DEVELOPMENT OF A pH CONTROL SYSTEM FOR NUTRIENT SOLUTION IN EBB AND FLOW HYDROPONIC CULTURE BASED ON FUZZY LOGIC

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Abstract : This paper outlines the development of a fuzzy-based control system for maintaining a proper acidity (pH) level of nutrient solution in ebb and flow hydroponic cultures. The nutrient solution pH is kept at a desired set point by controlling two valves: (1) **acid valve** (to control the addition of acid solution necessary) and (2) **base valve** (to control the addition of base solution necessary). The control algorithm has been developed based on membership functions of fuzzy set. In order to get smoothness, the fuzzy rules have twenty-one linguistic statement which are determined by methods of trials and errors using the membership functions based on the skilled operator's experienceApplying the fuzzy logic to control the pH of the nutrient solution increased the smoothness of the pH the during control course. Performance of the control system is discussed and recommendations are provided for future work.

Keywords : Hydroponics automation; ebb and flow system; nutrient solution; pH control; fuzzy logic controller.

1. INTRODUCTION

Ebb and flow hydroponic culture is a common practice in mass production of potted flower plants such as Chrysanthemum. In such a hydroponic culture, the nutrient solution flows into and fill the cultivation bench until a certain level, 5 – 10 cm from pot base. It remains ebb the plant growth media in a period of time, before it then flows back into the tank. During dry period, the plant roots absorb oxygen from air.

The parameters of the nutrient solution need to be controlled, among others are temperature, pH, and Electric Conductivity (EC). Various systems for controlling the temperature of nutrient solution have been developed. Yet, the control systems for pH and EC of a nutrient solution so far have not been developed even though they are very influencing factors on crop growth. The pH value can determine whether or not the crop easily absorbs the elements of the nutrient. In general, crop easily absorbs nutrient element at neutral level of pH (Sarwono Hardjowigeno, 1987). The suitable pH values for crop growth range from 6 to 7. Too high value of pH (above 9) or too low value (less than 4) is toxic for crop roots.

The pH value of a nutrient solution usually changes easily because of ion absorption by crop roots, CO_2 hydrolysis, and loosing of H^+ that tends to increase the number of the cation (Ponnanperuma, 1966; Mugwire, 1977; Bangerth, 1979 in Morimoto and Hashimoto, 1991). As a result, variation in pH of the nutrient solution is fully complicated.

Nevertheless, it is not easy to control the pH of the nutrient solution in NFT hydroponics system. The control process is usually characterized by complexity and fuzziness. In on-off system, it is difficult to get the accuracy of the control system. PID control could reduce the fuzziness but requires complex control system. Fuzzy logic is highly potential to deal with the complicated and fuzziness in such a biological processes. This is because of its flexible control capability.

The objective of this research was to develop a system for controlling the pH value of the nutrient solution used in potted flower cultivation such as Chrysanthemum with ebb and flow, to develop fuzzy logic control program for controlling the pH value.

2. MATERIALS AND METHODS

Figure 1 shows the schematic diagram of ebb and flow system with pH control system for nutrient solution. The culture vessel consists of six blocks, each of which containing four potted flowers. The nutrient solution flows into and fills the cultivation bench until a certain level, 5 – 10 cm from pot base. It remains ebb the plant growth media in ten minutes, before it then flows back into the tank and flows into the next block. The flow rate of the nutrition used in this experiment was 2.4 lt/min and the measuring apparatus was Hanna pH-meter of HI8710E type. Flowing 0.3 M H3PO4 and 0.4 M KOH from Marriott tube with constant debit did the solidity control. The valve used was of solenoid type with 1/8 inch in diameter. Calibration of the pH-meter was done on voltage basis using PCL-812PG interface. Flow rate calibration was also done on the Marriott tube as well as on the relay circuit.

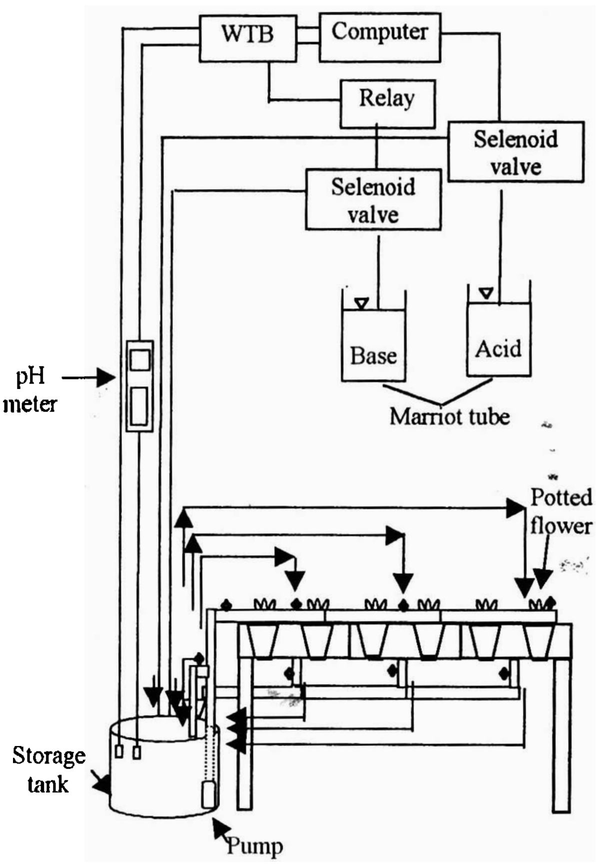

Figure 1. Schematic diagram of ebb and flow system with pH control system for nutrient solution.

The measurement result of the pH of nutrient solution was in the form of DC voltage and was transferred to shunt circuit in order to get input voltage at a range of 0 to 5 volt conforming to the working voltage of the PCL-812PG interface. This voltage became the reference digital signal for the computer to conduct data processing with control program. The output of the control action was the duration of the solenoid valve opening depended upon the input signal. The computer supplied voltage to the circuit relay that activated the solenoid valve.

Process error (E) was calculated based on the difference between the set point (Sp) and the actual pH. Positive value of E indicated that the position of the actual pH was above the Sp, and negative value of E indicated that the position of the actual was under the Sp. The error difference (dE) was the change in E to time. If the dE were positive, the error E had the tendency to increase. Conversely, if dE were negative, the error E decreased. Figure 2 shows the membership function of error and error change used in the fuzzification process.

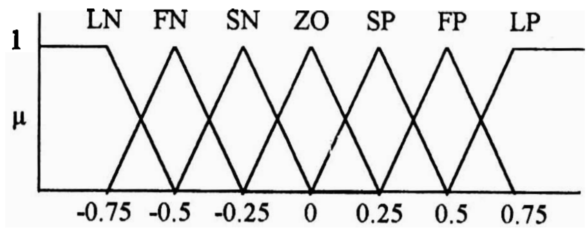

Figure 2. Membership function of error and error change.

Every numeric variable was plotted into a fuzzy system consisted of Large Positive (LP), Fair Positive (FP), and Small Positive (SP), Zero (ZO), Large Negative (LN), Fair Negative (FN), and Small Negative (SN). The control action was based on the decision matrix (Table 1) in which there are criteria of Quick Acid (QA), Fair Acid (FA), Slow Acid (SA), Neutral (ZO), Quick Base (QB), Fair Base (FB), and Slow Base (SB). The membership function of the control output is presented in Figure 3.

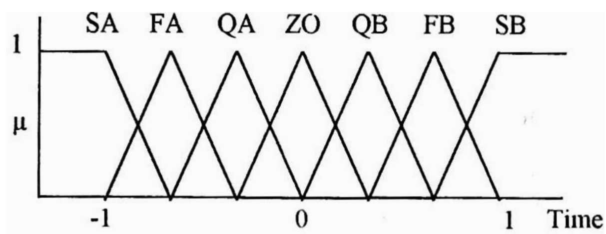

Figure 3. Membership function of output

Table 1. Decision matrix

E \ dE	NB	NS	NK	ZO	PK	PS	PB
NB	BL	BL	BL	BL	BL	BS	BS
NS	BL	BL	BL	BL	BS	BS	BC
NK	BL	BL	BL	BL	BS	BS	BC
ZO	BL	BS	BC	ZO	AC	AS	AL
PK	AC	AC	AC	AS	AS	AS	AL
PS	AC	AC	AS	AS	AS	AL	AL
PB	AC	AS	AS	AS	AL	AL	AL

Defuzzification was conducted by means of weighting to the absolute membership value from every label with the membership degree obtained. The final output of the fuzzy was the change in valve opening time, either for base tube or acid tube. The computer program for the control system was developed using the Pascal language in DOS environment.

3. IMPLEMENTATION RESULTS AND DISCUSSION

From the result of the calibration of valve opening of acid and base is known that the time required to increase the $[H^+]$ concentration was not equal to the time required to decrease it in the nutrient solution. Its need twenty-six seconds to change pH solution from 7.0 to 6.0 and a hundred seconds to increase pH from 6.0 to 7.0. That indicated that at the same period of time the ion $[H^+]$ freed by the H_3PO_4 acid was more than that of the ion $[OH^-]$ freed by the KOH base.

The supply of voltage from PCL to relay circuit resulted in "on" when the voltage reached 1.4 volt and "off" when the voltage decreased to 1.1 volt. These voltages conformed with the output voltage from the PCL-812PG having a range of 0 to +5 volts. The debit of the base and acid flows from the Marriott tube was kept constant at 1.3 cc/s for base solution and 4.3 cc/s for acid solution. The difference in the two figures was caused by the difference in the heads of the air inlet and outlet at the Marriott tubes for base and acid solutions, respectively.

In experiment, the initial pH of the solution was above the set point (6.695) and keep on moving to reach the desired set point, i.e., pH=6. The results of experiment for controlling pH of the nutrient solution in the 1st block until the 3rd block are presented in figures 4 to 6.

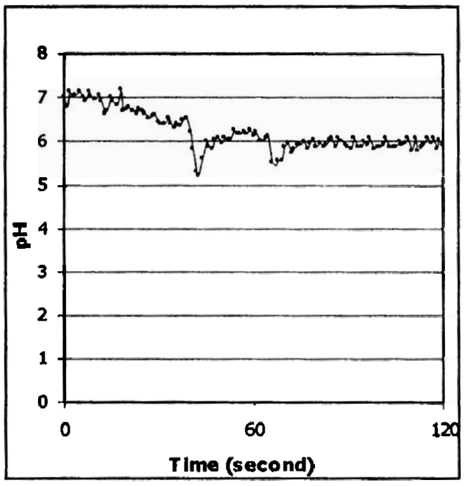

Figure 4. Graphic of pH control during the control process in first block.

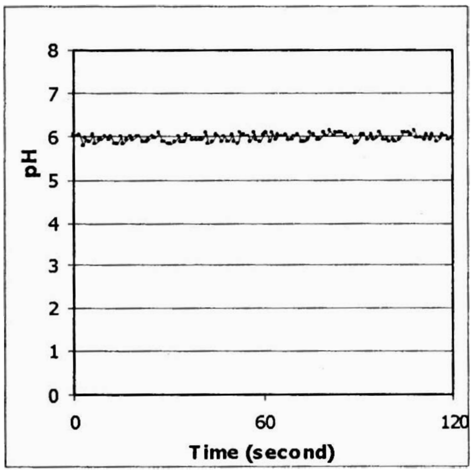

Figure 5. Graphic of pH control during the control process in second block.

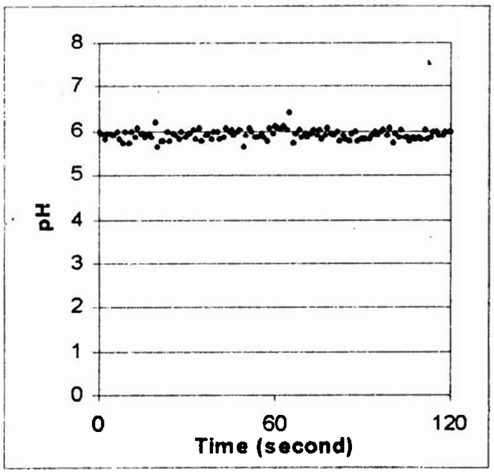

Figure 6. The result of pH control in the 3rd block.

Figure 4 shows that pH of the nutrient solution in first block can be controlled to approach the set point of pH=6. To decrease the pH toward the set point it requires 68 seconds. After reaching the set point, the pH of the solution did not change very much due to the small change in [H+] concentration.

Moreover, the straight line approaching the set point tendency of the error curve during the control indicates that the fuzzy logic control can maintain the solution pH at the set point. No overshoot occurs in this pH control. It means that the constructed decision matrix has been able to result in adequate control action.

Figure 5 and 6 shows that nutrient solution pH in second and third block can be controlled faster than in first block since in the acidity of the solution has been controlled in the 1st block before entering the 2nd and 3rd blocks. This reducing and speeding up the control process. The same phenomena occur in 3rd block and the following blocks.

Moreover, the straight line approaching the set point (Figure 4 to 6) indicates that the fuzzy logic control can maintain the solution pH at the set point. No overshoot occurs in this pH control. It means that the constructed decision matrix has been able to produce adequate control actions.

Figures 7 & 8 show the duration of the valve opening in the second minute of controlling. It can be seen from the figure that both of valves frequently open in turns since the control load is still high at the start. This frequency is decreasing at the following blocks.

4. CONCLUSION

The pH of uncontrolled nutrient solution tended to increase if used continuously. With fuzzy logic control, the solution pH could be maintained at the set point level. In the ebb and flow system, the highest control load occurs in the 1st block. Afterward, the control load in the following blocks is decreasing further.

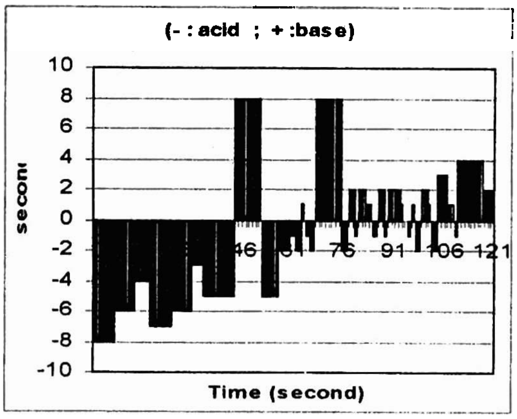

Figure 7. Duration of the valves (acid and base) opening during 120 seconds in first block.

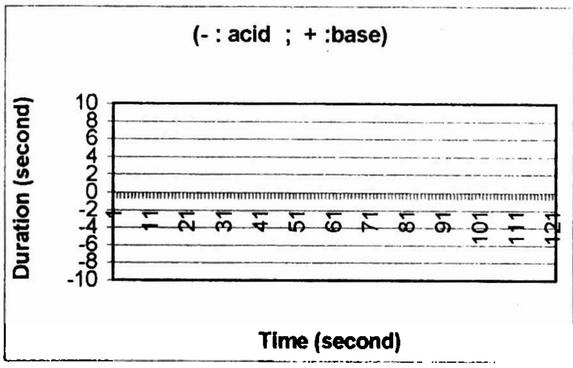

Figure 8. Duration of the valve (acid and base) opening during 120 seconds in second block.

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