Estimation of Electrical Conductivity and pH in Hydroponic Nutrient Mixing System using Linear Regression Algorithm

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Abstract

The purpose of this study was to study a relation between the electrical conductivity (EC) and the pH of the hydroponic nutrient mixing system and to find out EC and pH adjusting equation by using linear regression analysis in order to generate the mathematical equation. In the experiment use Green oak information to set EC and pH target in equation for adjusting. From the experiment researcher found the nitric acids that using in pH adjusting process has effect to increasing number of EC value from this researcher will design to adjusting EC value before adjusting pH because EC is indicator of nutrient that plant needs. In mixing tank adjust nutrient solutions by calculate from EC and pH adjusting equation and fill by manual in unit milliliter. The results of study were EC and pH adjusting equation can estimate amount to fill A & B solution in EC adjusting process, and amount of nitric acid in pH adjusting process in range of Green oak needs.

Keywords; *Hydroponics, Estimate EC and pH, Adjust EC and pH for hydroponics.*

I. Introduction

Recently, hydroponic systems have received considerable attention as a new method of growing plants without soil, using mineral nutrient solutions in a water solvent instead. The main advantages of hydroponics are shorter period of time for growth and productivity as well as less use of water and fertilizer in comparison with soil system [1]. The most widely used mineral nutrient solutions or fertilizers for hydroponics are Stock A and Stock B solutions. The former is consisted of calcium nitrate and iron chelate. The latter is composed of ammonium nitrate and some of potassium nitrate and other fertilizers. These two solutions must be separated prior to use because the formation of sediment can occur after mixing together. For mineral nutrient solutions in mixing system need always to control Stock A and Stock B solutions because it is absorbed by plant and evaporation. Stock A and Stock B need to mix in order to bring their concentrations closer together [2]. And mixing of stock A and stock B with tap water commonly called a nutrient solution.

Fertilizers of hydroponics are nutrient solutions in chemical form that contain six essential nutrients: N, P, S, K, Ca and Mg. Thereby Steiner created the concept of ionic mutual ratio which is based on the mutual ratio of anions: NO_3^- , $H_2PO_4^-$ and SO_4^{2-}, and the mutual ratio of cations K^+, Ca^{2+}, Mg^{2+}. Such a relationship is not just about the total amount of each ion in the solution, but in the quantitative relationship that keep the ions together; if improper relationship between them takes place, plant performance can be negatively affected. By measuring nutrient salt concentration or total ionic concentration of a nutrient solution, it can determine plant growth, development and production. The total amount of ions of dissolved salts in the nutrient solution exerts a force called osmotic pressure (OP). The osmotic pressure of the nutrient solution can be partially estimated by the EC value [3,4]. EC of the nutrient solution is a good indicator of the amount of available ions to the plants in the root zone [5]. The EC values for hydroponic systems range from 1.5 to 2.5 mS/cm. Higher EC hinders nutrient uptake by increasing osmotic pressure, whereas lower EC may severely affect plant health and yield [6]. It is necessary to regularly monitor nutrient solution and adjust EC concentration so that the solution is always in an appropriate range of EC for plant growth and development. The EC value decreases when nutrients are absorbed by plants. Therefore, the increase of EC can be achieved by adding nutrients into the solution. In contrast, the EC increases when water is removed from the solution through the process of evaporation and transpiration. This can be solved by adding pure water into the solution.

In hydroponic systems, plant productivity largely relies on two main factors are EC and pH values that determine nutrient uptake by plants. pH is an indicator that defines the relationship between the concentration of hydrogen [H^+] and hydroxyl [OH^-] ions. pH can be measured by pH measurement tool or pH sensor in order to specify acidity or alkalinity of the solution. The range of pH values is between 0-14. pH values below 7 exhibit acidic condition whereas pH values above 7 is considered alkaline condition. At a pH of 7, it is neither acidic nor basic, it is called neutral. The pH of a solution is significant to control the availability of the fertilizer salts in the forms that can be absorbed and utilized by plants [7].

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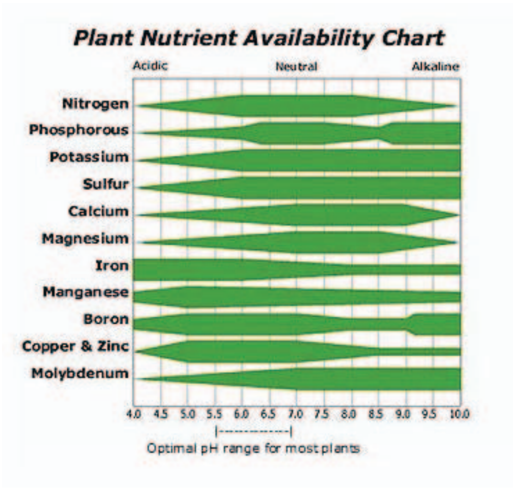

Fig. 1. Plant Nutrient Availability Chart

As shown in Fig. 1, the range of appropriate pH for most plants is ranges 5.5 to 7.0. However, different optimal pH values have been described for different species of plants. pH above or below the acceptable range can lead to nutrient deficiencies [8].

In order to increase efficiency of plant productivity, recent advanced technologies for hydroponics has been extensively developed for controlling the accurate and precise range of EC and pH of nutrient solutions. Generally, the system design to measure EC and pH by EC sensor and pH sensor in reservoir and send data to micro-controller for analysis, and are adjusted by micro-controller send command to control solenoid valves or pumps to fill solutions in next steps. Of which, artificial intelligence (AI) has been exploited as a control system capable of self-examination. Intelligent approaches are useful tools for mechanizing complex hydroponic system. Specifically, hydroponic system is designed to directly deliver nutrients solution to plant roots and continuously recirculate to reservoir for the adjustment of EC and pH process.

Linear Regression algorithm is a model to refer relation 2 variables between input and output. Linear regression is used for estimation and apply to find equation to develop in machine learning. In this research use linear regression to find equation to adjusting EC and pH of hydroponics.

In this study, researcher aimed to study a relationship between the EC and pH of the hydroponic nutrient mixing system and find out adjusting equation of EC and pH for hydroponics by using linear regression analysis, and to generate the mathematical equation.

II. Methodology

A. Design and analysis data.

Researcher use EC and pH of Green oak to design and collect data in 3 experiments are

- Experiment 1: Adjusting only EC, this experiment adjusting EC by fill A & B solution in reservoir and focus change of pH.
- Experiment 2: Adjusting only pH, this experiment adjusting pH by fill nitric acid in reservoir and focus change of EC.
- Experiment 3: Adjusting EC and pH to the EC and pH of plant. This process use the EC adjusting equation and pH adjusting equation. The equation for adjusting apply from linear regression from testing data.

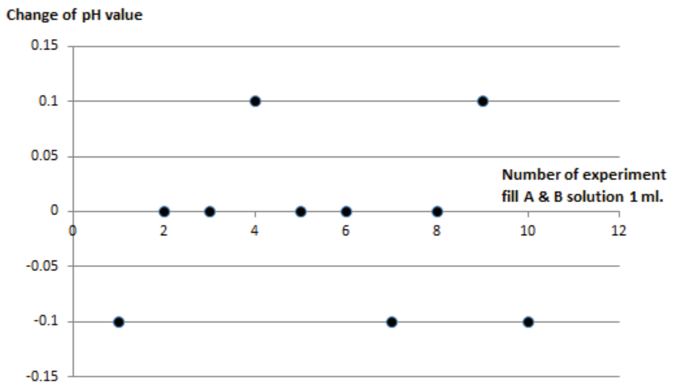

Fig. 2. pH change after the addition of increasing volume of mixed A&B.

From Fig. 2, is results from experiment 1 and present to the graph occur by fill A & B solutions in reservoir and measure pH value. This process focuses on value between change of pH and amount of A & B solution. Graph present change of pH in range 0.1 to -0.3 in opposite directions. If analyze from graph can explain amount A & B solution in this experiment not effect to pH value in one direction so change of pH might occur by pH measurement tool error.

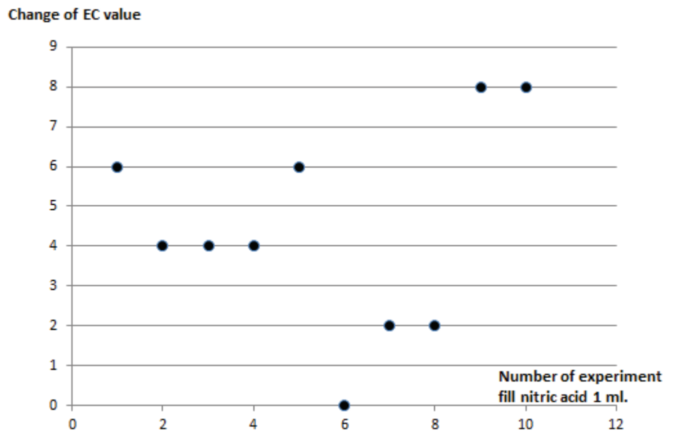

Fig. 3. EC change after the addition of increasing volume of nitric acid

From Fig. 3, is results from experiment 2 and present to the graph occur by fill nitric acid in reservoir and measure EC value. This process focuses on value between change of EC and amount of nitric acid. Graph present EC value increasing when fill nitric acid in reservoir. If analyze from graph can explain amount of nitric acid effect to EC value in same direction.

Experiment 3 before experiment researcher set data for keep data for learning data in linear regression to get EC and pH equation and keep data to testing equation.

- EC Plants in this research use EC of Green oak (range 1,200 – 1,800 $\mu S/cm$). Researcher set Min EC is 1,200 $\mu S/cm$. and Max EC is 1,800 $\mu S/cm$.
- pH Plants in this research use pH of Green oak (range 6.0 – 7.0). From this range researcher set Min pH is 6.0. and Max pH is 7.0.
- Water Volume set 10,000 milliliter.
- EC_{error} is a different between EC of plants and EC from real measurement. Find EC_{error} from this equation

$$EC_{error} = EC_{plant} - EC_{measure} \tag{1}$$

- pH_{error} is a different between pH of plants and pH from real measurement. Find pH_{error} from this equation

$$pH_{error} = pH_{plant} - pH_{measure} \tag{2}$$

B. Materials to collect data

Experiments were carried out by using

- A & B Solution for Hydroponics for adjusting EC in case EC error more than EC measure. In experiments use same amount of A & B solution follow from product description.
- Nitric acid 7% for adjusting pH in case pH error less than pH measure.
- Tap water use to control water volume and adjust EC and pH in case EC measure more than EC error and pH measure less than pH error.
- EC and pH meter

C. Linear Regression Implementation

General Linear regression equation

$$y = \beta_0 + \beta_1 x \tag{3}$$

where

y is the output of linear regression equation.

x is the input of linear regression equation.

β_0 is the y-intercept.

β_1 is the gradient.

- Find β_0 from this equation

$$\beta_0 = \frac{(\sum x^2)(\sum y) - (\sum x)(\sum xy)}{n(\sum x^2) - (\sum x)^2} \tag{4}$$

where

n is the Number of data.

- Find β_1 from this equation

$$\beta_1 = \frac{n(\sum xy) - (\sum x)(\sum y)}{n(\sum x^2) - (\sum x)^2} \tag{5}$$

- r is Correlation Coefficient use for measures the strength and the direction of a linear relationship between x and y on a relative scale -1 to 1. Find r from this equation

$$r = \frac{\sum xy - \frac{(\sum x)(\sum y)}{n}}{(S_x)(S_y)(n-1)} \tag{6}$$

where

S is the Standard Error of the Regression. Find S from

$$S_x = \sqrt{\frac{\sum x^2 - \frac{(\sum x)^2}{n}}{n-1}} \tag{7}$$

$$S_y = \sqrt{\frac{\sum y^2 - \frac{(\sum y)^2}{n}}{n-1}} \tag{8}$$

In this research use linear regression equations to apply and get 2 equations are EC adjusting equation and pH adjusting equation [9].

- Find EC adjusting equation from linear regression equation

$$Amount\ of\ A\ \&\ B = \beta_0 + \beta_1 EC_{error} \tag{9}$$

where

$Amount\ of\ A\ \&\ B$ is amount of A and B solutions (ml.) that use to adjusting EC in reservoir.

β_0 and β_1 find from (4), (5) by using data from experiments.

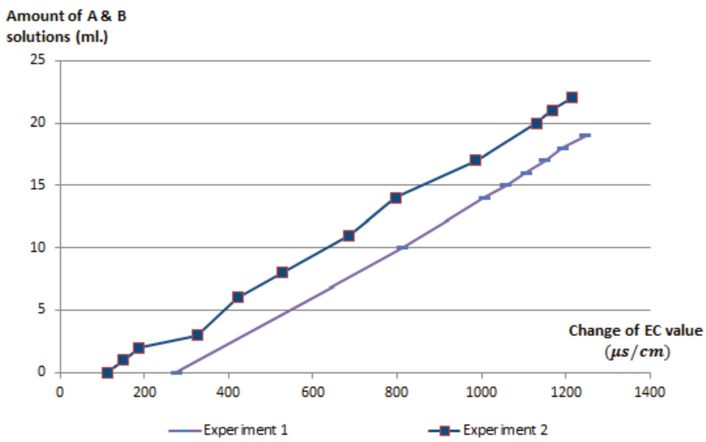

Fig. 4. Data from adjusting EC experiment

Researcher experiment to keep data for apply in linear regression. Fig. 4, present about relation between EC value and amount of A & B solution. If focuses on each experiment the line increasing to linear.

TABLE I. DATA TO APPLY EC ADJUSTING EQUATION

N	$\sum x$	$\sum y$	$\sum xy$	$\sum x^2$	$\sum y^2$
150	23,714	450	87,167	4,796,772	1,650

Equation (4) get β_0 = 0.58.

Equation (5) get β_1 = 0.02.

Represent β_0 and β_1 in (9) get EC adjusting equation.

$$Amount\ of\ A\ \&\ B = 0.58 + 0.02EC_{error} \quad (10)$$

Find Correlation Coefficient (r) from (6) get r = 0.9

where

S_x find from (7). S_x = 83.86

S_y find from (8). S_y = 1.42

- Find pH adjusting equation from linear regression equation

$$Amount\ of Nitric = \beta_0 + \beta_1 pH_{target} \quad (11)$$

where

$Amount\ of\ Nitric$ is amount of Nitric acid (ml.) that use to adjusting pH in reservoir.

β_0 and β_1 find from (4), (5) by using data from experiments.

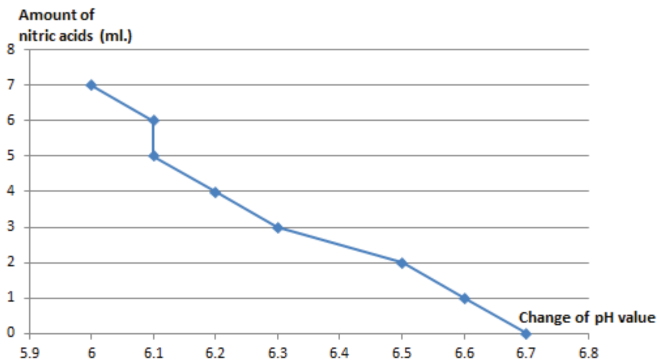

Fig. 5. Data from adjusting pH experiment

Fig. 5, present about relation between pH value and amount of nitric acid. If focuses on the line, value of pH decreasing to linear.

TABLE II. DATA TO APPLY PH ADJUSTING EQUATION

n	$\sum x$	$\sum y$	$\sum xy$	$\sum x^2$	$\sum y^2$
100	72.2	250	218	63.76	750

Equation (4) get β_0 = 0.17.

Equation (5) get β_1 = 3.22.

Represent β_0 and β_1 in (11)

$$Amount\ of\ Nitric = 0.17 + 3.22pH_{target} \quad (12)$$

Find Correlation Coefficient (r) from (6) get r = 0.99

where

S_x find from (7). Get S_x = 0.34

S_y find from (8). Get S_y = 1.12

III. RESULTS AND CONCLUSION

A. Test EC adjusting equation.

Researcher testing the equation in experiment by manual fill of A & B solutions in reservoir and control to fill in units of milliliter. If the output of equation has decimal, researcher design to rounded down the decimal if output has decimal less than 0.5 for easy to control. EC adjusting process need to adjust before pH adjusting process because in pH adjusting process that use nitric acid to adjusting have effect to increasing number of EC value is shown in Fig. 2.

TABLE III. EC ADJUSTING EQUATION TESTING

EC_{error} ($\mu S/cm.$)	$Amount\ of\ A\ \&\ B$ (ml.)	EC_{real} ($\mu S/cm.$)	EC_{real} - EC_{error} * ($\mu S/cm.$)
1082	22.22	1146	64
536	11.3	560	24
120	2.98	104	-16
1036	21.3	1054	18
582	12.22	590	8

Note : Researcher need EC_{real} - EC_{error} = 0

From testing EC adjusting equation can find precision of estimate by Standard error of the estimate of EC

$$S = \sqrt{\frac{\sum Error\ of\ EC\ equation^2}{n-2}} \quad (13)$$

The EC adjusting equation have standard error of estimate S = 42.1 that means range of EC after adjusting in this process will increase and decrease in range 42.1 from EC error.

B. Test pH adjusting equation.

TABLE IV. PH ADJUSTING EQUATION TESTING

pH_{error}	$Amount\ of\ Nitric$ (ml.)	pH_{real}	pH_{real} - pH_{error} *
1	3.39	0.9	0.1
1	3.39	1	0
1	3.39	0.9	0.1
0.6	2.102	0.5	0.1
0.6	2.102	0.6	0

Note : Researcher need pH_{real} - pH_{error} = 0

From testing pH adjusting equation can find precision of estimate by Standard error of the estimate of pH

$$S = \sqrt{\frac{\sum Error\ of\ pH\ equation^2}{n-2}} \quad (14)$$

The pH adjusting equation have standard error of estimate S = 0.32 that means range of pH after adjusting in this process will increase and decrease in range 0.32 from pH error.

C. Conclusion.

From experiments 1 and 2 the graph present relation between EC and pH. EC adjusting process need to adjust before pH adjusting process because EC value is the indicator of nutrient in chemical form that plant needs if fill nitric acid in pH adjusting process before nitric will increasing number of EC so that are not nutrient that plant need.

From experiment 3 in EC adjusting process amount of A & B solutions have direct relation with EC value is shown in Correlation Coefficient value (r) = 0.9 that means amount of A & B solutions are strong relation with EC value in the same directions. If A & B solutions are filled in reservoir, will increasing the number of EC. Researcher experiment by manual fill of A & B solutions (ml.) and test the EC adjusting equation that can estimate amount to fill A & B solutions precision in range +42.1 and -42.1 of EC error. This range researcher can acceptance because unit of EC value unit $(\mu S/cm.)$ that using is less than general unit of EC value $(mS/cm.)$.

Green oak have wide range with 1,200 to 1,800 $(\mu S/cm.)$ or 1.2 to 1.8 $(mS/cm.)$ if need to control EC in range can design to set EC target with mean is 1,500 $(\mu S/cm.)$ or 1.5 $(mS/cm.)$ the EC adjusting equation can estimate EC in range of Green oak from experiment.

From experiment 3 in pH adjusting process amount of nitric acid have direct relation with pH value is shown in Correlation Coefficient value (r) = 0.99 that means amount of nitric acid are very strong relation with pH value in the same directions. If nitric acids are filled in reservoir, will increasing the number of pH. Researcher experiment by manual fill of nitric acids (ml.) and test the pH adjusting equation that can estimate amount to fill nitric acids precision in range +0.32 and -0.32 of pH error. This range researcher can acceptance because Green oak have pH in range 6.0 to 7.0 if need to control pH in range will set pH target in mean is 6.5.

The results are appropriate for control EC and pH in range of Green oak needs and appropriate to system that researcher design to adjusting.

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