

Design and development of control and monitoring hydroponic system

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ABSTRACT

The global agriculture system faces significant challenges in meeting the growing demand for food production, particularly given projections that the world's population will reach 70% by 2050. Hydroponic farming is an increasingly popular technique in this field, offering a promising solution to these challenges. This paper will present the improvement of the current traditional hydroponic method by providing a system that can be used to monitor and control the important element in order to help the plant grow up smoothly. This proposed system is quite efficient and user-friendly that can be used by anyone. This is a combination of a traditional hydroponic system, an automatic control system and a smartphone. The primary objective is to develop a smart system capable of monitoring and controlling potential hydrogen (pH) levels, a key factor that affects hydroponic plant growth. Ultimately, this paper offers an alternative approach to address the challenges of the existing agricultural system and promote the production of clean, disease-free, and healthy food for a better future.

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1. INTRODUCTION

Hydroponics is the activity of planting without soil. Most people thought of hydroponics, when they think of plants that grow with their roots down directly into water with no growing medium. This is actually referred to as nutrient film technique (NFT). By exploring the wide range of hydroponic technologies available, farmers, and home growers alike can discover new ways to cultivate healthy, sustainable crops. Hydroponics provides healthier, disease free plants and faster than growing in soil. In soil less culture, plants are cultivated using a liquid solution of water and nutrients. Plants need light, water, nutrients, and carbon dioxide in order to grow. Appropriate temperature and suitable levels of nutrients are important for plants to grow. There are so many types of plants that can be grown up using the hydroponic method such as lettuces, tomatoes, and celery [1], [2]. In hydroponics, all its nutrients are delivered directly to its roots by bypassing the soil, which is much faster and more efficient at providing all the nutrients need to the plant.

Mendon *et al.* [3] was inventing an apparatus for automated monitoring and controlling a hydroponic installation which measures a variety of sensors, controls electrical devices, and provides a user with an interface through apps which accessible anywhere and anytime. According to the inventor, network connectivity or types of communications allows the user to manage the system build remotely and not forget to view updated data through just a display on a screen. Mog [4] showed that after a plant cultivating system

was built, a smartphone was programmed to control the system as a remote controller. The system consisted of a central monitoring personal computer (PC), a cultivating equipment control module, a remote control smartphone and a plant cultivating room. The power line communication method was applied for the communication between the monitoring PC and the cultivating equipment control module.

In pursuit of modernity country and improving the living standards of the people, economic activities, and tree felling activities of a country cannot be avoided. People often overlook the environmental problems developed from the implementation of economic activity and activity logging. These activities led to a few problems that will contribute to a huge difference in our environment [5].

Thus, hydroponic is an alternative method to overcome these problems and this method will offer healthier and disease-less products and help us to save the environment from all these problems. Crowe [6] stated that what has emerged over the past decade. However, is the utilization of warehouse space in some highly dense urban environments, for the purpose of large-scale commercial food production? This is because it believes that hydroponics can hold a large scale of plants. Since the whole system automatically performs all daily testing necessary, adjust the system level for potential hydrogen (pH) [7], nutrients, and water [8]. Automated hydroponic gardening is just as simple as soil gardening but yet able to produce a better result.

Some of the authors discuss the benefits of hydroponics as a method of crop production and its potential to treat partially treated wastewater [9]–[11]. They suggest that while successful experiments have been conducted, full-scale examples of using reclaimed water as a nutrient solution in hydroponic systems are limited, but may become economically viable with the recent interest in vertical farming and cannabis production.

Automated programming or system by means includes sensors, power supply, and at least one microcontroller and mobile interface for monitoring data by users. For past few projects carried out by Bakhtar *et al.* [12], emphasize temperature and humidity control. A diode sensor is used which is generally a silicon diode and acts as a temperature measurement transducer. While temperature sensor silicon is a diode specifically designed and optimized for this function which can be seen as widely used for temperature sensing applications [13]. For example, in the automotive industry and consumer products, where manageable costing and high accuracy are important.

Saaid *et al.* [14] explained in order to ensure optimal utilization by the plant, pH measurement for both acidity and alkalinity of nutrient solution should be monitored daily. A pH of 7 is basic, more than 7 is alkaline or basic and below 7 is acidic. 5.8 to 6.4 is the ideal pH value for absorbing nutrients by the plant roots, or slightly acidic. To avoid iron or some of the other metals deficiencies, pH is not allowed to be so high and if the pH is too low, calcium, magnesium, and of the macro element may be hindered [15]–[17].

This research also keeps manageable maintenance costing and make sure the plants grow faster than conventional methods. In required that action is needed, the user shall be notified via text message or mobile apps notifications. By analyzing several studies, the implementation of the basic communication between android applications with pH level measurement, temperature measurement, level measurement, ventilation system, and lighting system. It will offer an alternative way to overcome these problems and help to provide clean, disease-less, and healthier products for better future development.

2. RESEARCH METHOD

This chapter will explain briefly the method that is used in this paper starting from software development until hardware development. The chronology of methods and procedures used is important as it can save time and organize the work done for the research. Basically, this project will be conduct through software development and hardware development.

The software part of this hardware development is the controller. After Arduino has been identified as the controller for this project, the progress of creating a program that can help running the project according to the objective is proceeded. The program created in the Arduino integrated development environment (IDE) are included with the library, pH sensor part, global system for monitoring and pin declaration. Arduino are used to be linked with pH sensor, global system for mobile communication (GSM), float switch, and water pumps.

The program is created by mixing different parts for different purposes. Since Arduino is the main controller, the Arduino act as ‘the brain’ for this project which it controls all the movement and function of this project as Figure 1. Programs written using Arduino are called sketches. Figure 2 shows the full process of software development and how it works after all the software progress has been completed. After the supply has turned on, the first thing that the controller will do is pump out the water tank into the hydroponic tank. As the water filling the hydroponic tank, the water pump will be turned off once the float switch reaches its top. Then the water from the main tank will stop flowing to the hydroponic tank as the water reach its maximum level.

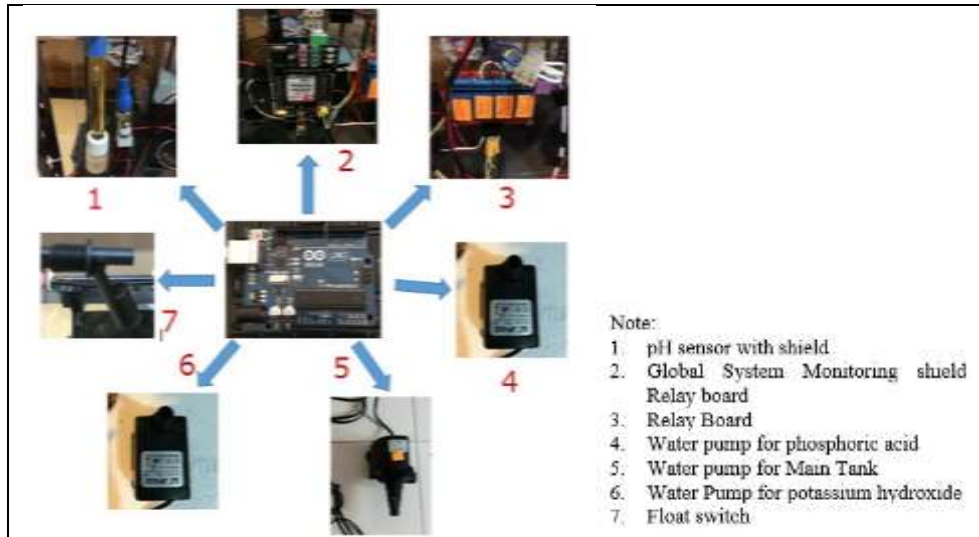


Figure 1. Parts that linked with Arduino

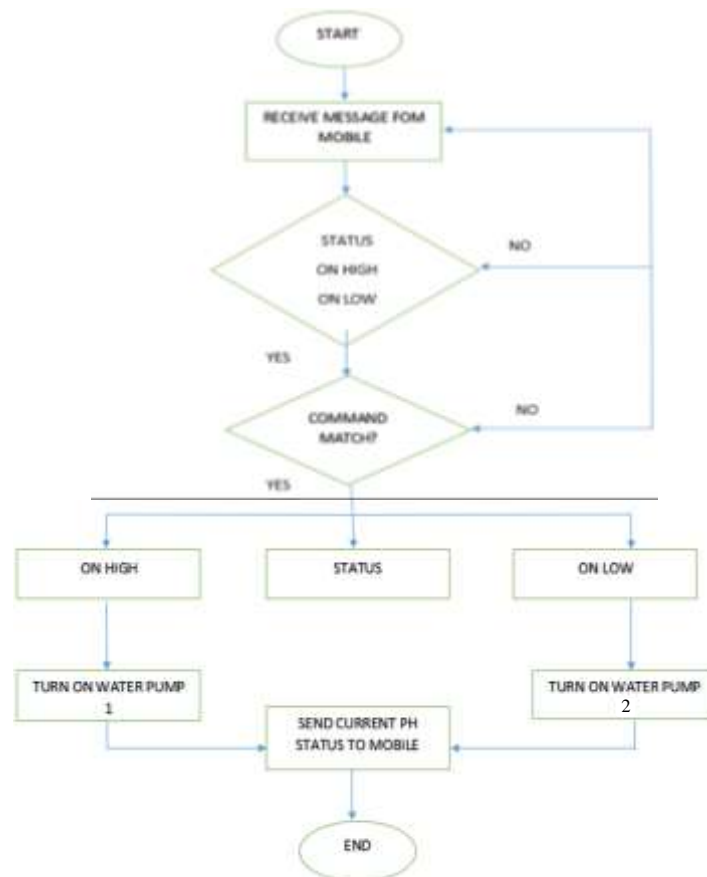


Figure 2. Flowchart of coding process

Next the controller will collect the current pH value in the hydroponic tank. As the project is linked with a mobile, the function of the mobile phone is to send commands so that the Arduino will act according to the command received. The command that can be sent to the controller is either STATUS, ON HIGH or ON LOW. All these commands will be sent using text messages function that already exists in mobile phones.

Each command has their own function. As for STATUS command, it is a command to collect the current pH value. The user need to send STATUS via text messages and send it to receiver phone. The user then will receive the current pH value in the hydroponic water tank. Here's how it works. After receiving the current pH value, user can decide either to increase or decrease the pH value according to its need. To increase the value of pH, command ON HIGH need to be send to user phone. T water pump will pump out the potassium hydroxide into the hydroponic tank. Then the stirrer will stir the water for about 17 seconds and then after 5 seconds the controller will sent the new pH value back to the user.

To decrease the pH value, command ON LOW are used and send signal to the board to activate the water pump that will pump out the phosphoric acid. The activation of the pump are followed with the stirrer being turned on for 17 seconds and after 5 seconds the user will get the new pH set by the controller. Figure 3 shown flow chart of the hardware development according to project planning. When the hardware part is done, it will be integrated with the whole system of the project. There also will be troubleshooting and testing. The procedure will be repeated until it reaches its target.

The first step for hardware development is to determine all types of components that will be used in this project. To conduct this project, there are some procedures involved in order to achieve the desired purpose. The criteria and specification of the component used are important so that it would be compatible with the project. After all component has been finalized, the circuit need to be constructed. In this project, we are using Arduino and we need to determine the type and number of pins that will be used. For example pH sensor will use one analog pin, GSM will use two digital pin and floating switch will be using one digital pin.

After all components is enough, then it is time to construct the circuit according to the simulation made before. When the circuit is has been constructed completely, it is time to test the circuit either it is suitable to use in the hardware. If it is not, then reconstruction is need. This process should be repeated until the suitable circuit construction is found and after that integration between software and hardware can be proceed.

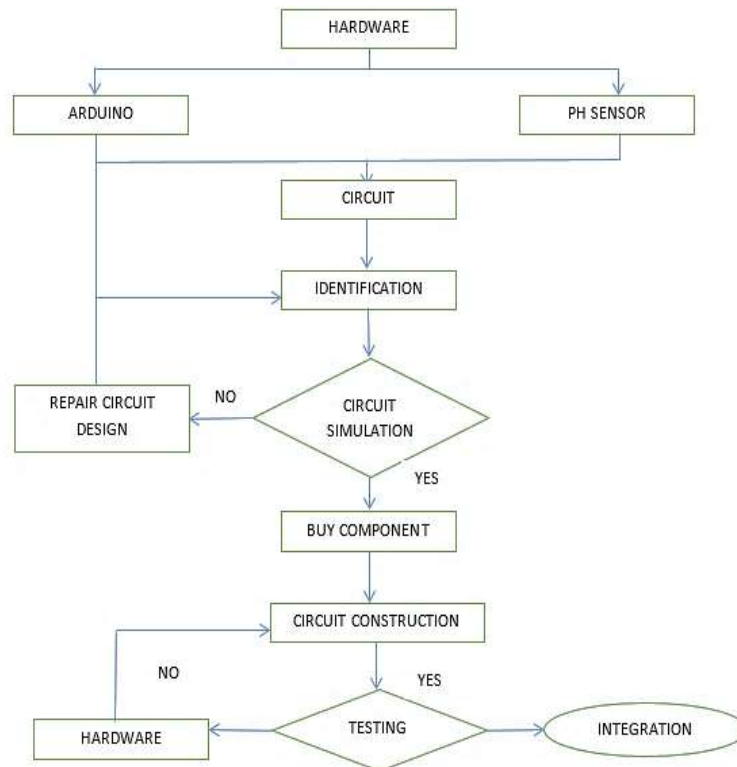


Figure 3. Flow chart of hardware development

3. RESULTS AND DISCUSSION

In this section, all the results and analysis have been discussed. The data are taken from different types of analysis and measurement in order to examine the accuracy and consistency of the system. Figure 4 shows a simple sketch on how the system flow. Basically, there will be 3 types of liquid will be pumped out into the

hydroponic tank. It takes 20 seconds for the water from main tank to fill the hydroponic that can contain 20 liters of water. The water pump used is Sunsun JP-023 which has output flow rate of 1000 liters per hour. For potassium hydroxide and phosphoric acid, the water pump used is Sunsun JP-032 which has flow rate of 350 liters per hour and each of it took for about 3 seconds to pump out 5 ml of both chemical. Excess water will be flow back to the water tank.

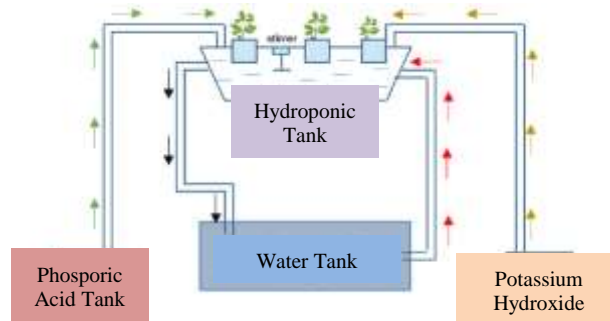


Figure 4. Sketch flow of water, phosphoric acid, and potassium hydroxide sketch

3.1. Experimental setup

Preparing phosphoric acid and potassium hydroxide is not an easy task. The mixture needs to be handled with care. Noted that all these soluble are suits to increase and decrease the pH value and can be well dissolved in 20 liters of water. Safira *et al.* [18] developed an autonomous pH monitoring and control system using a microcontroller to ensure water quality in good condition. While a feasibility study from Casillas-Romero and Begovich [19] implemented an automatic pH regulation system for a home NFT hydroponic system. In subsection 3.1.1, the procedure for making a 0.1 M solution of potassium hydroxide (KOH) in a 1000 ml stock solution is outlined. While in subsection 3.1.2, the procedure for making a 0.1 M solution of phosphoric acid (H_3PO_4) in a 1000 ml stock solution is provided.

3.1.1. Procedure for 0.1 M of potassium hydroxide, KOH in 1000 ml stock solution

In order to prepare a 0.1 M potassium hydroxide (KOH) stock solution for use in subsequent experiments, the following procedure was:

- 5.61 g of KOH powder is weighed using weighing scale.
- 500 ml of distilled water is added to a 1000 ml conical flask.
- 5.61 g of KOH powder is poured into the conical flask and added a distilled water until it achieved 1000 ml.
- KOH is swirled until it totally dissolved.
- Prepared solution is stored in the fume hood.

3.1.2. Procedure for 0.1 M of phosphoric acid, H_3PO_4 in 1000 ml stock solution

The procedure for preparing a 0.1 M phosphoric acid (H_3PO_4) stock solution, essential for subsequent experiments, is outlined:

- 5.24 ml of H_3PO_4 is measured using a measuring cylinder.
- 500 ml of distilled water is placed in 1000 ml conical flask.
- H_3PO_4 is poured in the conical flask alternately with a distilled water.
- Distilled water is added until it reached 1000 ml.
- The mixture is swirled and inverted to ensure it.
- Prepared solution is stored in the fume hood.

3.2. Signal obtained from pH sensor

The data on water pH has been gained by using a pH sensor. Basically, there were 3 classifications of acidity of water which are measured in the range of 0 to 14. For acid (pH below 7), neutral (pH7) and alkaline (pH bigger than 7). A few progresses has been made to collect data by connecting the controller to the PC and with the help of real term software, the data has been keep in an excel file and the result obtained can be presented in graph form.

By editing a few programs in Arduino, the controller can be linked to the real term software. This software is used to keep the data by saving the data gained in comma-separated value format (csv) and automatically the data will be saved in an excel file [20]. Different technic by Hidayanti [21] using mockup as an internet of things application for monitoring the hydroponic plant.

The data taken are pH value of the water in the hydroponic tank or main tank. Basically, pure water has a balance of hydrogen (H⁺) and hydroxyl (OH⁻) ions and is therefore pH neutral (pH7). When the water is less than pure it can have a pH either higher or lower than 7. To change the value of water pH, we need to use two types of chemicals which is phosphoric acid to decrease the pH value and potassium hydroxide to increase the pH value. At first, the data will be measured by dipping the pH sensor into pure water. Then the addition of phosphoric acid or potassium hydroxide is used to measure the level of pH after these chemical has been added. These result from the water pH to increase or decrease. The data gained are recorded.

Figure 5 shows that data taken from pH sensor are displayed in Arduino's serial monitor. The serial monitor is a separate pop-up window that acts as a separate terminal that communicates by receiving and sending serial data. Serial data is sent over a single wire and consists of a series of 1's and 0's sent over the wire. Basically, we are using the serial monitor to debug Arduino software sketches or to view data sent by a working sketch. All these data are the will are linked to the global monitoring system and will be sent to the user once the user request for a result.

```

PHSensorTest | Arduino 1.6.5
File Edit Sketch Tools Help

PHSensorTest
#include <SoftwareSerial.h> //we have t
#define rx 7 //define wh
#define tx 8 //define wh

SoftwareSerial myserial(rx, tx); //define ho

String inputstring = ""; //a string
String sensorstring = ""; //a string
boolean input_string_complete = false; //have we r
boolean sensor_string_complete = false; //have we r
float pH; //used to h

void setup() { //set up th
  Serial.begin(9600); //set baud
  myserial.begin(9600); //set baud
  inputstring.reserve(10); //set aside
  sensorstring.reserve(30); //set aside
}

void serialEvent() { //if the ha
  inputstring = Serial.readStringUntil(13); //read the
  input_string_complete = true; //set the f
}

void loop() { //here we g
  
```

Figure 5. Data from pH sensor presented in Arduino's serial monitor

Figure 6 shows that the data from pH sensor appear at the real term monitor. The real term is a terminal program specially designed for capturing, controlling, debugging binary, and other difficult data streams [22]. It is much better for debugging commas than hyper terminal. The use of real term is to capture data from pH sensor. The difference between real term and serial monitor is that data that appear in real term can be saved. The data taken is saved as csv. Csv format is a format that saved the data in an excel file and by saving in that format, data can be converted in graph form. This is very useful because the data in graph form can make it easier for us to interpret it compared to in the numerical form.

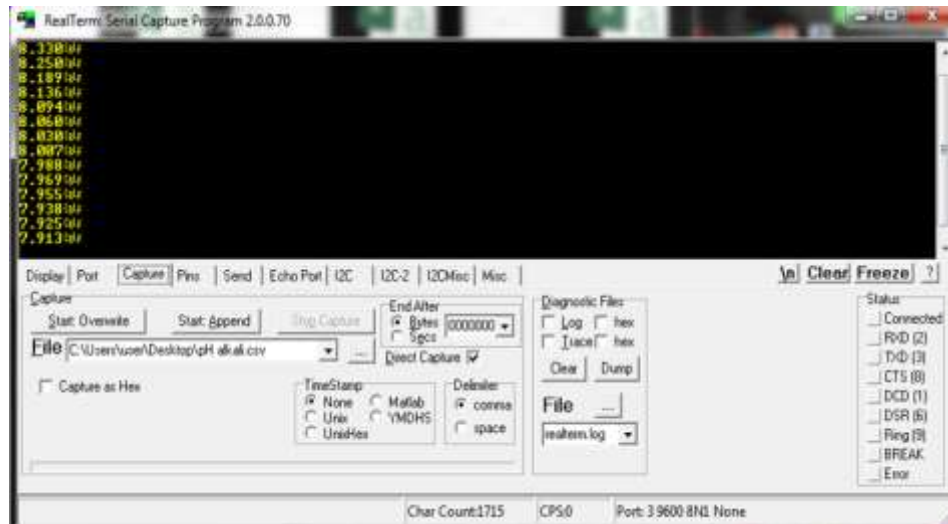


Figure 6. Real term software

3.3. Data of water acidity level

Potential hydrogen or pH is of paramount importance to any hydroponic grow operation because it affects the way that nutrients are absorbed into the plants. The data taken are the results of mixing the phosphoric acid and potassium hydroxide into 20 liters of water. The result gained are as follows. Noted the time taken for these data are estimated around two minutes.

Figure 7 shows that data taken for pure water. Theoretically, the pH for pure water should be 7 because pure water is not acid nor alkaline. The graph shows that the value drop from 7 and reach its steady state value which is around 5.9. The reason why it didn't reach value of 7 is because pure water is naturally included with contaminants. Contaminants in water such as cryptosporidium, giardia lamblia, and coliform bacteria. Research from the environmental protection agency (EPA) of United States proves that approximately 90 different types of contaminants that can be found in water. Drinking water, including bottled and tap water, may reasonably be expected to contain at least small amounts of some of these contaminants. This explain why we didn't get the pH value of 7 for pure water. Also, the water (distilled, deionized, or tap) are usually not "pure" (i.e., pH equal to 7). When it comes with contact throughout air, CO₂ gas begins dissolving in it, forming carbonic acid. The pH, therefore, will certainly slightly less than 7. Another reason is pH electrodes cannot give accurate pH values with distilled as well as deionized water. It is considered that the distilled and deionized water do not have enough ions provide for its electrode to perform properly.

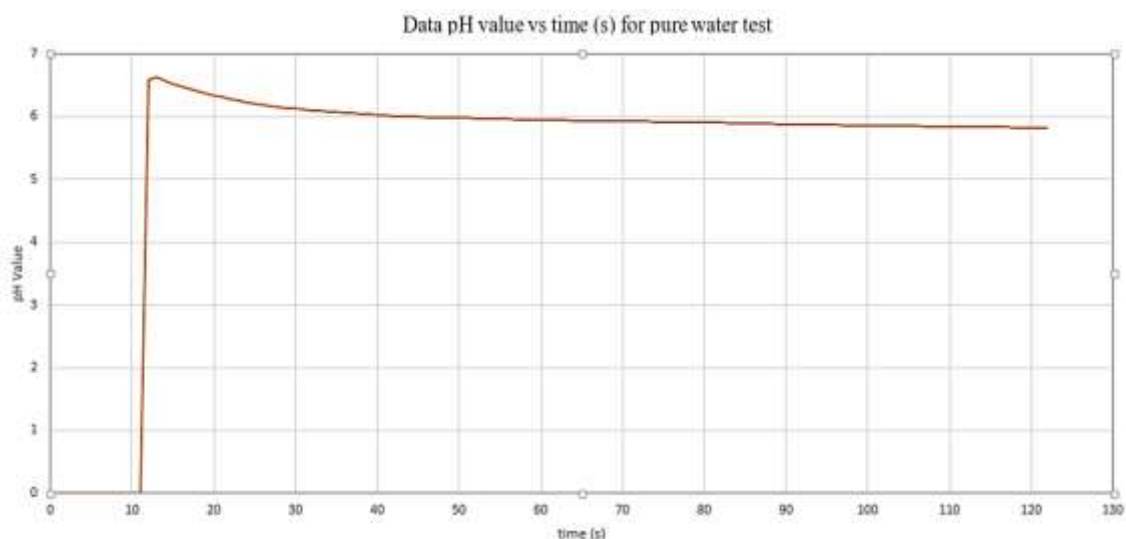


Figure 7. Data and graph of pH7 (neutral)

Figure 8 shows the pH data of pure water after it has been added to phosphoric acid. The amount of phosphoric acid added to the water is 5 ml. The graph shows that the value of pH after added with phosphoric acid are decreasing after phosphoric acid are added. Factually, water with a pH <6.5 could be acidic, soft, and corrosive. Acidic water could contain metal ions such as iron, manganese, copper, and zinc. In other words, acidic water contains elevated levels of toxic metals. This explains why the pH are decreasing.

Graph in Figure 9 shows the result of pouring 5 ml potassium hydroxide into 20 liters of water. The graph shows that the water pH is increasing and reach its steady state after 60 seconds. The reason of why the graph shows that the water pH is unstable before it reaches a steady state might be because the potassium hydroxide didn't dissolve well in the water. It reaches a steady state at pH level between 8 and 9 which indicates that the water is in alkaline level. Due to continental in water, there will be hard to increase the pH in beginning. Diopside, augite, olivine, monticellite, alkali amphibole, allanite, and andradite are among the continental contains in alkaline water.

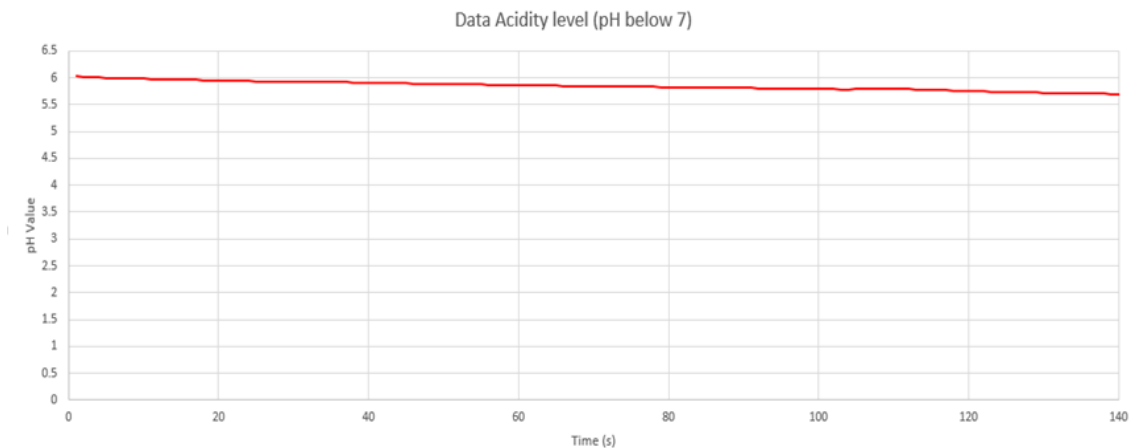


Figure 8. Data and graph of pH below 7 (acidic)

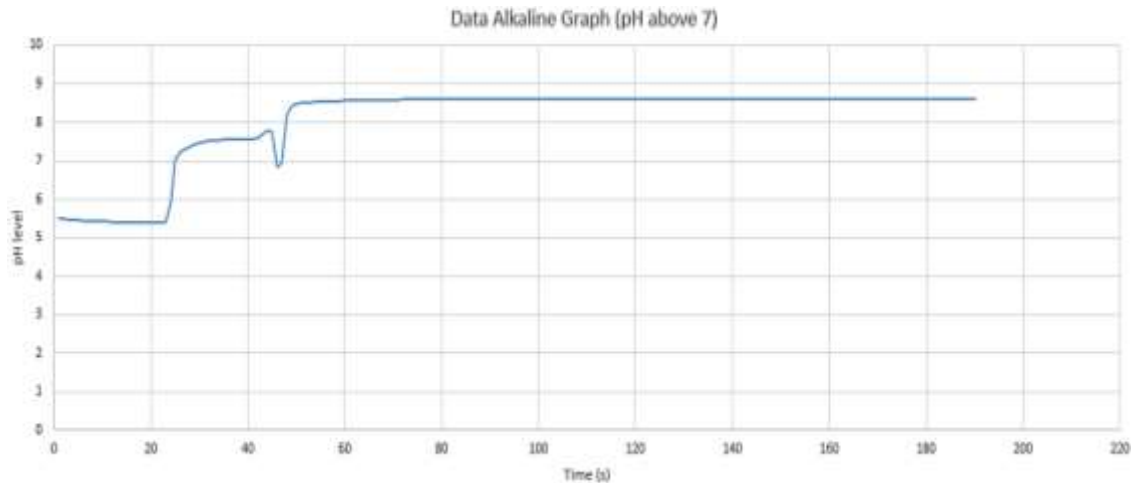


Figure 9. Data and graph of pH larger than 7 (alkaline)

3.4. Result comparison of conventional hydroponic system with the modern hydroponic system

As stated early, the target of this project is to improve the conventional hydroponic system with this project. In this part, a few comparisons have been made to detect the differences or things that have been improved as a result of this experiment [16]. The seeds that have been put in the vase and hydroponic cover and the growth are observed. This is the step of trying to get the data for modern hydroponic system and comparing it with the conventional method. The data gained has been compared. The data taken are the growth in 5 weeks and the parts of the data taken are the leaf, stem, and quality. The data taken are shown in Table 1.

Table 1. Comparison between the conventional and modern hydroponic method

Week	Modern hydroponic method Length (cm)		Conventional hydroponic system Length (cm)	
	Stem	Leaf	Stem	Leaf
1	0.6	0.7	0.6	0.7
2	1.3	1.0	0.2	0.5
3	3.0	2.7	2.8	2.2
4	6.7	5.6	4	3.3
5	8.5	6.6	5.1	4

Table 1 shows that the result of the conventional hydroponic method compared with the hydroponic method conducted using this project. Comparing the stem length and the leaf length of each week prove that modern hydroponics help plant to grow up faster than conventional product [22]–[25]. This is also proving that pH is an important element for the plant to grow up and to be able to control it helps us to gain a more good quality product and a healthy result.

4. CONCLUSION

Hydroponic is a cultivation that is good in every aspect. Cultivation of hydroponics helps in providing a good quality product, increase the level of health and can save a huge amount of cost. Hydroponic cultivation also didn't use any dangerous chemicals and user friendly. It also can be planted anywhere at any place and even housewives and children can practically plant. It is proven that hydroponic reduce human costs. Plants grown through this technique come with good quality and better nutritional value. Vitamin content is factually 50% more in hydroponically grown plants compared to conventional ones. Moreover, run-off in traditional gardening can lead to environmental degradation due to the high proportion of calcium, phosphorous and potassium content dissolved in it. But in hydroponic systems; water can be reused multiple times leading to water conservation with less expense incurred on it. Another improvement of the conventional hydroponic method. The water pH is one of the main factors that are very important for plants in hydroponic cultivation to live. To be able to control the pH helps the plant to absorb all the nutrients it needs such as calcium, magnesium, and boron.

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