Development of Hydroponics System and Data Monitoring Using Internet of Things

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***Abstract*— Hydroponic farming is gaining international attention due to its successful stockpiling of water and the development of high-quality foods. Formerly, majority of gardeners and farmers employed manual techniques and work. This has give impact on present and future food demand since the traditional farming system will not be able to meet due to urbanization, natural disasters, and climate change, among other factors. Therefore, the goal of this project is to design and develop the prototype of the hydroponics system and data monitoring in real time via IoT as well as to test the performance by collecting real-time data. The project used Arduino-Uno to control the system and to receive the readings from all of the sensors, such as pH, temperature, EC and water level. The Wi-Fi module will transmit the data wirelessly to ThingSpeak and Spreadsheet, allowing the farmer to monitor the plant performance through the use of an Internet of Things. Results show that the parameters fulfill the requirement by the proper guideline. Thus, the farmers could monitor the temperature and lighting schedules based on the sensors data, which will boost plant productivity and address other agricultural issues.**

Keywords—hydroponic farming, Agriculture, Internet of Things, Microcontroller, ThingSpeak, Spreadsheet.

I. INTRODUCTION

Due to a variety of man-made factors, including industrialization, urbanization, natural disasters, climate change, and the unrestricted use of chemicals in agriculture, soil-based agriculture is currently experiencing difficulties. Hydroponics, also known as soilless agriculture, is a brand-new alternative method of crop production. Plants can be grown hydroponically by being submerged in a nutrient-rich solution of water. Numerous plants, crops, or vegetables can be grown with hydroponics. In general, hydroponically grown produce has superior nutritional value, flavor, and yield quality than naturally grown produce on soil. Therefore, hydroponics would be a superior approach to produce various fruits, vegetables, and livestock feed as well as to meet the future demand for world nutrition[1-2].

The project by K. Kularbphettong et all. is to design and construct an automated system for managing and monitoring plant development in hydroponics, as well as to assess the impact of employing a prototype of this system. Temperature, humidity, and water are just a few of the important environmental elements that this system can regulate. The application system automatically mixes the chosen solution to produce the desired value. It also gathers data on the quantity of solution mixed at the time of planting and can be used to determine whether to grow a particular vegetable by estimating the cost of production and calculating its profitability [2].

The use of sensors in the greenhouse such as a Wireless Sensor System is an efficiency in agriculture by sending cloud data and monitoring values such as temperature, light, EC value and pH value. All data could be monitored via Thingspeak, including the week's temperature, total energy consumed, and all sensor value. It can turn lights on and off via the Blynk application [3].

The use of fuzzy logic control is proposed to automate the Electrical Conductivity (EC) and pH levels in Hydroponics Planting. Instead of just using conventional controls, Fuzzy logic would be utilized to adjust nutrition and pH levels. The proposed approach was validated using mobile vis Blynk [4].

Two farming practices; the classic soil-based method and the hydroponic system are compared in order to determine which will best meet present and future demand while using the fewest resources and at the lowest cost [5]. Cucumber and Armenian cucumber seeds were both used. Both systems' plant heights were measured, and Analysis of Variance (ANOVA) was used to analyze the data collection. The test will determine whether or not the type of seeds used, the planting method, and how they interact affect the plant's height. The experiment showed that the type of seeds has no discernible influence on the development of the plant. The hydroponic system has a higher growth rate; however, the planting method has a considerable impact on plant growth.

A compact hydroponic sensor module that utilizes simple oscillator circuits to monitor nutrient and water concentrations was developed in [6]. The system measured and communicated using a microprocessor and a sensor put on the board. This research measured oscillating frequency vs. water level, capacitance vs. water level and EC vs. 20 cm water level capacity.

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The smart agriculture with automation and IoT is also discussed in [7]. The paper's noteworthy features include a smart GPS-based remote-controlled robot. The smart irrigation was connected with data-driven real-time field control.

Therefore, the development of hydroponics system is intended to design the real time hydroponics system by developing the prototype and evaluating its performance. The contribution of this project is to incorporate an intelligent system specifically in IoT into the agriculture sector in Malaysia. With this development of hydroponics system, it can be used by every household in Malaysia by applying this technology and directly reducing the national rate of dependence on imported vegetables and fruits. This hydroponics system could monitor the plant and water quality consumptions through ThingSpeak and spreadsheet based on these parameters such as humidity, surrounding temperature, water level, the concentration of ions in the solution and the pH rate.

As a result, an automated hydroponics system based on the Internet of Things was developed to aid cultivation, and the system is capable of adjusting and controlling critical environmental elements that affect plant growth, such as temperature, humidity, and water.

II. Methodology

This system is developed using related theory and system design concepts to suit the requirements of farmer. The following approaches were used in the research:

A. *Hardware*

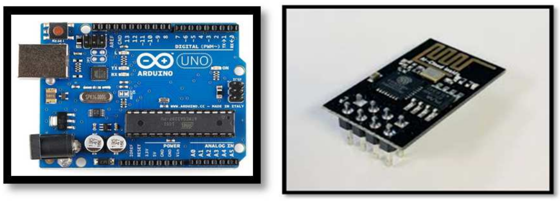

Fig. 1. a) Arduino Uno, b) ESP 8266

The Arduino Uno is used as a microcontroller as shown in figure 1(a) in this particular project. All of the coding will be combined, and due to the Arduino standard, it will be able to read and write all of the data, as well as to ensure that all of the sensors are functioning as intended. In this project, the Arduino ESP 8266 is used as a Wi-Fi module. The ESP 8266 could transmit the sensor data to the ThingSpeak and Spreadsheets as shown in figure 1(b). Due to the general specifications, this module could deliver all the data from each of sensors through Wi-Fi.

The DHT22 as shown in figure 2(a) is a simple digital temperature and humidity sensor. This sensor uses a powerful moisture sensor and a thermistor to test the ambient air and delivers a digital signal on the data pin. This project uses the DHT22 humidity sensor to detect whether the relative humidity.

The DS18B20 temperature sensor in figure 2(b) measures the liquid temperature. DS18b20 sensor is chose due to its robustness and could withstand immersion in concentrated water solutions at low or high temperatures in a hydroponics system.

Fig. 2. a) DHT-22, b) DS18B20 temperature sensor

In this project, an EC sensor measures water conductivity. This sensor may also measure water directly. The probe used to generate a voltage between electrodes in water or solution. The voltage drop represents the water's resistance, which is converted to conductivity. Water Detection Regulator Analog PH Sensor Kit Board Probe Shield is used for this project. The probe is submerged in water as a solution to determine the pH value. The above sensors are shown in figure 3.

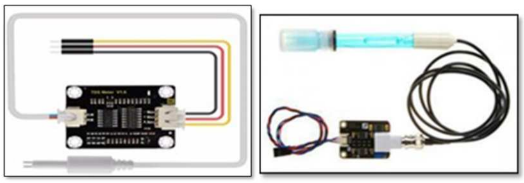

Fig. 3. a) EC sensor,b) WaterDetection Regulator Analog PH Sensor Kit Board Probe Shield

This project uses Module Detection Liquid Surface Depth Height T1592 as its water level sensors as illustrated in figure 4. In a compact, enclosed location, water level sensors are used to monitor and control liquid concentration.

Fig. 4. Water Level Sensor.

B. *Software*

The Arduino Uno board and the ESP8266 Wi-Fi module are programmed using the Arduino IDE as shown in figure 5(a). The pH sensor, water level sensor, and other sensors will all work with this software package's source code. The serial monitor output includes additional data such as the attention value.

ThingSpeak as in figure 5(b) will visualize all data in this project using gauges and graphs. Agriculturalists or users could monitor the plant growth based on the displayed data of pH, EC, water level, temperature, and humidity.

Fig. 5. a) Arduino IDE, b) ThingSpeak

The following figure 6 illustrates the block diagram of the system consists all required sensors for the design of prototype and to be used in the experiments.

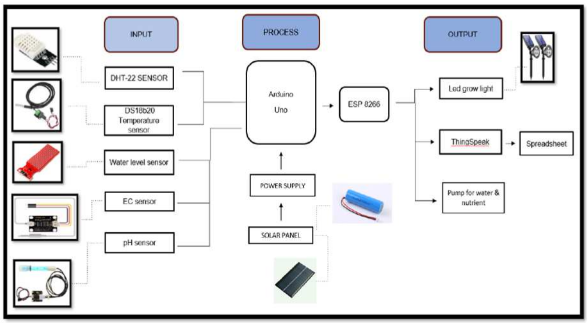

Fig. 6. Block diagram of the system.

The result acquired from the microcontroller, which is an Arduino Uno and ESP 8266, will be transferred to the ThingSpeak and spreadsheet, as well as a led grow light and a water and fertilizer pump.

Figure 7 shows the flowchart of the system. The pH sensor, a water level sensor, a DS18b20 temperature sensor, a humidity sensor, and an EC sensor, will be connected to the hydroponics system. The data from all sensors will be monitored through ThingSpeak. Pak Choi plant will be used in validating the performance of the system.

The optimal pH range for Pak Choi is 6.0-7.5. If the pH sensor detects a pH value more than 7.5, the system will communicate with ThingSpeak and add nutrition to the water in order to achieve the appropriate pH value. The pH value is critical in hydroponics due to it determines the availability of nutrients to the growing plants.

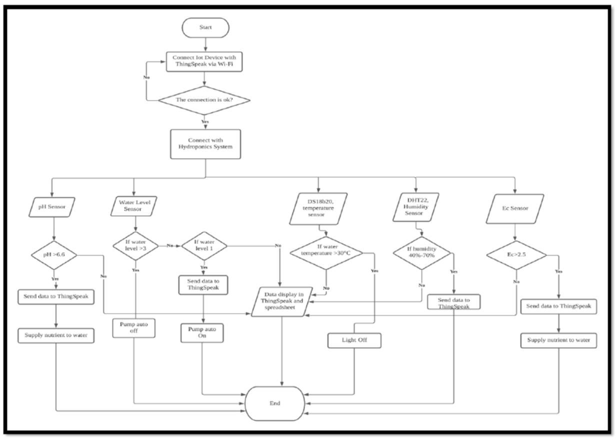

Fig. 7. The flowchart of the system.

Due to the small-scale project, this project makes use the water level sensor as the indication for ten-litre water tank. The ten litres of water are sufficient to serve as a water supply for the plant. A Pak Choi requires a minimum of 450 millilitres of water every day. If the tank's water level falls below a certain level, the pump will automatically replenish the tank with water. The water level sensor will be set to level 1, which indicates that the tank's water level is less than 2 litres, and the pump will be activated to feed water to the tank. Level 3 indicates that the water level in the tank has reached its maximum capacity of 10 litres.

The characteristics of Pak Choi in hydroponics by referring to [9] requires water temperature that is between 55 and 75-degrees Fahrenheit (13°C to 24 °C) as shown in table 1. Therefore, if DS18b20 sensor value is more than 30 degrees Celsius, the system will turn off the LED to reduce the temperature and send the data to ThingSpeak as the indication to bring the temperature down.

TABLE I. THE CHARACTERISTICS OF PAK CHOI

No	The characteristics of Pak Choi	
	Characteristic	***Measurements***
1	Planting	Germiinate from seed
2	Harvesting	Full harvest
3	Yield	7.3lbs/Foot of tower/Harvest
4	Pest and disease	Rare, more common are arphids and powdery mildew
5	pH range	6.0-7.5
6	EC/PPM	1.5-2.5/750-1250
7	Light hour	12-18
8	Temperature	Range:55-75°F

III. RESULT

This project involves the development of a prototype that could measure pH, water level, temperature, humidity, and EC in real time using ThingSpeak and a spreadsheet. The data will be presented in Thingspeak and will be stored in a Spreadsheet. In order to analyze the factors that could give impact to the plant growth and to determine whether the growth is compliance with the characteristics of Pak Choi, all data for each parameters will be graphed.

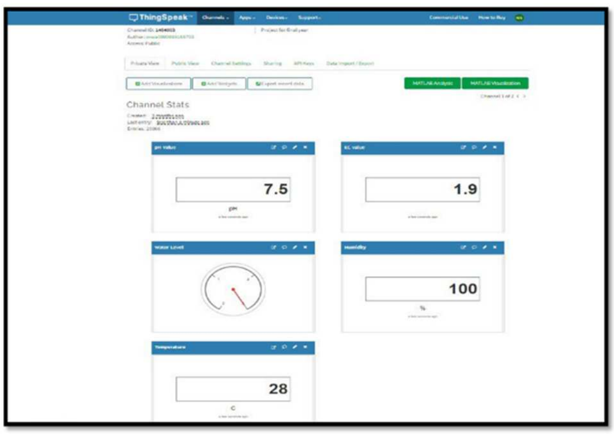

Fig. 8. Parameter value of pH, EC, water level, humidity and temperature shown in ThingSpeak

The real-time parameters are shown in Figure 8. The parameter value for pH is 7.5, which is within the range of the characteristic of Pak Choi. Field 2 is the EC value in real time data. The EC reading is 1.9 which is within the permitted range of EC value. According to Pak Choi's characteristic, the EC values should be in between 1.5 and 2.5. However, if it is higher than the recommended range, the plant's growth would be stunted. In the worst scenario, the plant will wither due to over-fertilization.

The ThingSpeak parameter value for water level is 3, indicating the tank's maximum capacity of 10 litres. However, if the indicator displays as 1, the tank has less than 2 litres of water. EC and pH values will be too high if the water level is less than 8-10 litres due to the concentration of liquid.

Humidity is displayed as field number 4. The plant could only absorb a specific amount of humidity and as a result, it produces less evaporation of water than most plants. If the plant loses too much water, the stomata will be closed and halting of photosynthesis. The current humidity level is 100% due to the plants could not evaporate any water,

Figure 8 depicts water at 28°C. The experiment was held and tested in a room, thus, the water temperature is between 25°C and 28°C. The suitable temperature for Pak Choi is between 12.78°C to 29.44°C.

	A	B	C	D	E	F	G
	created_at	entry_id	Field1 (pH)	Field2 (EC)	Field3 (Water Level)	Field4 (Humidity)	Field5 (Temperature)
145	2021-10-19 10:06:29 UTC	144	5.56	1.2	3	91.9	29.38
146	2021-10-19 10:06:46 UTC	145	5.56	1.2	3	92.1	29.38
147	2021-10-19 10:07:03 UTC	146	5.56	1.2	3	92.1	29.44
148	2021-10-19 10:07:20 UTC	147	5.56	1.2	3	93.6	29.38
149	2021-10-19 10:07:37 UTC	148	5.56	1.2	3	93.9	29.44
150	2021-10-19 10:07:53 UTC	149	5.56	1.2	3	94.1	29.44
151	2021-10-19 10:08:10 UTC	150	5.56	1.2	3	93.7	29.38
152	2021-10-19 10:08:27 UTC	151	5.56	1.2	3	96.2	29.44
153	2021-10-19 10:08:44 UTC	152	5.56	1.2	3	96	29.44
154	2021-10-19 11:25:59 UTC	153	5.56	1.2	2	94.3	29.56
155	2021-10-19 11:26:16 UTC	154	5.56	1.2	3	94	29.56
156	2021-10-19 11:26:33 UTC	155	5.56	1.2	3	95.2	29.5
157	2021-10-19 11:26:49 UTC	156	5.56	1.2	3	94.1	29.5
158	2021-10-19 11:27:06 UTC	157	5.56	1.2	3	95.5	29.56
159	2021-10-19 11:27:23 UTC	158	5.56	1.2	3	96.7	29.56
160	2021-10-19 11:27:40 UTC	159	5.56	1.2	3	95.1	29.56
161	2021-10-19 11:27:57 UTC	160	5.56	1.2	3	96	29.5
162	2021-10-19 11:28:14 UTC	161	5.56	1.2	3	93.8	29.56
163	2021-10-19 11:28:31 UTC	162	5.56	1.2	3	93.7	29.56
164	2021-10-19 11:28:48 UTC	163	5.56	1.2	3	93.8	29.56
165	2021-10-19 11:29:04 UTC	164	5.56	1.2	3	94.5	29.5
166	2021-10-19 11:29:21 UTC	165	5.56	1.2	3	95.4	29.56

feeds data from ThingSpeak

Fig. 9. Result in Spreadsheet

Figure 9 shows the data for each parameter in SpreadSheet. The total available data is 25841 entries for 30 days of monitoring process. The data for pH value, the EC value, the water level in the container, the humidity, and the water temperature, will be captured in every 17 seconds in ThingSpeak and Spreadsheet.

The time cycle is set to every 17 seconds since all of the parameters in this project, such as the pH and EC value, are crucial. If the plant does not received an adequate suitable range of pH or EC, it can be assumed that the plant does not receive enough amount of nutrients for growth.

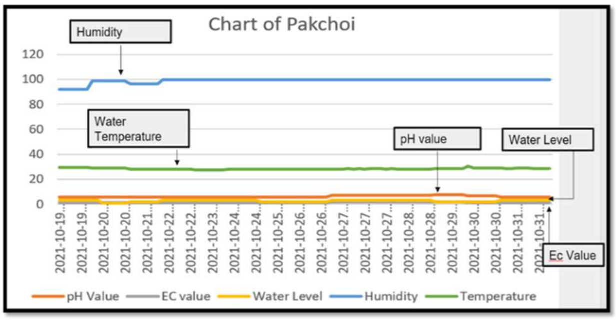

Fig. 10. The result for humidity, temperature, pH, EC and water level for PakChoi.

Based on figure 10, it shows the graph of Pak Choi growth. This is the sampling data for each parameters used in this project and the data were taken from 19 to 31st November 2021.

Humidity is represented by the blue lines at the top of the bar. The humidity experiences instability of the reading in the beginning due to the current weather. The humidity is inversely proportional to the temperature.

The green lines indicate the water temperature in the water tank. As this project was developed and tested in the room, therefore the recorded water temperature ware stable.

The other parameters are the orange lines represents the pH value, the yellow lines on the bar represent the water level, and the bottom of the bar line, represents the EC value. As overall, the parameters meet the requirement of Pak Choi's characteristics.

The sow seeds, the prototype and the Pak Choi plant during the monitoring process can be shown in figure 11.

Fig. 11. The sow seeds, the prototype and the Pak Choi plant during the monitoring process.

IV. Discussion and Conclusion

People now have a great platform to track and monitor their plants and garden surroundings thanks to the Internet of Things and Smart Hydroponic Systems. The smart irrigation system may be controlled by the user via the Blynk app on a smartphone, along with the hydroponic system, by continuously updating the state of the garden. This study thus shows a more effective way of controlling and keeping track of hydroponic system activities than the previous system.

In conclusion, the hydroponics system was successfully developed using ThingSpeak and Spreadsheet real-time data via the Internet of Things. The technology automatically controls the level of nutrition and offers a graphical user interface for simple maintenance and control. The hydroponics prototype can be developed with this project. In this study, data including pH, EC, and water temperature have been examined and validated to ensure they fit the criteria for Pak Choi's features. The testing method produced satisfactory findings, and the application is practical, which leads to an increase in production.

Data mining techniques will be applied to evaluate and forecast data regarding the amount and quality of the plant as part of a future study that will expand the system to incorporate more beneficial and adaptable linked devices.

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References

[1] S. Jan et al., “Hydroponics – A Review,” Int. J. Curr. Microbiol. Appl. Sci., vol. 9, no. 8, pp. 1779–1787, 2020.

[2] I.Ahmad, S.E. Shariffudin, A.F. Ramli, S.M. M. Maharum et al. "Intelligent Plant Monitoring System Via IoT and Fuzzy System", 2021 IEEE 7th International Conference on Smart Instrumentation, Measurement and Applications (ICSIMA), 2021.

[3] K. Kularbphettong, U. Ampant, and N. Kongrodj, “An Automated Hydroponics System Based on Mobile Application,” Int. J. Inf. Educ. Technol., vol. 9, no. 8, pp. 548–552, 2019.

[4] J. Pitakphongmetha, N. Boonnam, S. Wongkoon, T. Horanont, D. Somkiadcharoen, and J. Prapakornpilai, “Internet of things for planting in smart farm hydroponics style,” 20th Int. Comput. Sci. Eng. Conf. Smart Ubiquitos Comput. Knowledge, ICSEC 2016, 2017.

[5] M. Fuangthong and P. Pramokchon, “Automatic control of electrical conductivity and PH using fuzzy logic for hydroponics system,” 3rd Int. Conf. Digit. Arts, Media Technol. ICDAMT 2018, pp. 65–70, 2018.

[6] R. Gashgari, K. Alharbi, K. Mughrbil, A. Jan, and A. Glolam, “Comparison between growing plants in hydroponic system and soil based system,” Proc. World Congr. Mech. Chem. Mater. Eng., no. September, 2018.

[7] T. Nishimura, Y. Okuyama, A. Matsushita, H. Ikeda, and A. Satoh, “A compact hardware design of a sensor module for hydroponics,” 2017 IEEE 6th Glob. Conf. Consum. Electron. GCCE 2017, vol. 2017-Janua, no. Gcce, pp. 1–4, 2017.

[8] D. Saraswathi, P. Manibharathy, R. Gokulnath, E. Sureshkumar, and K. Karthikeyan, “Automation of Hydroponics Green House Farming using IOT,” 2018 IEEE Int. Conf. Syst. Comput. Autom. Networking, ICSCA 2018.

[9] ZipGrow TM Best Crops For Hydroponics A Reference Guide For Modern Farmers,” *ZipGrow*, [Online]. Available: www.Zipgrow.com.