Automated pH Controller System for Hydroponic Cultivation

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***Abstract*— Hydroponics is a technique to grow the plant without using the soil. This technique ensures the plant gets all nutrients needed from the water solution. There are many types of hydroponics technique. The Deep Water Culture (DWC) is one of the hydroponics technique types. DWC is a technique that grows the plant by supplying the nutrient direct to the root of the plant until the plant can be harvested. By using this technique, the plant root will be always submerged into the water that contains nutrient and oxygen. However, this technique manually controlled the pH water, which can give bad effect to growing of plant. In this research, the pH level in water solution will be automatically maintained by microcontroller and measured by sensor. Next, the period of pH level started to change and the effects of pH adjuster solution to the water solution are determined. Lastly, this research also focuses on the ability of the system can adjust the pH value in water solution for DWC. The water solution from the DWC container is transferred to the main tank to measure the pH level by sensor and make adjustment if needed and then transfer back to the deep water culture container to continue growing the plant. There are six stages in methodology for this project, which are details of study, hardware identification, software identification, hardware and software interfacing, analysis and troubleshooting, data and result collection. The result from the experiment test showed that the system able to decrease the pH level by 0.58 pH and increase the pH level by 1.15 pH.**

***Index Terms*— Hydroponic, pH level, Arduino microcontroller, Deep Water Culture**

I. INTRODUCTION

Hydroponics is a technique to cultivate the plant without using soil as a growth medium [1]. This technique supplies the nutrient needed by plant through the water solution. There are many types of hydroponics technique such as deep water culture, aeroponic system, drip system, EBB and flow (food and drink) system, N.F.T (nutrient film technique) and wick system [2]. Deep water culture (DWC) is one of the hydroponic system techniques that prepare the nutrient in water solution into the plant [3]. This technique will ensure the root of plant will absorb the nutrient in water solution to grow wisely [4]. By using this technique, there are several environmental factors that should be considered such as oxygenation, salinity, pH and conductivity of nutrient solution, light intensity temperature, photoperiod and air humidity [5]. There are two variables must be considered when growing the plant in nutrient solution, which is electrical conductivity (EC), potential of hydrogen ion (pH) [6].

Based on S. Nakoaka and A. Yamada in their research, they state the changing of pH level will affect to the photosynthetic activity of plants, due to CO2 is readily soluble in water and decreases the pH [7]. The maximal growth of plant can be achieved by increasing it capacity [8]. Since the pH value can give effect to the photosynthetic activity of plant, the pH level in water solution should be controlled to avoid the plant will be damaged. However, the DWC technique is not equipped with an automatic system that able to maintain the pH level in water solution, and the user need to adjust the pH level in water solution manually [9]. Therefore, this research was conducted to design a system that could maintain the pH level in water solution for DWC system, which could decrease and increase the pH level in water solution automatically. In order to make the system operate automatically, a microcontroller that can control the operation is required in this system. There are many types of microcontroller can be used in this project such as PIC controller, PLC controller and Arduino microcontroller [10, 11].

However, this project uses the Arduino mega 2560 microcontroller to control all of operation systems and to make the system automatically operate. This type was chosen because it used the low-power supply (7-12V DC) and used the simple C++ programming language to program it [12, 13]. This system also was equipped with the sensor to measure the pH level in water solution and transferred the compatible signal to microcontroller to process and provided an output signal to the actuator (valve) to drop the pH adjuster solution if required. This system can provide benefits to the production development for being more accurate, better control, high safety and reduce of manpower.

978-1-4799-8969-0/15/$31.00 ©2015 IEEE

II. System Descriptions

The pH level in water solution to the deep water culture is should be maintained to ensure the plant grows wisely. In this research, the mustard green was taken as a plant sample. The suitable range pH level for mustard green is 6.0 to 7.5 [14]. The nutrient is supplied to the plant by mixture the water solution with fertilizer before started to grow the plant. After that, the suitable of pH value of the plant must be set up first by using a keypad button that connected with the Arduino Mega 2560 microcontroller. Once, the pH level was entered the system will automatically make a comparison between pH level value in water solution with range of suitable pH level value. The pH level in water solution in the main, tank is measured by sensor (Atlas sensor brand), and the sensor provided an output signal then send to the microcontroller to make comparison and analysis. If the pH level value in water solution higher than pH level value, the microcontroller would send the signal to DC servo motor to drop the pH down to decrease the pH level value in water solution so that the pH level value in water solution within range of suitable pH level value for plant and vice versa.

Next, the system will transfer the water solution that contains pH level value that appropriate for plant to the container hydroponics to start growing the plant if the pH level in water solution in range of suitable pH level for plant. The dc pump is used to transfer the water solution to the hydroponics container to start growing the plant. After a certain period, the water solution in container hydroponics would be transferred to the main tank to check and measure the pH level in water solution back. This is because according to the experiment conducted, the pH level in water solution would change to exact value after a certain period. Figure 1 below shows the block diagram of an automated pH controller system for DWC.

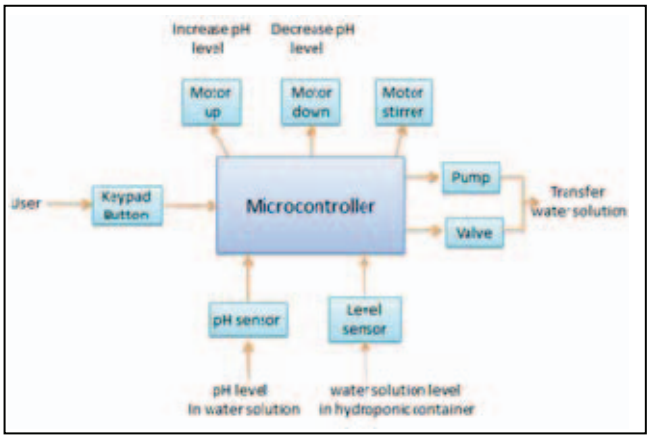

Fig. 1. Block diagram of an automated pH controller system

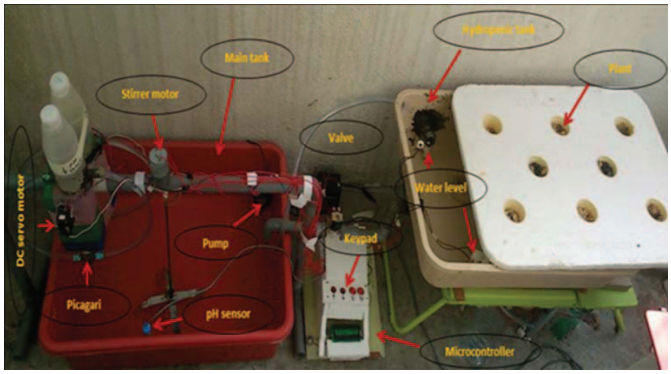

Fig. 2. Automated pH controller system

This system was used two tanks, which were main tank and hydroponics tank. The position of the hydroponics tank was placed above the main tank so that the water solution in the hydroponics tank could be easier to transfer back into the main tank for the rechecking the pH level in water solution after a certain period. By this way, to transfer the water solution into the main tank can be done by solenoid valve. It made the cost of the project can be reduced. To stand the pH adjuster dropper and stirrer, the PVC pipes were used.

III. Experimental Test

In order to ensure the project operates based on the theory and ideas the experimental test step must be applied. In this step, there are several experiments are conducted to find the relationship between manipulated variable and control variable. Besides that, the experimental also is important in case to find the behavior of operation or discovering the something unknown that can give influence to the operation and the result. In this project, there are three experiments are conducted:

A. Measurement of an amount of pH down and pH up are dropped by the actuator..

This experiment was conducted to obtain the amount of pH down and pH up dropped by the actuator when the number of rotation of a servo motor increase. The reading amount of pH down and pH up was taken until the number of rotation of servo motor achieved five rotations.

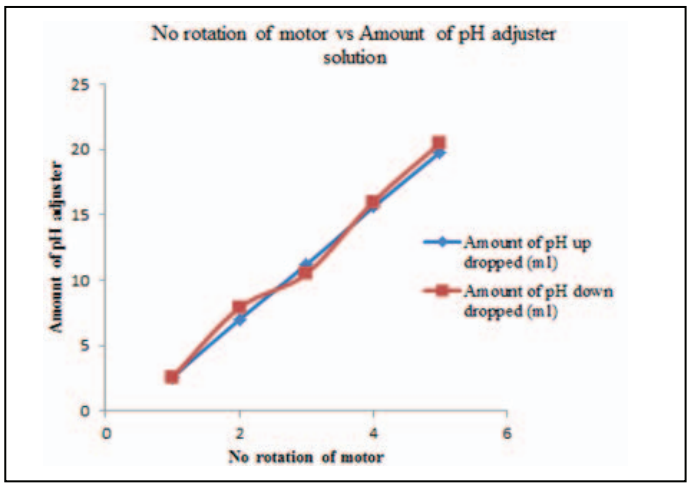

Fig. 3. Amount of pH down and pH up are dropped by the actuator.

Figure 3 shows relationship between numbers of rotation of servo motor and amount of pH adjuster dropped (pH Up and Down solution). The reading of an amount of pH adjuster dropped by the actuator was taken until the rotation of motor equal five. From the graph, the minimum amount of pH adjuster could be dropped by the actuator was 2.6ml for one rotation of motor. Based on the figure 3 above the amount of pH adjuster (pH Up and Down solution) can be changed by adjusting the number of rotation of motor. These data were important in order to find the suitable amount of increment or decrement of pH value when the pH adjuster dropped into water solution. These data have been used as a reference in case to find the suitable number rotation of motor to drop the pH adjuster.

B. Measurement of changing on pH value in the main tank with two different pH sensor

The purpose of this experiment was to find a relationship between pH value in water solution that contained of 500ml nutrient vary with time. This experiment gave the data that required to finding the period of pH value began to vary. This experiment was tested for 10 litters of water solution in the main tank.

TABLE I. MEASUREMENT OF PH VALUE IN 10 LITTERS OF WATER SOLUTION USING ATLAS SENSOR AND PH-0091 PEN TYPE SENSOR.

Day	pH Value		
	ATLAS sensor	*pH-0091 Pen type sensor*	*Different*
1	7.44	7.74	0.30
2	6.88	7.40	0.52
3	6.70	7.41	0.71
4	6.80	7.28	0.48
5	6.84	7.45	0.61
6	6.89	7.42	0.53
7	6.86	7.45	0.59
8	6.86	7.53	0.67
9	6.73	7.41	0.68
10	6.95	7.48	0.53
11	6.85	7.45	0.60
12	6.81	7.50	0.69
13	6.82	7.62	0.80
14	6.87	7.72	0.85
15	6.88	7.82	0.94
16	6.92	8.05	1.13
17	6.81	7.91	1.10
18	6.67	7.30	0.63
19	6.39	6.59	0.20
20	6.02	6.29	0.27
21	6.03	6.31	0.28
22	6.05	6.35	0.30
		Average	**0.59**

This experiment was conducted for 10 litter's water solution in main tank and mixture with 500ml fertilizer. The measurements were taken by two different sensor, which using ATLAS sensor and ATC sensor in order to compare accuracy of ATLAS sensor. The pH-0091 Pentype PH meter is a sensor that has ±0.2 pH value. As shown in table I there was a slightly different measurement between ATLAS sensor and ATC sensor. Based on the Table I, the ATLAS sensor has average error factor +0.59 respect to pH-0091 pen type PH sensor. The data was recorded and forward to be as a reference when growing the plant. From the result of this experiment, the increasing in time is decreased the pH level in water solution. The changing of pH value in water solution started to have dramatically changed at day 16th. This was because the fertilizer starts to give a response to the water solution and influence the pH level in water solution. The chemical of fertilizer caused the pH level in water solution has dramatically been changing. Therefore, the pH level in water solution must be controlled or adjusted before day 16th.

C. Measurement of changing on pH value in a main tank effected from pH down and pH up solution.

This experiment was conducted to find the changing of pH value in a main tank when the 2.6ml of pH down and pH up are applied. In this experiment, 10 litters of pure water were put into the main tank. A pH value in the first reading was recorded after 10 minutes. Stir the solution with a stick stirrer and after ten minutes the value of pH condition in the main tank was recorded. The reading of pH value in the main, tank was continued recorded after four hours and eight hours. The experiment was started by dropped a 2.6 ml of pH down/pH up

solution first into the main tank. The measurements of pH value were measured for five days.

TABLE II. MEASUREMENT OF PH VALUE BY APPLIED PH UP SOLUTION.

Day	pH up (ml)	*pH value (ATLAS Sensor)*		Different	pH value (pH-0091 Pen type sensor)		Different
		Before	*After*		*Before*	*After*	
1	2.6	7.44	8.58	1.14	7.77	9.02	1.25
2	2.6	7.44	8.68	1.24	7.70	9.35	1.65
3	2.6	7.49	8.34	0.85	7.69	9.25	1.56
4	2.6	7.46	8.78	1.32	7.68	9.39	1.71
5	2.6	7.45	8.65	1.20	7.73	9.46	1.73
			Average	**1.15**		**Average**	**1.58**

TABLE III. MEASUREMENT OF PH VALUE BY APPLIED PH DOWN SOLUTION.

Day	pH Down (ml)	*pH value (ATLAS Sensor)*		Different	pH value (pH-0091 Pen type sensor)		Different
		Before	*After*		*Before*	*After*	
1	2.6	7.41	6.93	0.48	7.43	6.65	1.18
2	2.6	7.46	6.91	0.55	7.72	6.74	0.98
3	2.6	7.48	6.98	0.50	7.69	7.01	0.68
4	2.6	7.43	6.70	0.73	7.68	6.82	0.86
5	2.6	7.44	6.81	0.63	7.72	6.75	0.97
			Average	**0.58**		**Average**	**0.93**

Table II showed the increment of pH value when 2.6ml of pH up solution was applied into 10 litters of pure water. Table III showed the decrement of pH value when 2.6ml of pH down solution was applied into 10 litters of pure water. The measurements were taken within five days as shown in Table II and III. In this experiment, Table II shows that the average of changes in pH about 1.15 and the Table III shows that the average of changes in pH about 0.58. The both of tables showed the different between before and after were not constant for every measurement. Therefore, the average for data set above was determined to easier making analysis. There was a slightly different of average between measurement of pH value by applied pH down solution and pH down solution.

The result from every experiment will be discussed to find the relationship and to make a conclusion to find the final solution from the result. The minimum amount of pH adjuster could be dropped by the actuator was 2.6ml for one rotation of motor. The result from a first experiment showed the amount of pH solutions (pH up and down) can be changed by adjusting the number of rotation of motor. There was a slightly different measurement between ATLAS sensor and ATC sensor. The ATLAS sensor has average error factor +0.59 respect to pH-0091 pen type pH meter. The increasing in time is decreasing the pH level in water solution. The changing of pH value in water solution started to have dramatically changed at day 16th. In this experiment, the average of changes in pH for applied pH up solution is approximately to 1.15 and the average of changes in pH for applied pH down solution is approximately to 0.58 pH. The both of a result showed the different between before and after were not constant for every measurement.

IV. CONCLUSION

In conclusion, development of an automatic pH level controller system for deep water cultivation (DWC) technique using Arduino Mega 2560 as microcontroller was successfully done. The system was successfully dropped the pH solution (Up/Down) into water solution in case to maintain the pH value. Besides that, this system also successfully ensures the level of water solution would be transferred to the hydroponics container at a desired level. From the experiment 1, the amount of pH adjuster can be increased by increasing the rotation of motor depends on the changing of pH value versus time. In this case, one rotation of motor was already enough to maintain the pH value back. From the second experiment, the increasing of time would be resulting to decreasing of pH level in water solution. Therefore, there was a need to increase the pH level of water solution back since it changes versus time. Based on the third experiment, there was enough to increase the pH level to a suitable pH level for plant after it changes with time if using one rotation of motor to drop the pH up solution.

ACKNOWLEDGMENT

The authors would like to thank Faculty of Electrical Engineering; and, Research Management Institue (RMI), Universiti Teknologi MARA (UiTM), Shah Alam, Selangor, Malaysia for the grant awarded to present these research findings. Grant file: 600-RMI/RAGS 5/3 (55/2013)

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