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Lighting and Air Temperature Monitoring and Control of Hydroponic System using Internet of Things (IoT)

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Abstract: The efficiency of plant's growth rate depends heavily on the environmental factors. Parameters such as temperature, humidity, lighting quality, pH, and nutrients should be provided to a plant in a sufficient amount. If one of these parameters below than the ideal growth limit, it will impact the growth of the plant. Thus, farmers need to give more attention for their plants to produce a healthy plant. Other than that, it will increase their workload because they have to interact with plant all the time and their daily activities will be affected. Besides that, insufficient information or data about the plants will also lead to ineffective production of crops. To overcome these problems, one of the solutions is to use Internet of things (IoT) in their growth method. This study is intended to design a monitoring and control system for the hydroponic application. Parameters such as surrounding humidity, lighting quality and temperature was controlled using NodeMCU microcontroller unit with the help of an internet connection. Sprinkler system and growth lights were used to control and provided the plant with sufficient amount of temperature and lights. ThingSpeak cloud application was used to gather and store data in cloud storage whereas, Blynk application was used to monitor and control the system. To identify the difference between the growth rate of controlled parameter and uncontrolled parameter system, another system without the controlled parameters has been setup. The system which developed in this project will reduce the workload of the farmers. The farmers can monitor and control their plants from wherever there are or on the go. All the temperature and humidity data were stored in the cloud storage for the future usage. It is shown that the growth rate of Chinese kale plant has increased consistently using system with controlled environment compared to system without any parameter controlled.

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Keywords: IoT, Internet of Things, NodeMCU, Hydroponic.

1. Introduction

Plants are the main source of food for living things. Without it, living things cannot survived well. In this era, there is a lot of factor affecting the healthy growth of the plants. Environmental stress or environmental factors are the cause that affecting the plant's growth, if any environmental factor is less than ideal, it will limits the plant's growth. In addition, global warming and dramatic climate change is one of the factors that impact the growth rate of a plant. The plants are difficult to thrive in an extreme weather condition because the extreme temperature will decrease the water availability in the soil and changes the soil's conditions. Environmental factors such as surrounding humidity, temperature, lighting quality, water, pH condition, and nutrients are very important for a plant to grow. These environmental factors needs vary differently according to the plant type.

Hydroponic is the technique of growing plants without soil and the nutrient are supply directly to the roots. People can grow plants in the place that the usual or traditional agriculture is simply impossible by using the hydroponic system. In the hydroponic plantation farmers can control the environmental factors of the plant and can create a suitable environment for a plant to thrive. By using the latest technology farmers can easily control those factors and this will reduce their workload. Internet of Things is one of the promising new technology which can used to monitor and control process.

This project intended to create a monitoring and control system of the air temperature and lighting of the hydroponic plant using the Internet of Things. Data collection of temperature and humidity using controlled and uncontrolled hydroponic system will be done. Analysis of the effect of the environmental factor towards the plants will be studied.

2. Literature review

Currently, Internet of Things (IoT) attracts more attention to technology development and innovations. The IoT have the ability to connect existing network machine infrastructure to the environment. [1]. Physical world can be merge with the computer systems and virtual resources available on the Internet to provide useful and recordable data for end-users [2].

2.1 Hydroponic system

The hydroponic system is a technique for growing plants in a water filled with nutrient rich solution. It does not use soil but rather the root system is supported using an inert medium for example perlite, rock wool, clay pellets, peat moss or vermiculite [3]. Currently, hydroponics is used in commercial greenhouse vegetable production around the world. Agriculture technology developed rapidly in urban areas, it is often called urban farming or urban agriculture [4]. Nutrient Film Technique or known as NFT is one of the famous methods used in the hydroponic plantation system. Figure 1 shows the arrangements of NFT method. This method is suitable for all types of hydroponic plants due to the easy manageable and controllable solution concentration of fertilizer and the germination process of the plant.

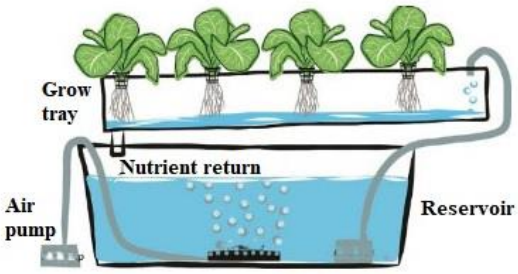


Figure 1: NFT Hydroponic system.

2.2 The working principle of IoT

Internet of Things (IoT) is an environment where all sensors, actuators, and other devices (heterogeneous objects/devices) being connected together with wireless communication devices where they can communicate with each other, deliver and record data and also do the controlling phase without any human intervention. [5]. The cloud computing and IoT system are integrated with each other such as the cloud computing are prepared the store's space for IoT components to deliver to the cloud. [6].

2.3 IoT using NodeMCU

NodeMCU ESP8266 is the main component used to monitor and controlling the hydroponic system. NodeMCU is commonly used as a microcontroller which can connect with the internet with help of the ESP8266 Wi-Fi chip. NodeMCU is an open-source firmware IoT platform. [7]. NodeMCU boards can read inputs from the sensors for instance temperature reading from the temperature sensors, air humidity from the humidity sensors and turn it into an output.

2.4 The effect of temperature towards plants

One of the important elements for the plant to survive is temperature. The development and the growth rate of the plant is dependent on the surrounding temperature. Each plant has an optimum temperature range for optimum growth. In recent years heatwaves or extreme temperatures have become more intense and may last longer.[8]. Due to this, crops that grows in colder environment have the effect of decreasing growth rate and thus productivity to the farmers. The needs to study the minimum and maximum temperature allowable for plant's growth is important to be understand. [9].

2.5 Artificial lighting for plant growth

Artificial lighting is also important for plant's growth as quality lighting gives plant energy for it to perform photosynthesis. Most of the growth chamber use fluorescent lamps, particularly those having enhanced blue and red spectra, to achieve photosynthetic photon necessary for high productivity [10].

3. Methodology

Several methods from previous researches have been adopted in order to meet the requirement of this project and to make sure the system successful.

3.1 NFT hydroponic system arrangement

There is various hydroponic system used by the farmers to grow their plants. NFT system is chosen after conducting some researches on the hydroponic application. The NFT system is one of the effective systems used in the hydroponic field. The nutrient water flow through the channel and the inert media which is placed in the plant pot will absorb the nutrient and help the seed to germinate. The inert media will maintain its moisturizes to help the plant to germinate by providing the nutrients. The nutrient flow into the channel with the help of the submersible water pump.

Figure 2 shows the full arrangement of the NFT hydroponic system with control system. The lighting system was placed above the channel to ensure all the plants in the pots receive enough lights. A support frame was made to place the growth lights above the channels. The DHT 11 sensor was placed near the potholes to collect the data of the plant's temperature from time to time. The sprinkler system act to disperse water to reduce temperature whenever limit is reached. The sprinkle tube was connected with a water pump and placed near a tank to make sure a sufficient amount of water is available to sprinkle whenever it is needed. In this project Chinese kale have been chosen as the plant to be observed.

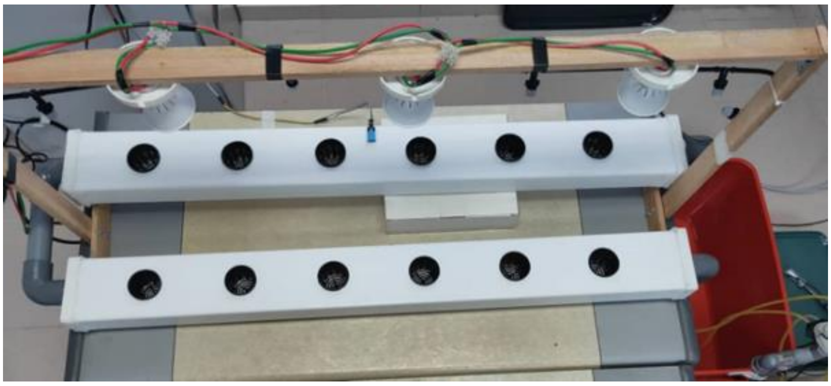


Figure 2: Controlled hydroponic system arrangement.

3.2 Installation of IoT in the hydroponic

Microcontrollers are the main component in the IoT application. NodeMCU microcontroller was used in this project to monitor and control the lighting and air temperature also for collecting the data from the hydroponic system. The microcontroller needs to integrate with the IDE software to upload the coding in the microcontroller and the microcontroller runs the system according to the program. Blynk application is used to control and monitor the hydroponic system from the smartphone.

3.2.1 Software integration

An integrated development environment (IDE) software was used to develop the main coding. Integration of ThingSpeak to store the data collected from sensors and uploaded it to the cloud is used so user can view and process the data anytime. The system runs 24 hour without stop. Other than that, Blynk coding was included to ensure the microcontroller can be operated from the smartphone. This application makes the monitoring and controlling work easier for the user.

3.2.2 Graphical user interface (GUI)

Graphical user interface using the Blynk application is one of the easiest and user-friendly methods that can be used to integrate or communicate with microcontrollers and sensors. Figure 3 shows the chosen widgets for this project that are gauge, buttons, and the timer. The gauge is used to display the data of the temperature and humidity, the button is to switch on and off the sprinkler pump and the growth lights, lastly the timer widget is used to switching on and off the growth lights automatically and the timer is set to 16 hours daily. This ensures the plants receive sufficient light intensity daily.

Figure 3: Widget selection of the project.

3.2.3 Hardware integration

The connection between the sensors and the microcontroller was connected in the proper pins. Each pin in the microcontroller and the sensor has a different function. For controlling the lighting and the sprinkler pump the wire of the pump and light was connected with the 5V relay and microcontroller. The wire from the main current source connected with the 5V relays and from the relay, the wire connected with the lights and pumps. Converter is used to convert the AC to DC supply. The relay act a switch to connect and disconnect the current flow when switching on and off the relay with the help of the microcontroller. Once the microcontroller connected with the relay the switching on and off process can be done from the smartphone. Once the user receives notification, the sprinkler pump is switch on and once the notification is stopped its shows the temperature under the limit. Whereas, for controlling the lights, the timer, and the button widget in the Blynk application was used. The growth light can either switch on and off automatically or manually with the help of the button widget. Figure 5 shows the DHT 11 and microcontroller pin connection and figure 6 shows the growth light pin connection with the relay and the microcontroller. Tables 1 and 2 explains the pins involved in microcontrollers, relays, and sensors connection.

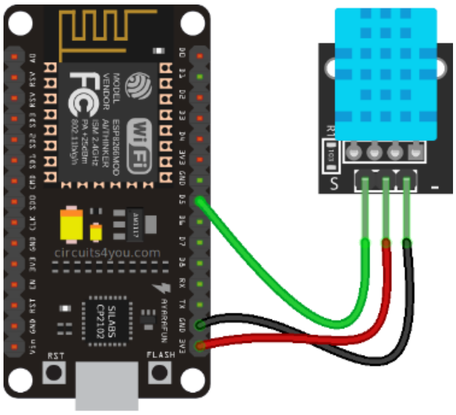


Figure 5: Pin connection between NodeMCU and DHT11 sensor.

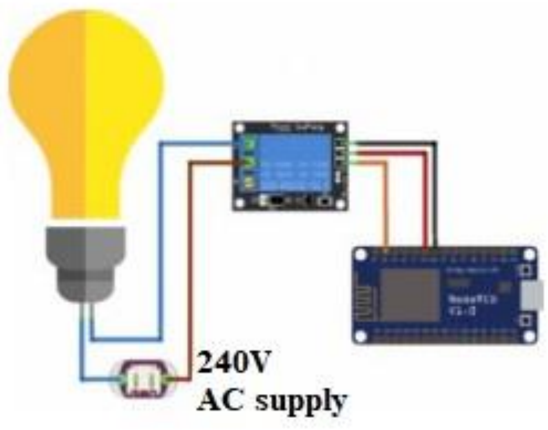


Figure 6: Growth light connection with relay and NodeMCU

Table 1: Pin connection of NodeMCU and DHT11

Pin	NodeMCU Pin	DHT11 Pin
1	3v3	Positive (+)
2	GND	Negative (-)
3	D4	$+V_o$

Table 2: Pin connection of NodeMCU and Relay

Pin	NodeMCU Pin	Relay Pin
1	D0	IN
2	3v3	Vcc
3	GND	GND

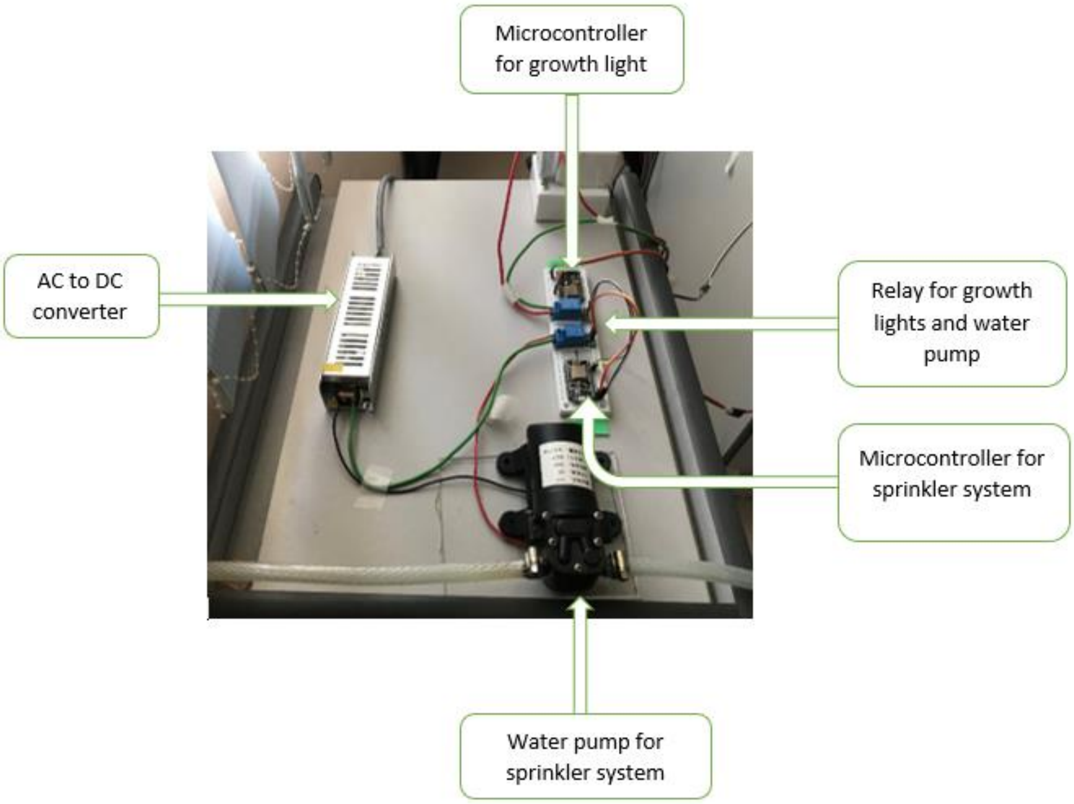


Figure 7: Complete component arrangement for the controlled system.

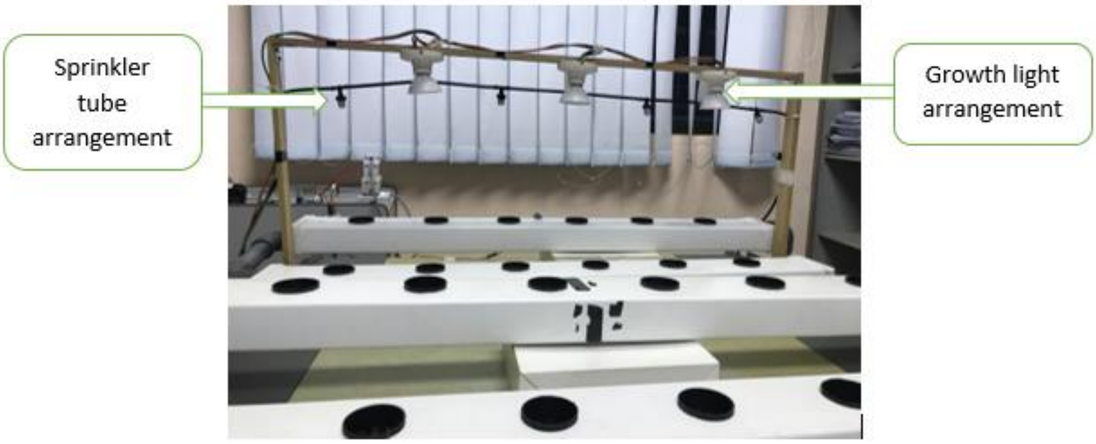
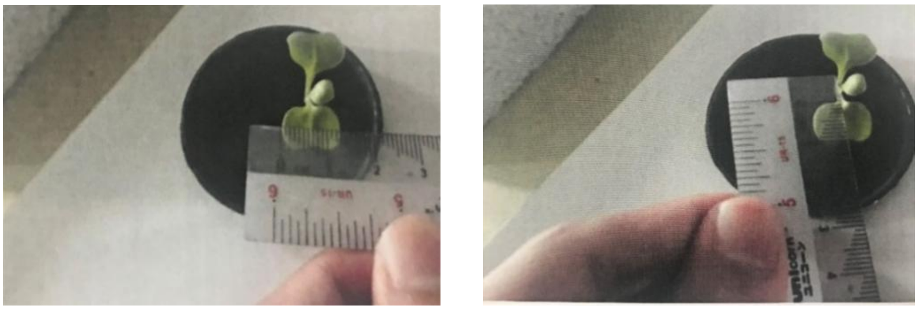


Figure 8: Complete controlled hydroponic system arrangements.

Figure 7 shows the full arrangement of the components used for the controlled hydroponic system. All the components were connected with the microcontroller and provided with an electricity connection all the time. A Wi-Fi modem was placed in the experiment room to ensure the microcontrollers always stay connected with the internet connection. While, Figure 8 shows the arrangement of the sprinkler system and the arrangement of the growth light in the support frame.

4. Results and Discussion

The Chinese kale plant was monitored for 1-month period to measure the growth rate of both controlled and uncontrolled parameters of the plants. After 5 days of seeding the data was recorded. The length and width of the plant's leaves were measured using a ruler. The data of length and width of the both system's plant leaves were recorded and compared to identify the effect of controlling the parameters. Both the system was provided with the same amount of nutrients all the time. Figure 9 shows the method of measuring the length and the width of the Chinese kale plant and the plant shown in the figure is grown under the controlled hydroponic system.



Figures 9: Measuring method of the length and width of the leaf

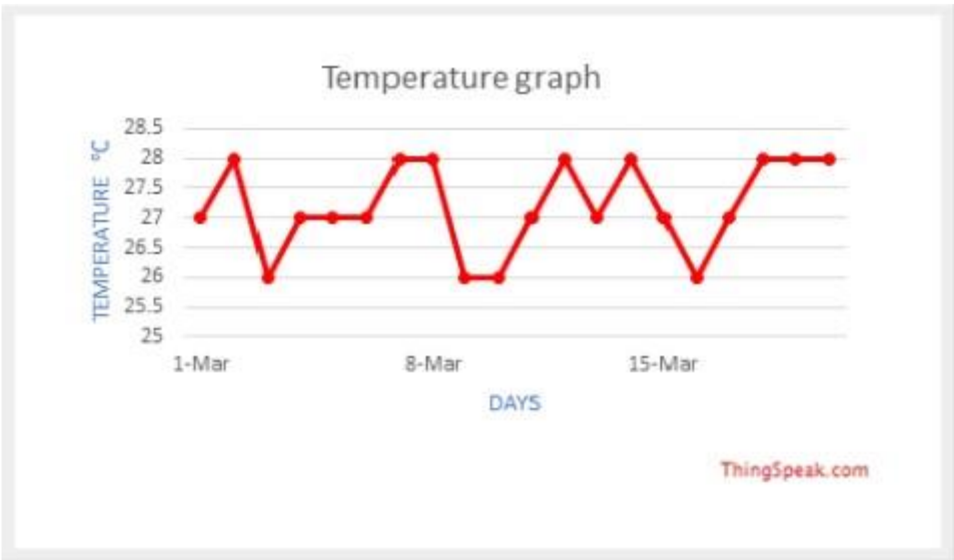


Figure 10: ThingSpeak temperature data collection.

Figure 10 shows the data collection of the temperature in ThingSpeak application. The data was collected daily for 1-month period. The graph shows the average temperature of a day during the monitoring period. In addition, the temperature was controlled by the sprinkler system whenever the temperature exceeds 28 degree Celsius. Besides, the lighting exposure to the plant was also maintained 16 hours light and 8 hours of dark for 1 month period.

Table 3: Data collection

System	Leaf height	Leaf width	Unit	Days collected
Controlled	2.5	2.5	cm	25
Uncontrolled	2.0	1.9	cm	25

Table 3 shows the data obtained from the leaf of the plant on the last day of the monitoring period. From the data obtained it is identified the controlled system leaf was grown well compared to the uncontrolled system. Based on the table 3, the leaf length and width of the controlled system was grown bigger and wider compared to the uncontrolled system plant's leaf.

4.1 Data comparison

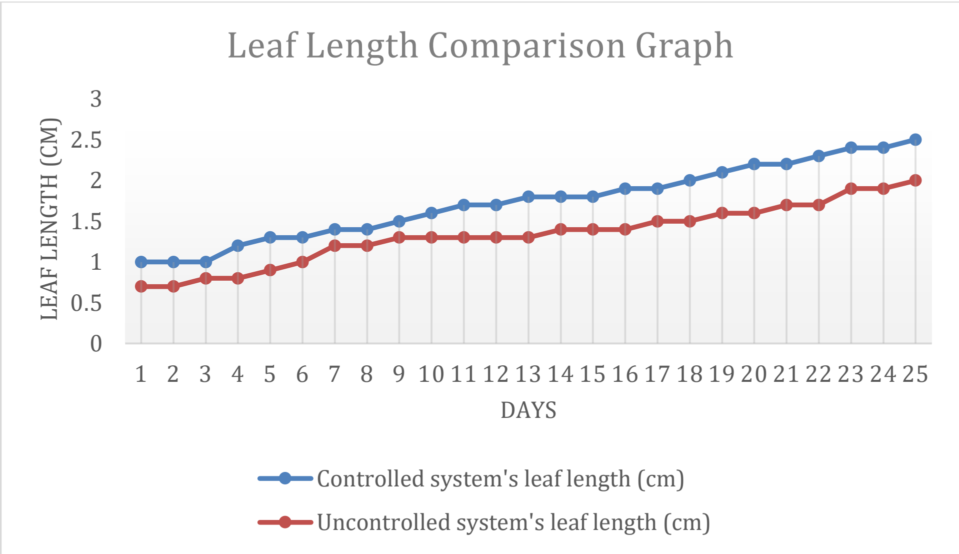


Figure 11: Comparison graph for leaf length.

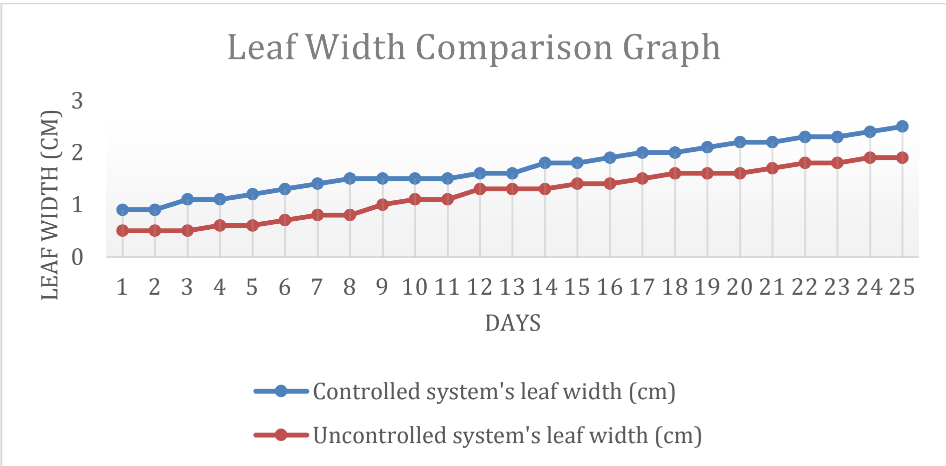


Figure 12: Comparison graph for leaf width.

Based on the Figure 11 and figure 12 shown, the growth rate of the controlled system's plant leaves was grown well compared to the uncontrolled system. After the observation period, the length and width of the controlled system plant's leaf is 2.5 cm and 2.5 cm, respectively. Whereas, the uncontrolled system plant's leaf length and width is 2.0 cm and 1.9 cm, respectively. This proves that the parameters play an important role in the plant growth. The environmental factor such as temperature, humidity, and lighting exposure give plants the energy and strength to grow healthier.

The controlled system plants receive a limited amount of temperature and the lighting depends on the plant types. Every different type of plant needs different amount of temperature and lighting exposure. This graph proves that the uncontrolled system plant growth rate is lower. Chinese kale is a plant which grows best under colder conditions, so the plant should not be expose in higher temperature surrounding. 28-degree Celsius is the optimum temperature the Chinese kale plant and in the controlled system, the temperature was maintained 25 to 28-degree Celsius and below all the time. This provides a colder environment for the Chinese kale plant. Other than that, the plant also must be provided with a sufficient amount of lights to gives the plant energy to grow. 16 hours of light and 8 hours of dark is the suitable timing for the Chinese kale plant to grow [14]. The plants were received blue and red combination lights exposure 16 hours daily. The nutrients for each hydroponic system were provided with the same amount all the time to identify how the temperature and the lighting exposure affecting the growth of the Chinese kale plant. This experiment proves that every plant must be provided with a sufficient amount of temperature, humidity, nutrients, lighting exposure, and so on for it to grow fast and healthy. IoT implementation in the hydroponic system helps to reduce the monitoring work of the plants all the time.

5. Conclusion

At the end of this study, all objectives have been successfully achieved. As a result of controlling the parameter, it is identified that the controlled hydroponic system plants were grown well compare to the uncontrolled hydroponic system plants. The leaves of the controlled system plants were grown bigger and wider at the end of the observation period. This is identified by measuring the length and width of the plant leaves. The leaf length and width of the controlled system was 2.5 cm and 2.5 cm, respectively whereas the length and width of the uncontrolled system were 2.0 cm and 1.9 cm, respectively. This proves that the parameters such as temperature, humidity, and light exposure impact the growth rate of the plants. The Internet of Things in agriculture will bring the agriculture sector to the next level. As a recommendation for continuation of this current project in future, the Peltier cooling system can be used to control the temperature as an additional system. Other than that, image processing data collection method can be used because the data is based on the growth rate of the plant, and the IoT system can be upgraded and improved as a multipurpose system using the suitable sensors for the hydroponic application.

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