Automatic Control of Electrical Conductivity and PH Using Fuzzy Logic for Hydroponics System

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Abstract— **Hydroponics is the method of growing plants without soil. A mineral nutrient is given to plants by using water solvent only. The important factor in this method is the control of the Electrical Conductivity (EC) and pH values at the appropriate level through whole planting time. However, the control of these two parameters requires skill and knowledge to avoid wasting resources such as labor and nutrient. This paper proposed the application of fuzzy logic control for automatically controlling the EC and pH values in Hydroponics Planting. Fuzzy logic is applied to decide on the adjusting nutrient and pH in steads of the classical rules. The proposed method has experimented in the DRFT hydroponics greenhouse with the planting of green oak lettuce. The results show that a system based on fuzzy logic control can efficiently adjust EC and pH value for helping the growth of plants. In addition, the system also reduces the waste of resources.**

Keywords— Fuzzy Logic; Hydroponics; EC; pH; Green oak

I. INTRODUCTION

Hydroponics system is becoming increasingly popular in many countries in the recent years. Due to a closed system that can regulate the number of chemicals used for control growth and protect against pests. So, the yield comes with a high quality and look tasty. The hydroponics system uses a water-based recirculation system that contains essential nutrients for plant growth. Important parameters are conductivity (EC) and pH values which must be controlled within the optimal range for plant growth and the type of plant at all times. This requires skills and experience of the farmer to adjust these parameters for preservation quality of the crop, residue of chemicals and resource consumption. There are many researchers propose the automatic computer system for controlling of pH and nutrient uptake of hydroponics plants. These systems use the concept of the Internet of Things (IoT) technologies to construct the plant nutrient monitor and control devices and the artificial intelligence software to support a decision making for adjusting a suitable parameter for plant growth. All parameters in the crop area are always measured using sensing network and a user can access these data through the Internet. When the system determines that some parameters need to be adjusted, such as pH value is higher or EC is lower than the appropriate range, the system will response through the addition of Acid or nutrient in the growing area. Most response decisions are based on the concept of expert system, often in form of the conditional rules. In this paper, the fuzzy logic is applied in the decision to adjust the EC and pH values instead of using the traditional condition rules. This proposed method has experimented with 40 of green oak salad planted in a crop field that wide 1x2 meters in 4 weeks of growth. The experiment evaluate the time taken to adjust two nutrient parameters from the measured value to the appropriate range. The adjustment time is compared with the manual adjustments, the results show that fuzzy logic can be used to adjust pH and EC value to the appropriate range faster than the manual adjustments. It can be concluded that the nutrient control for Hydroponics with fuzzy logic control is suitable for planting green oak. In addition, the growth of plants is similar to self-cultivation but the fuzzy logic based system can effectively reduce the cost of nutrients.

II. LITERATURE REVIEW

A. Hydroponic

Hydroponic is planting cultivation that uses water and without use soil. Dynamic Root Floating Technique (DRFT) system is one of the categories of cultivation hydroponic. DRFT system constantly flows nutrient dissolved in the water used in the planting crops to provide nutrient solutions, through the plant root at a constant depth in the planting tray. This nutrition flows in the tray through plant root and therefore returns to the mixing tank, so on in this study, the system implemented in agriculture with hydroponic DRFT model shown in Fig.1.

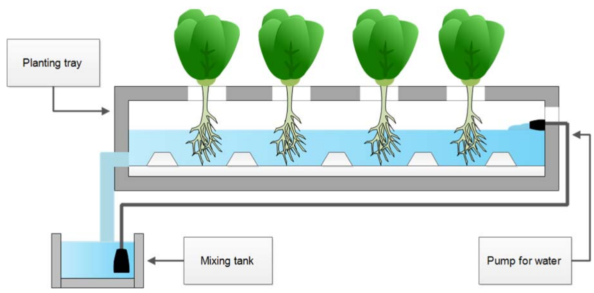


Fig. 1 Dynamic Root Floating Technique (DRFT)

B. Estimate EC and pH

Basically, the hydroponic system uses water to circulate the nutrient solution to the plants. The most commonly used of nutrient solution or fertilizer for hydroponics are Stock A and Stock B solution. The hydroponics fertilizer in this research is the formulated solution produced from the Royal Project Foundation. These solutions are suitable for small cultivation or in the researches. The fertilizer need to be mixed between hydroponics Stock A and Stock B. The ratio between Stock A and B is one-to-one. Then mixed fertilizer is filled in the 120 liters of water. The mixed fertilizer has to be filled every 3 days to maintain the level of concentration of nutrients in the planting tray. For the nutrient solution in a mixed system, stock A and Stock B are continuously controlled to suit the absorption of plants. Stock A and Stock B must be mixed together at the appropriate concentration for each crop. The stock A and Stock B combination with mixing water are generally referred as the nutrient solution. The researchers about the nutrient solution for plants found in literature as follows.

The relationship between Electrical conductivity (EC) and pH of the hydroponic nutrient solution is investigate in [1][5]. The mathematical equations of the relationship are also generated for parameter adjustment by using linear regression analysis with the EC and pH values. In the experiment, the green oak data was used to determine the EC and pH goals in the equation to adjust. In [1] have found that the nitric acid used in the pH-adjusting process has the effect on the EC value. The researchers then designed to adjust the EC value before adjusting the pH value since the EC is the indicator of the nutrient. Plant fertilizer in the mixing tank, adjust the nutrient solution by calculating the EC and pH equation and manually fill in milliliter (ml.).

The study in [2] uses fuzzy logic to control the EC and pH conditions of a NFT-based hydroponic system based on the concept of Internet environment of things (IoT). The experiment is based on a proportional small-scale process consisting of a control tank 4 tanks (nutrient stock A, nutrient stock B, acid solution, and alkaline solution) and a mixing tank with adjustable flow pump using 12 obscure logic rules. The EC and pH rules will remain in the defined range. Based on the specified input range. The time needed to recover the EC and the pH from the outside to the range is about 15 minutes.

The research in [3] proposed that the pH level in the water solution can be automatically monitored and controlled by the microcontroller and measured by the sensors. If the pH level begins to change, then the system will adjust the pH level to the suitable solution. For DWC (Deep Water Culture) Hydroponics system, water solution from DWC container is transferred to the main tank to measure the pH level with the sensor and make adjustments if necessary and then move back to the main tank. Deep water tank to grow the plant. There are six steps for this approach: study details, hardware identification, software identification, hardware and software connections, data collection and analysis and resolution.

In addition, [4] proposed the method that aims to use EC and pH control systems in automatic containers. Automatic control system received the signals from microcontrollers. For microcontrollers, the pH and EC regression equations was applied to the effect of the reservoir to increase the EC or pH in the same direction. In EC and pH adjusting equations, three variables were used. Measure the EC or pH (input) and volume of A & B solution or nitric acid. The test results show that the system using EC adjusting equates to more than 80.8% EC accuracy. The pH equation can control more than 95% accuracy.

III. SYSTEM DESIGN

A. Nutrient solution control system

The nutrient solution control system consists of four part controls.

- Solution 1 that drain alkaline (pH up) to increase pH
- Solution 2 that drain acid (pH down) to decrease pH
- Solution 3 that drain Stock A to increase EC
- Solution 4 that drain Stock B to increase EC

Hydroponics system designed in this study uses pH sensors and EC sensors which connect to the data processing system and can display information based on concept of IoT system.

B. Fuzzy Logic Control Method

Fuzzy logic is the one of approximation techniques. This is different from rational rule. Application of fuzzy logic is used to simulate a knowledge or an experience of experts by using a reason or decision on human circumstances. This can be written in the linguistic form of the normative system to simulate expert judgment on complex problems. Fuzzy logic implementation to apply and control the computer system by using some conditions to control the system. To analyze the nutrient uptake of plants [6]. Shown in Fig.2.

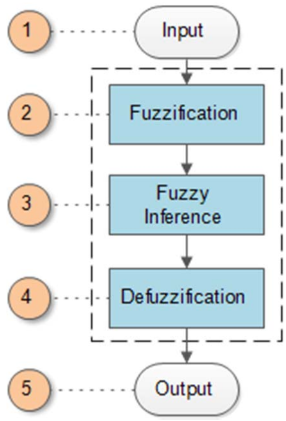


Fig. 2 Fuzzy Logic Control

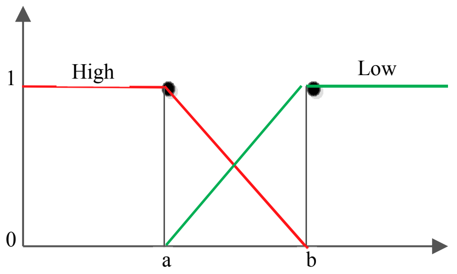
Fig. 2 Show steps of the application of fuzzy logic control consists of:

1. The first step is to determine the variables involved in the process to be defined and to function fuzzification. In this case, there are six variables to simulate.

- Input variable: pH and EC
- Output variable: solution 1, solution 2, solution 3 and solution 4.

2. The second step (Fuzzification) performs a mapping procedure to fill in the ambiguity set presented in the form's membership function. Purpose of fuzzification is getting a membership level. Calculate the membership value for the following functions (μ) for input variables and output variables.

- PH Acid (x) consists of two linguistic values, namely: high and low. The membership functions are as follows:

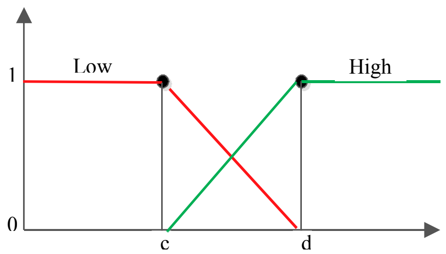


Value degree of membership:

$$\mu phAcid_{High}(x) = \begin{cases} 1, & x < a \\ \frac{b-x}{b-a}, & a \leq x \leq b \\ 0, & x \geq b \end{cases} \quad (1)$$

$$\mu_{phAcid\_Low}(x) = \begin{cases} 1, & x \geq b \\ \frac{x-a}{b-a}, & a \leq x \leq b \\ 0, & x \leq a \end{cases} \quad (2)$$

- PH Alkaline (x) consists of two linguistic values, namely: low and high. The membership functions are as follows:

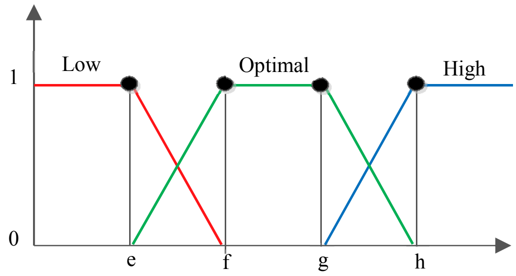


Value degree of membership:

$$\mu_{phAlkaline\_High}(x) = \begin{cases} 1, & x \leq c \\ \frac{d-x}{d-a}, & c \leq x \leq d \\ 0, & x \geq d \end{cases} \quad (3)$$

$$\mu_{phAlkaline\_Low}(x) = \begin{cases} 1, & x \leq c \\ \frac{d-x}{d-c}, & a \leq x \leq d \\ 0, & x \leq d \end{cases} \quad (4)$$

- EC (x), consist of three linguistic values, namely: Low, Optimal and High. The membership functions are as follows:



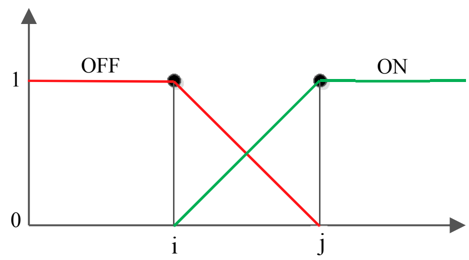
Value degree of membership:

$$\mu_{EC\_Low}(x) = \begin{cases} 1, & x \leq e \\ \frac{f-x}{f-e}, & e \leq x \leq f \\ 0, & x \geq f \end{cases} \quad (5)$$

$$\mu_{EC\_Optimal}(x) = \begin{cases} 0, & x \leq e \text{ and } x \geq h \\ \frac{x-e}{f-e}, & e \leq x \leq f \\ 1, & f \leq x \leq g \\ \frac{h-x}{h-g}, & g \leq x \leq h \end{cases} \quad (6)$$

$$\mu_{EC\_High}(x) = \begin{cases} 1, & x \geq h \\ \frac{d-g}{h-g}, & g \leq x \leq h \\ 0, & x \leq g \end{cases} \quad (7)$$

- Solution 1 (z), Solution 2 (z), Solution 3 (z), Solution 4 (z) each consists of two language values, OFF and ON. The membership functions are as follows:



Value degree of membership:

$$\mu_{solution\_OFF}(z) = \begin{cases} 1, & z \leq i \\ \frac{j-z}{j-i}, & i \leq z \leq j \\ 0, & z \geq j \end{cases} \quad (8)$$

$$\mu_{solution_{ON}}(z) = \begin{cases} 1, & z \geq j \\ \frac{z-i}{j-i}, & i \leq z \leq j \\ 0, & z \geq i \end{cases} \quad (9)$$

3. The third step (Fuzzy Inference Engine) is set rules fuzzy in solution variable value for each rule fuzzy. The following rule-based in this system :

TABLE I. TABLE FUZZY RULES

The first rules	
Acid High	Acid Low
IF PH Acid High AND EC Low **THEN** Solution 1/ON ,3/ON ,4/ON	**IF** PH Acid Low AND EC Low **THEN** Solution 1/OFF ,3/ON ,4/ON
IF PH Acid High AND EC Optimal **THEN** Solution 1/ON ,3/OFF ,4/OFF	**IF** PH Acid Low AND EC Optimal **THEN** Solution 1/OFF ,3/OFF ,4/OFF
IF PH Acid High AND EC High **THEN** Solution 1/ON ,3/OFF ,4/OFF	**IF** PH Acid Low AND EC High **THEN** Solution 1/OFF ,3/OFF ,4/OFF
The second rules	
Alkaline Low	Alkaline High
IF PH Alkaline Low AND EC Low **THEN** Solution 2/OFF ,3/ON ,4/ON	**IF** PH Alkaline High AND EC Low **THEN** Solution 2/ON ,3/ON ,4/ON
IF PH Alkaline Low AND EC Optimal **THEN** Solution 2/OFF ,3/OFF ,4/OFF	**IF** PH Alkaline High AND EC Optimal **THEN** Solution 2/ON ,3/OFF ,4/OFF
IF PH Alkaline Low AND EC High **THEN** Solution 2/OFF ,3/OFF ,4/OFF	**IF** PH Alkaline High AND EC High **THEN** Solution 2/ON ,3/OFF ,4/OFF

4. The fourth step (Defuzzification) converts fuzzy sets into a number. The method used in defuzzification process is a weighted average. Calculate crisp vale Y using the following formula:

$$\text{Activation action} \quad (Y) = \frac{\sum \mu_x y_x}{\sum \mu_x} \qquad (10)$$

IV. RESULTS AND CONCLUSION

A. Test adjusting equation.

This research measures the EC and pH values for planting green oak salad. To experiments tree type of adjustment:

- Experiment 1 manually EC adjustment only for planting green oak salad. For the suitable range value of 1.8 - 1.9, add A & B solution in the nutrient mixing tank.
- Experiment 2 manually PH adjustment only for planting green oak salad. For the suitable range value of 5.5 - 6.5, add nitric acid to the nutrient tank and focus on EC changes.
- Experiment 3 adjustment both EC and pH simultaneously. This process uses both EC equation and the pH equation for the application of fuzzy logic proposed in this study.

B. Hydroponics system

This experiment used hydroponics greenhouses planted with DRFT (Dynamic Root Floating Technique), which have developed to suit the country in Thailand by increasing air circulation and nutrient solution of plants. The greenhouse has size 1x2 m for 40 early thatched roofs with a transparent plastic to make it resistant to UV rays of sunlight and lateral coverd for insect protection. Moreover, the water system is a closed system, the system that is widely favor in Thailand, where water levels that flow through the plant roots are quite deep, is about 1-10 cm so that the water flows through the roots and increase the amount of air by crops root. This research study crops grown of green oak salad. Fig 3. shows the DRFT hydroponics greenhouse for experiment in this research which can control three essential nutrients (Acid, Alkaline, and Mixed Stock A+B).

Fig. 3 Hydroponics greenhouse for Experimental (DRFT)

C. Experiment Results

Table 1. Shows an example of the adjustment in Experiment 3, the implementation of the fuzzy logic algorithm in the program can adjust pH and EC. The results shows that the fuzzy logic with 12 rules can control parameter to the optimal value by deciding turn on or off four solutions.

TABLE II. THE TESTING RESULTS

No.	Current Value pH	Set Range pH	Action (Output)	Current Value EC	Set Range EC	Action (Output)	Time (Second)
1	7.9	5.5-6.5	Solution 2 ON	0.31	1.8-1.9	Solution 3,4 ON	10
2	7.4	5.5-6.5	Solution 2 ON	0.57	1.8-1.9	Solution 3,4 ON	10
3	6.9	5.5-6.5	Solution 2 ON	0.74	1.8-1.9	Solution 3,4 ON	10
4	6.7	5.5-6.5	Solution 2 ON	0.98	1.8-1.9	Solution 3,4 ON	10
5	6.2	5.5-6.5	Solution 1,2 OFF	1.43	1.8-1.9	Solution 3,4 ON	10
6	5.7	5.5-6.5	Solution 1,2 OFF	1.57	1.8-1.9	Solution 3,4 ON	10
7	4.8	5.5-6.5	Solution 1 ON	1.84	1.8-1.9	Solution 3,4 OFF	10
8	3.5	5.5-6.5	Solution 1 ON	1.89	1.8-1.9	Solution 3,4 OFF	10
9	3.1	5.5-6.5	Solution 1 ON	1.94	1.8-1.9	Solution 3,4 OFF	10
10	2.8	5.5-6.5	Solution 1 ON	2	1.8-1.9	Solution 3,4 OFF	10

Next, the performance of the fuzzy logic control method for nutrient adjustment is compared to two traditional methods as the baseline methods. The performance of each method is measured by the amount of nutrients filled in the mixing tank, which affects the PH and EC values. Two traditional methods are as follows:

1. Solution control by the farmer who is inexperienced and has no basic knowledge in cultivation.

2. Solution control by the expert who understands the principles of fertilizer and cultivation.

By controlling the nutrients in the same system, the experimental results demonstrate the change of PH and EC value changing with respect to time as show in Fig. 4 and Fig. 5.

Both figure are set the time as the x-axis and the y-axis are assigned to pH and EC. The dotted line displays the appropriate range for the crop. For example, the optimum pH range is 5.5-6.5 and the optimal EC range is 1.8-1.9. More time has shown that more nutrients are needed in the mixing tank.

Depends on the experiment, adding alkaline into a mixing tank with 120 liters of water can increase the pH to ± 0.5 and by adding 5 ml of pH down solution can reduce the pH to ± 0.1 while for the EC by adding 50 ml of a solution. And a 50 ml of a solution in a 120 liters water tank can increase EC ± 0.05. The increases or decreases pH is directly proportional to the pump activation time as well as the EC parameter. The pH value increases or decreases. It's more than a long response time. The process input the acid or alkaline is required and the EC value need such process as well. In order to control the solution in the suitable pH range, both traditional controls use about 100 minutes. But fuzzy logic control can overcome by uses only 60 minutes. For the suitable EC range, the fuzzy logic control also shows the best result. It spends about 100 minutes while both baseline methods spend about 105 minutes. It can be said that the fuzzy logic control can reduces resources (Acids, Alkaline, and mixed Stock A+B) and also reduces labor for fertilization

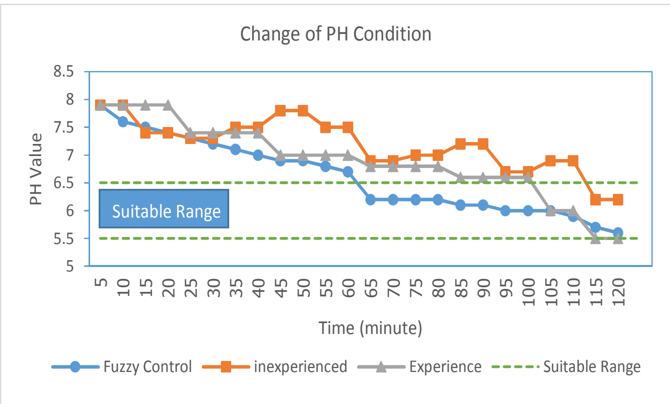


Fig. 4 Time Comparison of Adjustment PH

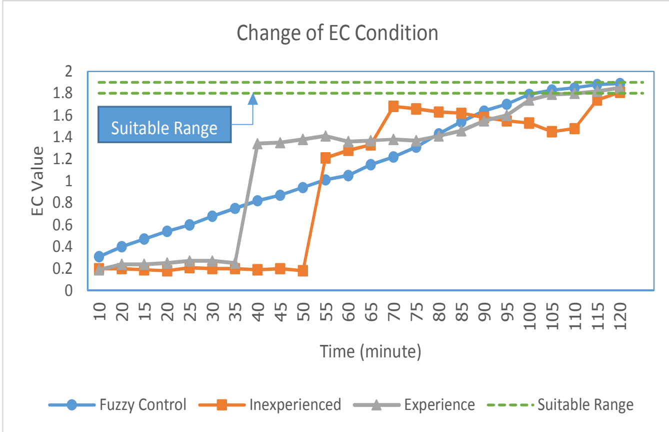


Fig. 5 Time Comparison of Adjustment EC

The performance of the proposed system is investigated. The observation focuses on the response time that occurs when the pH and the EC value are reached. The sensor reads the current pH and EC for 10 minutes to obtain a more stable reading. It will be seen that the non-professional will spend the longest time. And the experts have reduced the time. But fuzzy logic can be adjusted the fastest obviously. The less time-consuming step has the effect of reducing the amount of substance used, which can reduce the amount of the nutrient solution by almost two times. This result has a positive effect on the growth of the green oak tree as follows.

Figure 6. Shows the growth rate of green oak salad. It shows the average number of leaves and the height of the stem. The rate of increase of leaves is shown in the left y-axis and the height of the stem is shown in the y-axis right and the planting time is in the x-axis over a period of 6 weeks. Both graph line increase all the planting time, in figure 6. Shows that the nutrient control is appropriate for the green oak.

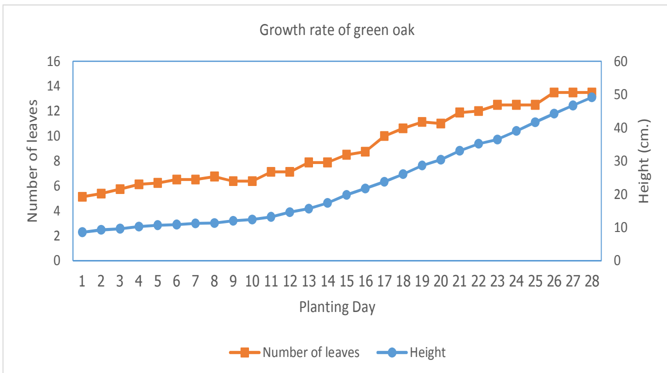


Fig. 6 Growth rate of green oak

V. CONCLUSION

This research introduces an expert system for the concept of hydroponic control. The fuzzy logic control is used in the decision-making process of pH and EC, which can work well for humans. This experiment adjusts the pH and EC to the optimum range for green oaks. The results show that the use of fuzzy logic control can better control the adding nutrients to plants. Reduce the amount of nutrient solution and reduce the workload. So the system can be used for complete hydroponic control. For further research, it is the exploration the range of controlling the amount of solution which is suitable for each plant. More over the studies of appling the approach to control the growth rate and the impact of the process are also ongoing.

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