Characteristics of Water pH Value Based on Effect of Acid and Alkaline Solution for Hydroponic Cultivation Technique

M.F.Saaid, Ahmad Ihsan Mohd Yassin and Nooritawati Md Tahir

Abstract— **Hydroponics is a technique to grow the plant without using the soil. This technique ensures that the plant gets all the nutrients needed from the water solution. The roots of plant will absorb the nutrient in water solution for the plant to be able to grow normally with several environmental factors to be considered namely oxygenation, salinity, pH level, conductivity of the nutrient solution, light intensity temperature, photoperiod as well as air humidity. Among all these factors, the pH value is one of the vital factors since the pH value contributes extremely study, the pH characteristic is investigated and evaluated specifically for hydroponics-based cultivation. Initial results showed that the pH changed drastically and sustained its value upon adding acid and alkaline at the highest concentration with an average of water pH value of 3.24 (after adding alkaline) and 4.66 (after adding acid). The pH value was consistently stable after this water mixture is left for 4 minutes. Note that the pH value is recorded from the 60th seconds upon mixed. Upon several experimental conducted it was found that the pH value changed minimally and could be neutralized upon adding purified water. In addition to that, results showed that the pH sensor can be placed in any position of the water tank based on the similar values of pH throughout the experiments.**

Index Terms—**Hydroponic cultivation, pH value, Acid and Alkaline**

I. Introduction

Hydroponics is a subset of hydroculture namely the method of growing plants without soil [1]. There are many types of hydroponics technique such as aeroponic system, deep water culture, flow (food and drink) system and drip system, flood & drain and, N.F.T (nutrient film technique) and wick system [2]. The hydroponics method used mineral nutrient solutions in a water solvent to ensure the plant gets all the nutrients required from the water solution [3]. It already known that nutrients element specifically carbon, hydrogen, oxygen, nitrogen, phosphorus, potassium, calcium, magnesium, sulphur, iron, copper, zinc, manganese, molybdenum, boron, chlorine and nickel are needed by the plant to grow healthy [4]. The absorption of water and nutrients takes place behind the root tip through modest root hairs. The technique in which the roots absorb water and nutrients is known as diffusion [5, 6].

The solubility of nutrients in a hydroponic solution or soilless growing substrate is influenced by pH, particularly for metal micronutrients that turn out to be less accessible for root uptake as the pH increased [7]. This is because pH is a logarithmic measure of hydrogen ions concentration in solution. On the other hand, the acidic solution has a higher relative number of hydrogen ions which its substances dissociated to release hydrogen ions or react with water to form hydrogen ions. The alkaline solutions have a higher corresponding amount of hydroxyl ions which its elements separated release hydroxyl ions or react with water for hydroxyl ions. A pH value can be categorised or scale in three parts; 0.0 - 6.9 as acid, 7.0 as neutral and 7.1-14 as alkaline. A standard pH value to grow plants are between pH 4 to 7, and the recommended pH for hydroponic culture is between 5.5 to 5.8 because the overall availability of nutrients is optimized at a slightly acid pH [8]. However, based on pH characteristic through the titration curve, it is indeed challenging to sustain the pH value to be between 4 to 7 without proper close monitoring or controlling the pH value either semi-automated or fully automated [8, 9].

The pH value is important to make sure the plant receives the maximum absorption of nutrients elements required. The plant will lose its ability to absorb some of the features if the pH value is not in the accurate range. As discussed in [10, 11], a pH less than 7 is said to be acidic, and solutions with a pH greater than 7 are basic or alkaline. If the pH value is closer to 1, it is known as more acidic while the pH value closer to 14 is alkaline in nature. For instance, the broccoli and lettuce need pH between 6.0 to 6.5, cucumber plants need 5.5 to 6.0 pH, and tomato plants need 5.5 to 6.5 pH value [12]. If the pH values are not in a suitable range for each plant category, it will lose its ability to absorb the nutrients required by the plant. Hence, the plants are not able to maximise the absorption of nutrients and thus suffer deficiency due to the unsuitable pH value [13, 14]. Therefore, it is vital in ensuring the specific pH value according to the plants. For that reason, this research explored further a method to maintain the pH

This manuscript is submitted on 8th May 2019 and accepted on 3th September 2019. M.F.Saaid, A.I.M Yassin and Nooritawati Md Tahir are from Faculty of Electrical Engineering, Universiti Teknologi MARA, Shah Alam, 40450, Selangor, Malaysia. (email: noori425@uitm.edu.my)

value for the plants. Besides, some characteristic of pH value is tested and analysed.

II. Literature of Previous Work

A study related to pH value was important, especially to grow plants. O. Belmehdi et al. in [15] proven that the different pH value affected the germination of O.elongatum (Morocco herbs). From the test, the authors concluded that the optimum germination percentage of O.elongatum was 91% at pH 6. At pH 4 that is more acidic, the germination percentage was only at 74% and at pH 8 that was more alkaline in nature the germination percentage was only at 68%.

Conversely, Yina Zou et al. in [16] stated that one of the important parameters for the aquaponic system was to balance the pH value at the same time for fish, plants and microbes as well. This study reported nitrogen transformations based on the pH value. It was reported that the optimum pH value was at 6 as compared to pH 7.5 and 9.

On the other hand, note that growing medium for the plant was important in growth factors. The pH in the growing medium was highly significant for plant nutrient availability. As reported in [17], weight for stem in dry condition was more sensitive to the high value of pH as compared to leaf and root. The root weight also lowers in a growth process at pH 8 as compared to pH 4 to 7. Thus, it is proven that the different level of pH value affected the plant growth in terms of plant production, quality and health. Therefore, many studies were done to develop a system that can neutralise and control the pH value to a suitable range for each plant.

Furthermore, according to [18] pH neutralization is a process of neutralizing a solution safe to be used for the environment. However, it is indeed difficult to control pH neutralization because of many nonlinear characteristics process. Therefore, study to control pH value was important to be included in a control system using several pH controlling methods such as Proportional-only (P), Proportional-Integral (PI), and Proportional-Integral-Derivative (PID).

In addition, R. Izumi et al. in [19] mentioned that controlling pH value was one of the methods for checking the health status of plants. The suitable value of pH to be supplied to plants was indeed vital for better growth. Here, the researchers have designed a prototype sensor based on MEMS technology for measuring pH and EC value. This sensor was used to manually measure the pH value and monitor the needed pH range.

Additionally, as reported in [20], pH value was one of the factors for producing quality plants. The authors have developed a remote monitoring system for hydroponics plant media. The system built included a pH, EC, LDR sensor for measuring the suitable pH value from the plants. All the data was stored in the web server and further used for monitoring based on recorded data. The drawback is the system could be used for monitoring solely, and any further steps to sustain the correct pH value need to be done manually.

III. Research Method

This section will discuss in detail the experimental and analysis method that has been developed in measuring the pH level.

A. Effect of Acid and Alkaline to the pH Values of Water

As stated earlier, the purpose of this research is to determine the changes in pH values in water tank for every droplet of acid and alkaline solution. In this experiment, the pH down solution that contained acid was used to reduce the pH value level and pH up solution (alkaline) for increasing the pH value level. The water volume was fixed at 3000ml. The initial pH values of the water were recorded prior to experimental as reference. Firstly, one ml solution of pH up is dripped into the water via syringe. Water in the tank is replaced with new water before repeating the same step namely dripping of 1ml pH up. The change of pH values for the 1ml solution is recorded until the pH values reached a constant reading. The amount of 1ml was selected as the amount to be mixed into 3000ml of water due to ease of measuring changes of water pH value. The amount of 1ml was sufficient due to significant pH value changes upon applying pH up and pH down solution as discussed in Section IV.

B. Effect of Acid and Alkaline to the pH Values of Water in Tank Versus Time

In addition to that, the time at which the constant pH value level is reached was analysed too namely the constant time of the pH reacted with acid or alkaline. Firstly, 1ml alkaline (pH up solution) is dropped into 3000ml water. Prior to this, the water pH value was measured. This step is repeated for every 30 seconds until 300 seconds (five minutes). This experiment is needed to determine the period of pH value versus time response.

C. Effect of pH Value in Water Versus Time by Gradually Increasing the Amount of Acid and Alkaline

The purpose of this experiment was to measure and analyses changes in pH value if the concentration of acid or alkaline is increased. Firstly, the acid solution was added with 1ml into 3000 ml water in a tank. Then, 1ml acid was added for every four minutes. The data was collected for every 30 seconds in order to measure changes of pH value in water upon adding either acid or alkaline solution. The pH value data was collected until a consistence pattern is obtained.

D. Determine the Accurate Position for pH Sensor in A Tank

In this experiment, the absorption of pH down (acid) and pH up (alkaline) solution is tested either it can be uniformly mixed with water in the entire tank. This test was important to estimate the correct positioning of the pH sensor. After 60 seconds, the pH value of the water was measured through an eight different position as shown in Figure 1. The same procedure is repeated for the alkaline solution.

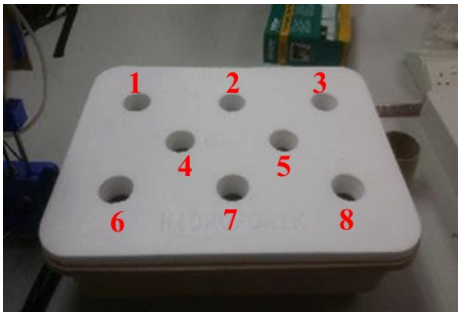

Fig. 1. Eight different pH sensor position for pH measurement

IV. Experimental Results and Analysis

In this section, all the results attained based on the four experimental conducted are reported and discussed.

A. Effect of Acid and Alkaline to the pH Values of Water

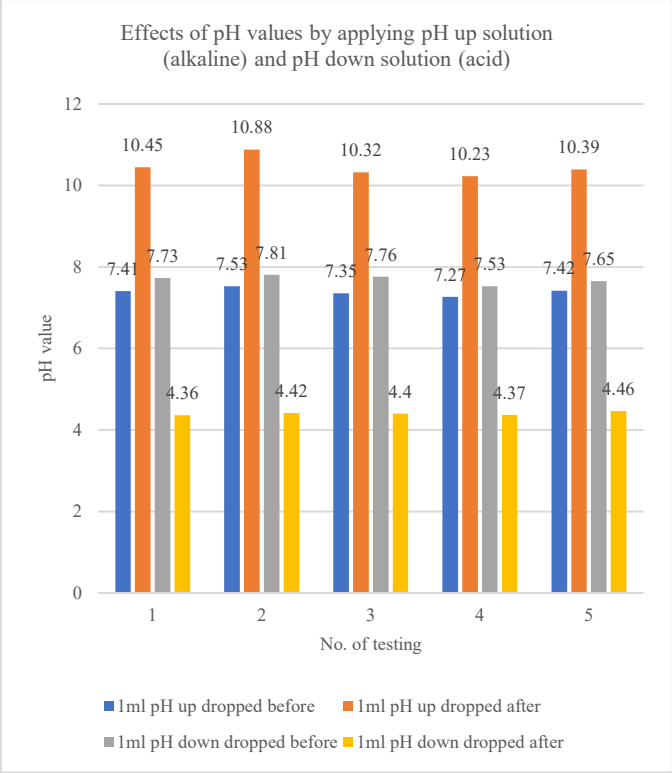

Fig. 2. Results of pH values by applying pH up solution (alkaline) and pH down solution (acid)

Figure 2 showed the increment and decrement of pH value water for each 1ml pH up solution (alkaline), and 1ml pH down solution (acid) dropped into the 3000ml water. The testing for pH up and pH down was conducted separately. The pH value increased consistently for every 1ml pH up dripped. This step was repeated for five times. The same procedure was repeated using an acid solution too. As shown in Figure 2, the average pH value difference for before and after dropped pH up and pH down was about pH 3.06 and 3.29.

From the results attained for both acid and alkaline, it showed that there were changes in pH value. Recall that, to control the specific acceptable range of pH level needed by the plants, a precise amount of acid or alkaline is required. The accurate amount of pH solutions (acid or alkaline) are difficult to calculate by adding 1ml since it caused substantial changes in pH value. Therefore, another experiment namely investigating the effect of acid and alkaline occurrences versus time is done and further observe if pH values will change gradually upon adding more pH solutions.

B. Effect of Acid and Alkaline to the pH Values of Water In Tank Versus Time

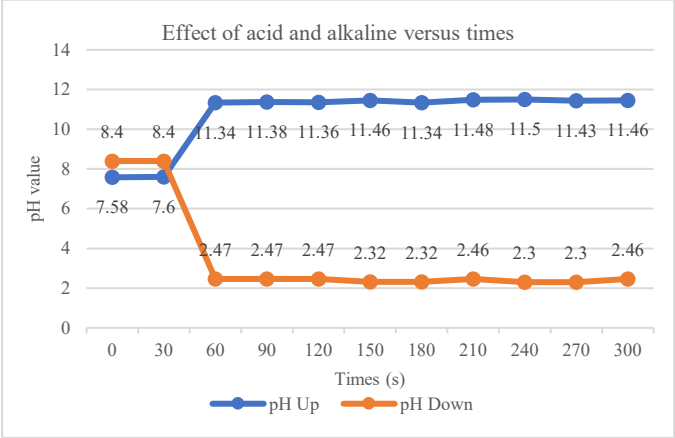

Fig. 3. Water pH value for both acid and alkaline case versus time

Figure 3 showed the pH value recorded from 30 seconds up to 300 seconds. Based on the results attained, it was found that by adding the 1ml alkaline solution to the water has increased the pH value to 11.34 after 60 seconds. Also, the pH value gradually increased to 11.46 until 300 seconds. Refer to the plot in figure 3, it is observed that the pH value changed minimally for every 30 seconds and this proven that water was fully reacting with hydroxyl ion. As for the second test for the case of acidic, a 1ml acid solution is added by reducing the amount of acid. After 60 seconds, the water pH value was at 2.47. It can be seen the pH value changes minimally too up to 300 seconds. Hence, from this result, the pH value is consistent after 60 seconds for both acid or alkaline. Therefore, this is a suitable time to begin the measurement of pH value.

C. Effect of pH Value in Water Versus Time by Gradually Increasing the Amount of Acid and Alkaline

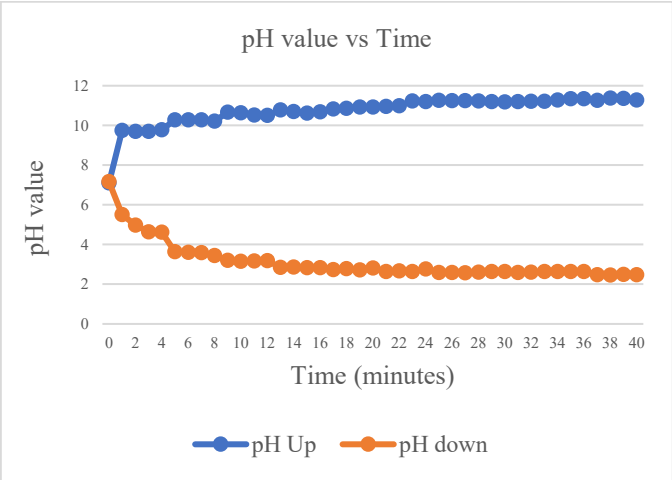

Fig. 4. Increment and decrement pattern of pH value against time

Figure 4 showed an increment and decrement of pH values for 40 minutes after a total of 10ml pH up solution (alkaline), and pH down solution (acid) applied. After 4 minutes of adding 1ml of alkaline, the pH value has increased drastically to 9.77. The pH value continues increasing to 10.27 after another 1ml alkaline at the fifth minutes.

Further, it is observed that very minimal value of pH is increased at a small pace after the alkaline is added up to 6ml, specifically six times of 1ml dropped in the water. After the next 1ml of alkaline was added, the pH value showed a constant value, and this pattern remains the same until the tenth 1ml alkaline. Overall, a total of 10ml were added. Figure 3 also showed that the decrement pattern of pH value after the total 10ml acid (pH down) was dripped. Overall the pH value of water decreased from 7.16 to 2.48 after 40 minutes with a total of 10ml acid added.

Refer to figure 4; it is observed that the pH value showed a constant pattern after 4 minutes of adding alkaline or acid solution. This can be seen based on graph plotted from 0 to 300 seconds. This showed that acid and alkaline had been absorbing by the water. Figure 4 also showed that the pH value of the water was almost constant at a value of 14 as most alkaline and value 0 as most acid. This is because the water was maximized with the acid or alkaline, and it can be neutral by adding water. Also, the alkaline pH water can be neutral again by adding an acid solution to the water and vice versa.

D. Determine the Accurate Position for pH Sensor in A Tank

The correct position of pH sensor in the water tank is vital to measure precise pH value. Therefore, eight different locations of pH sensor have been tested for this purpose, and the result shown in figure 5.

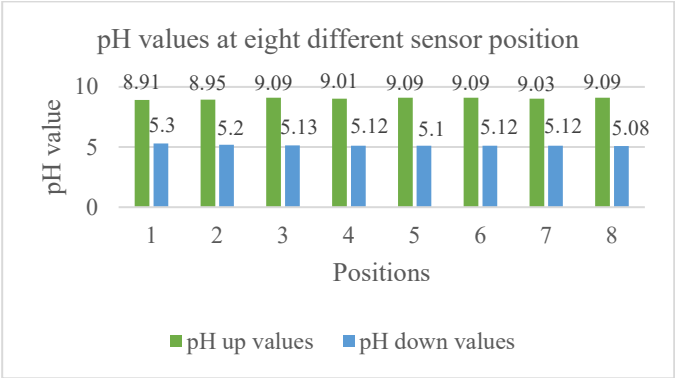

Fig. 5. Increment and decrement pattern of pH value against time

Figure 5 showed the pH value measured at eight difference position upon adding of alkaline solution. From figure 5, the lowest pH value after adding of alkaline was 8.91 at position 1 with the highest value 9.09 in position 3, 5, 6, and 8. The difference between the lowest and highest pH values were 0.18 that indicated the alkaline was successfully absorbed with water if mixed it properly.

Figure 5 also showed that the pH value measured at eight difference position after an acid solution applied to the water. From figure 5, the lowest pH value was 5.08 in position 8, and the highest was 5.3 in position 1. Once again, it found that the difference between the lowest and highest pH value was only 0.22, which mean that the acid was also successfully absorbed by water upon proper mixing. This result proved that the pH sensor could be placed at any position in the tank since the water pH values are similar upon proper mixing using both acid and alkaline.

Based on the experimental and testing conducted as discussed in section IV, results attained proven that water reacted upon adding acid and alkaline solution. The pH value of water decreased after mixed with acid and increased upon mixed with alkaline, as also discussed by L.Bousset et al. [21].

V. CONCLUSION

As a conclusion, from the experiments conducted and results attained, the pH value changed drastically after the acid or alkaline solution added to the water. However, upon continuously adding a solution of either acid or alkaline for four minutes and above, the pH value changed minimally and reached the consistency value accordingly. Additionally, based on the experiments done, it can be concluded that the pH sensor able to place at any position in the main water tank due to similar results attained. The results showed that this is an important study regarding the effect of acid and alkaline for hydroponic cultivation technique because of any changes in pH value would affect the plant growing ability. For future works, real-time data about acid and alkaline effect to grow a plant are needed to analyse to obtain better pH characteristics accuracy.

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REFERENCES

[1] R. da Silva Cuba Carvalho, R. G. Bastos, and C. F. Souza, "Influence of the use of wastewater on nutrient absorption and production of lettuce grown in a hydroponic system," *Agricultural Water Management,* vol. 203, pp. 311-321, 2018/04/30/ 2018.

[2] S. Lee and J. Lee, "Beneficial bacteria and fungi in hydroponic systems: Types and characteristics of hydroponic food production methods," *Scientia Horticulturae,* vol. 195, pp. 206-215, 2015/11/12/ 2015.

[3] Y. Takeuchi, "3D Printable Hydroponics: A Digital Fabrication Pipeline for Soilless Plant Cultivation," *IEEE Access,* vol. 7, pp. 35863-35873, 2019.

[4] T. S. Anderson, L. T. Goldstein, and M. B. Timmons, "Root nitrification capacity of lettuce plants with application to aquaponics," *Aquacultural Engineering,* p. 101997, 2019/06/28/ 2019.

[5] K. Roberto, *How To Hydroponics*: Future Garden Inc 2003.

[6] R. Vidhya and K. Valarmathi, "Survey on Automatic Monitoring of Hydroponics Farms Using IoT," in *2018 3rd International Conference on Communication and Electronics Systems (ICCES)*, 2018, pp. 125-128.

[7] R. W. Dickson, P. R. Fisher, W. R. Argo, D. J. Jacques, J. B. Sartain, L. E. Trenholm*, et al.*, "Solution Ammonium: Nitrate ratio and cation/anion uptake affect acidity or basicity with floriculture species in hydroponics," *Scientia Horticulturae,* vol. 200, pp. 36-44, 2016/03/08/ 2016.

[8] B.Bugbee, "Nutrient Management in Recirculating Hydroponic Culture," *Proceedings of the South Pacific Soilless Culture Conference,* pp. 99-112, 2003.

[9] V. Aparna, "Development of automated pH monitoring & control system through USB Data Acquisition," in *2014 6th IEEE Power India International Conference (PIICON)*, 2014, pp. 1-6.

[10] T. P. Robinson and G. Metternicht, "Testing the performance of spatial interpolation techniques for mapping soil properties," *Computers and Electronics in Agriculture,* vol. 50, pp. 97-108, 2006/02/01/ 2006.

[11] T. Kaewwiset and T. Yooyativong, "Electrical conductivity and pH adjusting system for hydroponics by using linear regression," in *2017 14th International Conference on Electrical Engineering/Electronics, Computer, Telecommunications and Information Technology (ECTI-CON)*, 2017, pp. 761-764.

[12] A. Phutthisathian, N. Pantasen, and N. Maneerat, "Ontology-Based Nutrient Solution Control System for Hydroponics," in *2011 First International Conference on Instrumentation, Measurement, Computer, Communication and Control*, 2011, pp. 258-261.

[13] Helmy, M. G. Mahaidayu, A. Nursyahid, T. A. Setyawan, and A. Hasan, "Nutrient Film Technique (NFT) hydroponic monitoring system based on wireless sensor network," in *2017 IEEE International Conference on Communication, Networks and Satellite (Comnetsat)*, 2017, pp. 81-84.

[14] N. Crespo-Mendes, A. Laurent, H. H. Bruun, and M. Z. Hauschild, "Relationships between plant species richness and soil pH at the level of biome and ecoregion in Brazil," *Ecological Indicators,* vol. 98, pp. 266-275, 2019/03/01/ 2019.

[15] O. Belmehdi, A. El Harsal, M. Benmoussi, Y. Laghmouchi, N. Skali Senhaji, and J. Abrini, "Effect of light, temperature, salt stress and pH on seed germination of medicinal plant Origanum elongatum (Bonnet) Emb. & Maire," *Biocatalysis and Agricultural Biotechnology,* vol. 16, pp. 126-131, 2018/10/01/ 2018.

[16] Y. Zou, Z. Hu, J. Zhang, H. Xie, C. Guimbaud, and Y. Fang, "Effects of pH on nitrogen transformations in media-based aquaponics," *Bioresource Technology,* vol. 210, pp. 81-87, 2016/06/01/ 2016.

[17] G. G. Kafle, D. J. Midmore, and R. Gautam, "Effect of nutrient omission and pH on the biomass and concentration and content of steviol glycosides in stevia (Stevia rebaudiana (Bertoni) Bertoni) under hydroponic conditions," *Journal of Applied Research on Medicinal and Aromatic Plants,* vol. 7, pp. 136-142, 2017/12/01/ 2017.

[18] N. H. S. Abdullah, M. N. Karsiti, and R. Ibrahim, "A review of pH neutralization process control," in *2012 4th International Conference on Intelligent and Advanced Systems (ICIAS2012)*, 2012, pp. 594-598.

[19] R. Izumi, A. Ono, H. Ishizuka, K. Terao, H. Takao, T. Kobayashi*, et al.*, "Biological information (pH/EC) sensor device for quantitatively monitoring plant health conditions," in *2017 IEEE SENSORS*, 2017, pp. 1-3.

[20] B. Siregar, S. Efendi, H. Pranoto, R. Ginting, U. Andayani, and F. Fahmi, "Remote monitoring system for hydroponic planting media," in *2017 International Conference on ICT For Smart Society (ICISS)*, 2017, pp. 1-6.

[21] L. Bousset, M. Ermel, B. Soglonou, and O. Husson, "A method to measure redox potential (Eh) and pH in agar media and plants shows that fungal growth is affected by and affects pH and Eh," *Fungal Biology,* vol. 123, pp. 117-124, 2019/02/01/ 2019.