Vol. 14, No. 6 (2025): 2102 - 2110
http://dx.doi.org/10.23960/jtepl.v14i6.2102-2110

JURNAL TEKNIK PERTANIAN LAMPUNG

ISSN 2302-559X (print) / 2549-0818 (online)
Journal homepage : https://jurnal.fp.unila.ac.id/index.php/JTP

Design of an Automatic Temperature and Humidity Control System Prototype for Rice Seedling Nursery

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Article History:

Received : 24 March 2025
Revised : 11 April 2025
Accepted : 27 April 2025

Keywords:

Automatic,
Humidity,
Prototype,
Rice seedlings,
Temperature.

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ABSTRACT

Temperature and humidity control in rice nurseries is carried out to maintain the quality of rice seeds and avoid planting failure. Control is carried out using a prototype automatic device equipped with a water pump for watering and a mist maker plus a fan for humidifying. Based on observations, the prototype tool operates according to the given program. The water pump will turn on when the time shows 07:00 a.m. and 02:00 p.m. Meanwhile, the mist maker plus fan will turn on according to the regulated temperature and humidity conditions and can be applied to several regions in Indonesia. However, at the research site it will turn on when the temperature is > 27 °C and the humidity is < 70% and will turn off when the temperature reaches 27 °C and the humidity is 86%. The optimal air temperature for rice growth ranges from 19–27 °C with humidity in the RH range of 70–86%. Observations were carried out in two treatments, namely conditions with control and conditions without control. The results of seedling with control are better than without control. This can be seen from the growth of rice seedlings with control having a higher value than rice seedlings without control.

1. INTRODUCTION

One critical stage in ensuring crop quality during food crop cultivation is the nursery phase. Nursery activities aim to prepare healthy, ready-to-plant seedlings. Optimal rice seedling growth is highly dependent on environmental conditions, particularly temperature and humidity. Unsuitable temperature or humidity levels can negatively impact seedling quality and health, ultimately affecting harvest yields. Excessively low or high temperatures may also predispose plants to diseases (Puspitorini *et al*., 2024).

At the rice nursery in the Agricultural Machinery Service Unit (UPJA) Tani Makmur Rogojampi, Banyuwangi, temperature and humidity control are still not implemented. Rice seedlings only receive manual watering. As a result, after 14 days when the seedlings are ready for planting there are always some that are damaged and fail to grow. The damage to the rice seedlings is due to the lack of labor for watering, leading to uneven water distribution and drought. Drought has a significant impact on the physiological properties and yield of rice (Margaret *et al*., 2024). The losses incurred by UPJA Tani Makmur related to seedlings are also caused by the absence of periodic monitoring of conditions (temperature and humidity). Manual temperature and humidity control is often inefficient and prone to human error. Therefore, an automatic temperature and humidity control device could be an effective and efficient solution.

An automatic temperature and humidity control system can be implemented using a microcontroller, namely the Arduino Uno. Arduino functions as the controller for all components (Devi *et al*., 2018). The Arduino will help automatically regulate the temperature and humidity of the rice seedlings based on the given commands. Meanwhile, the tools used to control temperature and humidity in the rice seedling environment include a mist maker, a fan, and a watering system with a water pump. These tools can monitor and adjust environmental conditions in real time, ensuring the rice seedlings are always in optimal conditions for growth. Using these tools will reduce farmer workload, increase consistency in seedling management, optimize resource use, and support sustainable agricultural practices.

2. MATERIALS AND METHODS

2.1. Microcontroller Operating System

Temperature and humidity rice nurseries was automatically controled using a microcontroller. This microcontroller was equipped with a program for automatic climate control. The program created was run by Arduino. When first time turned on, Arduino will activate the program to turn on the assembled components, such as the DHT11 sensor, RTC, LCD, and Card Reader. The temperature and humidity readings from the LCD was processed by Arduino to determine the condition of the mist maker, fan, and water pump. The mist maker will turn on according to the set temperature and humidity conditions that can be applied to several areas in Indonesia. At the research location, the mist maker will turn on when the temperature is > 27 °C or humidity is < 70% and will turn off when the temperature has reached ≥ 27 °C or humidity has achieved 86%. To adjust the time of the water pump to turn on at 07.00 WIB and 14.00 WIB, we use RTC. This aims to ensure the desired plant watering time. The operational design can be seen in Figure 1.

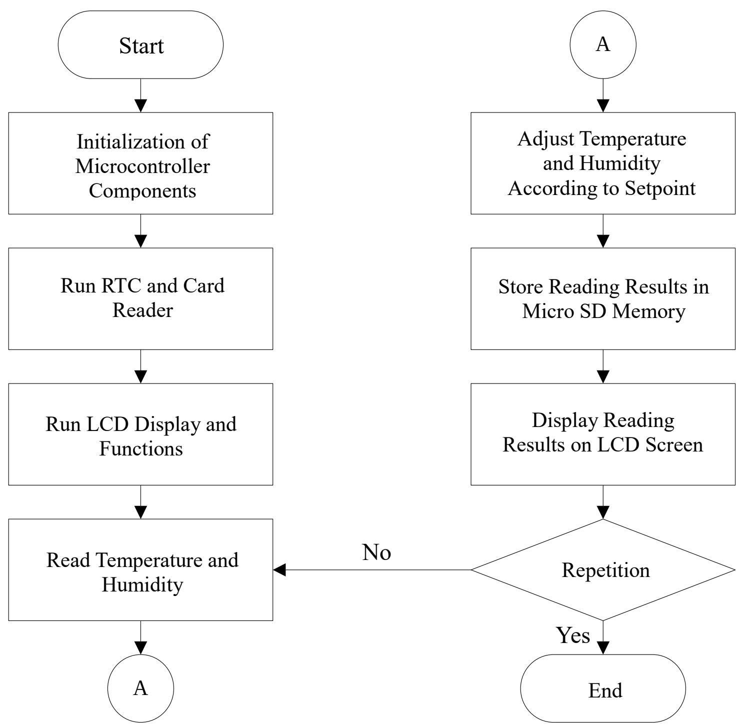


Figure 1. Operational design of the microcontroller-based automatic temperature and humidity control system

2.2. Functional System

The design of the automatic temperature and humidity control device comprises several components, including an Arduino Uno, relay, DHT11 sensor, RTC module, card reader module, LCD, mist maker with an additional fan, and a water pump. The functional design was illustrated in Figure 2.

The functions of the components are as follows: the Arduino Uno serves as the central unit for processing programs and data; the RTC module functions as a time and date input; the card reader module is used for data storage; the LCD displays information obtained from the DHT11 sensor and RTC module; the relay acts as a switch to connect or discon-

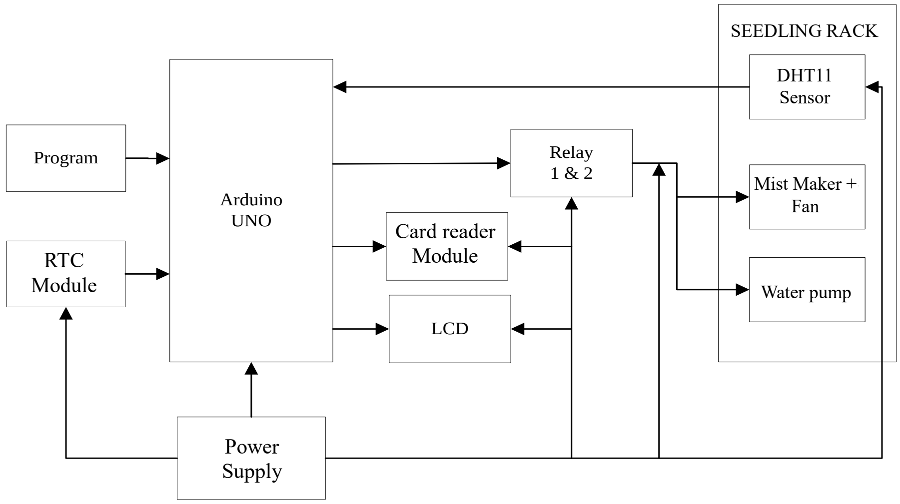


Figure 2. Block diagram of functional design

nect electrical current; the DHT11 sensor functions as a temperature and humidity reader; and the seedling rack serves as a cultivation area for rice seedlings, where the temperature and humidity control device operates. The seedling rack includes a mist maker, which transforms water into mist. The mist maker produce mist at a rate of approximately 1 liter over 4–5 h (Iswahyudi *et al*., 2019). The working principle of the mist maker involves producing vapor that does not rise but instead circulates around the device (Aziz & Suprianto, 2019).

2.3. Structural Design of the Temperature and Humidity Control Device

The structural design of the microcontroller and temperature and humidity controller can be seen in Figure 3 and Figure 4. The control system design consists of three parts: the microcontroller, input, and output. The microcontroller functions as the brain connected to the temperature and humidity sensors that will give commands based on the data read (Kurniawan *et al*., 2020). The microcontroller used in this control system is an Arduino Uno. The Arduino Uno will process the data read by the input section, namely the RTC and the DHT11 sensor. The RTC is a module used to access time data with a format set to 24 hours and a date that can be adjusted automatically (Andriawan, 2018). Meanwhile, the DHT11 sensor functions to measure local temperature and humidity (Aulia *et al*., 2021). This sensor is quite resistive with a fast response and an affordable price (Srivastava *et al*., 2018). Then, the Arduino will send commands to the output section, namely the LCD (liquid crystal display), SD card reader, and relay. The LCD is used to display data in various forms such as characters, numbers, letters, or graphics (Natsir *et al*., 2019). The SD card reader helps the microcontroller to read the gcode file stored on the SD card (Darwis, 2020). The relay functions to control the ON/OFF power of electrical equipment (Kurniawan & Lestari, 2020).

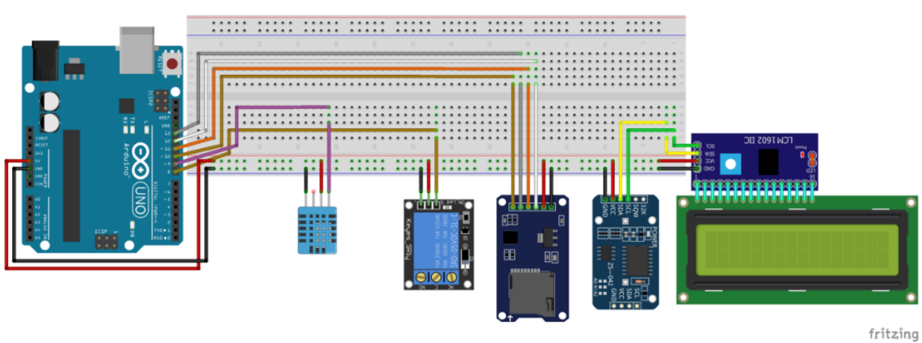
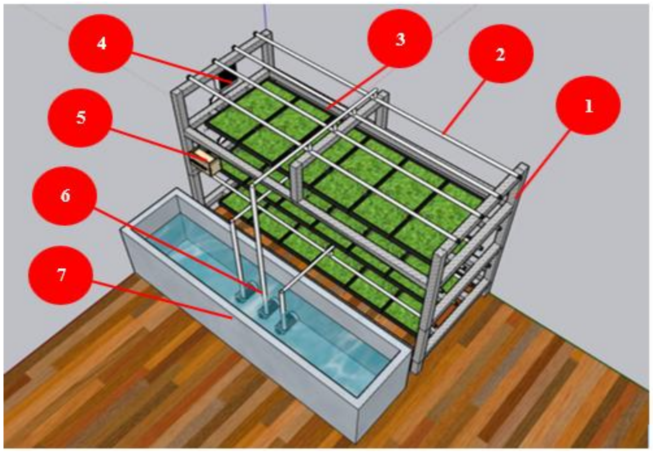


Figure 3. Structural design of the microcontroller



Legends:
1. Seedling Rack
2. Irrigation installation
3. Rice seedling tray
4. Mist maker + Fan
5. Control system box
6. Water pump
7. Water tank

Figure 4. Structural design of the temperature and humidity control device

2.4. System Performance Testing

The performance test of the temperature and humidity controller was conducted to determine the comparison of growth and damage to rice seedlings under controlled and uncontrolled conditions. The performance of the system and the temperature and humidity controller was tested in the field. System testing was conducted to determine the functionality of the tools and modules used in the temperature and humidity controller. Testing was carried out on three parts, namely the DHT11 sensor, mist maker plus fan, and water pump. First, the DHT11 sensor was tested by taking repeated temperature and humidity readings at 10-second intervals. Second, the mist maker and fan were tested before data collection. Third, the water pump test was to determine the suitability of the water pump's operation with the time read by the RTC module. Data was obtained from the LCD and data that had been automatically stored in the micro SD card.

3. RESULTS AND DISCUSSION

3.1. Microcontroller Programming

Designing a microcontroller program using Arduino consists of three stages: initialization, void setup, and void loop. Initiation is used to identify variables (names), microcontroller pins, and the initial values of the input variables used. Commonly used commands are define, const int, or int (Amarudin *et al*., 2020). Void setup is used to initialize variables, declare pins to be used, use libraries, and is only executed once by Arduino (Youda & Juli, 2022). Libraries assist in enabling the program to interpret functions properly—such as enabling sensors to read temperature data (Setiawati *et al*., 2020). Once the initiation definitions are complete, the *void setup* stage is used to activate the necessary modules and functions to ensure their proper operation. The *void loop* stage serves to execute and continuously run the program in a repetitive cycle, as managed by the Arduino (Youda & Juli, 2022). In this stage, four main routines are implemented in the designed program: temperature and humidity measurement, data display on the LCD, irrigation and cooling control, and data storage.

3.2. Control System Design and Device Prototype

The control system and device prototype are integrated into a single unit. The control system is enclosed within a plastic casing to protect it from water produced by the water pump and mist maker. The control system of the automatic temperature and humidity control device prototype is shown in Figure 5.

3.3. System Prototype Performance Testing

3.3.1. DHT11 Sensor Testing

The DHT11 sensor test was conducted to ensure the temperature and humidity sensor functioned properly. Observations were carried out 14 times across three different time periods. The temperature and humidity test results are presented in

Figure 5. Prototype of the automatic temperature and humidity control device

Tables 1. Based on the table (temperature and humidity test results), the sensor was tested 14 times. The tests were conducted in the morning at 07:00 a.m., in the afternoon at 02:00 p.m., and in the evening at 07:00 p.m. to observe temperature and humidity variations across different times of day. The tables show that the observed temperature variation was approximately 1 °C, while the humidity variation was about 1%. These results indicate that the DHT11 sensor operated effectively. The accuracy specification for temperature is ±2 °C, and for relative humidity, it is ±4% (Najmurrokhman *et al*., 2018).

Table 1. Temperature and humidity test results using the DHT11 sensor

No.	Temperature (°C)			Humidity (%)		
	Morning	Afternoon	Night	Morning	Afternoon	Night
1	28.20	31.70	29.80	74	63	74
2	28.30	31.80	29.50	74	63	74
3	28.20	31.70	29.50	74	63	74
4	28.20	31.70	29.50	73	63	74
5	28.20	31.70	29.80	73	63	74
6	28.20	31.70	30.00	73	63	73
7	28.10	31.70	30.00	73	63	73
8	28.10	31.70	30.30	73	63	72
9	28.10	32.00	30.40	73	63	72
10	28.10	32.10	30.40	73	63	72
11	28.10	31.90	30.40	73	63	72
12	28.10	32.10	30.20	73	63	72
13	28.20	32.10	30.00	73	63	71
14	28.50	32.10	30.00	73	63	71

3.3.2. Testing the Functionality of the Mist Maker with Fan

Based on Figures 6 and 7, the temperature and humidity test results for the mist maker with fan show that the system operated in accordance with the programmed parameters. The mist maker with fan activates when the temperature reaches 28 °C and deactivates when it drops to 27 °C. In Figure 7, the humidity value does not fall below the minimum threshold required to activate the mist maker and fan; therefore, the system remained off during the entire test. This indicates that the program is functioning correctly, as the mist maker and fan are designed to activate when the temperature exceeds 27 °C or the humidity falls below 70%, and to deactivate when the temperature reaches 27 °C or the humidity reaches 86%.

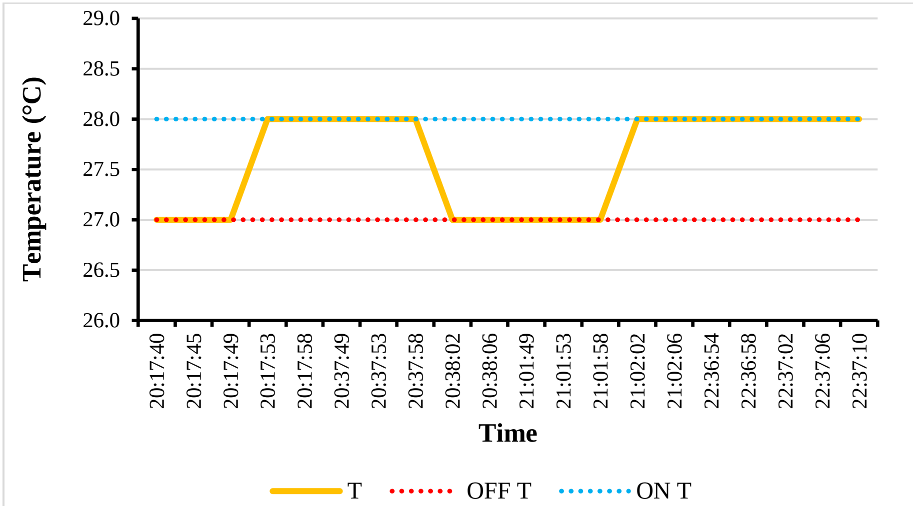


Figure 6. Graph of temperature test results for mist maker + fan

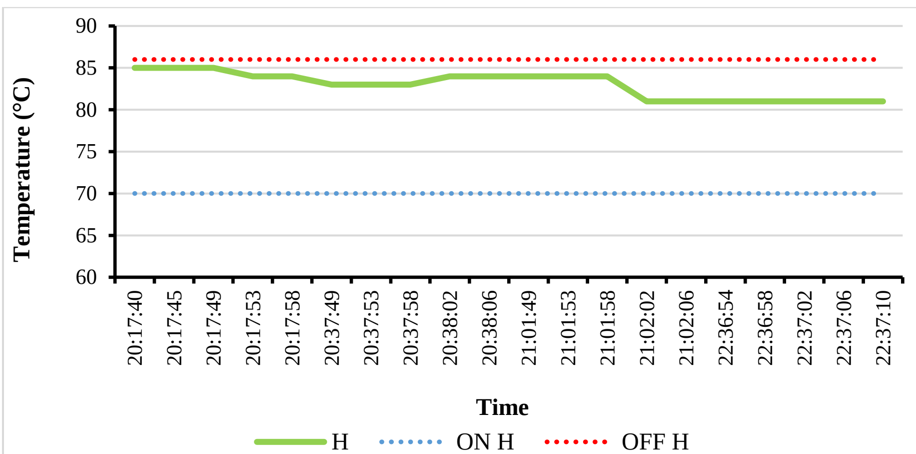


Figure 7. Graph of humidity test results for mist maker + fan

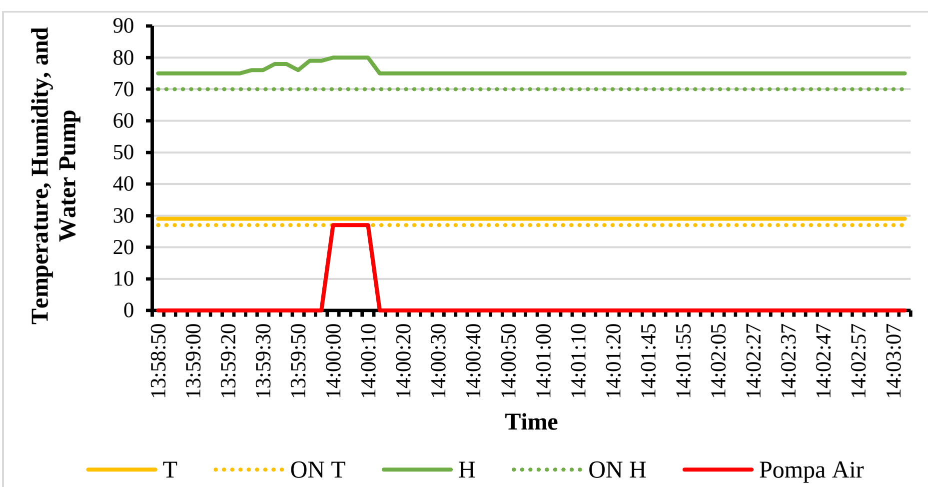


Figure 8. Graph for water pump test results

3.3.3. Water Pump Functionality Test

The functionality test of the water pump confirmed that it operated in accordance with the programmed instructions. As shown in Figure 8, the water pump is programmed to activate at 02:00 p.m. for a duration of 10 seconds before switching off. This result demonstrates proper system behavior, as the pump is scheduled to operate at 07:00 a.m. and 02:00 p.m. The control system, utilizing a microcontroller for irrigation water management, is considered a suitable solution for addressing water supply challenges (Nasarudin *et al*., 2020).

3.4. Observation of the Temperature and Humidity Control Device

3.4.1. Temperature and Humidity Monitoring

Temperature and humidity observations were conducted using the DHT11 sensor over a 24 hour period, under two different conditions: with control and without control. The controlled condition involved the activation of the mist maker with fan and automatic irrigation via a water pump. The uncontrolled condition did not include the use of the mist maker, fan, or water pump. A comparative graph of temperature and humidity under both conditions is presented in Figures 9 and 10. Based on the observations conducted, two temperature curves were recorded, namely T1 and T2. T1 represents the temperature measured by the DHT11 sensor when the mist maker and fan were activated. In contrast, T2 represents the temperature measured without activation of the mist maker and fan. T2 shows higher values compared to T1 due to the absence of a cooling system to reduce the temperature during heat buildup. As shown in Figure 9, when the temperature reading (T1) exceeds 27 °C, the cooling system is activated to reduce the prototype's internal temperature.

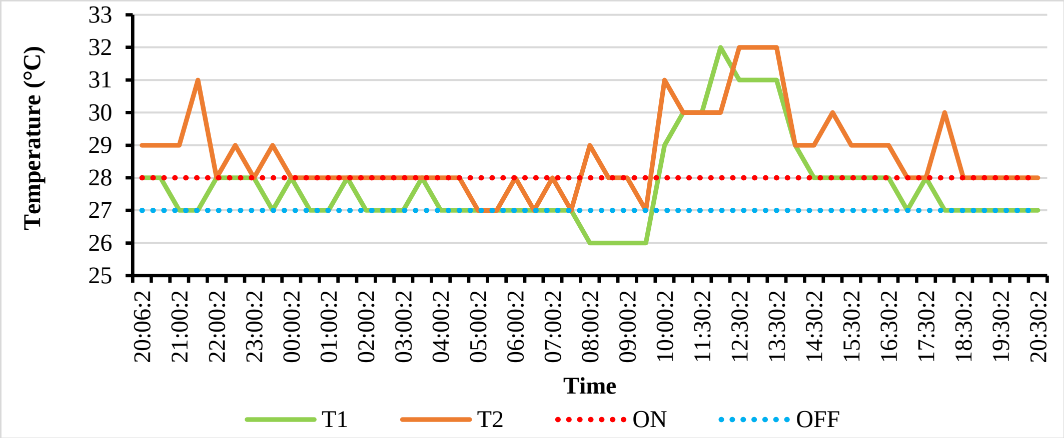


Figure 9. Temperature comparison of rice seedlings with control (TH1) and without control (TH2)

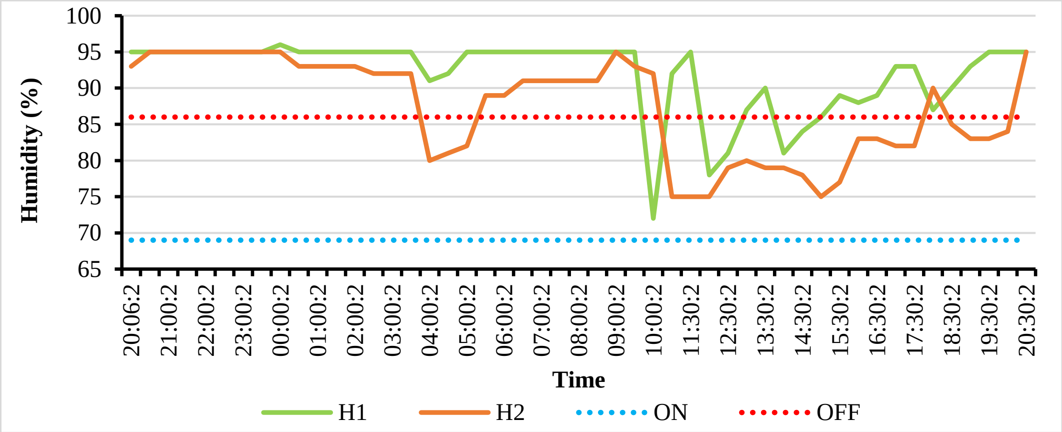


Figure 10. Comparison of humidity during rice seedlings with control (TH1) and without control (TH2)

Once the temperature reaches 27 °C, the system is deactivated. This behavior indicates that the T1 seedlings are more likely to thrive, as the system continuously attempts to maintain an optimal temperature even during warmer periods. The optimal temperature range for rice plant growth is between 19 °C and 27 °C (Paski *et al*., 2017).

Based on the observations conducted, two humidity graphs were obtained: H1 and H2. H1 represents the humidity recorded by the DHT11 sensor with the activation of the mist maker and fan. Meanwhile, H2 represents the humidity recorded by the DHT11 sensor without the activation of these systems. H2 consistently shows lower values than H1, as it lacks the cooling system (mist maker and fan) to increase the humidity. This observation demonstrates the inverse relationship between humidity and temperature. When H1 (humidity) higher, the T1 (temperature) is lower, and vice versa. This inverse correlation between temperature and air humidity is in accordance with the findings of Rosianty *et al*. (2018), who noted that higher air temperatures result in lower humidity due to condensation (precipitation) of moisture molecules. As shown in Figure 10, the humidity values were suitable for rice seedling growth. Humidity levels in the RH range of 70-86% are conducive to the healthy growth of several plants (Wahono *et al*., 2014).

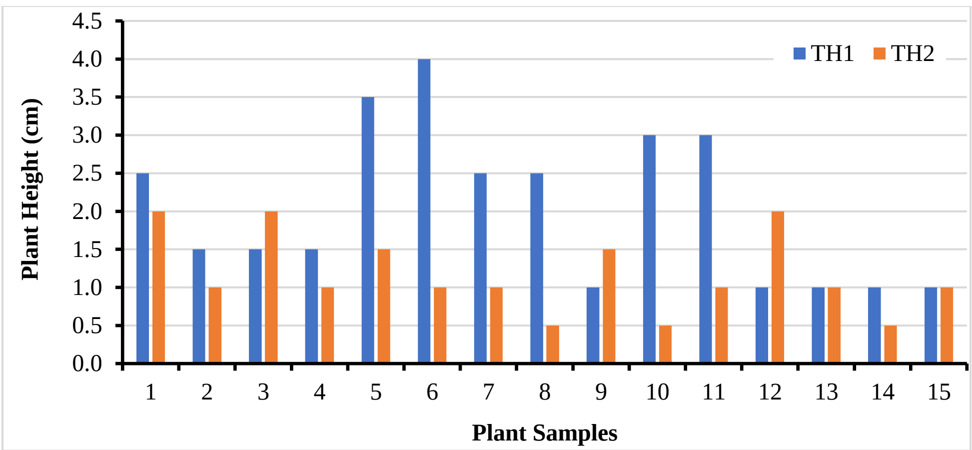


Figure 11. Comparison of rice seedling growth with control (TH1) and without control (TH2)

3.4.2 Observation of Plant Growth with Control and without Control

Plant growth observations with and without control were conducted over a period of 6 days. The first 3 days were used to obtain data for TH1, and the following 3 days were used to obtain data for TH2. As shown in Figure 11, the growth of the plants in TH1 was higher than in TH2. This is because TH1 had automatic cooling activation using a mist maker and fan to control temperature and humidity. Therefore, TH1 had sufficient water availability compared to TH2. This indicates that temperature and humidity control, as well as water availability, significantly affect rice seedling growth. The more ideal the temperature and humidity conditions for the plants, along with adequate water availability, the better the growth results. During the growth process, rice plants require a certain amount of water, and in environments with sufficient water availability and favorable conditions, photosynthesis activity increases, leading to improved plant growth (Rusmawan *et al*., 2018).

4. CONCLUSION

Based on the results and discussion of this study, it can be concluded that the prototype performed well. The automatic water pump for irrigation worked effectively, but cooling with the mist maker + fan was insufficient to regulate temperature and humidity conditions. Therefore, a replacement such as a fogging system is recommended. Data storage can be conducted online using applications like Blink to avoid errors with the micro SD card. The results of the tests and observations met expectations; plants with control (TH1) performed better than those without control (TH2), as evidenced by the higher growth rates of TH1 compared to TH2.

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