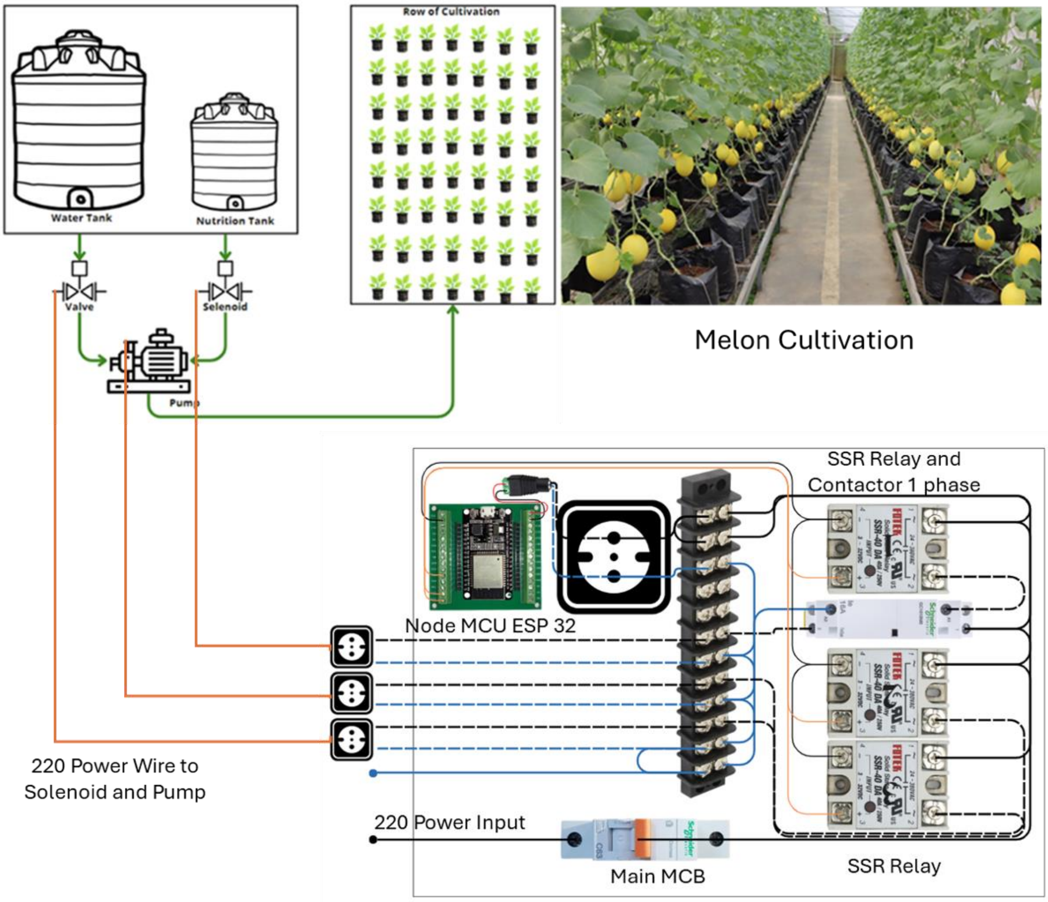


**Figure 3.** Schematic of water and nutrient delivery design on Melon Productions

The node MCU ESP 32 is a microcontroller as a communication device between the controller and servers. Nutrient delivery scheduled was set in server using a MySQL database was used to operate the nutrient delivery. Data and communication using the State Transfer Application Programming Interface (REST API). The code for communication using REST API in the microcontroller devices was:

```
void loop() {
  if (WiFi.status() != WL_CONNECTED) {
    Serial.println("WiFi tidak terhubung, mencoba ulang...");
    WiFi.begin(ssid, pass);
    while (WiFi.status() != WL_CONNECTED) {
      delay(500);
      Serial.print(".");
    }
    Serial.println("WiFi terhubung kembali");
  }

  WiFiClientSecure client;
  client.setInsecure(); // Gunakan setInsecure untuk mengabaikan sertifikat SSL

  const int httpsPort = 443;


  if (!client.connect(host, httpsPort)) {
    Serial.println("Gagal menghubungi server");
    delay(5000); // Coba ulang setelah 5 detik
```

```
    return;
  }

  String linkRelay = "https://" + String(host) +
"/ds_atp/_db/api_aktuator_melon.php";
  HTTPClient httpRelay;
  httpRelay.begin(client, linkRelay);
  int httpCode = httpRelay.GET();

  if (httpCode > 0) {
    String responseRelay = httpRelay.getString();
    responseRelay.trim();
    Serial.println(responseRelay);

    // Parsing respon untuk setiap aktuator
    int actuator[] = {AKTUATOR_A, AKTUATOR_B, AKTUATOR_C, AKTUATOR_D, AKTUATOR_E,
AKTUATOR_F};
    String responses[6];
    int idx = 0;
    int start = 0;
    for (int i = 0; i < responseRelay.length(); i++) {
      if (responseRelay[i] == ',') {
        responses[idx++] = responseRelay.substring(start, i);
        start = i + 1;
      }
    }
    responses[idx] = responseRelay.substring(start);

    for (int i = 0; i < 6; i++) {
      if (responses[i] == "AKTUATOR_" + String(i+1) + "_ON") {
        digitalWrite(actuator[i], HIGH);
      } else if (responses[i] == "AKTUATOR_" + String(i+1) + "_OFF") {
        digitalWrite(actuator[i], LOW);
      }
    }
  } else {
    Serial.printf("Gagal mendapatkan respons, error: %s\n",
httpRelay.errorToString(httpCode).c_str());
  }

  httpRelay.end();
```

In servers sided, there are code to communicate between devices and servers through internet connections. The code accept the data sent request from devices, accept data from database and sending data or action to the microcontroller devices to run the actuator. Code that was used in the server side for controller are mentioned in this line:

```
<?php
include_once "db_conn.php";
date_default_timezone_set('Asia/Jakarta');
$currentTime = date("H:i:s");
$relay = "No data available";

$sql = "SELECT id_aktuator, kondisi FROM `schedule_melon` WHERE waktu <= '$currentTime'
ORDER BY waktu DESC LIMIT 2";
$result = mysqli_query($mysqli, $sql);
$relayConditions = array_fill(0, 2, "No match");
if ($result && mysqli_num_rows($result) > 0) {
```

```
    while ($row = mysqli_fetch_assoc($result)) {
        $id_aktuator = $row['id_aktuator'];
        $kondisi = $row['kondisi'];

        if ($id_aktuator >= 1 && $id_aktuator <= 2) {
            if ($kondisi == 1) {
                $relayConditions[$id_aktuator - 1] = "AKTUATOR_" . $id_aktuator . "_ON";
            } else if ($kondisi == 0) {
                $relayConditions[$id_aktuator - 1] = "AKTUATOR_" . $id_aktuator . "_OFF";
            }}}}
echo implode(",", $relayConditions);
?>
```

### User Interface Design

User interface design was used in the Cascading Style Sheets (CSS) and Bootstrap, both being very contributively in making an attractive, user-friendly interface. Cascading Style Sheets define the style elements, such as colors, fonts, and layouts, that will be used to ensure coherence in visual appearance for better user experience. Bootstrap is a popular CSS framework that enhances the design by providing a structured and grid-based layout, which is responsive and adaptive to various screen sizes for ensuring the usability of the design across various devices. In addition, the system has already prepared a set of elements for the construction of the interface, such as buttons, navigation bars, and forms. This allows developers to have a professional look with time saved in development. The interactivity allowed by this tool of CSS in combination with Bootstrap is not only beautiful but also usable and intuitive to the end user. Figure 4 shows the design of the user interface layout and design.

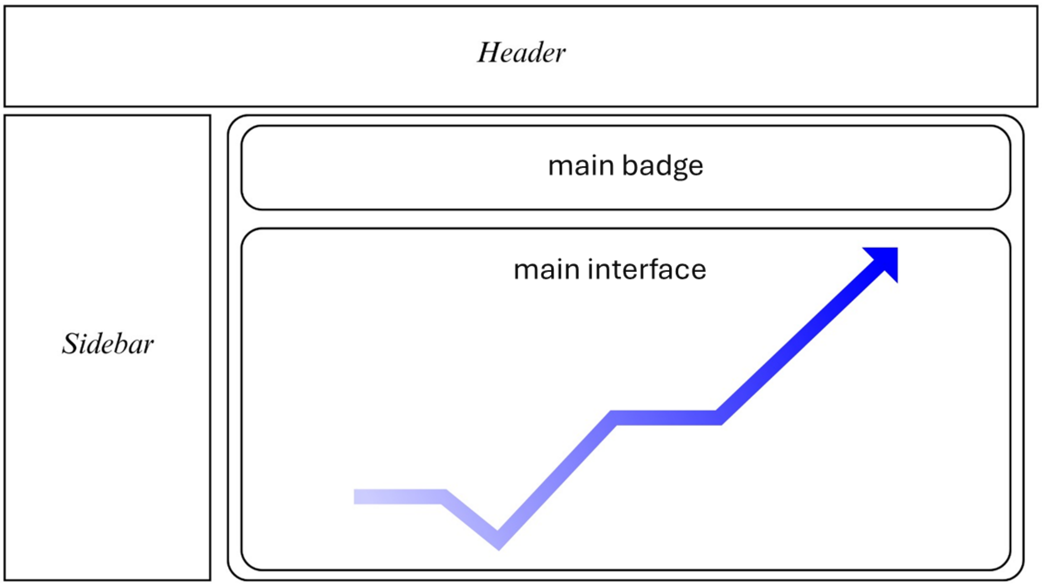


**Figure 4.** User Interface Design of Monitoring and Control

### Cost Evaluation

Cost evaluation was conducted to evaluate the construction cost of low-cost monitoring system using IoT in the melon greenhouse. The cost evaluation only for monitoring and control did not include the greenhouse peripheral.

### System Testing

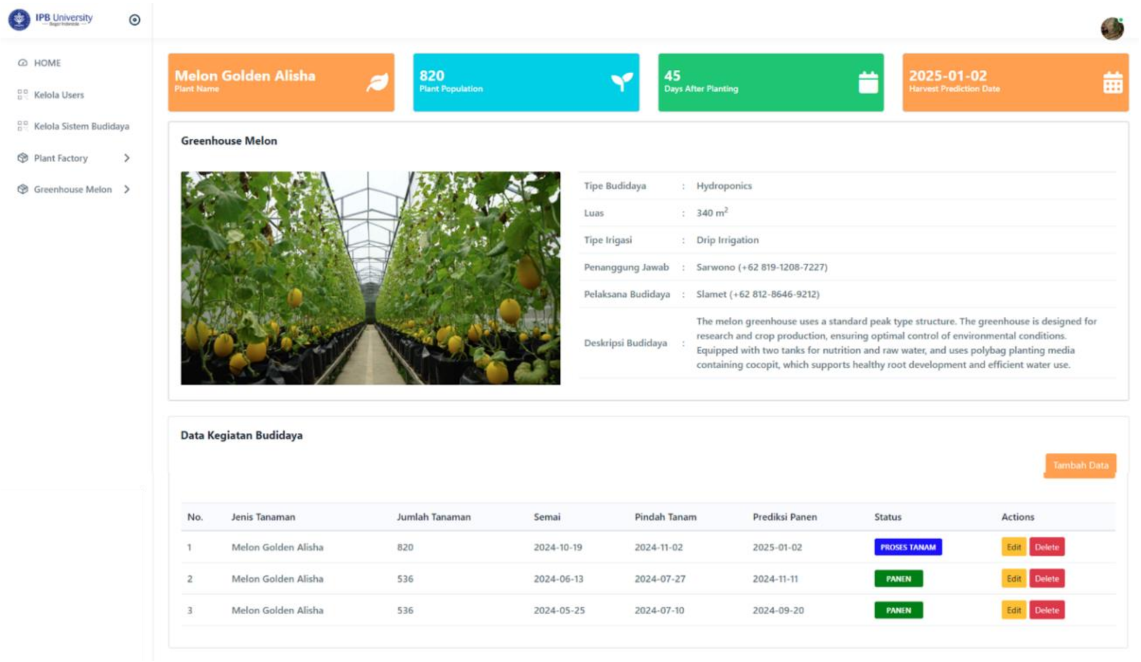
The system was tested and implemented on Agribusiness and Technology Park IPB University greenhouse for melon cultivation using drip irrigations and cocopeat media. There are several testing processes such as: sensor calibration, hardware testing, and user feedback.

## RESULT AND DISCUSSION

### System Implementation

In this step, the system was implemented using several programming languages such as PHP programming languages, MySQL database, CSS and bootstrap for appearance of user interface. This system will be implemented as a user-interactive, functional application using PHP, MySQL, CSS, and Bootstrap. PHP itself is a pervasively utilized server-side scripting language required in the back-end side to process requests and generate dynamic content, responding to user interactions. PHP fits particularly well into web development because of its versatility and capability to integrate seamlessly with databases such as MySQL. MySQL shall, in return, provide a database management system that can be utilized in making the storage and retrieval and management of data via an effective and efficient mechanism. The system shall ensure that the user data, configurations, and any dynamic content used by the application are accessible and stored in a structured format. The combination of PHP and MySQL forms the basis for developing a responsive, data-driven system capable of handling a range of user interactions effectively.

Users should log-in to the system to use the system. After logging in to the system the user can show the menu in the main dashboard (Figure 5). The cultivation information page presents a series of data elements, including the number of plants, the date of transplantation, and the predicted harvest date. Additionally, this page provides details about the agricultural cultivation facility, the individual overseeing operations, and pertinent contact information. The type of crop being cultivated is also specified. In this page also included the information of each greenhouse cultivations such as the melon cultivar, number of plants, nursery time, and harvesting time predictions.



Melon Golden Alisha
Plant Name

820
Plant Population

45
Days After Planting

2025-01-02
Harvest Prediction Date

Greenhouse Melon

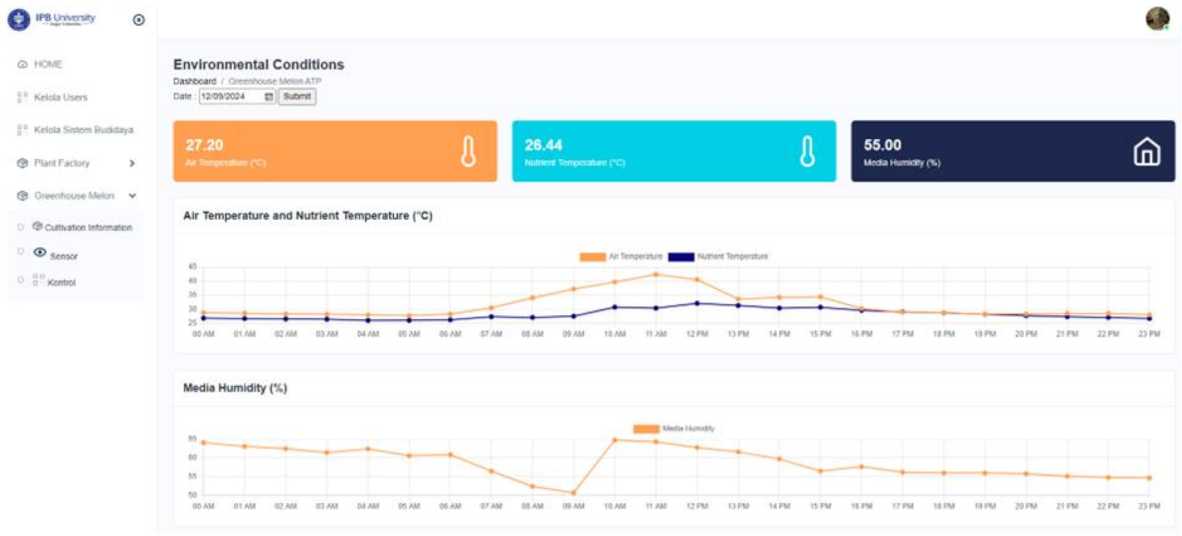
Tipe Budidaya : Hydroponics
Luas : 340 m$^2$
Tipe Irigasi : Drip Irrigation
Penanggung Jawab : Sarwono (+62 819-1208-7227)
Pelaksana Budidaya : Slamet (+62 812-8646-9212)
Deskripsi Budidaya : The melon greenhouse uses a standard peak type structure. The greenhouse is designed for research and crop production, ensuring optimal control of environmental conditions. Equipped with two tanks for nutrition and raw water, and uses polybag planting media containing cocopit, which supports healthy root development and efficient water use.

Data Kegiatan Budidaya

| No. | Jenis Tanaman | Jumlah Tanaman | Semai | Pindah Tanam | Prediksi Panen | Status | Actions |
|---|---|---|---|---|---|---|---|
| 1 | Melon Golden Alisha | 820 | 2024-10-19 | 2024-11-02 | 2025-01-02 | PROSES TANAM | Edit Delete |
| 2 | Melon Golden Alisha | 536 | 2024-06-13 | 2024-07-27 | 2024-11-11 | PANEN | Edit Delete |
| 3 | Melon Golden Alisha | 536 | 2024-05-25 | 2024-07-10 | 2024-09-20 | PANEN | Edit Delete |

**Figure 5.** Main Pages of web-based Interfaces

The cultivation monitoring system page of the greenhouse melon contains four parameters of air and nutrient temperature, air humidity, and light intensity, which can be observed in Figure 6. Air temperature is the temperature that monitors inside the greenhouse every 10 minutes and shows on an hourly basis. Then the graph shows the air temperature inside the greenhouse. Another piece of information is the humidity of media to monitor the media condition and nutrient delivery. If the nutrient delivery and water was successfully intake to the media, the media humidity will stable and upper 50%.


Environmental Conditions

Dashboard / Greenhouse Melon ATP

Date : 12/09/2024

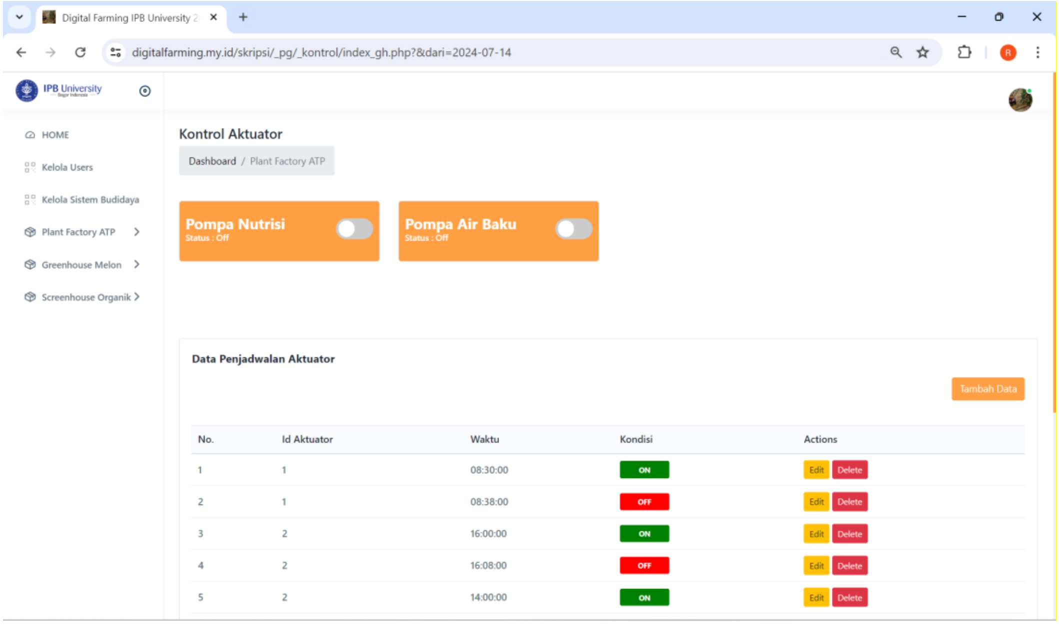
27.20 Air Temperature (°C)

26.44 Nutrient Temperature (°C)

55.00 Media Humidity (%)

**Figure 6.** User Interface for display daily data collected from sensors (web-based)

User interfaces for control the nutrient delivery was designed for user on controlled operations (Figure 7). User can chose the action using the switch control button to change the pump operation time using web-based interfaces. This interfaces are able to interact between users. Microcontroller and actuator devices in internet of things environment.


digitalfarming.my.id/skripsi/_pg/_kontrol/index_gh.php?&dari=2024-07-14

Kontrol Aktuator

Dashboard / Plant Factory ATP

Pompa Nutrisi Status : Off

Pompa Air Baku Status : Off

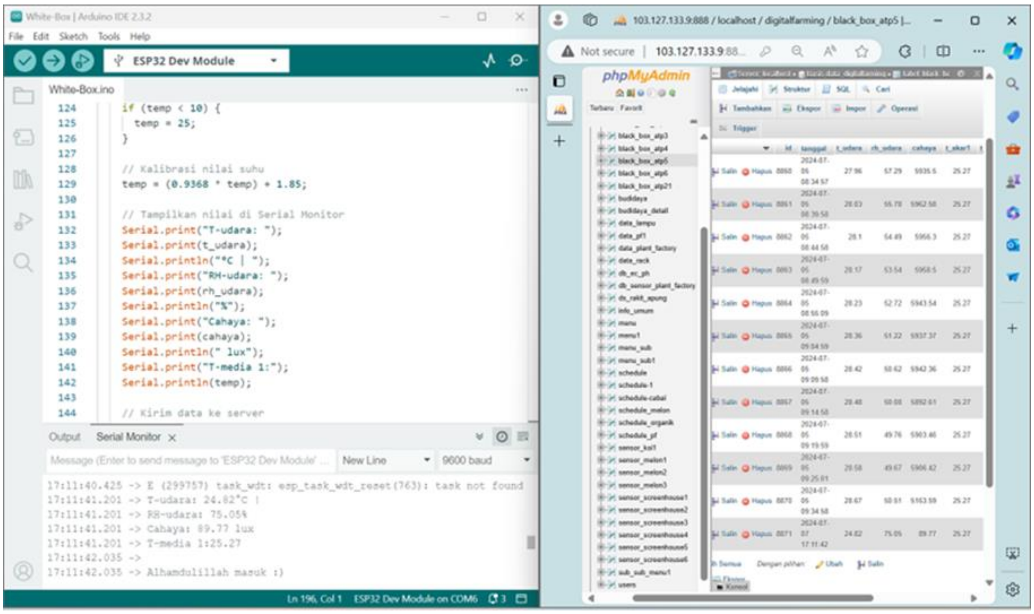
Data Penjadwalan Aktuator

| No. | Id Aktuator | Waktu | Kondisi | Actions |
|---|---|---|---|---|
| 1 | 1 | 08:30:00 | ON | Edit Delete |
| 2 | 1 | 08:38:00 | OFF | Edit Delete |
| 3 | 2 | 16:00:00 | ON | Edit Delete |
| 4 | 2 | 16:08:00 | OFF | Edit Delete |
| 5 | 2 | 14:00:00 | ON | Edit Delete |

**Figure 7**. User Inteface for Control the actuator

## Hardware Testing

The process of hardware functional testing commences with an assessment of the efficacy of the connection to Wi-Fi, which is necessary for accessing the internet. The objective of Wi-Fi connection testing is to ascertain that the ESP32 board can establish a connection to the internet and send and retrieving data from the database. The monitoring system is tested through sensors to ascertain the functionality of the sensors in capturing environmental data and transmitting it to the database. Furthermore, the amount of data sent to the database is observed, with an interval of sending data every five minutes. This results in a total of 288 data points being sent within a 24-hour period. The results of the hardware functional testing demonstrate that the ESP32 board can establish a connection to the Wi-Fi network. Furthermore, the sensor box deployed in the mini plant factory has been observed to successfully transmit data to the database, with the quantity of transmitted data ranging from 250 to 287 units per day (Figure 8).



```
if (temp < 10) {
  temp = 25;
}

// Kalibrasi nilai suhu
temp = (0.9368 * temp) + 1.85;

// Tampilkan nilai di Serial Monitor
Serial.print("T-udara: ");
Serial.print(t_udara);
Serial.println("°C | ");
Serial.print("RH-udara: ");
Serial.print(rh_udara);
Serial.println("%");
Serial.print("Cahaya: ");
Serial.print(cahaya);
Serial.println(" lux");
Serial.print("T-media 1:");
Serial.println(temp);

// Kirim data ke server
```

```
17:11:40.425 -> E (299757) task_wdt: esp_task_wdt_reset(763): task not found
17:11:41.201 -> T-udara: 24.82°C |
17:11:41.201 -> RH-udara: 75.05%
17:11:41.201 -> Cahaya: 89.77 lux
17:11:41.201 -> T-media 1:25.27
17:11:42.035 ->
17:11:42.035 -> Alhamdulillah masuk :)
```

**Figure 8.** Hardware Testing to Insert Environment Data to the Database through IoT

### Cost Evaluation

Cost was evaluated on two scenarios consisting of our proposal using the NodeMcu ESP32 with custom sensor and existing condition in ATP IPB greenhouse. The existing condition of the IoT sensor for monitoring was 955.73 USD and our proposal was 358.24 USD (Table 1). Those two scenarios still indicated that the system was low cost compared to the industrial sensor in the market. In markets there were several devices existed with the prices more than 1,000 USD such as Aggrotech models and etc.

**Table 1.** Price Comparison of Several Sensor (in USD)

| **Function** | **Existing Condition** | **Our Proposal** | **Existing Condition (USD)** | **Our Proposal (USD)** |
|---|---|---|---|---|
| Control Nutrition | Nutrient Delivery control (not including tank and pump) | Using Node MCU ESP 32 sensor Packages | 214.51 | 153.22 |
| Temperature Sensor (°C) | THS01 | DHT21 | 8.27 | 2.76 |
| Air Humidity (%) | THS01 | DHT21 | 8.27 | 2.76 |
| Light Intensity (lux) | Not included | BH1750 | - | 4.90 |
| Soil Moisture | MS01 | Soil Moisture | 185 | 17.47 |
| Hosting (per year) | packages from devices | shared hosting | 55.16 | 18.39 |
| Control Nutrition | Nutrient Delivery control (not including tank and pump) | Using Node MCU ESP 32 sensor Packages | 214.51 | 153.22 |
| Temperature Sensor (°C) | THS01 | DHT21 | 135 | 2.76 |

| | | | | |
|---|---|---|---|---|
| Air Humidity (%) | THS01 | DHT21 | 135 | 2.76 |
| | **Total Cost** | | **955.73** | **358.24** |

### User Acceptance Test

A system test was conducted on a sample of 20 participants, comprising visitors, employees, and technicians of ATP IPB. The participants were directed to a website that had been developed with the system and were instructed to utilize its functionalities. Following the utilization of the system, the participants were required to complete a questionnaire comprising ten statements. The resulting System Usability Scale (SUS) value was 79, which is a positive outcome. Users are able to use the applications and user interfaces with very easy ways by log in to the system and change the parameters. Users are also able to use the application and accept the interfaces and functionality that was designed.

The SUS value was converted into a scale for the assessment of the system's usability, employing parameters such as grade scale, adjective ratings, acceptability ranges, and Net Promoter Score (NPS). The control-enabled monitoring system was assigned a grade of B on the grade scale and a rating of good on the adjective scale. It also fell within the acceptable range and was categorized as passive for the NPS score, indicating that it is suitable for user acceptance but lacks active promotion (Figure 9). However, the NPS value suggests that with further development, the system could enter the promoter category and increase its usability value.

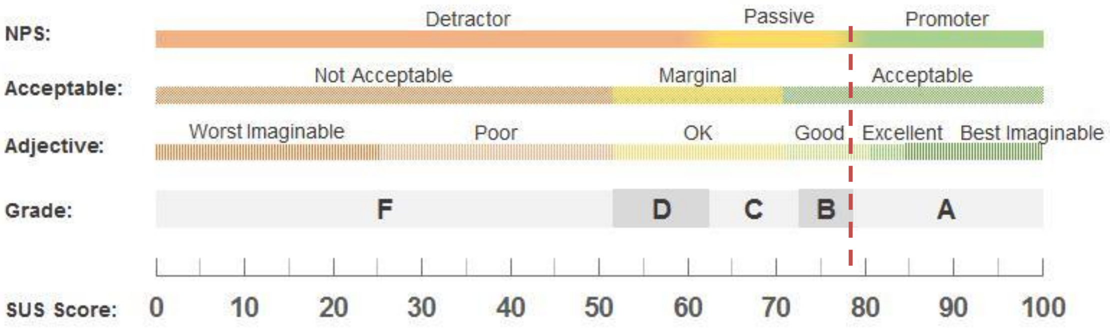


**Figure 9.** User Acceptance Test Result using System Usability Scale

## CONCLUSION

System monitoring was developed using several sensors to monitor air temperature, air humidity, media humidity and solar radiation inside the greenhouse. Then, water and nutrient delivery system was developed to control the volume of drip. A web-based user interface was developed and deployed in a website interface. The cost of IoT based monitoring and control that was designed was 358.24 USD. The system was deployed and tested at Agribusiness and Technology Park IPB University. The system is still categorized as low-cost technology for monitoring and nutrient delivery control. The system can be implemented in other locations with several modifications or directly used with existing configurations.

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## CONFLICT OF INTEREST

The authors declare that there is no conflict of interest regarding the publication of this article.

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