The Performances of Environmental Control Systems to Hydroponics Agriculture Based on Microcontroller

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***Abstract*— Hydroponic cultivation is one of the common modern farming systems. The effectiveness of the agricultural system refers to the appropriate environmental factors that can be controlled such as temperature, humidity, light intensity, and concentration of solutions that support the growth of cultivated plants. Hydroponic farming will develop increasingly as long as it is supported by technological aspects that are able to control the environmental factors automatically. The objective of this research is to come up with a device that can measure environmental factors as indicators of hydroponic farming using a microcontroller-based controller system. The method used is the measurement test method, which consists of testing the parameters of air temperature, humidity, water temperature, light intensity, nutrient concentration, and pump work, which are then reviewed by literature studies. The results showed that the air temperature sensor (DHT11) had an average temperature accuracy of 22.7-25.3 oC, the humidity sensor (RH) had an average accuracy of 50% - 73.6%. Light intensity sensor (BH1750) averaged to 1289 lx. While the solution of height sensor (HC-SR04) was able to read a 25% decrease in solution for 1 week. Moreover, nutrition concentration sensor testing (TDS Probe) provided an accuracy of the average nutritional concen-tration of 1493 ppm for 24 hours**

***Index Terms*— Agriculture; Control System; Environment; Hydroponics; Microcontroller.**

I. Introduction

The increasing human population on earth has caused the significantly increased need for food. However, the supply and demand of food do not matched by the availability of agricultural land as a means of production to increase agricultural output. Agricultural land has undergone many changes and one of the changes is the reduced availability of agricultural land due to its conversion to the increasing number of housing developments each year [1]. This conversion has a great impact on the declining rates of the production of agricultural products. Therefore, one of the ways to address the limited agricultural land is to implement an effective cultivation system to support the availability of agricultural products to remain available [2]. In this regard, hydroponics, a modern agricultural system, is currently being developed [3] to address this issue. Cultivating with hydroponics does not need to require extensive land. It is also easy to maintain and has a high selling value.

Hydroponics is a method of cultivating plants without using soil as prioritizes water media that has been mixed with nutrients [4]. Hydroponic methods and techniques vary in their systems. A popular hydroponic system is the Nutrient Film Technique (NFT). NFT is a method of cultivating hydroponic plants by utilizing thin and shallow water flows through the roots of growing plants in the water layer, which contains nutrients, and it is circulated so that plants can get enough water, nutrients and oxygen [5]. One of the critical success factors in a hydroponics cultivation system is the relatively stable and controlled environmental conditions. The influence of environmental factors consists of air temperature, availability of water and nutrient solutions, humidity, and light intensity, which greatly affect the growth and development of plants. In order to make it easy to balance and adjust environmental factors with planted plants, it is necessary to apply technology that can work in a controlled manner by controlling the parameters needed and adding other technologies so that it can directly provide information in the form of data. In addition, a system that works automatically is needed to facilitate human work [6]. Automatic control can be realized with the implementation of the microcontroller system. Further, the system can work alone to control automatically so that users can simply monitor and obtain information.

The microcontroller system is a small computer that is very easy to use and can be used to control systems and easy to develop because it can be connected by interconnected equipment modules, carry out activities of a repetitive in nature and interact with other supporting components [7]. Therefore, the microcontroller system can easily operate the hydroponic maintenance control[8]. The microcontroller system will be applied to a tool that functions to control, maintain, and obtain work information to the user.

The purpose of this study is to design a tool system that can work automatically using a microcontroller to automatically control the environmental conditions in a hydroponic aquaculture system in order to maintain a stable growth and development, which subsequently increases yields.

II. Methodology

The study began with the design of concepts and application programs. It was conducted in May to July 2019 at the State Polytechnic of Subang, Subang Regency, West Java. The materials used in the manufacture of a hydroponic condition control system consist of microcontroller, sensor and electronic components as shown in Table 1. The Specifications of Tools and Materials and the concepts of electrical series are as shown in Figure 2.

The method used in this research is measurement test methods and literature studies. The test method is done by connecting all sensors to the Arduino Uno microcontroller power supply, and connecting the output pins of all sensors. The measurements were made on environmental parameters including; light intensity, humidity, water capacity, nutrient concentration, air temperature, and water temperature. The data from the test results of environmental parameters are taken and then supported by data from literature. The literature study is used to support the technical aspects and the results of tested parameters. The research concept flow is presented in Figure 1.

Table 1
The Specifications of Tools and Materials

No.	Name	Specifications
1	Arduino Uno	Microcontroller or Processor [9]
2	Board PCB	Circuit board connecting components
3	Nutrition Sensor	Sensor for measuring the concentration of solution in the TDS Probe type water
4	Air Temperature and Humidity Sensor	Sensors for measuring air temperature and humidity type (DHT11)
5	Water Temperature Sensor	Sensor for measuring water temperature type DS18B20
6	Light Intensity Sensor	Sensor to measure the intensity of light BH1750 type
7	Ultrasonic Sensor	Sensor for measuring distance type HC-SR04
8	Power cable	The connecting cable to each of the Nokia 5110 type electronic components
9	LCD screen	Display data or graph
10	Peristaltic Pump	Pump water
11	Power Adapters	Pump water
12	Box	Tool container
13	Relay	Circuit breaker
14	Water pump	Water booster engine type WP-3600
15	Standard digital thermometer	Control

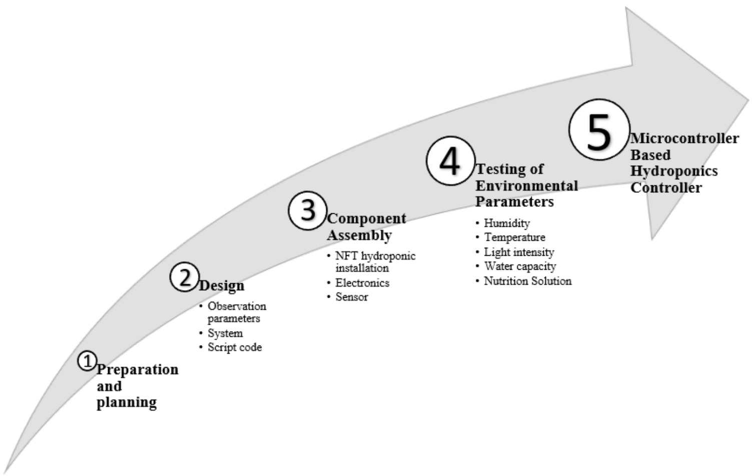

Figure 1: Flow chart of a microcontroller-based hydroponic installation control system making environment condition design

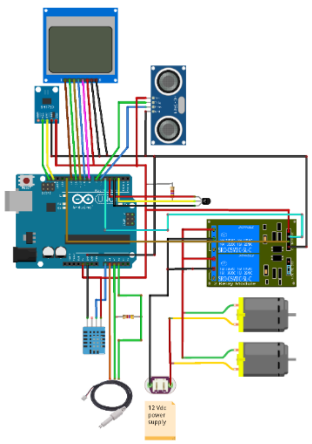

Figure 2: The concepts of electrical series

III. RESULTS AND DISCUSSION

The aim of the hydroponic control system test was to control and measure parameters and to replenish nutrients automatically in a controlled manner. The design of the device consists of a series of electronic components, a programming system that regulates or runs the work of the device in a controlled manner. A series of electronic components was designed into a single unit. Arduino Uno was used to automatically run the environmental controller in a hydroponic installation. It is specifically tailored to the needs, and this will affect the type of processor used [10]. In cases where a more complex design and program is created, it must match the type of controller used [11]. The hydroponic environment controller consists of four separate device components and can be connected when used via a USB port. The device consists of a control room or control center, a nutritional pump, a gauge for the height of the capacity of the nutrient solution, and a device for measuring water temperature and nutrient concentration.

Control center device is an important component that contains a processor or microcontroller component in it. In addition, there are sensor components, LCD, and other supporting electronic circuits. Control center device specifications as follows.

Table 2
Specifications of Control Center Tools

Name	Specifications
Microcontroller	ATMEGA328
Operating voltage	5 V
Input voltage	7-12 V
USB port	4 port
Power port	1 port
Display	LCD 84 X 48 pixel
Sensor	DHT11; DHT11; BH1750

The main NFT hydroponic controller consists of a microcontroller component as a control center. In the microcontroller component, a system made on the Android IDE is inserted. The system consists of all work procedures that are expected to run each component of the tool. The system can work in a controlled manner continuously as long as it is connected to electric power [12]. In addition, there are three sensors that operate within the device to measure the environmental parameters, namely the air temperature, humidity measuring type DHT11 sensor and water temperature sensor using a DS18B20 type sensor. As for the height of the volume, the HC-SR04 ultrasonic sensor and the sensor for light intensity with the type BH1750 were used. TDS Probe and aquarium pump model WP-3600 with 1000 / LH filling capability were used to measure the nutrient concentration [13].

A. Nutrition Pump

i. Tools of Nutrition Pump

The provision of nutrients in hydroponics is very important for the continued growth and development of plants and optimization of the crop production [14]. Nutrient pump tool filled the nutrients into the container of nutrient solution, and it was separately designed from the central control device. The working principle of nutrient filling is based on the condition of the concentration of the container containing the nutrient solution less than 1000 ppm (parts per million), so the system will work to pump the nutrients into the nutrition container for 6 seconds of filling based on the measurement of components or water temperature measuring devices. there are two pumps in the tool, which work on each nutrient solution A and nutrient solution B. The specifications of the nutrition pump tool are; Relay (Switch) 2 Channel, Power Port (Dc) 1 Port, Peristaltic Pump 2 Motors, Pump Voltage 12 Vol, Flow Rate 100 Ml / Min.

ii. Test of Nutrition Pump

The test was done to investigate whether the pump working system perform the automatic control of nutrient filling. The test was carried out by applying two ppm concentration conditions, which are below 1000 ppm and above 1000 ppm. At concentration below 1000 ppm, the pump will work to replenish nutrients into the reservoir. The nutrient filling lasted for 6 seconds, which results in 5 ml of nutrient A and nutrient B. If the measurements do not show nutrient concentrations above 1000 ppm, then the device will continue to refill until the nutrient concentration is above 1000 ppm. When the nutrition concentration reaches above 1000 ppm, the pump performance will automatically stop and do not replenish nutrients. The shape of the nutrition pump is shown in Figure 3. The nutrient and booster pump was connected to the control center.

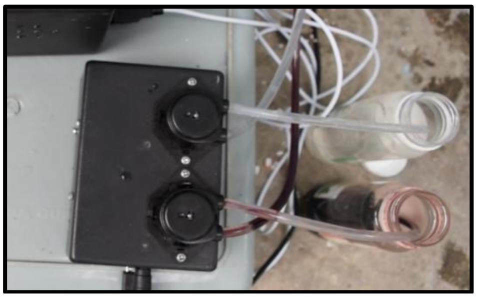

Figure 3: Nutrient and booster pump connected to the control center

B. Nutrient Concentration and Nutrition Concentration Device

The measurement of the height of the solution used a sensor that serves to measure the availability of nutrient water in a container. The instrument will emit an exit signal and reflect it on the surface of the solution using an ultrasonic sensor (Figure 4). In the ultrasonic sensor, HC-SR04 type has an atomic structure of piezoelectric crystals causing contractions to expand or shrink, a voltage polarity that is given: this is called the piezoelectric effect [15]. This will trigger an ultrasonic wave signal at 40 kHz. If the signal hits an object then the signal will be reflected and received by the ultrasonic receiver [16].

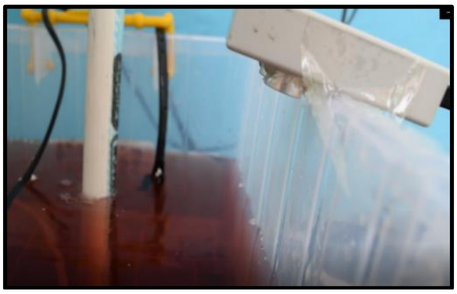

Figure 4: Application of HC-SR04 sensor type as regulator height of solution

The height measurement of the nutrient solution was tested for 30 days and observational data was taken daily. The results of testing the level of solution height and nutrient concentration are presented in Figure 5. Based on the graph in Figure 5, the test results on the height of the solution has decreased in volume for 7 days. From the 1st to the 7th day, the capacity was measured at 100%. From the 8th to the 14th day, the volume decreased by 25%, whereas from the 15th until the 21st day, the volume decreased by 50%. Entering on the 22nd day until the 28th day, the volume decreased by 75%. Finally, on the 29th and 30th day, the height of the solution has reached the lower limit of volume and needs to be added with water and nutrient solution again so that the control system can work.

The different in the measurement of the TDS probe nutritional concentration with conventional TDS was used as a control. It is caused by different levels of precision in these components. When compared with the conventional TDS nutrition concentration gauges, the results were more stable than the TDS probes tested. It is found that the influencing factors are the level of accuracy of the device, and the electronic circuit that has not been optimal and requires further development. One way to develop it is by using a conductivity sensor with three forms of electrodes where the results that are the closest to the value of the reference device are thin plate electrode-shaped conductivity sensors [17].

(a)

(b)

Figure 5: Data on test results for (a) height of solution, and (b) concentration in nutrition

C. Tools of Air Temperature Measurement

The tools of air temperature measurement used a component of the air temperature sensor type DHT11. The test was carried out for 24 hours in a hydroponic installation planted with leaf vegetables, *Pakcoy*. It was done to measure the effect of air temperature and the accuracy of measurements on the components of the air temperature sensor as long as the tool works in the environmental conditions for *Pakcoy* plants. The working principle of the sensor is to measure the temperature of the air temperature around the *Pakcoy* plant and the measurement data can be displayed digitally. The comparison data testing results are presented in Figure 6.

Based on Figure 6, the measurements of air temperature using a DHT11 sensor and a digital thermometer as a control show a very significant difference to the results given. The lowest measurement using the DHT11 sensor occurs at the 1st to 7th hour, around 01.00 - 06.00 WIB with an average air temperature of 21.5 ^{o}C. It experienced the temperature that recalled at the 7th to 11th hour, in which the sun had appeared and the measurements were at the highest temperature occurred at 12.00 - 15.00 WIB with a range of 30 ^{o}C air temperature. At the 15th to 20th hour, the air temperature has decreased. This is due to the position of the sun that began to fall or set until late at night with an average temperature of 25 ^{o}C.

In the measurement of air temperature using a digital thermometer in Figure 6, the conventional test obtained higher measurement results than the measurements using a DHT11 sensor with a temperature difference of about 2-3 ^{o}C. That is because the results of the DHT11 sensor measurement results have not been calibrated because they are still using the settings of the device and have not been calibrated after the acquisition of the sensor. As the result of test, the DHT11 sensor has an error or the relative error range of temperature measurement of 20-30 ^{o}C compared to the measurements using a digital thermometer. The factors that influence the DHT11 air temperature sensor are the range of measurement values, physical dimensions, reading speed and one of the most influencing factors is the accuracy of measurements [18]. DHT11 air temperature sensors include sensors that are relatively inexpensive. However, there is a sensor that is more precise than DHT11 is the DHT22 air temperature sensor. Another sensor that is more precise and accurate than DHT11 and DHT22 is the SHT11 type sensor, but it is relatively expensive [18].

However, the use of DHT11 sensor can still be used as one of the benchmarks to support the growth of leaf vegetables, such as the *Pakcoy* plants. As shown in Figure 1, if the DHT11 sensor is able to measure the average daytime air temperature of 25.3 ºC and at night average 22.7 ºC. The difference in temperature measurement values during the day and night affects the results and quality [19]. Leaf vegetables such as spinach, Chinese cabbage, mustard greens, *Pakcoy*, lettuce, and celery have plant morphology that is much thinner and sensitive to high temperature conditions and able to grow optimally in the temperature range of 15-25 ºC [20].

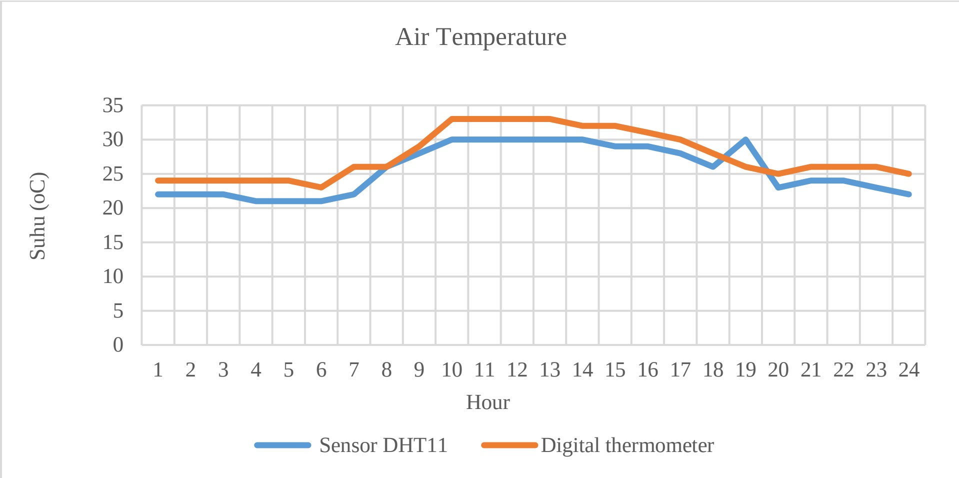

Figure 6: Comparison of air temperature measurement data for Pakcoy plants

D. Water Temperature Measurement

The tools of water temperature gauge on the device using DS18B20 sensor components was connected to a central control device that was connected via USB. The test was carried out for 24 hours, and it was done to measure the effect of air temperature on the components of the air temperature sensor while the tool is working. DS18B20 sensor can measure difficult or wet water temperatures digitally and has water resistance. There is no need to worry about data degradation when used for long distances since the data output of the temperature sensor is in digital [21]. Based on Figure 7, the effect of the measurement of water temperature (DS18B20), air temperature (DHT11) and digital thermometer show the lowest water temperature values, which is in the 1st to 7th hour with an average water temperature of 24 ºC. Then, the water temperature increases with an average water temperature of 25 ºC in the 8th to 17th hours. The water temperature drops again with an average of 26 ºC in the 18th hour to the 24th hour. The different factor between air temperature and water temperature lies in the response of each sensor located. The air temperature sensor (DHT11) is located in the control box, while the water temperature sensor is in the water. Additionally, the observed water media is not exposed to sunlight.

E. Humidity Measurement

Moisture testing was carried out for 24 hours on lettuce and *Pakcoy* plants. Based on the results of humidity sensor testing with DHT11 (Figure 7), it showed that the humidity measurement has an average of 73%, which occurs at the first hour to the 7th hour. The measurements have decreased in the range of 70% - 38%, which occurs at the 7th to the 13th hour. While the humidity increases again at the 15th hour to the 24th hour, which is measured from 39% - 70%. While the measurement of humidity using a digital thermometer (control) is obtained from the measurement data, which is quite accurate and has a measurement difference of 3-10%. The principle of humidity measurement is the measurement of a moisture vapor contained in the air, while the high and low humidity depends on the temperature, air pressure, wind movement, quality and quantity of radiation [22].

Based on Figure 8, the DHT11 sensor during the daytime has an average humidity (RH) of 50%, and at night the average air temperature is 73.6%. The DHT11 sensor can read a humidity value of around 70% due to the humidifier being unable to raise the humidity value to match the control [23]. The humidity needed by *Pakcoy* to meet the growth requirements, is humidity ranging from 60% -90% [20]. While the humidity needed by lettuce as a condition for growth is the humidity ranges from 80-90%, which is good for its growth[24].

F. Measurement of Light Intensity

The intensity of light greatly affects the conditions of a place such as humidity and temperature based on the measurements of the amount of incoming light. Lighting in a room is generally defined as the level of lighting in the workplace, namely the imaginary horizontal, which is located 0.75 meters above the floor in the entire room [25]. The measurement of the effect of light intensity is measured by the high or low amount of light. The light intensity test was carried out for 24 hours to measure the effect of light intensity on the sensor components (BF1750) used, while the tool is working.

Based on the data from Figure 9, the intensity of the light received by the sensor has increased the amount of light entering in the 5th to 11th hour. While in the 12th hour to 19th hour, the amount of incoming light has decreased. The lowest light intensity occurs at the 1st hour to 4th hour and at the 20th hour to 24th hour. The range of the intensity of the incoming light is based on the incoming light at the 1st hour, the 5th hour, and the 5th hour 18th to 24th hour, the environmental conditions when observed have a light intensity of less than 50 lx, which is sourced from the light of the lamp. In contrast to the intensity of the light coming in at 6th to 18th hour, the environmental conditions of the sunlight source of intensity is more than 500-2500 lx with an average of light received at 14331 lx. The light intensity sensor (BH1750) can be fully used as a reference for a measure of the strength of the light.

The BH1750 sensor is a digital light sensor that is able to measure light intensity more accurately, and it is easier to use when compared to other sensors with lux (lx) output without the need to perform calculations [26].

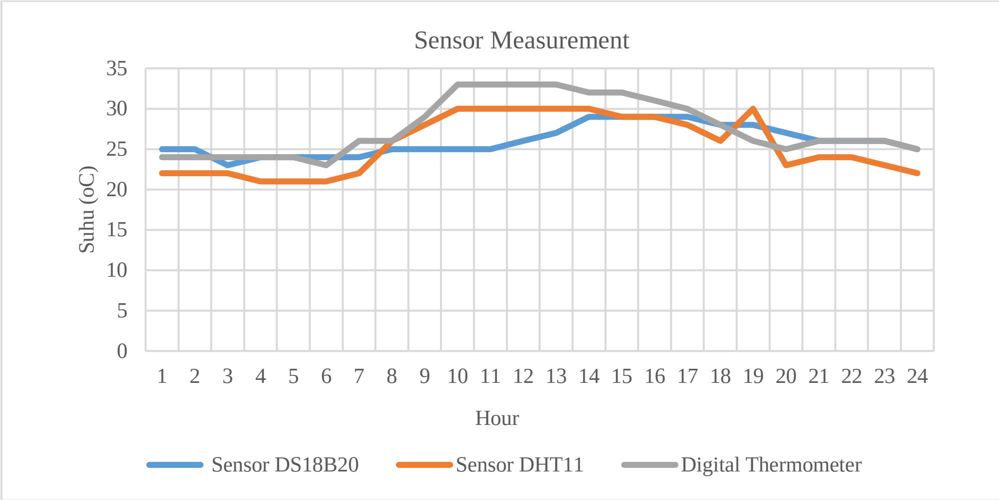

Figure 7: Data on the effect of DS18B20 sensor measurement, DHT11, and digital thermometer on temperature in Pakcoy plants

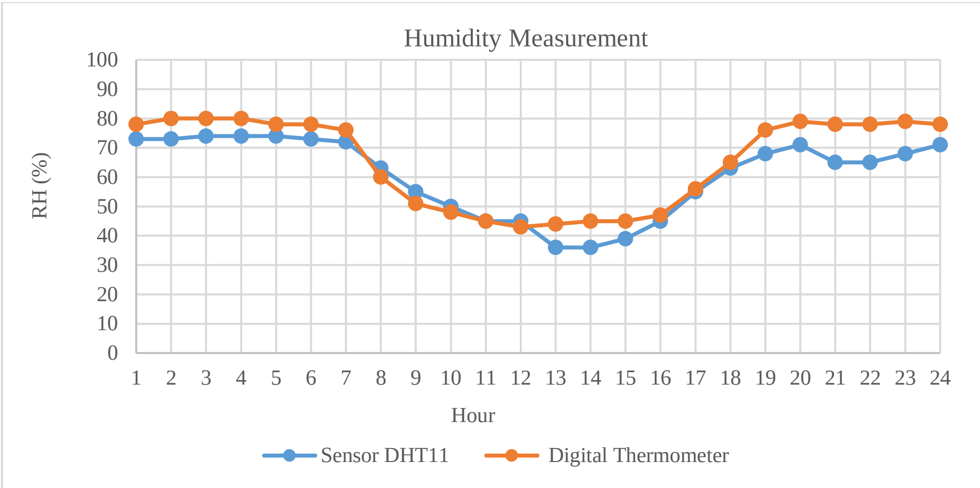

Figure 8: Data on the effect of humidity measurement on temperature in Pakcoy plants

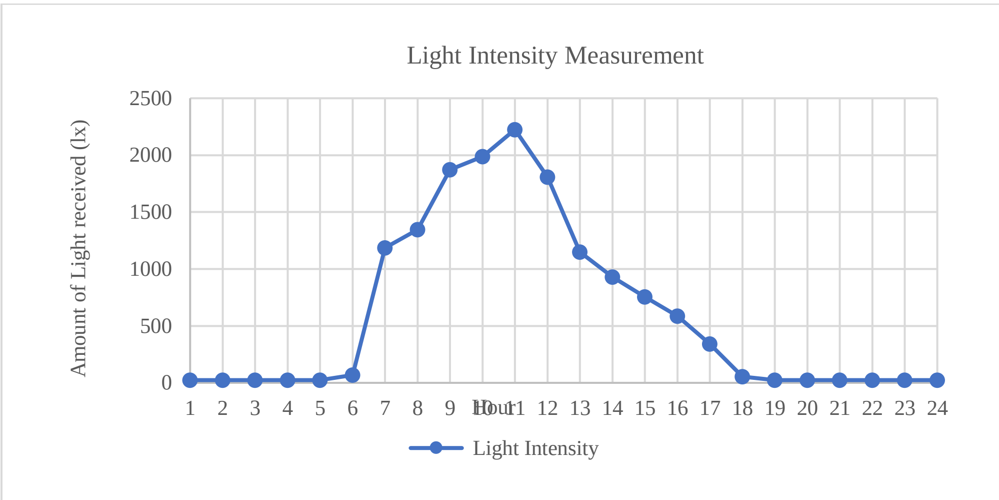

Figure 9: Light intensity measurement data

IV. CONCLUSION

Based on the test results of environmental parameters, it can be concluded that the result of the DHT11 air temperature sensor test during the day has an average accuracy of 25.3 ºC and at night 22.7 ºC. In addition, humidity (RH) during the day has an average accuracy of 50% and at night 73.6%. The test of the light intensity with the BH1750 sensor during the daytime averaged 1289 lx and at night the average was 30 lx. The test of the height solution using the HC-SR04 sensor is able to read a 25% decrease in solution for 1 week in a container with a capacity of 44 liters of water and an average decrease of a solution of 31% for 24 hours. Nutrition concentration testing with a TDS Probe sensor provides an accuracy of an average nutritional concentration of 1493 ppm for 24 hours.

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