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PAPER

IoT-Based Automatic Hydro-Organic Smart Farming System in Greenhouse with Solar Panels for Khok Nong Na

Nantinee Soodtoetong, Surachet Channgam, Eakbodin Gedkhaw(✉)

Department of Management Science, Chandrakasem Rajabhat University, Bangkok, Thailand

eakbodin.g@chandra.ac.th

ABSTRACT

In this research, we propose IoT-Based Automatic Hydro-Organic Smart Farming System (AHOSFS) in Greenhouse with Solar Panels for Khok Nong Na, design and development with Internet of Things and solar energy. Data is collected from sensors for the following factors that affect plant growth: humidity, temperature, light, pH, EC, air quality, water temperature, and water level. The Firebase cloud-based application was used to collect all the data, and it enables farmers to monitor and control the system using their smartphones. The results showed AHOSFS can mix water and nutrient solution, which measure pH of 6.61 and EC of 1.23, control water level and mix nutrient solution in appropriate quantities. Green oak can thrive at pH levels between 6.0 and 7.0, EC levels between 1.1 and 1.7, and humidity level between 75 and 85. The sensor measured temperature value between 18 and 25 °C, which was adequate for the growth of green oak. Sensor also measured water temperature between 25 and 28 °C. The comparative value of cultivation in a hydro-organic system deployed between AB solution, organic fertilizer Formula 1 and Formula 2 found that organic fertilizer formula 1 has an effective and approximate AB solution at 81.64%. The fertilizer formula 2 has AB solution at 89.72%, which was more secure at a comparable level.

KEYWORDS

IoT, smart farming, hydro-organic, solar power, Khok Nong Na model

1 INTRODUCTION

Internet of Things technology [1] is a network of devices with embedded electronic circuits, software, sensors, and network connections. It enables those objects to collect and transfer data among these objects, which users can access and control these things from anywhere through the Wireless Sensor Network (WSN) [2].

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The Internet network's expansion is what gave rise to the idea of the Internet of Things, the purpose of which is to connect devices of various standards to establish a network via which they can communicate with one another. Internet of Things used in precision agriculture [3], the integration of sensor systems that measure humidity, sunlight, temperature, plant databases system, irrigation systems, adjust the amount of light and temperature adjustment system that work in harmony [4], to create the most accurate and optimal plant growth conditions which farmers can track and control from smartphones, enables farmers to obtain information to be used in the management of various fields within the farmland in real time in a controlled IoT environment.

Hydro-organics is an integration of growing vegetables based on the hydroponics method [5] of growing plants using water instead of soil. Combined with organic farming methods, it is the cultivation of agricultural crops grown without the use of pesticides using organic methods [6]. Hydro-organics brings the strengths of organic and hydroponic methods in growing vegetables. Organic solutions result from fermentation organic waste produced from daily consumption, such as milk, fruit, cow dung, butter, yoghurt, sugar, honey, etc. Organic substances are the source of the vital elements that plants require, including nitrogen, oxygen, phosphorus, iron, calcium, magnesium, and carbon. The studies have indicated that some nations, including the United States, do not yet accept hydro-organic vegetables as being organic. This is because hydroponic growing techniques use concentrated plant nutrient solutions dissolved in water and immersing plant roots to collect nutrients, as well as the possibility of harming consumers by watering the nutrient solution through plant leaves [7]. People who are sensitive to this substance may show symptoms such as nausea, vomiting, diarrhea, difficulty in breathing, unconsciousness, and near death since nutrient solutions are thought of as compounds that include significant levels of nitrates, which are nitrogen radicals. Because hydroponic farming cannot be converted into an organic aseptic system, the United States Department of Agriculture released a statement in 2017 rejecting produce from hydroponic farms as organic produce [8–9].

Another significant issue with hydroponic farming is that organic fertilizers cannot be applied directly to the plants. However, researchers have found ways to use organic fertilizers to create nutrient solutions [10], which not only solves the issue but also helps to prevent some diseases like bacterial wilt, etc. It is an innovation that is gaining popularity and acceptance in many nations, including the United States of America, New Zealand, Japan, etc. It is a biological approach to disease control. Additional Internet technologies are present here, for instance, the creation of a hydroponic crop management system using the Internet of Things to automatically control and manage work in the hydroponic farm [11–12] and the creation of a control system for the use of nutrients. This technology applies forward chaining [13] artificial intelligence to hydroponics, creating remote control systems [14–15, 31] for hydroponic plant growth and utilizes big data [16–18] for predictive analytics for smart agricultural decisions. The design and implementation of a Wireless Sensor Network for precision agriculture operating in API mode [19] has been proposed and has proposed a way to use machine learning [20] to analyze big data for precision farming. It is an advanced technology that will help to improve the various dimensions of agricultural data.

In this research, we propose IoT-Based Automatic Hydro-Organic Smart Farming System (AHOSFS) for the Khok Nong Na Model in Greenhouse with Solar Panels. The system aims to control cultivation factor in appropriate ex. pH, water level, air, temperature and relative humidity by using a simple mechanism. The system also controls water level and nutrient solution consumption and gathers data from sensors then collected in cloud. Data is collected, managed, used, and shared via the internet by users, controlled via smartphones, making it easier and more efficient for farmers to manage based on their successes and study results. It also uses solar energy to power the entire house system. The paper presents innovative smart farming system, Khok Nong Na and Internet of Thing in section 2. Then, section 3 presents the proposed method. Experimental results are presented in Section 4. Finally, the conclusion is shown in Section 5.

2 LITERATURE REVIEW

2.1 Innovative smart farming system

Smart Farming [21, 32] is a new type of farming that uses technology, robots, or machines with high precision to assist in farming by focusing on the environment, consumer safety, and the most efficient use of resources. The current agricultural labor is steadily shrinking, necessitating the use of technology to aid in the work [33–34]. To improve operations and employ technology to do so, the agriculture industry must also adapt. This will lead to higher productivity and operational efficiency. There are three key components in smart farming: 1. planting area location 2. data analysis to match crop cultivation timing and 3. land management, which must be done with the use of technology that is appropriate, not wasteful of resources, and must be compatible with the cultivation of the species. These components rely on electronic devices such as sensors, smartphones, etc. to transmit data, and record data via connection with the Internet. For example, precise watering control to adjust the amount and timing by controlling through cutting-edge technology such as cellphones and laptops; and the use of EC sensors to help determine how much fertilizer should be in the water when hydroponically growing plants. Precise fertilization of plants like salad growing through the irrigation system assist in lowering production costs, raise productivity in each region and establish production standards for customer-requested product quality control. Thus, the product is more expensive than that from conventional farms.

2.2 Khok Nong Na

Khok Nong Na Model [22] is a strategy for resolving water management issues at the Natural Agriculture Foundation and the Sufficiency Economy Institute. His Majesty King Bhumibol Adulyadej, King Rama IX of Thailand's royal speech on new theories of agriculture has been applied to manage water and agricultural areas appropriately to enable farming with the knowledge and characteristics of that region. It combines contemporary farming techniques for animal husbandry. It consists of three areas in one location: Khok, Nong, and Na. The operational strategy involves planning for water use, planning for rice planting, soil improvement, and food production that is sufficient for consumption, establishing both short-lived and long-lived crops, rearing fish, and chickens, and introducing renewable energy to the region. The operational strategy involves planning of water use. developing soil fertility and increasing harvesting of food to fulfill consumer needs. Additionally, planning for rice planting establishing both short-lived and long-lived crops, rearing fish and chickens, and introducing renewable energy to the region. Khok Nong Na Model area is divided into 3 parts: 1) the hump or the high area, caused by bringing soil excavated to make a well or a swamp to make a hill so high as a hump. On the hump, plant 3 forests, 4 benefits, 2) swamps or water sources, caused by digging a pond to collect water for use in cultivation, raising aquatic animals or growing aquatic plants and for consumption, 3) paddy field, utilize it as a rice plantation, raise fish to defeat pests of rice and as food and other crops in rotation.

The guidelines of Khok Nong Na model are 5 keys: bearing, wind, soil, water and people, which are the heart of proper space design. It mainly depends on the needs of the owner, who will make the most use of that space. Therefore, the design of the area must explore the direction of the rising and setting of the sun in each season because in each season the direction and time are different. In addition, inhabitants' requirements must be considered. Considering the advantages, uses, culture, and profession that must be appropriate for the life of the residents. These 5 significant factors, when used in their respective agricultural regions, use the best methods and provide the most benefits [23]. By dividing the area as follows in the ratio of 30:30:30:10: the first 30% is used to create a pond and Klong Sai Kai as a supply of water, the second 30% is used for rice cultivation, and the third thirty 30% is used to create a hump or forest. Planting 3 forests will provide 4 benefits: tree planting, edible wood, economic wood, and timber. The final 10% of the area is for housing, which is advantageous for breeding animals like fish, cattle, buffaloes, chicks, etc. [22].

2.3 Internet of thing

The concept of the Internet of Things is to connect diverse computer devices and different protocols so they may communicate with one another. Through the network, users may access and manage these objects from any location by establishing connections between devices that can be connected to a satellite communication network, a mobile phone network, an LPWAN network, or a short-range communication device connection [35]. The Internet has been used extensively in precision agriculture by connecting a network of sensor devices, smartphones, and various automatic controllers [24] so that farmers with smartphones [4, 25] or computers can readily access and see those data. Farmers get information to utilize in real time managing different fields within the farm region.

When the Internet of Things is used in precision agriculture, it integrates sensor systems that measure humidity, sunlight, temperature, systems, plant databases, and irrigation systems, adjust the amount of light [26] and temperature using adjustment systems that collaborate to produce the most accurate and optimal environment for plant growth. By gathering and analyzing data about the amount of humidity in the farmland obtained from a network of sensors in the Precision Farming system that monitors humidity and drought, for instance, farmers can estimate harvest times and crop yields in addition to saving and using resources as needed. This enables the farmers to decide how to manage the water supply more effectively [27].

Therefore, in this research, the researcher examined the environmental elements that will be used in the smart hydro-organic farming system in the greenhouse for Khok Nong Na. Moreover, IoT sensor was selected from the following.

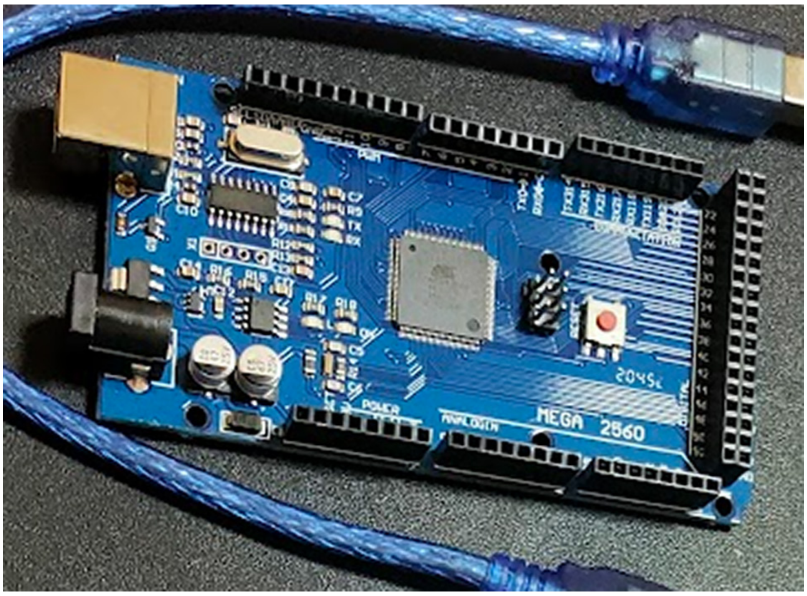

Fig. 1. Arduino Mega 2560 R3 microcontroller board

Arduino Mega 2560 R3 microcontroller board is the flagship board in the Arduino family using Atmega2560 as the main microcontroller. Programs can be developed with the Arduino IDE program to control the operation of the board and can work according to instructions or control programs developed for use in controlling other electronic connected devices.

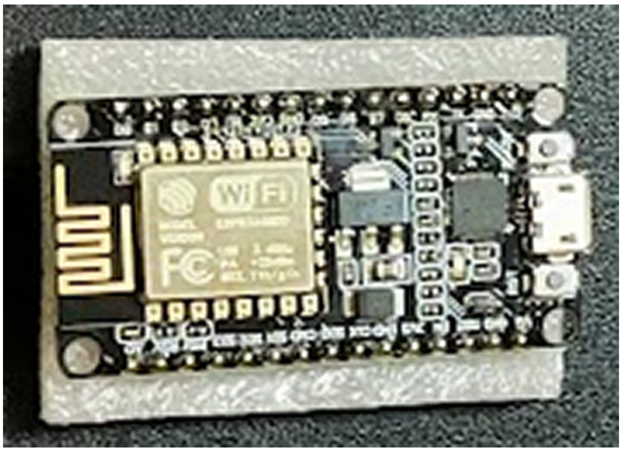

Fig. 2. NodeMCU ESP8266

NodeMCU ESP8266 is a Wi-Fi module for Arduino boards. Developing the program with the Arduino IDE program enables controlling the operation of the board and command to control the device.

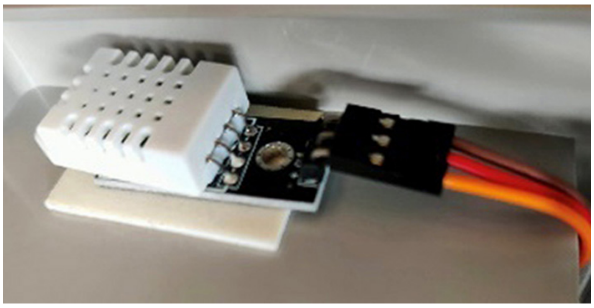

Fig. 3. Temperature sensor (DHT22)

Temperature sensor (DHT22) is a sensor device used to measure the ambient temperature, unit is Celsius or Fahrenheit and can measure humidity. When the ambient temperature is above *30* degrees, the Arduino board will spray water to reduce the heat.

Fig. 4. The acid-base (pH) measuring device

The acid-base (pH) measuring device is a measure of the pH in water containing nutrient solutions, which is the main factor of growing hydro-organic vegetables. It sends the measured data to the Arduino device and to the cloud.

Fig. 5. Electrical Conductivity (EC)

Electrical Conductivity (EC) is an electric conductivity measuring device between two metal rods immersed in water containing a nutrient solution to measure the EC value.

Fig. 6. Water level sensor

Water level sensor is used to measure water level for Arduino board. This sensor has a high sensitivity and can be applied to measure the amount of rain and send an alert about the water level.

Fig. 7. Light intensity sensor

Light intensity sensor can measure light in Lux unit, can measure 0 to 5 k Lux, can be connected to a microcontroller via I2C, choose 2 device numbers (I2C Address), and supports all formats of light sources (Light Source).

Fig. 8. Light intensity sensor

The waterproof temperature sensor module accepts 3–5.5V power supply and measures the temperature in the range of –10 to 85 degrees. The cable is connected to the sensor as a terminal.

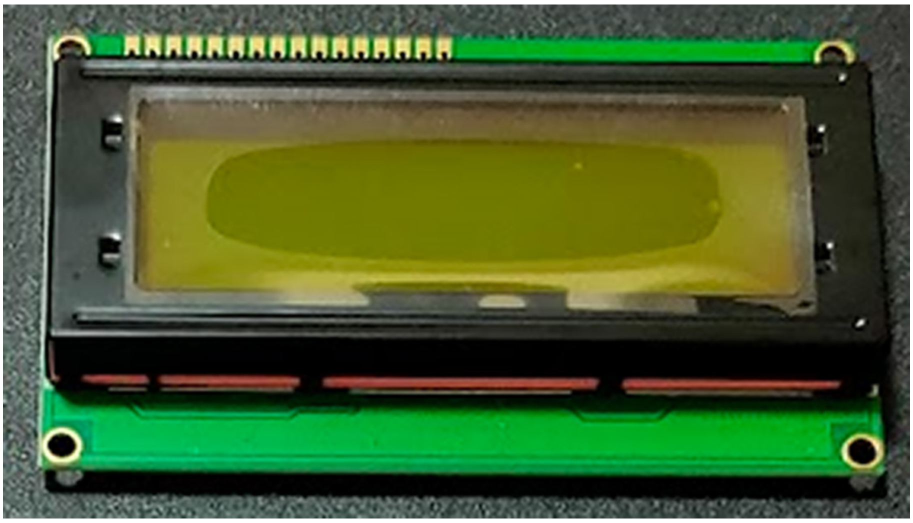

Fig. 9. LCD display

LCD 20 × 4 is the LCD display module with I2C interface that displays characters according to fixed channels, such as a 20 × 4 LCD, which means that, in a row, there can be 20 characters and there are 4 lines available.

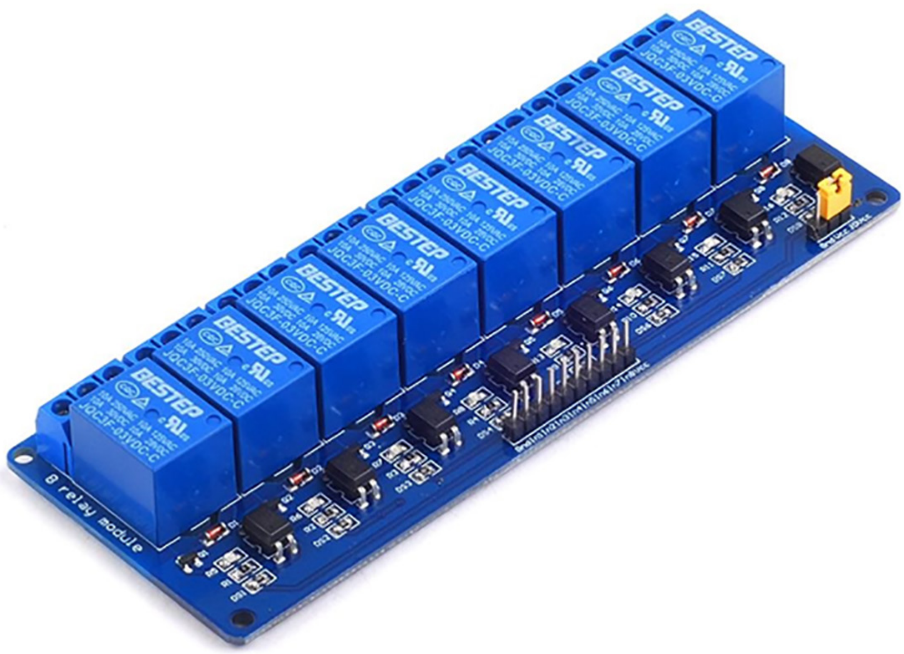

Fig. 10. Arduino relay board

Arduino relay board 8 channel controls on/off. There are 2 relay modules that can be used for 5V power supply, suitable for Arduino control, which sends active low control signals.

Fig. 11. Air quality sensor

Air quality sensor can measure 2 values: TVOC and eCO2, and is easy to connect via i2c.

3 RESEARCH METHODOLOGY

In the research, IoT-Based Automatic Hydro-Organic Smart Farming System in Greenhouse with Solar Panels for Khok Nong Na use the method of growing vegetables in a nutrient solution, NFT (Nutrient Film Technique), combined with Deep Flow Technique (DFT), in which the mineral solution mixed in water flows through the roots of plants continuously. This method is popular in Thailand because it takes up less space compared to planting in the ground. It can also control pests better than the method of planting in the ground. It is shown in Figure 12.

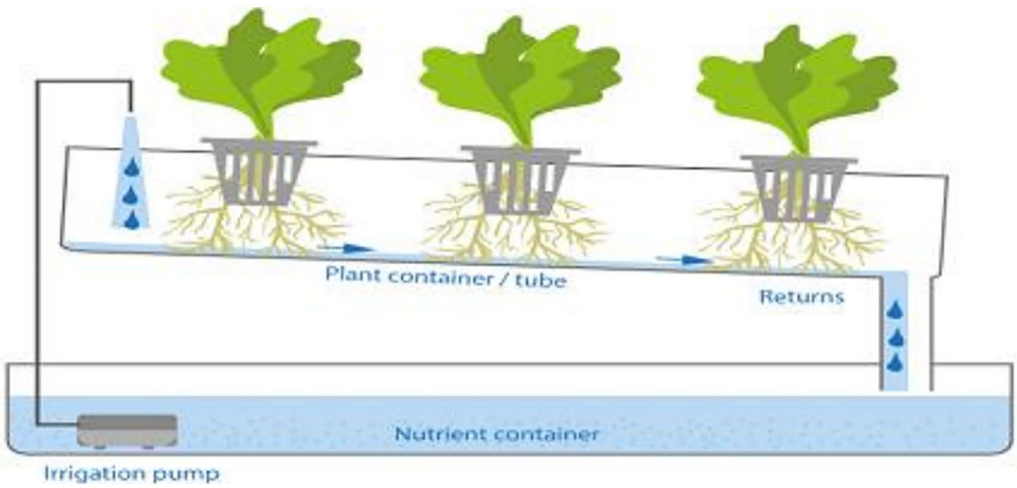

Fig. 12. Nutrients Film Technique [5]

Hydro-organic growing plants are cultivated in a closed greenhouse system to control and reduce the problems of maintenance as in an open system, the temperature, humidity, pests, wind, and disease outbreaks cannot be controlled. In this research, an automatic control system controlled humidity, greenhouse temperature, water level measurement and receive signal from sensor to allow the control panel to process and then command the relay to turn on the water pump to increase the amount of water and solution automatically. Greenhouses designed as a combination of Nutrient Film Technique (NFT) [28] and Deep Flow Technique (DFT) [29] are a plant growing method in which roots are directly immersed in the solution, a length of 8 meters, a width of 3 meters and a height of 2 meters. The size of the vegetable plot is 6 meters long, 2 meters wide and 90 centimeters high. There are 7 planting tracks, 196 holes, the distance between the planting holes is 15 centimeters, and PVC pipe is 2 inches in size as shown in Figure 13.

Fig. 13. Greenhouses and hydro-organic vegetables plot

It has a joint pipe connection with a water level adjuster to adjust the water level to be used. It can adjust the water level in the rail freely, which is useful when there is power outage and the water pump cannot continue to work. Therefore, the cultivation trough changes from a flowing water system to a still water system to be able to cultivate further. Normally, if there is no water level adjuster, the water will be completely drained from the spout and vegetables will be damaged after lack of water within 20–30 minutes. In addition, the water leveler can effectively increase the water level in the pipe. It is shown as in Figure 14.

Fig. 14. A joint pipe connection to adjust the water level

There are 4 components in the overall system: 1. Microcontroller receives instructions from sensor interfaces to process values and deliver to actuators, 2. Sensor interfaces consist of temperature sensor, humidity sensor, and light intensity sensors, and deliver all data to a microcontroller, 3. Actuator is LCD display giving on-off status of the motor pump as well as the humidity, temperature, light intensity, air quality, and water level, and 4. Solar cell power as shown architecture in Figure 15.

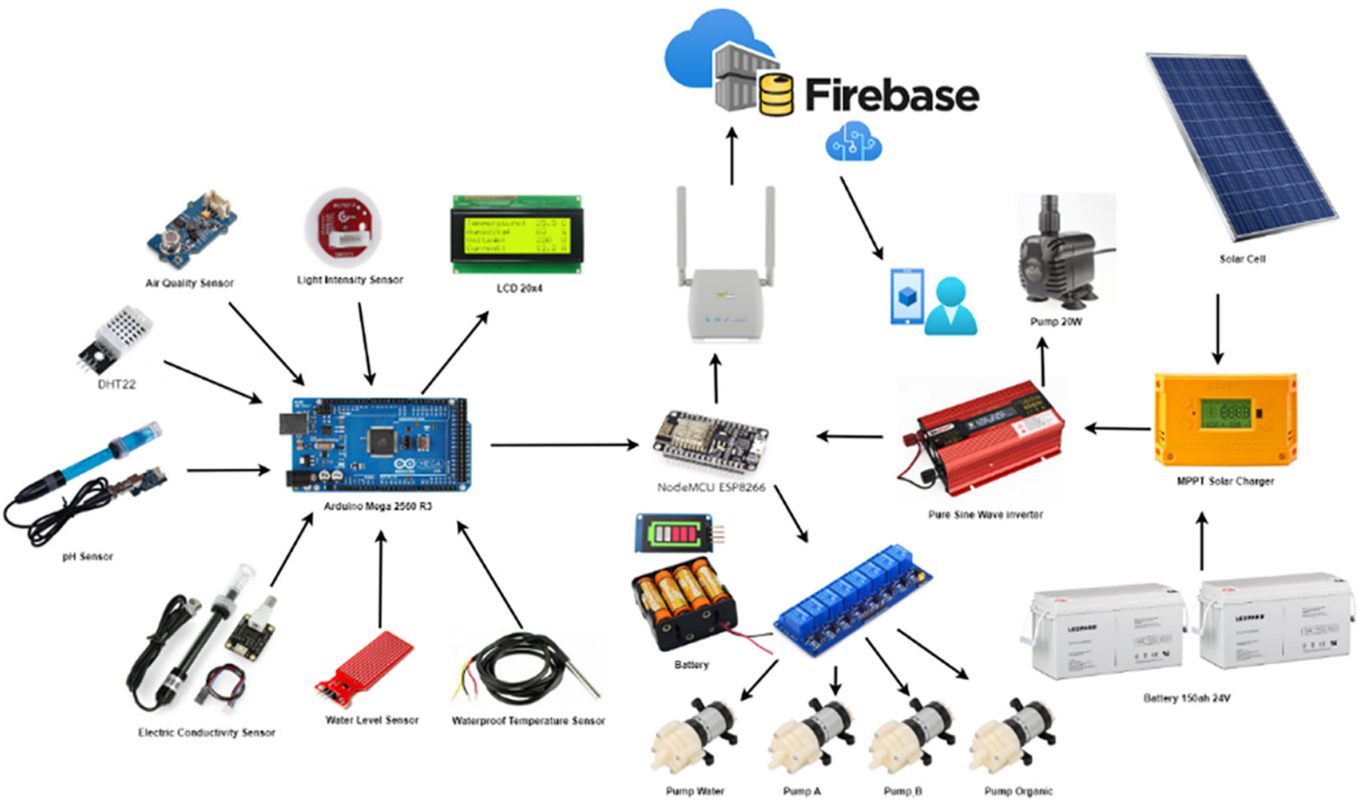

Fig. 15. The proposed architecture of hydro-organic smart agriculture system

Figure 15 is the architecture of hydro-organic smart farming system that we designed. The details are as follows.

1. The welding between DHT22 and Arduino Mega 2560 R3 board by arranging jumper wires as shown in Table 1.

Table 1. The welding between DHT22 and Arduino Mega 2560 R3

Pin on Arduino Mega 2560 R3	Pin on DHT22
RX0->2	DATA
5v	VCC
GND	GND

2. The welding between light intensity sensor and Arduino Mega 2560 R3 by arranging jumper wires as shown in Table 2.

Table 2. The welding between light intensity sensor and Arduino Mega 2560 R3

Pin on Arduino Mega 2560 R3	Pin on Light Intensity Sensor
SCL	SCL
SDA	DATA
5v	VCC
GND	GND

3. The welding between water level sensor and Arduino Mega 2560 R3 by arranging jumper wires as shown in Table 3.

Table 3. The welding between water level sensor and Arduino Mega 2560 R3

Pin on Arduino Mega 2560 R3	Pin on Water Level Sensor
A0	S
5v	+
GND	–

4. The welding between NodeMCU ESP8266 and Arduino Mega 2560 R3 board by arranging jumper wires as shown in Table 4.

Table 4. The welding between NodeMCU ESP8266 and Arduino Mega 2560 R3

Pin on Arduino Mega 2560 R3	Pin on NodeMCU ESP8266
10	D0
11	D1
3.3v	Vn
GND	GND

5. The welding between LCD and Arduino Mega 2560 R3 board by arranging jumper wires as shown in Table 5.

Table 5. The welding between LCD and Arduino Mega 2560 R3

Pin on Arduino Mega 2560 R3	Pin on LCD
SCL	SCL
SDA	SDA
5v	VCC
GND	GND

6. The welding between air quality sensor and Arduino Mega 2560 R3 board by arranging jumper wires as shown in Table 6.

Table 6. The welding between air quality sensor and Arduino Mega 2560 R3

Pin on Arduino Mega 2560 R3	Pin on Air Quality Sensor
A14	SIG
5v	VCC
GND	GND

7. The welding between pH sensor and Arduino Mega 2560 R3 board by arranging jumper wires as shown in Table 7.

Table 7. The welding between pH sensor and Arduino Mega 2560 R3

Pin on Arduino Mega 2560 R3	Pin on pH Sensor
A1	P0
5v	VCC
GND	GND

8. The welding between EC sensor and Arduino Mega 2560 R3 board by arranging jumper wires as shown in Table 8.

Table 8. The welding between EC sensor and Arduino Mega 2560 R3

Pin on Arduino Mega 2560 R3	Pin on EC Sensor
A3	P0
5v	VCC
GND	GND

9. The welding between relay and Arduino Mega 2560 R3 board by arranging jumper wires as shown in Table 9.

Table 9. The welding between relay and Arduino Mega 2560 R3

Pin on NodeMCU ESP8266	Pin on Relay
D2	In1
D3	In2
D4	In3
D5	In4
5v	VCC
GND	GND

To develop a smart hydro-organic farming systems in greenhouse and applications, we have developed an Arduino IDE program to enable connected sensor devices to process various measurements and then send the values of different environmental factors to be saved on cloud database [30]. Figure 16 illustrates how to monitor and manage the smart hydro-organic farming system in a greenhouse for Khok Nong Na.

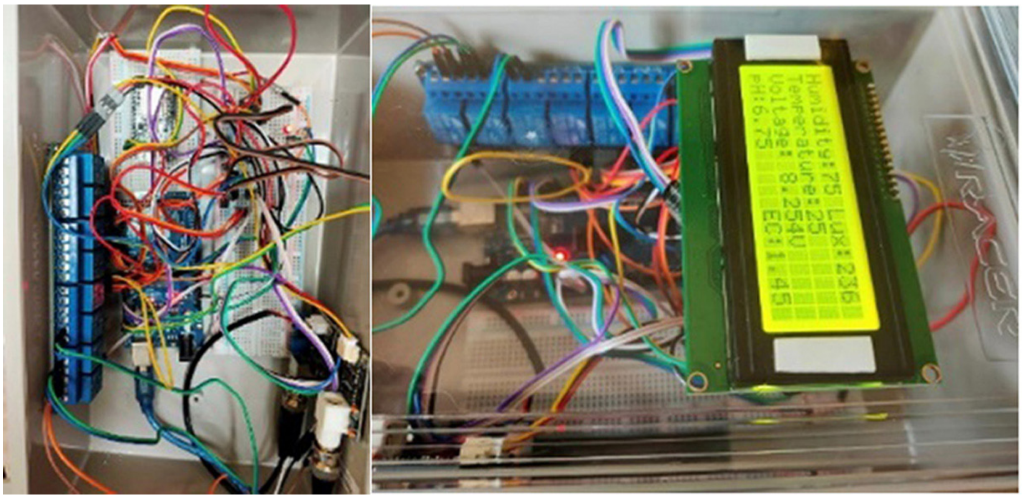

Fig. 16. The welding of sensor devices in smart hydro-organic farming systems in greenhouses

We created a smart hydro-organic agriculture database for a greenhouse by using Firebase real-time database, which can be seen in Figure 17.

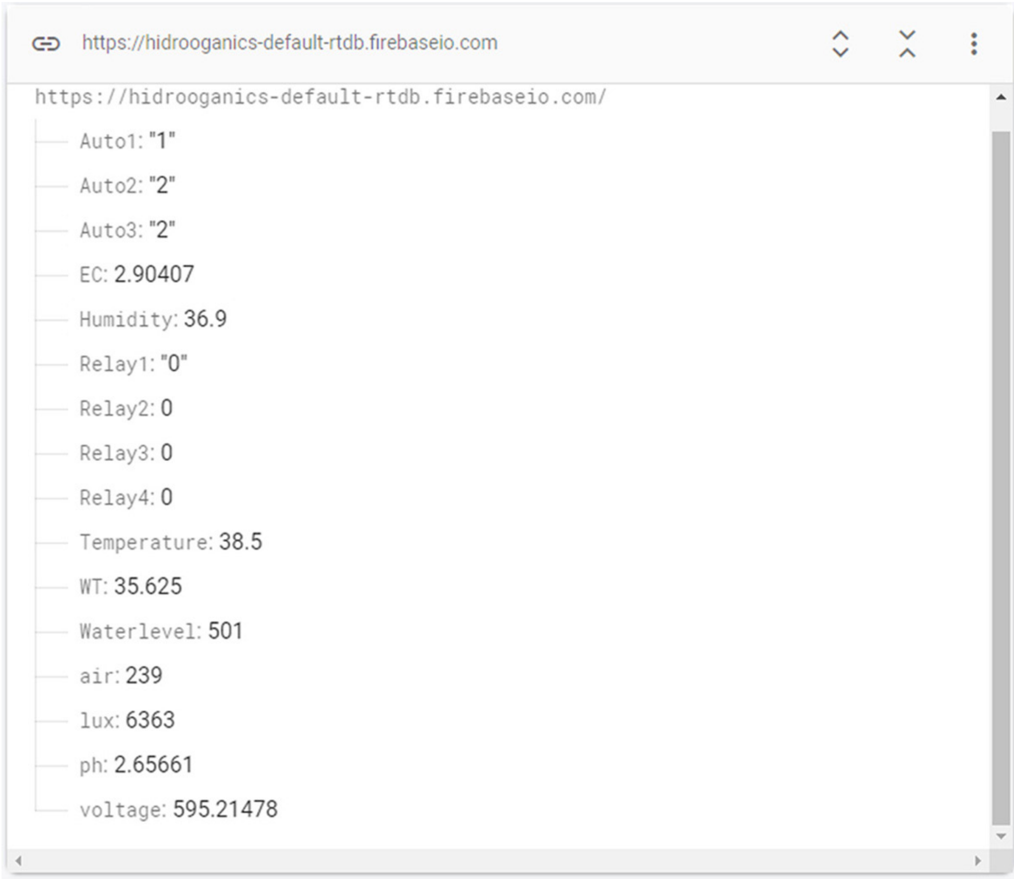

Fig. 17. Database smart hydro-organic farming systems in greenhouses

We used the system design and database developed by the MIT App Inventor program to develop applications of smart hydro-organic agriculture in greenhouses. According to the correlation model between the detailed data and the relationship between the data in the cloud, the application was used to track information about plant growth used in the experiment, temperature, and pH of the water, optimum density of minerals, and to monitor and control the cultivation of quality vegetable crops. Then we evaluated the design and development of application to be accurate, complete and meet user needs. Sensors transmit data via Wi-Fi to save values in the cloud. A feature recognition system was developed for hydro-organic precision agriculture information system to produce quality vegetables in the greenhouse. Check the display of the application to be used to display the numbers in real time. The application can be displayed as shown in Figure 18.

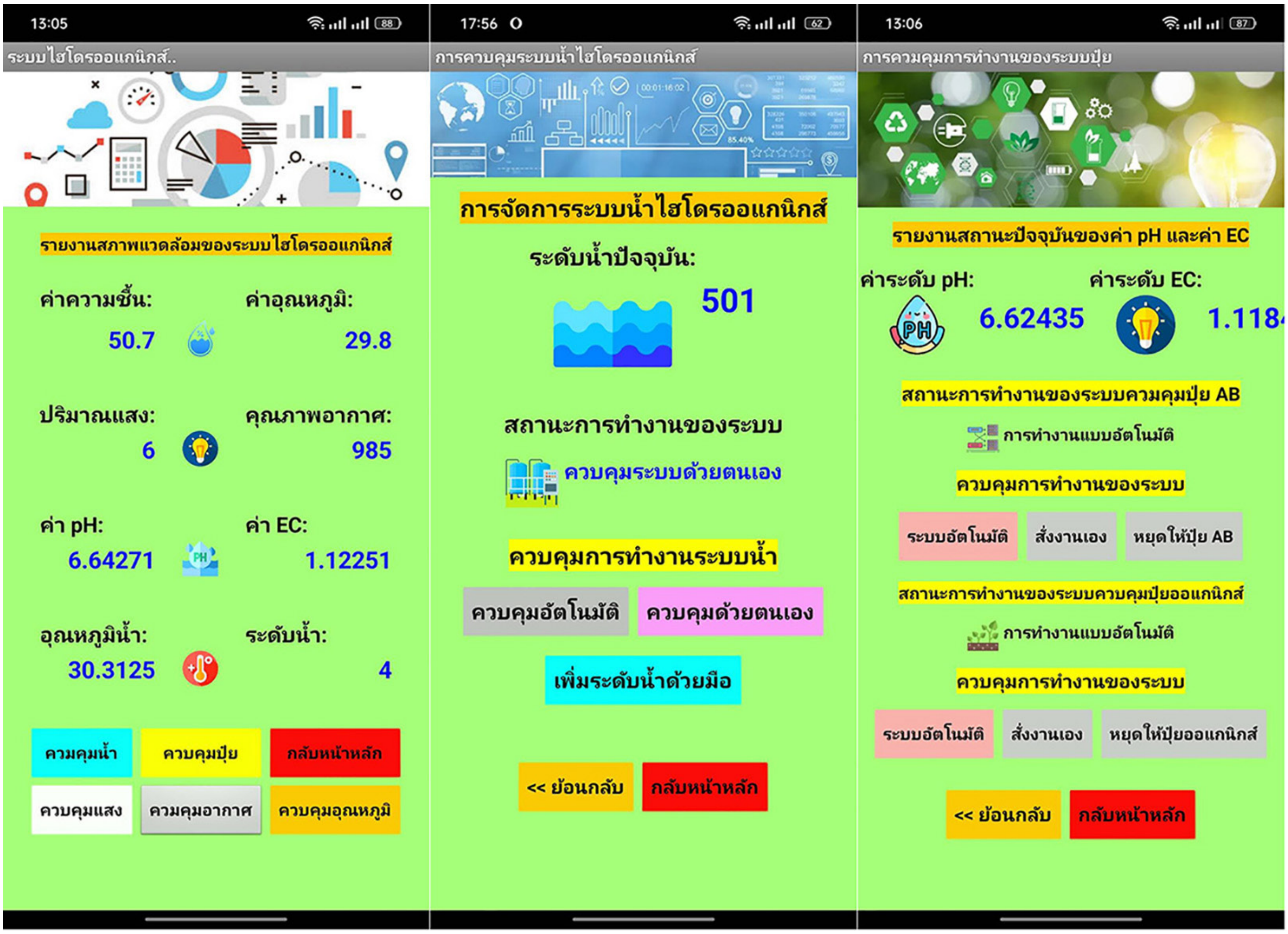

Fig. 18. Application of smart hydro-organic farming systems in greenhouses

For hydro-organic vegetable cultivation to grow hydro-organic vegetables, the researchers used green oak, which is an economical vegetable that is gaining popularity and has a high price that is suitable for growing in a hydro-organic system as shown in Figure 19.

Fig. 19. Hydro-organic vegetable cultivation

In this research, bio-fertilizers were produced for growing hydro-organic vegetables with two formulas, one is Assoc. Prof. Dr. Jureerat Leesmith's formula, consisting of 64 kg. of guava, 8 kg. of papaya, 8 kg. of melons, and molasses—20 kg., 20 liters of water, accelerator (Por-dor.2) 2 sachets. The other is Somyot Raksawong's formula, consisting of 1 part vegetables, fruits or leftovers and 1 part molasses or brown sugar. The first formula produced by chopping guava, thai melon and papaya (both peel and seeds) thoroughly. Then pour and mix 2 sachets of Por-dor.2, molasses and clean water, stir well. Packed into a fertilizer bag after composting in a plastic bucket with a lid for a period of 7 to 8 days. The second formula is to mix the ingredients together. Then leave it for 7 days where the fermented water will start to turn brown, smelling sour. If the marinade is light brown and the it smells foul, it indicates that the sugar is not enough, add more molasses. The bad smell will gradually disappear and continue to marinate. It is shown in Figure 20.

Fig. 20. How to bio fertilizer

The alternative energy used was solar energy. The researcher used a 450 W solar panel, an MPPT solar charger controller, a 500W Pure Sine Wave Inverter connected to a 150ah battery, a 24V system, which was used with Wi-Fi router connected to the internet, a 20W water pump and the power supply to the whole house hydro-organic smart farming system. It can be seen in Figure 21.

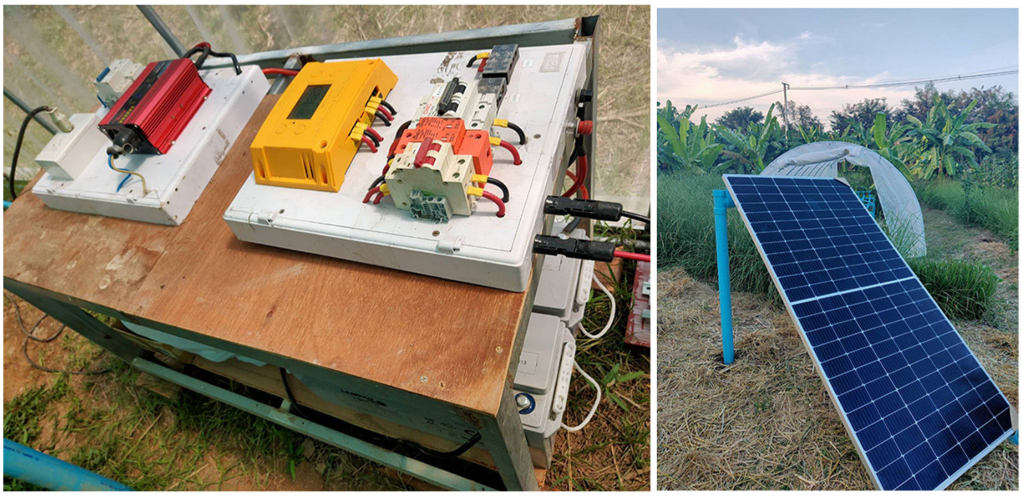

Fig. 21. Alternative energy, solar power

4 RESULT AND DISCUSSION

Accuracy tests were conducted on water and nutrient solutions for Khok Nong Na's smart hydro-organic farming system in greenhouses based on the experiment comparing the usage of an autonomous system verses a human operator to mix water and a solution. From the beginning of the hydro-organic vegetable growth in the greenhouse until the day of the hydro-organic vegetable harvest, statistics were collected every three days at 10:00 a.m. to record the results of the experiment. The result shows up in Table 10.

Table 10. The results for accuracy of water and nutrient solutions

No.	Autonomous System		Human Operator	
	pH	EC	pH	EC
1	6.48	1.32	5.54	1.63
2	6.36	1.25	5.63	1.83
3	6.79	1.11	5.93	1.75
4	6.40	1.27	6.47	1.61
5	6.67	1.23	6.17	1.82
6	6.57	1.15	6.48	1.87
7	6.60	1.17	5.86	1.80
8	4.62	1.12	6.49	1.68
9	6.79	1.40	5.94	1.64
10	6.98	1.27	5.70	1.85
Average	6.61	1.23	6.02	1.75

The test results for water and nutrient solutions are shown in Table 10. It was found that the sensor can measure the average pH to be 6.61 and the average EC to be 1.23, allowing the automatic system to mix the water with the solution. The average pH and EC were 6.02 and 1.75, respectively. The hydro-organics system's automation and the farmer's control both successfully managed the level of the water and nutrient solutions, where green oak vegetables can thrive at pH levels between 6.0 and 7.0 and EC levels between 1.1 and 1.7.

Humidity measurement, greenhouse temperature, and water temperature were measured by the smart hydro-organic farming system in the greenhouse for Khok Nong Na. Using an automated measuring system, the smart hydro-organic farming system in the house was examined to assess the humidity values, greenhouse temperature, and water temperature. From the beginning of the hydro-organic vegetable growth in the greenhouse until the day of hydro-organic vegetable harvest, statistics were collected every three days at 10:00 a.m. to record the result of the experiment. Figure 22 illustrates the result.

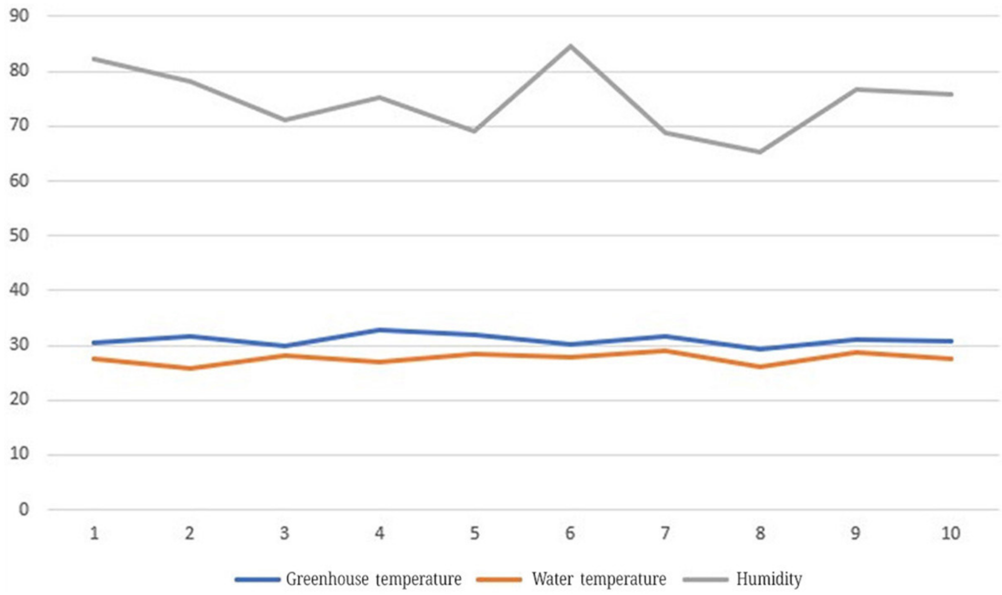

Fig. 22. The accuracy results of humidity, greenhouse temperature and water temperature

Figure 22 displays the accurate test results for the Khok Nong Na smart hydro-organic farming system's humidity, greenhouse temperature, and water temperature. The humidity level detected by the sensor was discovered to be between 75 and 85 percent, which was ideal for the growth of green oak. According to research, the optimum temperature inside for growing green oak vegetables is between 18 and 25 degrees Celsius. The sensor's water temperature was found to be between 25 and 28 degrees Celsius. It was discovered that as noon drew nearer, the temperature continued to increase, making the vegetables shrivel. In the evening, when the temperature dropped to normal and was favorable for the growth of green oak vegetables, the vegetables returned to normal.

The researcher recorded the average growth data of vegetable plants. The planting results were compared with the use of AB nutrient solutions and bio-nutrient solutions for both formulas in greenhouses and planted by farmers to control their production (cm) by recording the data from the 15th, 22nd, 29th, 36th and 43th days of green oak in different solutions. It is displayed as in Table 11.

Table 11. The results of green oak growth measurements with hydro-organic systems in greenhouses

Period (Day)	AB Nutrient Solution		Formula 1 Nutrient Solution		Formula 1 Nutrient Solution	
	Autonomous	Manual	Autonomous	Manual	Autonomous	Manual
15	7.60	7.30	5.40	5.30	6.70	6.40
22	14.30	13.90	10.50	9.10	12.40	12.10
29	16.40	15.60	13.70	3.50	15.30	14.80
36	20.20	19.80	18.30	17.20	18.80	18.20
43	27.80	26.20	22.80	21.30	24.50	24.00

Table 11 shows the results of green oak growth measurements in hydro-organic systems in greenhouses. It was found that during the 15-day growing period, the application of nutrient solution AB gave the highest height, followed by formula 2 nutrient solution and formula 1 nutrient solution. In the 22-day growing period, the application of AB nutrient solution gave the highest height, followed by formula 2 nutrient solution and formula 1 nutrient solution. In the 29-day growing period, the application of AB nutrient solution gave the highest height followed by formula 2 nutrient solution and formula 1 nutrient solution. In the 36-day growing period, the application of AB nutrient solution gave the highest height followed by formula 2 nutrient solution and formula 1 nutrient solution. And in the 43-day growing period, the application of nutrient solution AB gave the highest height followed by formula 2 nutrient solution and formula 1 nutrient solution, respectively.

5 CONCLUSION

This study, IoT-Based Automatic Hydro-Organic Smart Farming System in Greenhouse with Solar Panels for Khok Nong Na, aims to design and develop an automatic hydro-organic vegetable growing system in the greenhouse with the application of Internet of Things technology. It operates this by controlling, tracking, and collecting data on humidity, temperature, light, pH, EC, air quality, water temperature, and water level values, all of which have an impact on plant growth. Develop applications using the sensor data and store data in the Firebase cloud to allow farmers to track and manage the system from their smartphones. The entire hydro-organic system uses solar power to generate all its own electricity. The results of the experiment demonstrate that the autonomous hydronic system's precision can be combined with water, as measured by the sensor, which typically measures pH at 6.61 and EC at 1.23. Green oak thrives at pH levels between 6.0 and 7.0, EC levels between 1.1 and 1.7, and humidity levels between 75 and 85 when water and nutrient solutions are properly controlled. The measured temperature is between 18 and 25 °C, and the sensor's water temperature is between 25 and 28 °C, which is ideal for the growth of green oak. Green oak plants cultivated in a hydro-organic system in a greenhouse and treated with AB solution and Formula 1 and Formula 2 organic fertilizers were measured for growth. It was found that the use of organic fertilizer Formula 1, the yield was similar to that grown using AB solution at 81.64%, and using organic fertilizer formula 2, the yield was similar to that of growing using AB solution at 89.72%, which was more secure at a similar level. In future work, New AI technology, machine learning, and deep learning technologies will be used by researchers in their investigations and conclusions arrived at to enhance the system's intelligence.

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8 AUTHORS

Nantinee Soodtoetong received the B.S. in Mathematic from Kasetsart University in 2003 and the M.S. in Management Information System from National Institute of Development Administration in 2008. Now, she is a Ph.D. candidate of King Mongkut's University of Technology North Bangkok, Thailand, in Management Information System. Her current research interests include data analytics and machine learning (E-mail: nantinee.s@chandra.ac.th).

Surachet Channgam received the B.S. in computer science from Bansomdejchaopraya Rajabhat University, Thailand, in 2001. He obtained his M.S. Ind. Ed. in Computer and Information Technology from King Mongkut's University of Technology Thonburi, Thailand, in 2009, and received Ph.D. degree Program in Information and Communication Technology for Education, from King Mongkut's University of Technology North Bangkok, Thailand, in 2020. His current research interests include Information and Communication Technology for Education (E-mail: surachet.c@chandra.ac.th).

Eakbodin Gedkhaw received the B.S. in computer science from Maejo University in 2004 and the M.S. in Information Technology from Naresuan University in 2009. He is currently pursuing the Ph.D. degree with the Department of Information Technology, King Mongkut's University of Technology North Bangkok, Thailand, in 2021. His current research interests include image processing, sign language recognition, machine learning, deep learning and IoT (E-mail: eakbodin.g@chandra.ac.th).