Automated Hydroponics Notification System Using IOT

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Abstract—This research was conducted to increase the productivity of farmers and to plan the planting of crops by farmers when using a hydroponics system that controls various environmental conditions, in which plant growth factors such as temperature, humidity, water temperature, pH and electrical conductivity are important factors for hydroponics. The Internet of Things control and notifications enabling farmers to quickly modify and improve their crop treatment. This research focuses on use of the Internet of Things to control plant growth factors. Displays and alerts are communicated to the user through a web application where, when comparing plants with controlled growth factors and unregulated systems, it can be seen controlled plant growth factors are in the desired range of the plant, whereas in uncontrolled systems there are unwanted values range of plant, which can cause the plant to not fully grow or even to wither. In this system, farmers are able to view plant growth factor data and can retrospectively view graphs displayed on the web application by this controlled system when the measuring sensors in the system are in range that plants do not want it will alert farmers to the crops they are planting, to assisting farmers to prevent crop malnutrition damage of plant. Monitoring of environments using IoT, including alert allow them to fix the system quickly and with minimal damage to crops.

Keywords—hydroponics, internet of things, notification, automated

1 Introduction

Rural people everywhere are moving to the cities to pursue a better life, abandoning their former occupations in agriculture, and in Thailand this has caused a significant shortage of agricultural products. From the results of previous research, it was predicted that there would be a lack of resources by 2050. The growth in the current worldwide population of 7.9 million people has motivated studies on how to address these concerns [1].

Planting in soil has limitations since it causes plants to grow poorly. Poor drainage is caused by deterioration of the soil, and cultivating plants in the soil requires a lot of cultivation space and is labor intensive. For the above reasons, hydroponics was created [2]. Hydroponics is the cultivation of plants in a nutrient solution specifically so that the roots float in a nutrient solution [3]. Without sufficient nutrient solution, hydroponic plants may not grow well [4]. One of the hydroponics cultivation techniques is NFT hydroponics, which is a good technique for farmers. In this hydroponics system, special care is required to control the water temperature, acidity, and nutrient solution [5].

In terms of environment control, it allows plants to grow faster depending on temperature, humidity, pH and electrical conductivity, which are indispensable factors in plant growth in a hydroponics system [6]. The optimal environmental conditions are managed by regulating the conductivity and pH of the nutrient solution; in this case, pH is essential in controlling the growth of plants during each growing period, and nutrient control supports the rapid growth of plants [7]. However, plants require light for photosynthesis, which is part of their natural cycle [8].

Crops can be cultivated with hydroponic systems using the Internet of Things, which allows farmers to automate hydroponics and monitor the system's environment [9]. The Internet of Things (IoT) is a technology that uses the internet to connect everything without involving humans. To put it another way, the Internet of Things can be perceived and connected to the environment via the internet, allowing humans to be aware and connected [10]. The Internet of Things helps with communication and storage data in remote areas, and can make us aware of information through an interface. Furthermore, these automation systems have the potential to improve agricultural efficiency [11].

In agriculture, the Internet of Things has been utilized to control the environment of cultivated plants. Due to unexpected climate change caused by humans or nature, plants are affected and have low yields. As a result, maintaining an optimal climate by controlling humidity and temperature is essential for plant growth in hydroponics system [12]. The Internet of Things is more applied in intelligent farming [13]. Hydroponics has enabled the growth rate of hydroponic cultivation using the Internet of Things-controlled environment is up to 50% higher than that of soil cultivation [14].

In this paper, we develop a hydroponic system based on the Internet of Things. Sensors are connected to a WIFI module for connectivity and monitoring the plant environment [15]. The wireless sensor node becomes a tiny device with limited battery resources. Processing and memory are cut down as well. It is now possible to collect environmental data with accurate sensors and send those data to the control station with high efficiency [16]. Therefore, optimization by using the Internet of Things and data analysis to help simulate and manage plant growth by controlling plant growth factors improving agricultural efficiency and increasing productivity for users. Furthermore, this work aims to increase yield efficiency and accelerate plant growth by controlling plant growth factors, reducing fertilizer residue in plants, and allowing users to automatically control the watering without measuring the data all the time.

2 Experimental design

2.1 Hydroponic cultivation

One of the significant issues in agriculture is environmental problems. The fertile areas are declining due to environmental pollution, and farmers are escaping to residential life [17]. In agriculture, climate is an unforeseeable factor over which we have no control. It is crucial for growing crops as inclement weather may make the cultivated area no longer fertile due to pollution or residue problems [18]. Currently, approximately 3.5% of the global area is cultivated in greenhouses using soilless cultivation techniques with nutrient solutions [19]. There are several types of hydroponics today, but the most popular is NFT hydroponics, which has roots directly immersed in a nutrient solution by nutrient solution that flows through piping as a 1–3 mm thin film. The slurry flows continuously and is pumped with circulation back to the storage tank. NFT Hydroponics shows the flow of the water acquisition system from the water storage to transport the nutrient-rich water to the plants grown in layers 1 and 2, and after that water will flow back to the reservoir again. This method can save water for the farmers as shown in Figure 1.

The advantage of NFT hydroponics is that there is no need to control the irrigation as due to the constant supply of water. By to the continuous water supply, this approach prevents and eliminates various plant pathogens. In addition, hydroponic crops are also there is empowering agriculture with automated technology and decision making to improve productivity with quality, and high yield [20]. Many related factors affecting the growth of plants are being studied: temperature, humidity, light, pH, and electrical conductivity. This is done by adopting Artificial Intelligence to help in the analysis and control of plant growth factors. Revathi Nukala et al and Xiaotao Ding et al have studied the growth of tomatoes with light, temperature, and humidity controls. They applied a Bayesian optimization close to the result of the actual values of the crops. In general, controlling the environmental factors temperature, humidity, and light is sufficient for good growth. However, it has been found that other essential plant growth factors include pH and electrical conductivity. The former should be 5.5–6.5 while electrical conductivity should be 1.8–4.8 [21], [22].

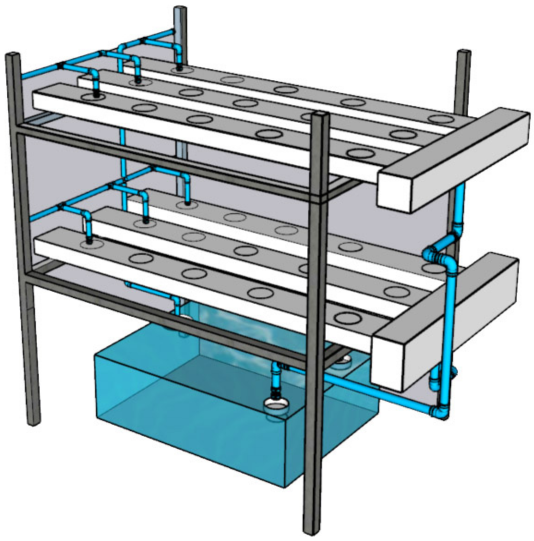

Fig. 1. Prototype design of NFT hydroponics system
(This figure is provided by authors)

Hydroponic cultivation requires that the factors Temperature, Humidity, Water temperature, light intensity, pH and electrical conductivity are controlled for the plants to grow correctly, and hydroponics is an alternative way for farmers to grow crops instead of in soil, to avoid residues or herbicides. This hydroponic cultivation, therefore, meets the needs of farmers and consumers for clean and organic vegetables. Typically, in hydroponics, sensors are installed in a hydroponics system including a DHT22 sensor, waterproof temperature, pH, electrical conductivity, and light sensors. We studied factors affecting plant growth prior to the installation of these sensor. All sensors installed are crucial for controlling the environment and plant growth in hydroponics. We measure the system status with sensors in the water reservoir. The AB nutrient solution is mixed into the water in the container. The sensors in the water storage tank consist of waterproof temperature, pH, and electrical conductivity sensors. They perform measurement every 5 minutes, sending results to the control box, it then manages to control the water pump automatically after receiving the value for processing. The control box contains a light sensor for measuring temperature and humidity inside the system room. When the data from sensors is taken to the control box, it sends the data to a database, which shows the sensor value that has been measured to the user through the website, including the value from measurement along with data graph visualizations. The user can choose to control manually the system, as shown in Figure 2.

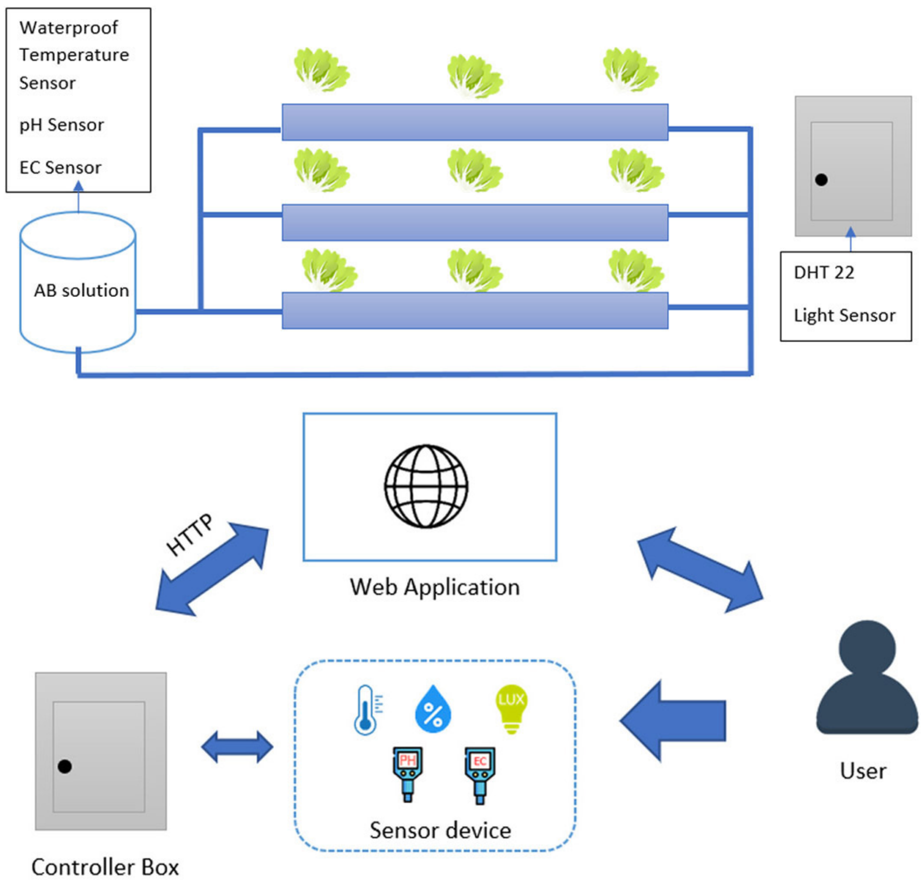

Fig. 2. Common sensors in hydroponics systems

Our work aims to design and install a sensor system in a limited area and manage data using a smartphone or a computer with a website to control the system. The principle of the working system is to receive data from the sensor layer with various sensors installed. The measured signals consist of temperature and humidity, light, pH, and conductivity. When data from the sensor layer is received, it is forwarded to processing in the processing layer. The measured signals pass through Internet intermediary or network layer transfers to the processing layer. After the data are processed, results are displayed to the user through the dashboard shown in Figure 3.

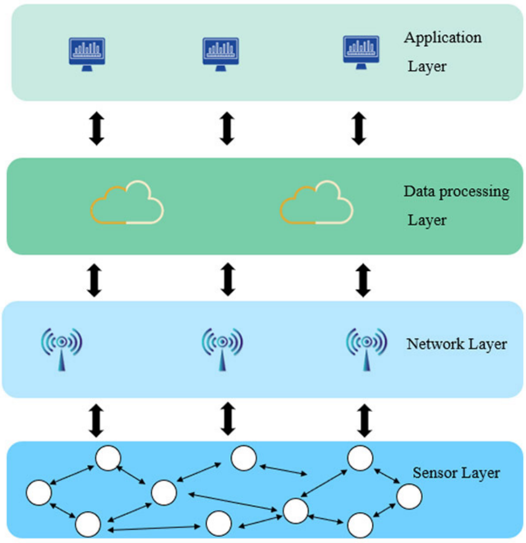

Fig. 3. Four-layer architecture of a sensor network

2.2 System specification

We use sensors to measure the environment in the hydroponics system, as shown in Table 1.

Table 1. Hardware specification

Parameter	Sensor	Voltage
Node MCU	ESPINO 32	2.3–3.6V
Temperature	DHT22	3.3–3.6V
Humidity	DHT22	3.3–3.6V
Water temperature	DS18B20	5V
pH	pH sensor	5V
Electrical conductivity	EC sensor	5V

The most influential factors for growing plants in a closed hydroponics system are the following: water temperature, closed room temperature, relative humidity, light intensity, pH, and electrical conductivity. We controlled the growth factors to within an optimal range for plant growth. The selected ranges used in this experiment intended for the plants to grow best are shown in Table 2.

Table 2. Sensor threshold values

Sensor	Condition
Temperature	15–30°C
Humidity	50–70 RH%
Water temperature	22–28°C
pH	5.5–7.2
Electrical conductivity	1.1–1.8 mS/cm

The efficiency of the system depends on the selection of individual sensors for suitability and for low cost as well. This system is very flexible for users.

Temperature. Temperature control is therefore important for growing plants in hydroponics. DHT 22 sensor is used to measure the air temperature in a closed room equipped with this hydroponics system. The DHT22 is a high-precision sensor. The measurement range of the sensor is from –40°C to 80°C with an accuracy of ±0.5°C. The DHT22 sensor sends a signal to the microcontroller board in order to receive the temperature values in the area where the sensor is installed. The operation of the device is based on the programming written in the Arduino IDE.

Humidity. Humidity is another key factor for control in hydroponics. Humidity informs about the fraction of water vapor in the air, and the relative humidity depends on the temperature. Relative humidity can be expressed in terms of pressure, or as mass fraction. Relative humidity is often referred as RH and as a percentage between 0% and 100% RH, and gives the amount of water in proportion to saturation level. We use the DHT 22 to measure humidity in the area where the sensor is installed. The function of the sensor works as the temperature measurement signal which is sent to the microcontroller board.

Temperature of water. Hydroponics requires to monitor the water temperature to keep the temperature from getting too high or too low. We utilize a DS18B20 sensor to measure the temperature of the water. The measurement range of the water temperature sensor is from –55°C to 125°C, with a 2°C accuracy. The water temperature is measured every 10 minutes. We use alerts to the system to manage the temperature. The function of the water temperature sensor measures the temperature of the water in the immersed part of the sensor and transmits the temperature data as a digital signal to the microcontroller board for display.

pH. The pH is very important for the growth of plants. It is measured in the range 1–14. In general, if the pH is less than 7, the solution is acidic, while pH 7 and over is alkaline. The accuracy of the pH sensor is ±0.1 pH units. At a constant temperature of 25°C and with acidity, the optimum range for plants is 5.5–7.2 pH, for good plant growth. The pH monitoring is necessary in hydroponics on a frequent basis to maintain plants in optimal condition. This is accomplished by immersing the probe in the area to be measured. The sensor then transmits the data as an analog signal to the microcontroller board. pH sensor applications Calibration is required for use to ensure accurate and accurate sensor measurements.

Electrical conductivity. EC stands for electrical conductivity, which means the conductivity of water that depends on purity of the water. In hydroponics, EC is measured for the nutrient solution and the pH measurement complements the EC value. The electrical conductivity can indicate the amount of nutrients available in solution. The measurement range of the electrical conductivity sensor is 0–20 mS/cm. However, the electrical conductivity measurement does not need a large measuring range, which would increase the cost of sensors, instead the range 0–10 mS/cm is sufficient in our context. The optimum electrical conductivity is 1.1–1.8 mS/cm for maximal plant growth. The EC sensor transmits analog data to the microcontroller board which can be easily connected the probe to the sensor module. The EC value indicates the water quality in the crops. The calibration of EC sensor is required at least once a month to ensure measurement accuracy and reduce errors in the analyzed data.

Light intensity. A light intensity sensor is a device that changes the resistance value when light hits it to measure data. 0–65535 Lux. Inside the sensor there is an analog-to-digital converter circuit so that the data can be used without having to go through mathematical methods. The color range of light required by plants is from blue to red, so the wavelengths suitable for growing plants are in the range 400–700 nm, and when the light intensity falls below 4.31 Lux, plants will stop photosynthesis. Therefore, hydroponics provides the optimal range of light, which enables plants grow faster.

3 Results

To evaluate and compare the crop efficiency in the closed-room NFT hydroponics system, we used the data from sensors for both the environmental and non-environmentally controlled plant growth systems. We used 5-day plant growth data to determine the optimum plant growth efficiency. More effectively, we compared the controlled environmental factors with the natural plant growth without control of the growth factors.

3.1 Comparison of analyzed sensor data

Comparison of the sensor data measured was done against standard data ranges. Measurement data from control systems of hydroponics and unregulated hydroponics systems were compared with the appropriate ranges for plant growth, for temperature, humidity, water temperature, pH and electrical conductivity. We do not measure photoperiod because we use artificial light for plant growth in the range that the plants need. The humidity was not included in our part of the project, and the humidity effects on plant growth will be studied in future work. The uncontrolled crops were all damaged, probably because the pH of water. Temperature in the controlled hydroponics system is shown in Figure 4.

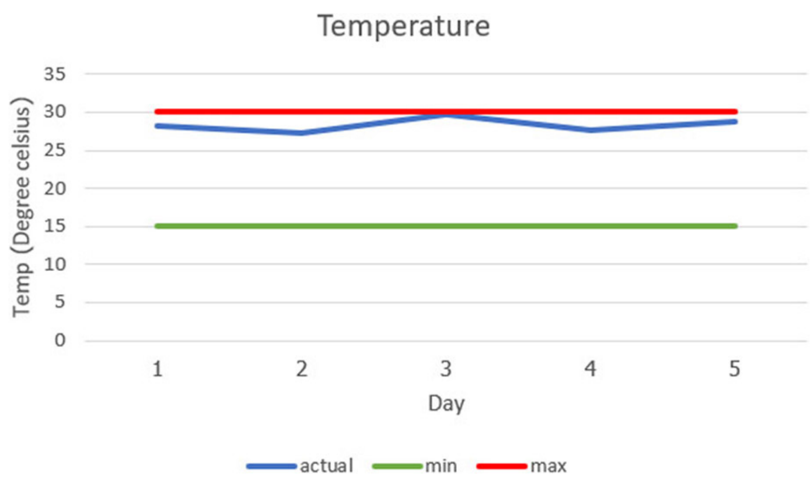

Fig. 4. Temperature in controlled case

The optimum temperature for plants for a controlled hydroponics system shows that the average intraday value is within the optimum range. There will be some days when the graph goes up to the highest value because of the heat from the artificial lights that we have turned on as shown in Figure 5. However, the duration of light received by the plant may be insufficient for photosynthesis. Water temperature, in addition to room temperature, is required for plant growth.

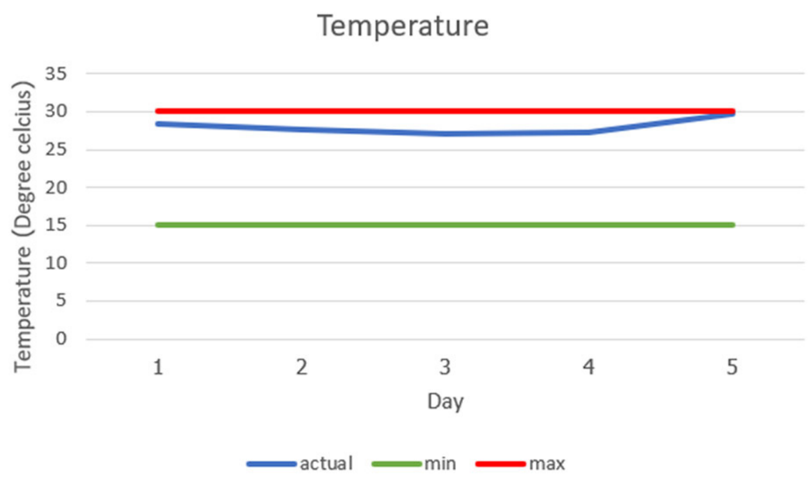

Fig. 5. Temperature in case without control

Hydroponics is the cultivation of plants without soil. The transport of water to plants is extremely important. Sensors in regulated and unregulated systems had temperatures higher than the room temperature, caused by the water pump running all the time and heating the water by input of energy. The resulting water temperatures were still within the optimum range for plant growth as shown in Figures 6 and 7.

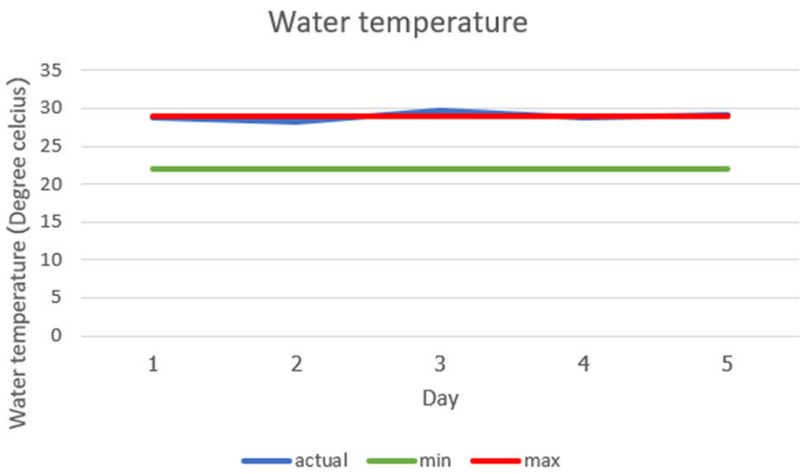

Fig. 6. Water temperature in controlled case

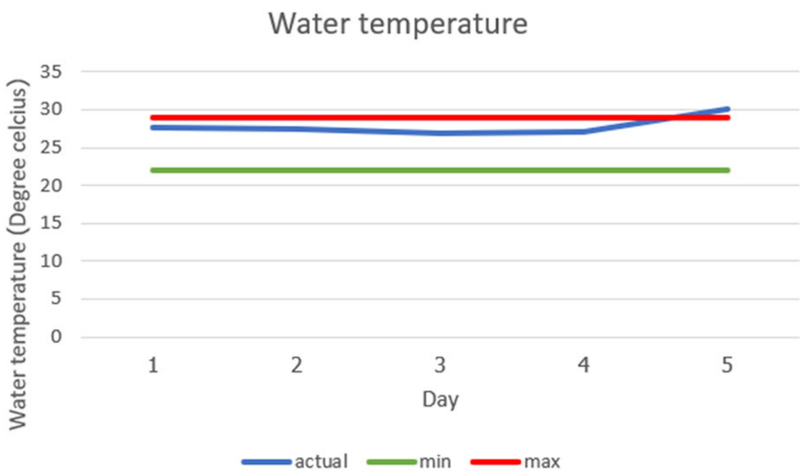

Fig. 7. Water temperature in case without control

pH is very important for growing plants. It can be seen that the plants cultivated without control had high pH, although within the optimum range. This may have damaged plants in the uncontrolled system. The pH data are shown in Figures 8 and 9.

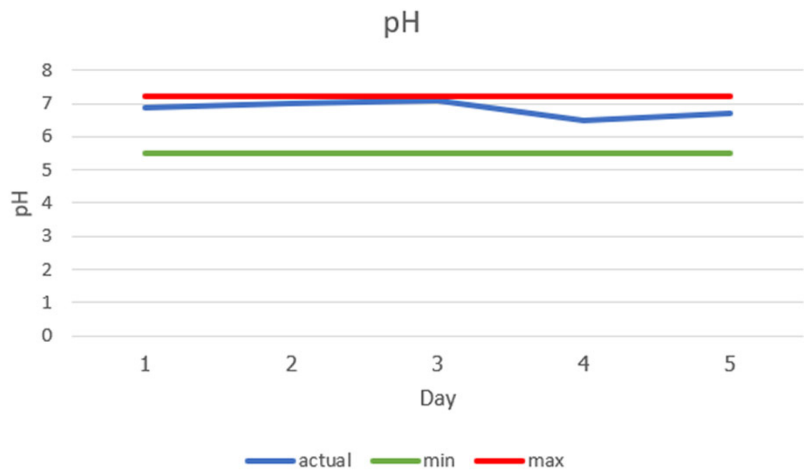

Fig. 8. pH in controlled case

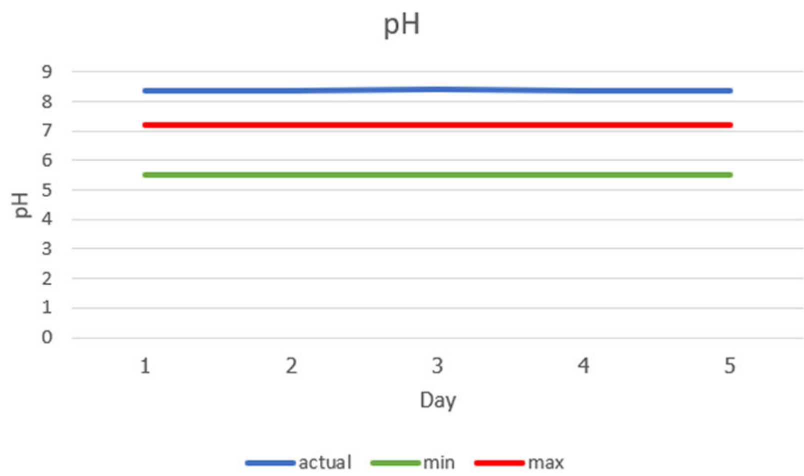

Fig. 9. pH in case without control

In addition to the above factors, we measured the electrical conductivity of the water to compare with the range required by the plants. The measurements from the controlled system are shown in Figure 10. The electrical conductivity was more suitable for the crop than in the not controlled system. The pH may have affected the electrical conductivity in the system without control, shown in Figure 11.

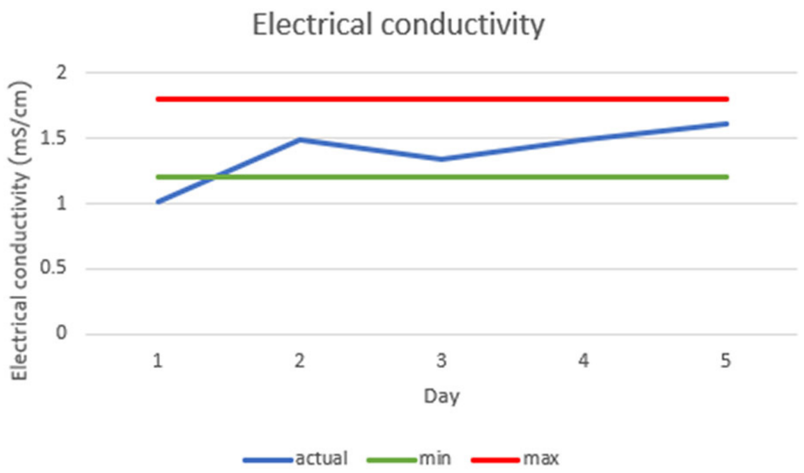

Fig. 10. Electrical conductivity in controlled case

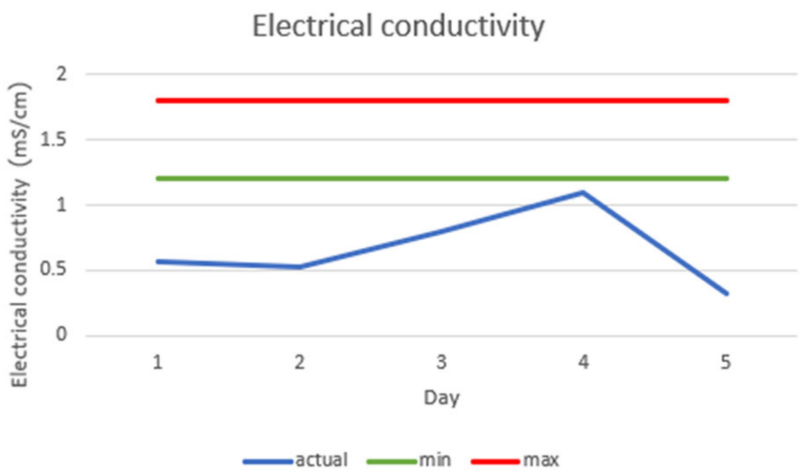

Fig. 11. Electrical conductivity in case without control

The system will display the results on the web. The farmers are able to access sensor data from their mobile devices, which gives farmers convenience and ability to view sensor data for use in planning and crop management. When the system has a malfunction, such as a power outage or sensor failure, the installed system has a will have a notification to the farmer. The data page in the dashboard displays data from the sensors used to measure the environment in the system. The displayed data includes temperature, humidity, water temperature, pH and EC. The displayed data is the latest data obtained from the sensors stored in the base. data through measurements of sensors in the system as shown in Figure 12.

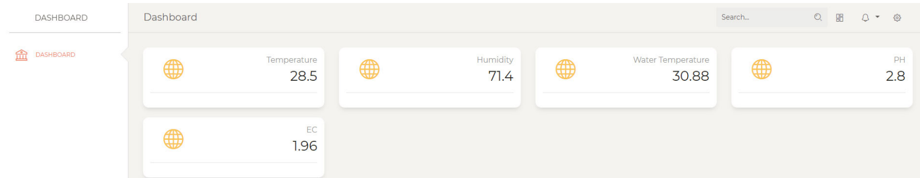

Fig. 12. Data display in the dashboard

The data obtained from the sensors are collected in real time and can be shown to farmers as a result of the sensor installation for further analysis. In the dashboard, in addition to displaying data, it can also be displayed in graphs, so farmers can view historical data for decision-making in system management. The display section can be automated where users can choose to view only the data they want or they can view all of the data through the graph display in the dashboard as shown in Figure 13.

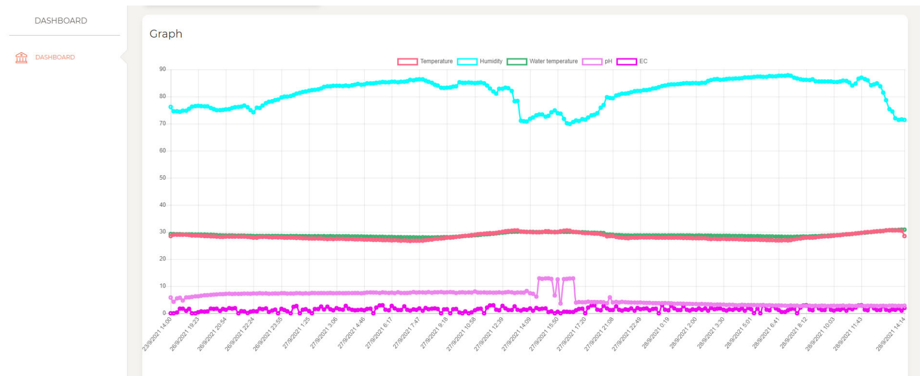

Fig. 13. Graph from sensor

3.2 Conclusion

This study applied the Internet of Things to manage an NFT hydroponic system in a closed laboratory room. Plants in hydroponic cultivation combined with remote monitoring in this intelligent agriculture system had efficient growth. The system also allows farmers to monitor crop growth and assists them in making decisions, about production planning and planting, and the interface can be tailored to the needs of farmers. By adjusting the appropriate parameters for the plants, this system provides automation.

3.3 Discussion

A simulation of the system demonstrates that it accurately guides farmers to make the right decisions to reduce mistakes and avoid damage to crop, which help farmer manage their crops and increase their productivity. Farmers will be able to boost their yields and manage their crops more efficiently as a result of this developed system.

The farmers can obtain information for decision-making and interact with the control system both manually and automatically. The approach demonstrated can be altered and applied to other plants. Furthermore, the data records can be used for long-term data analysis and decision-making, which meets the needs for effective resource allocation. Machine learning and forecasting are used in the last stages of development to improve the system's efficiency.

In future work, the plant moisture study and use of algorithms to predict crop yields, and to apply control with greater accuracy, may allow us to grow multiple crops in the same system instead of planting only one type of crop in the system. The algorithm does not need to be adjusted because it learns by itself and makes the system intelligent using popular adaptive algorithms including artificial intelligence, neural networks, and deep neural networks. More complex algorithms allow the system to learn innovatively and make faster decisions to increase crop yields. In addition, it is interesting to use a learning algorithm that performs a comparative analysis of optimal performance for the system.

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