Vol. 12, No. 1 (2023) : 70 - 81
DOI : http://dx.doi.org/10.23960/jtep-l.v12i1.70-81

JURNAL TEKNIK PERTANIAN LAMPUNG

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

Temperature and Humidity Monitoring in Dry Land of Cayene Pepper Based on Internet of Thing (IoT)

Ida Ayu Widhiantari [1]✉, Joko Sumarsono [1], M. Abul Auni Annawawi [1]

[1]Agricultural Engineering Department, Faculty of Agricultural Technology and Agro-industry, Universitas Mataram, West Nusa Tenggara, INDONESIA.

Article History :

Received : 30 June 2022
Received in revised form : 27 October 2022
Accepted : 6 December 2022

Keywords :

Internet of thing,
Humidity,
DHT22 Sensor,
Air temperature.

✉Corresponding Author:
dayutari12@gmail.com

ABSTRACT

In general, plant growth will be disrupted if the environmental temperature is not suitable, even the plants will be damaged, which can cause a decrease in quality and quantity. Problems that often occur and are difficult to avoid include temperature and humidity conditions on agricultural land. Therefore it is necessary to do handling to be able to minimize the occurrence of damage that can occur in the land caused by environmental influences. This study aims to design a temperature and humidity monitoring system based on the Internet of Things (IoT). The research was carried out by designing electronic circuits from monitoring systems, hardware, software, and testing the systems that had been made. Technology supported by the use of DHT22 sensors can read temperature and humidity data in real time. Based on the research results, it was found that the DHT22 sensor used worked with the best accuracy on day 21 with an error percentage of 0% and the worst accuracy occurred on day 31 with an error percentage of 18.5%.

1. INTRODUCTION

Sambelia District is one of the sub-districts in East Lombok Regency which is an area with dry land. This is because the Sambelia area is included in areas with relatively low rainfall. Based on monthly rainfall data from 2010-2019 obtained at the Sambelia station taken from BMKG (Meteorology, Climatology and Geophysics Agency) class A Kediri, West Lombok, the rainy season in Sambelia sub-district only lasts for approximately 2-4 months per the year. Annual rainfall in the East Lombok region ranges from 900–1800 mm per year with the number of rainy days ranging from 70–150 rainy days per year.

Many types of vegetable plants are planted on agricultural land in Sambelia District, one of which is cayenne pepper. Many factors can affect the growth and development of plants in carrying out vegetable cultivation activities, including temperature and humidity. Air temperature and humidity greatly affect plant growth, including cayenne pepper plants. Changes in temperature and humidity conditions can affect the quality and quantity of cayenne pepper. According to (Maulidah *et al*., 2012), the impact of climate change has led to a decrease in the quantity and quality of cayenne pepper production which in 2009 reached 1,237 kg decreased to 615 kg in 2010 in Pagu District, Kediri Regency. Chili plants can grow well usually at a fairly high ambient temperature. Chili plants are one of the horticultural crops that have a fairly high selling value and are much needed, especially for the people of Lombok to meet their daily consumption needs or to be sent outside the region.

Chili plants can grow well at a temperature range of 21 -27 °C in the vegetative phase while entering the generative phase the ideal temperature ranges from 16-23 °C (Nurfalach, 2010). In general, plant growth will be disrupted if the ambient temperature is not appropriate, such as the plant will be damaged and can even cause a decrease in quality and quantity. Air humidity is the amount of water vapor contained in the air mass at a time and in a certain area.

Problems that arise on agricultural land such as temperature and humidity conditions, are difficult to avoid. Temperature change is one of the important problems that can affect germination, growth and yield of plants. Air temperatures that are too low can slow down the flower formation process, resulting in a longer harvest time. The optimal temperature for the growth of cayenne pepper is around 20-25 °C during the day and a minimum of 16 °C at night (Lysandra, 2018).

One of the things that can be done is to minimize the occurrence of damage that can occur on land caused by environmental influences, such as using a temperature and humidity monitoring system based on the Internet of Things (IoT). Monitoring the temperature and humidity of the air, can minimize the occurrence of crop damage due to environmental influences. The use of IoT is very practical where it is able to retrieve the data needed from one place and remotely using sensors to be able to control other objects (Wardani & Lhaksmana, 2018). The interaction that is needed is only direct users to the computer, so it does not involve a lot of manpower (Prakoso *et al*., 2022). In addition, the use of IoT can also be developed into an application that is integrated with the Arduino operating system (Wasista *et al*., 2019). IoT acts as a means to present sensor readings that appear on the LCD screen in real time which can be accessed by connecting to the internet network (Kurniawan *et al*., 2021).

This monitoring activity is supported by the use of humidity sensors and temperature sensors that can read data in real time and are connected via a smartphone, making it easier for farmers to monitor the condition of the land and cayenne pepper they are cultivating. With an IoT-based monitoring system, it provides convenience and saves energy for farmers, because it can control the condition of land and plants remotely and can be done anywhere, most importantly connected to the internet.

Demand analysis is carried out through literature studies or gathering information related to research. In an effort to develop an IoT-based temperature and humidity monitoring system, it refers to several references and research, including (Gunawan *et al*., 2019) which examines a monitoring system for soil moisture, temperature, pH and automatic watering of tomato plants based on the IoT. Other works include (Efendi & Narji, 2020) which examines the application of simulated soil moisture detection measuring devices using the Arduino Uno Microcontroller device, as well as (Maharani *et al*., 2019) which examines the control of temperature and humidity (RH) on the vegetative growth of red chili (*Capsicum Annuum* L.) at the plant factory. In addition, IoT is also used to monitor the temperature and humidity of a room, where sensors directly detect and display reports on smartphones when changes occur (Hakiki *et al.*, 2020). The purpose of this study was to test the performance of the air temperature and humidity monitoring system on the Internet of Things (IoT)-based dry chili peppers.

2. MATERIALS AND METHODS

2.1. Tools and Materials

The tools used in this study were electric soldering iron, DHT22 sensor, SHT10 sensor, NodeMCU type ESP8266, Real Time Clock (RTC), Micro SD Card Adapter, laptop, rainbow cable, internet connection, Liquid Crystal Display (LCD) 16×2, hole PCB fiber 9×15 cm, stem thermometer, digital voltmeter, Cayenne application, Fritzing software and Arduino IDE software. The materials used in this study were soil with dust fraction, cayenne pepper seeds, and NPK fertilizer.

2.2. Method

The research method used is an experimental method of simulation experiments carried out through research stages including preparation of planting media in the form of beds with the addition of NPK fertilizer, designing a series of systems and creating a program language for monitoring temperature and humidity in dry land based on IoT.

2.2.1. Electronic Design

The electronic design of the system circuit is carried out using the Fritzing application. Fritzing is an open source software for designing electronic circuits (Ardiansyah, 2019) Fritzing is usually used by designers and electronics hobbyists to design various electronic equipment. Fatoni *et al.* (2015) said that the use of this software does not have high difficulties, this is because software users only need to drag and drop components in the available work area.

2.2.2. Hardware Design

The electronic components that have been prepared are assembled into an IoT-based temperature and humidity monitoring system based on the electronic design that has been made. Figure 1 shows an assembled Internet of Things-based temperature and humidity monitoring system uses two NodeMCU ESP8266 microcontrollers version 1.0 official board to monitor the research area. NodeMCU is an open source IoT platform and this board consists of hardware in the form of “system on chip” ESP8266 from ESP8266 made by Esperessif system (Bimanta *et al*., 2022). NodeMCU ESP8266 serves as a center for sensors and modules that are run (Hidayat *et al*., 2021). The NodeMcu module can be connected from one device to another by connecting the sensor to an existing Wi-Fi network (Ouldzira *et al*., 2019).

This data processing and display system is equipped with an RTC module, 16×2 LCD, and a Micro SD Card Adapter or data storage module and is connected to a digital sensor, namely the DHT22 sensor type. One DHT22 Sensor for ambient temperature and humidity sensors. This system is capable of working 24 hours with the ability to process and calculate digital numbers, receive data from sensors, store data on an SD card via the Micro SD Card module, and display data on the LCD and the Cayenne application. The DHT22 sensor has a function to measure temperature and humidity conditions, where this sensor has 4 pins namely VCC, Data, NC, and GND (Sofwan *et al*., 2020).

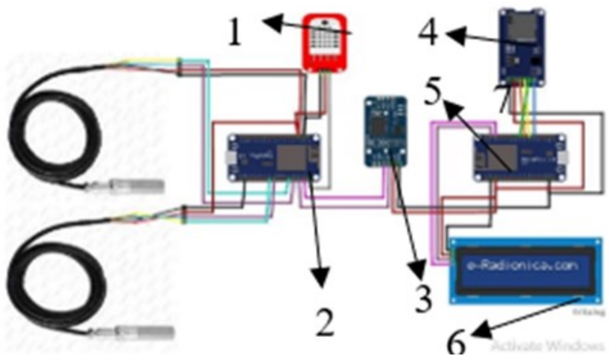

Figure 1. Toolkit schematic: (1) DHT22, (2) NodeMCU(1) (ESP8266), (3) RTC, (4) *Micro* SD *card*, (5) NodeMCU(2) (ESP8266), (6) LCD

2.2.3. Software Design

The design of this software focuses more on making programs using the Arduino IDE (Integrated Development Environment) software. This application is useful for creating, opening and editing Arduino source code or sketches (Santoso, 2016). Arduino is known as an open source electronic platform based on the ease of application of hardware and software (Sulistyanto *et al*., 2015). The working principle of Arduino is that Arduino installs the DHT22 sensor, which then the DHT22 sensor reads the temperature and humidity values (Silalahi *et al*., 2021). Programs created using the Arduino IDE software can run on the NodeMCU microcontroller used, it is necessary to install the ESP8266 board first, so that later types of ESP8266 boards will appear such as NodeMCU 1.0 (ESP-12E Module) as seen in Figure 2, NodeMCU 0.9 (ESP -12E) Module), Olimex MOD-WiFi-ESP8266(-DEV) and so on in the board sub menu.

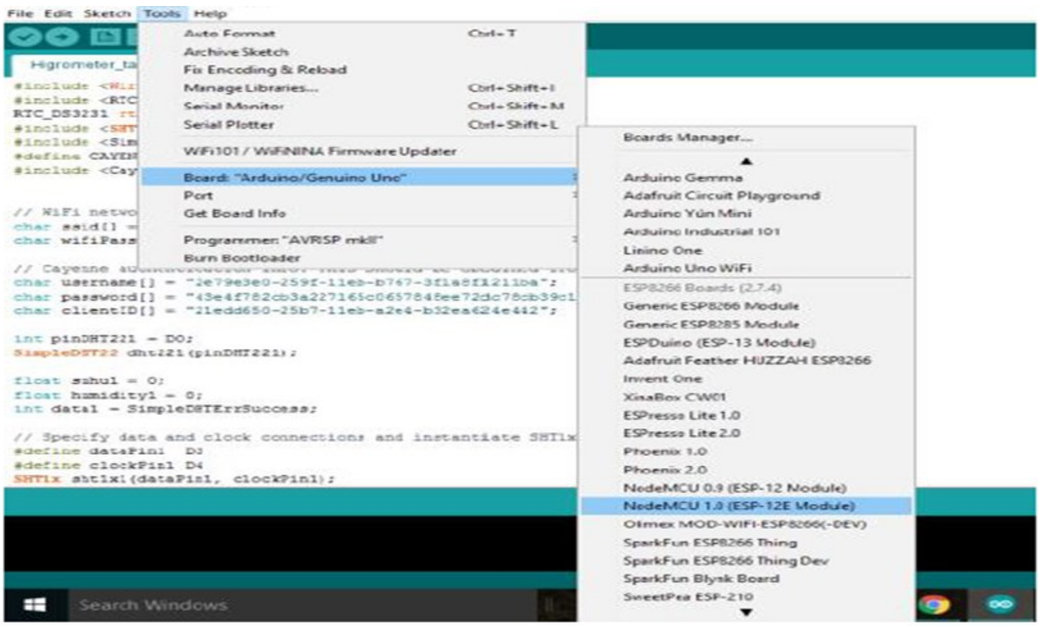

Figure 2. Selection board type of the NodeMCU 1.0 (ESP-12E Module)

Monitoring system IoT-based temperature and humidity using two NodeMCU microcontrollers. This microcontroller works on the process sub system. Each of these microcontrollers has its own program, so that the process sub-system is divided into 2 parts, namely NodeMCU1 and NodeMCU2 as shown in Figures 3 and 4.

Figure 3. The NodeMCU1 program

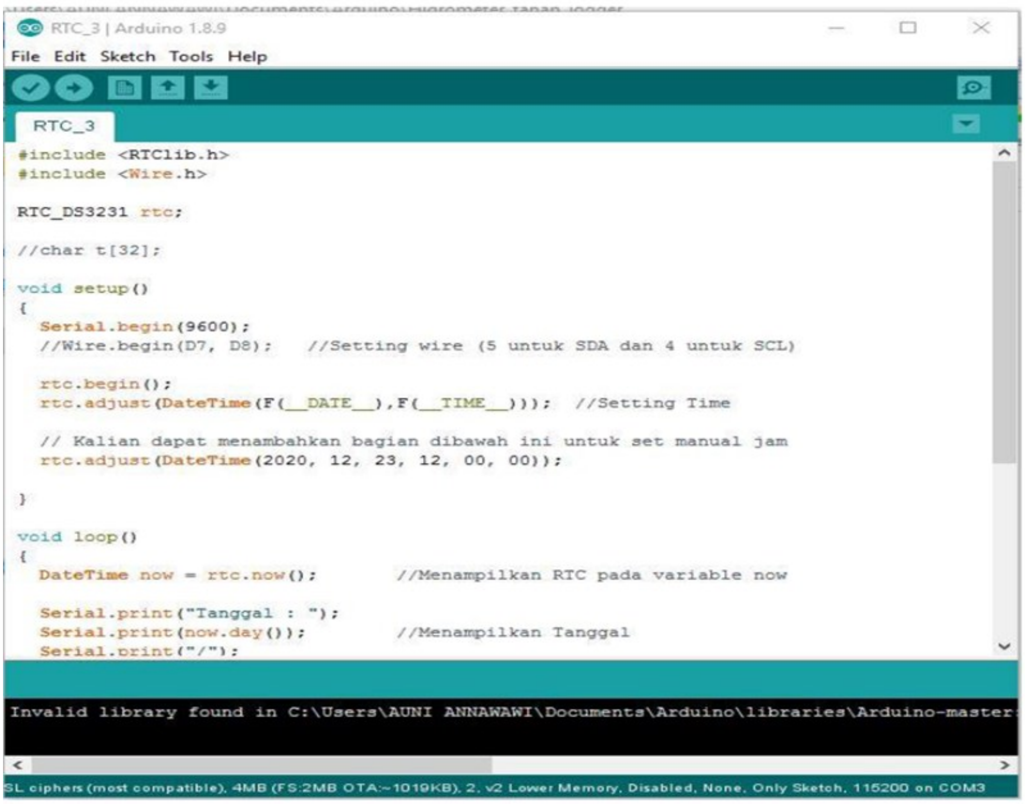

Figure 4. The NodeMCU1 program

In the NodeMCU2 section, connected components such as RTC, LCD and Micro SD Card Adapters. Testing the NodeMCU2 connection with the RTC, LCD and Micro SD Card Adapter is carried out by uploading the program that has been made to the NodeMCU ESP8266 microcontroller used. This program intends to display the temperature and humidity or display data from sensor readings (DHT22 and SHT10) on the LCD and store the data on the SD card based on a predetermined setting point. Displaying data on the LCD and storing data on the SD card for this system is done every 15 minutes.

2.3. Research Parameters

The parameters of this study are air temperature, air humidity, and the percentage error rate. The temperature and humidity around the research area were measured using a DHT22 sensor type which was placed in the middle of the research area.

The accuracy value is determined based on the relative error calculation. The absolute error (E_a) of a measurement is defined as the difference between the true value and the measured value. The absolute value of this error is determined by the following formula (Saptadi, 2014):

$$E_a = |x_i - x_p| \quad (1)$$

Meanwhile, the relative error is determined from the comparison between the absolute error and the actual value. The relative error value is determined by the following formula:

$$E_r = \frac{E_a}{x_p} \times 100\% = \frac{|x_i - x_p|}{x_p} \times 100\% \quad (2)$$

where E_r is relatif error (%), E_a is absolut error, x_i is measurement value, and x_p is true value. The measurement value in this study comes from the value generated by the DHT22 sensor, while the true value comes from the readings of standard measuring instruments such as a stem thermometer and SHT10 for measuring humidity.

2.4. Research Procedure

The land to be studied is soil with a dust fraction located in Senanggalih, Village, Sambelia District, East Lombok Regency, West Nusa Tenggara Province. Land preparation is carried out starting from measuring the land to be used which is 4×4 m in size, loosening the soil, making beds, to the fertilization process.

Schematic design of the system circuit is carried out using the Fritzing application. After the fritzing process is complete, the schematic that has been created can be exported in JPG, PNG, SVG, or PDF format to be used as a guide in system assembly. After the required components are ready, system component assembly is carried out using a soldering iron and tin and a digital voltmeter as a tool to check the connection between the sensor pins and the NodeMCU microcontroller pins. The next step is to make the programming language. Making the programming language is done using the Arduino IDE application. The program verification stage is confirmation from the program that has been made, whether the program meets the requirements to carry out monitoring in the research area. If program verification can run, then the process of uploading the program to NodeMCU can be carried out, conversely if the system is not verified then an examination is carried out on the circuit schematic design and program language that is made. Furthermore, sensor calibration is carried out by adjusting the sensor reading value with the reading value of a standard measuring instrument, namely a stem thermometer. If the sensor reading does not match the standard measuring instrument reading, then it is adjusted by adjusting the setting point in the program language. On the other hand, if the sensor readings and standard measuring instruments are correct, then the sensors are ready for use.

The whole system test was carried out for 34 days. Temperature and humidity readings were tested for two days. The test without planting cayenne pepper was carried out once every 24 hours, namely on 29 December 2020 from 17:08 WITA to 30 December 2020 at 17:08. Testing the land with the condition of planting cayenne pepper plants was carried out once every 24 hours, namely on January 8, 2021, from 00:03 WITA to 23:51 WITA. Field testing with cayenne pepper was carried out to analyze the results of system measurements or find out the accuracy of the feasibility of the system from January 8, 2021 to February 8, 2021, by utilizing the average measurement data per day from morning, afternoon and evening.

3. RESULTS AND DISCUSSION

3.1. Testing of IoT-Based Air Temperature and Humidity Monitoring Systems

After the system has been designed and calibrated, the next step is to test the equipment in the research area. Testing of the IoT-based temperature and humidity monitoring system was carried out for 2 days. Testing this system is divided into two stages: the first stage is empty test for 1 day and the second is the test stage with chilies planted for 1 day as well. The calibration of the DHT22 sensor was carried out using a standard stem thermometer as a reference. The DHT22 sensor shows different temperature and humidity reading values from the stem thermometer, so it needs to be changed in the program language section to be reprogrammed. The program language is presented in Figure 5.

```
  Cayenne.virtualWrite(0, suhu1 + 1);
  Cayenne.virtualWrite(1, humidity1 - 14);
  Cayenne.virtualWrite(2, temp_c1);
  Cayenne.virtualWrite(3, humiditytanah1 + 4);
  Cayenne.virtualWrite(4, temp_c2);
  Cayenne.virtualWrite(5, humiditytanah2);
  Cayenne.loop();

if (waktuSekarang - waktuAwal >= interval) {
  //kirim serial
  Serial.print(",");
  Serial.print(suhu1 + 1, 1);
  Serial.print(",");
  Serial.print(humidity1 - 14, 1);
  Serial.print(",");
  Serial.print(temp_c1, 1);
  Serial.print(",");
  Serial.print(humiditytanah1 + 4, 1);
  Serial.print(",");
  Serial.print(temp_c2, 1);
  Serial.print(",");
  Serial.print(humiditytanah2, 1);
  Serial.print(",");
```

Table 5. Program language for sensor calibration

3.3. Testing of Land Without Cayenne Pepper Plants

System testing is carried out on land that has not yet been planted with cayenne pepper or is called an empty test. At this stage the test was carried out for 1 day from

17:08 WITA (central time) of December 29 2020) to 17:08 WITA (central time) of December 30 2020 with the aim of finding out whether the land is ready or not for planting cayenne pepper. Data obtained from readings by the sensors used are updated and stored on the SD card every 0.15 seconds to be processed in the form of an Excel graph.

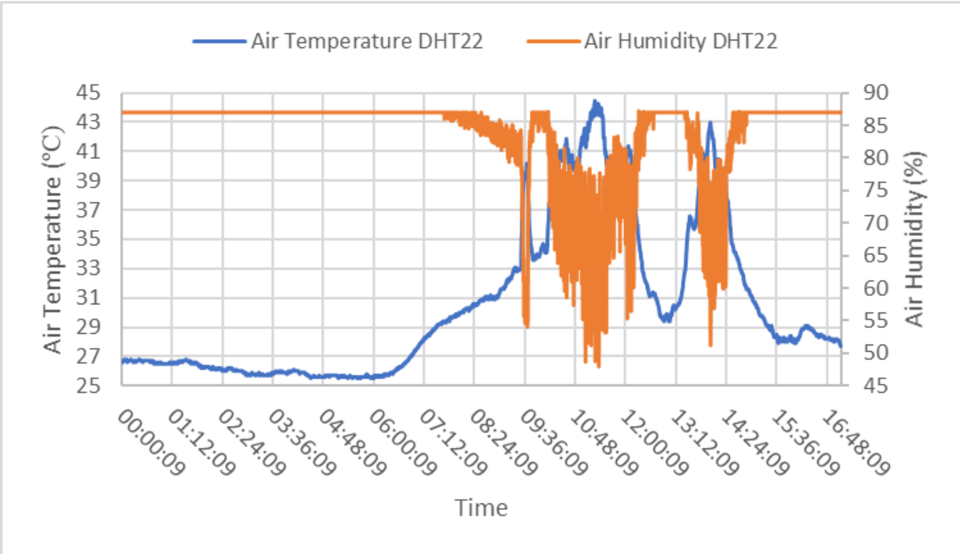

Figure 6. Graph of the relationship between temperature and humidity with time in the blank test

Based on the graph, it is known that at 09:36 WITA to 14:24 WITA there was a significant increase in ambient temperature and a decrease in humidity and instability which was read by the DHT22 sensor. The maximum ambient temperature that is read is 44.5°C and the minimum ambient humidity that is read is 48.1%. This is due to the influence of the rain that fell during the test. High temperature conditions during hot weather and decreased temperature when it rains affect the humidity conditions of the environment. The higher the air temperature, the lower the humidity, and vice versa. According to (Cahyono, 2003) cayenne pepper plants in their growth require optimal environmental temperature to grow, namely the annual average ranges from 18°-30°C and humidity of 60-80%. So when compared between references and measurement results, it can be said that the condition of the prepared land is not optimal.

3.3. Test Phase Using Chili Planted Land

System testing at this stage was carried out after the land was planted with cayenne pepper. At this stage the test was carried out for 1 day on January 8, 2021 from 00:03 WITA to 23:51 WITA. The data obtained from readings by the sensors used is updated and stored on the SD card every 15 minutes for data processing and displayed in the form of an Excel graph.

Based on the graph in Figure 7, it is known that there is a decrease in environmental humidity and a significant increase in ambient temperature and occurs unstable which is read by the DHT22 sensor. The minimum environmental humidity is 37.6% and the maximum ambient temperature is 48.6oC at 11:50 WITA. However, according to (Saputro *et al*., 2010) states that the maximum air temperature is reached around

14:00 WS (local time). This is due to environmental conditions, namely that during the day the air temperature will increase due to radiation received faster than the loss of radiation because it is radiated by the earth's surface, so the data obtained is not in accordance with existing references. This was influenced by several factors, one of which was due to the weather conditions that day it was raining. Based on measurements of rainfall on January 8, 2021, using a 100 ml graduated glass it was obtained rainfall intensity of 100 ml/d, whereas light intensity measurement using a digital lux meter recorded 52,850 Cd on the same day.

High temperature conditions can cause water absorption to be hampered, the rate of leaf photosynthesis decreases, and can also damage the thylakoid membrane which plays a role in the process of photosynthesis (Prakash *et al.*, 2004). In addition, an increase in air temperature can also accelerate the life cycle of plant-disturbing organisms (OPT), resulting in increased attacks from these pests (Forrest, 2016). High temperature conditions can be overcome by several actions including damming the greenhouse and providing watering automatically when the ambient temperature increases until suitable environmental conditions are obtained.

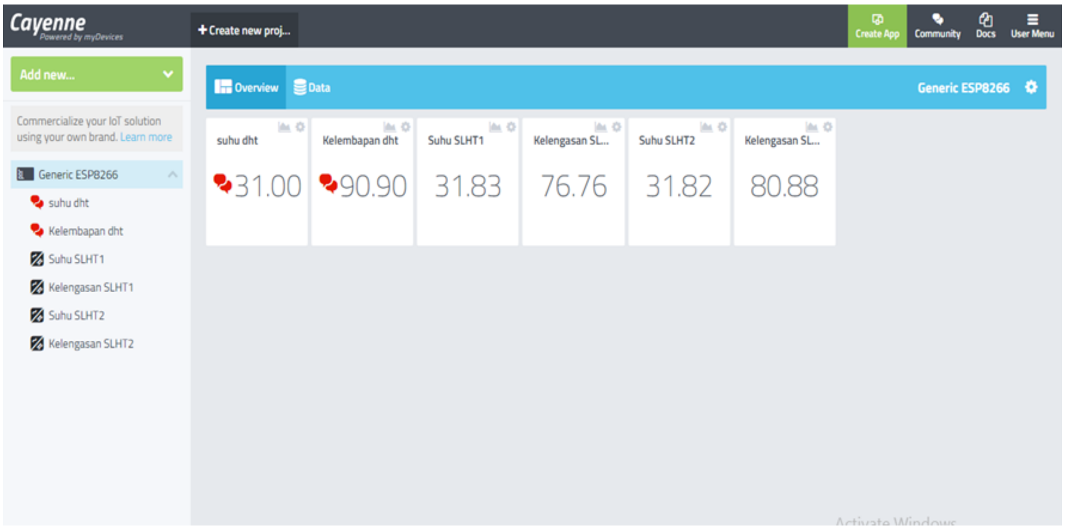

Figure 7. Display of air temperature (*suhu*) and humidity (*kelembapan*) monitoring data

Figure 8 shows the display of temperature and humidity monitoring data in the chili cultivation business. The use of this monitoring system is very helpful in monitoring changes in temperature and humidity that occur in the environment around the field. Monitoring carried out can help cultivators to know the condition of the land so that they can provide treatment according to needs, for example watering so that the plants do not lack water and can grow well.

3.4. System Measurement Results Analysis

The analysis of system measurement results was carried out by collecting data by the system for 32 days, starting from January 8, 2021 to February 8, 2021. The data measurement used is the average measurement per day from morning, afternoon and evening. The readings from the sensors are compared with the measurement results by a standard measuring instrument. The results of temperature readings by the DHT22 sensor are lower than the stem thermometer (ie. DHT22 sensor = 30.5^{o}C and stem thermometer = 31^{o}C). Air humidity readings by the DHT22 sensor show quite a comparison with the SHT10(2) sensor as a comparison (ie. DHT22 sensor = 95.0% and SHT10 sensor = 81.7%). Based on these conditions, then number +1 is added in the program language line of Cayenne.virtualWrite(0, suhu1) and Serial.print(suhu1, 1); whereas number -14 is added in the program language line of Cayenne.virtualWrite (1, humidity1) and Serial.print(humidity1, 1); and number +4 is added in the program language line of Cayenne.virtualWrite(3, humiditytanah14) and Serial.print (humiditytanah1, 1). As shown in Figure 5, the reading results from the DHT22 and SHT10 sensors can match those of the device measure the respective comparators after reprogramming.

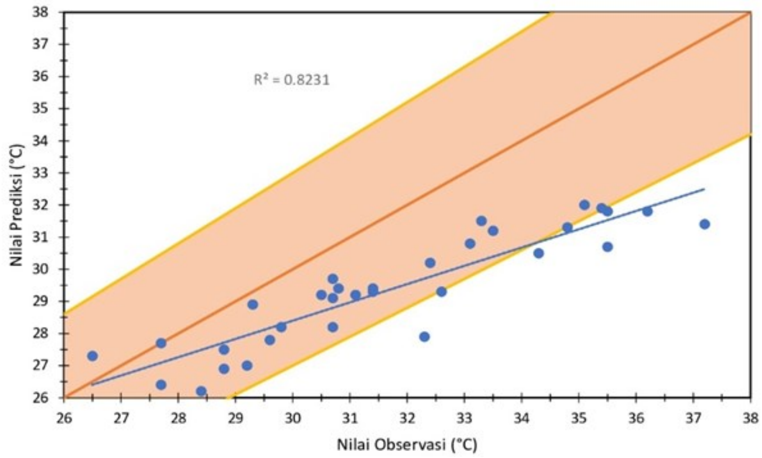

Figure 8. Graph of environmental temperature testing

Based on Figure 9, an R^2 value of 0.8231 is obtained. This shows that the relationship between the observed value and the predicted value for the air temperature reading value has a fairly high closeness, indicated by the R^2 value which is close to 1. The R^2 value ranges between 0 and 1 ($0 < R^2 < 1$) (Sugiarti & Megawarni, 2012). The relative error calculation results show that the DHT22 sensor used works with the best accuracy on day 21 with an error percentage of 0% and the worst accuracy occurs on day 31 with an error percentage of 18.5%. Based on the opinion (Saptadi, 2014) states that the results of the error percentage above 10% indicate the need to recalibrate. Figure 9 also shows that 24 data points (out of 32) fall within the observed yield area of ±10% error. The trend graph shows that the higher the ambient temperature, the lower the predicted data compared to the observation data. Conditions that result in a high percentage error value usually occur during daytime conditions. In daytime conditions, for example on day 31, there was an increase in ambient temperature of up to 37.2 ºC which was read by the DHT22 sensor while the average temperature measured on a standard stem thermometer was 31.4 ºC. Therefore, the average temperature per day has a temperature difference that is quite far between the stem thermometer and the DHT22 sensor.

4. CONCLUSION AND SUGGESTION

Based on data analysis, it was found that the measurement results of the DHT22 sensor for monitoring IoT-based air temperature and humidity are still acceptable with an error value of up to 18.5%. However, the measurement results show that sensor predictions tend to be underestimated at increasing ambient temperatures. It is suggested, therefore, that for further research that additional sensors with different types are needed for air temperature and humidity monitoring so that results can be compared and closer data between prediction and observation are expected.

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