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Nutrient Film Technique (NFT) hydroponic nutrition controlling system using linear regression method

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Abstract. Nutrient Film Technique (NFT) hydroponic cultivation could be an alternative to overcome the increasing food need. Nutritional needs supply of hydroponic plant are one of parameters that need to be considered. NFT hydroponic nutrient controlling system aims to facilitate farmers to maintain the amount of nutrition according to plant needs. This system uses linear regression method to control the amount of nutrients. The accuracy results obtained from controlling system experiment are 87.84%.

1. Introduction

Recently, the number of human population was increasing rapidly. The increasing of human population will also causes increasing of food demand. But the availability of agricultural land is decreasing. In addition, the climate change can cause crop failure. Hydroponic can be an alternative way to solve this problem.

Hydroponics is a method of cultivating plants without using soil as a planting medium. Hydroponic systems use water which is given a nutrient solution as a plant need [1]. One of the hydroponic techniques that used is Nutrient Film Technique (NFT). In NFT technique, plant roots are placed in a layer of shallow water that circulated and contains nutrients. The advantage of using NFT technique is plant growth is easier to control.

In the hydroponic plants cultivation, some parameters need to be considered. One of the most important parameters is TDS/EC nutrient solution. Each plants require a different balance of composition and amount of nutrients. The amount of nutrients that given must be according to the plant's needs, such as lettuce requires TDS value of 400-600 ppm [2]. The value of TDS or EC level is effected on plant growth, development, dan yields [3]. Giving too little or excessive amount of nutrients, can cause crop yields not optimal, or can even cause crop failure. Therefore, a system that able to control nutrient solution is needed.

Hydroponic nutrition controlling system is using TDS sensor to measure value of nutrition. This system can maintain TDS values to suit plants nutrition needs by using linear regression method.

2. Literature review

The research of Electrical Conductivity and pH Adjusting System for Hydroponics by using Linear Regression [4], control the micro-controller to adjust EC dan pH values in reservoir by using linear regression method. EC and pH are measured without using sensors but using EC and pH measurement tool, so the input system is given manually.

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In the research Estimation of Electrical Conductivity and pH in Hydroponic Nutrient Mixing System using Linear Regression Algorithm [5], presents relation between A&B solution with EC, amount of nitric acid with pH, relation between EC dan pH in hydroponic nutrient system to get the adjusting equation value of the nutrient solution using linear regression analysis.

In research Nutrient Film Technique (NFT) Hydroponic Monitoring System Based on Wireless Sensor Network [6], system is made to ease farmer to monitor hydroponic cultivation in real time using WSN. This system using EC sensor to measure value of nutrient solution.

This paper aims to propose automatic hydroponic nutrient controlling system with linear regression method by using analog TDS sensor. This system can be controlled in real time.

3. System design and methods

3.1. System design

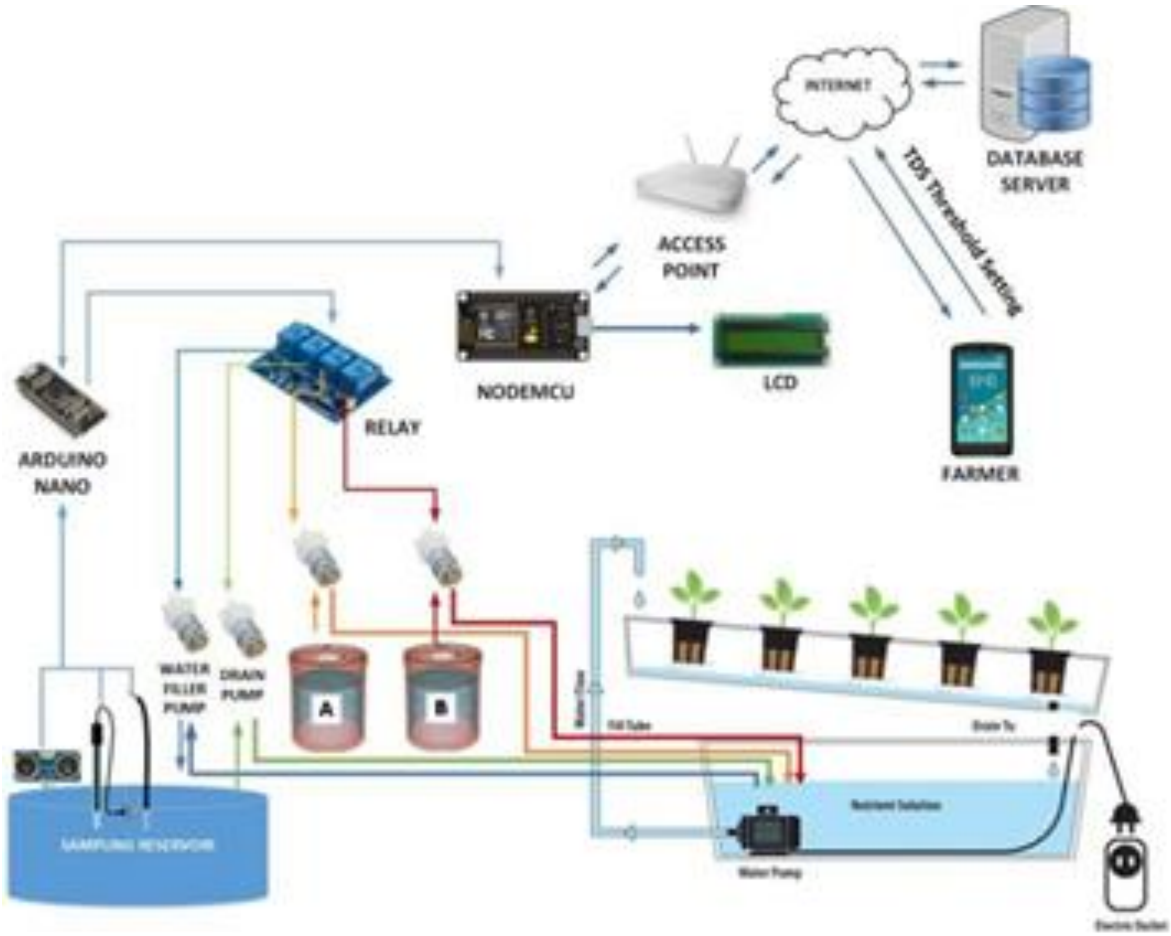

Figure 1. Controlling system of NFT hydroponic plant.

The nutrient hydroponic controlling system consist of NFT hydroponic module, Nodemcu and Arduino Nano microcontrollers, relay, 12V DC pump, Analog TDS sensor, DS18B20 temperature sensor, WLAN internet connection that connected to database server and web, and media access information. Fig. 1 shows the design of nutrient hydroponic controlling system.

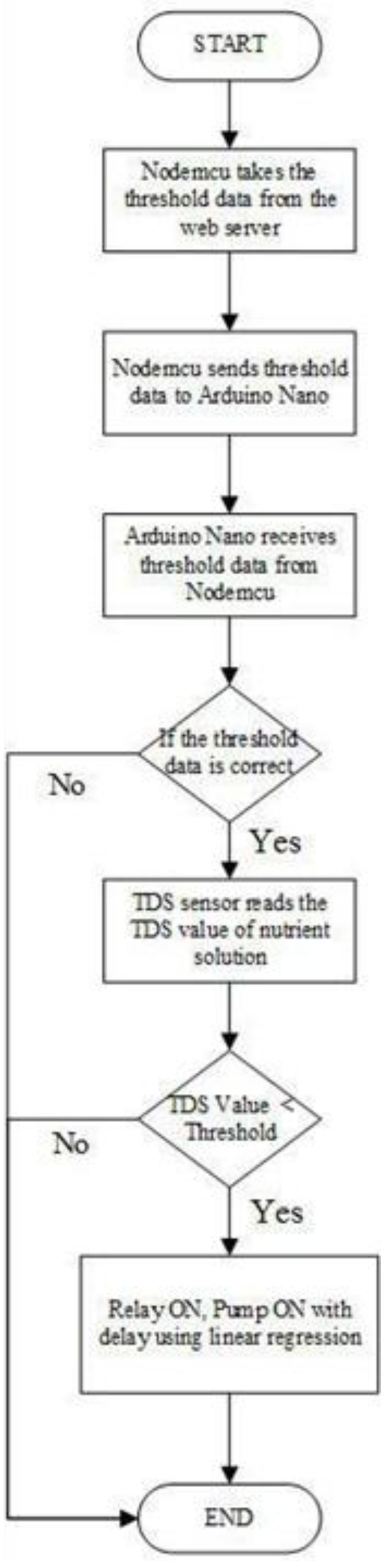

Figure 2. Nutrient hydroponic controlling system flowchart.

Based on Fig. 1, the system works as feedback from monitoring TDS values. Nodemcu micro-controller will retrieve the threshold data from the web server and then send it to Arduino Nano. Nodemcu will

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give an order to the Arduino Nano to monitor the nutrient value of the nutrient solution. Monitoring using analog TDS sensor, DS18B20 temperature sensor that placed in the sampling reservoir. Furthermore, Arduino Nano will compare the nutrient value from the results of monitoring with a predetermined threshold. Fig. 2 shows the flowchart of nutrient hydroponic controlling system.

When the value of nutrient monitoring results is less than the predetermined threshold, then the controller will give a back response. The response is an order to the Arduino Nano microcontroller to activate the relay which connected to the actuator. In this system the actuator is 12 Volt DC pump. This pump will pull nutrients to the nutrient solution reservoir so that the nutrient value suits the plant's needs. In this system linear regression is used to adjust the activate time of relay that connected to 12V DC pump. The system will set the activate pump delay according to the linear regression equation. The equation is obtained from the sample data collection experiment which is then processed using simple linear regression

3.2. Linear regression methods

This research using linear regression's equation to control pump delay of AB mix nutrient solution. The general equation of linear regression is:

$$Y = a + bX \tag{1}$$

Where
Y is dependent variable
X is independent variable
a is y-intercept
b is regression coefficient

3.2.1. b can be find by using:

$$b = \frac{[n\,\Sigma\,XY] - [(\Sigma X)(\Sigma Y)]}{[n\,\Sigma\,X^2 - (\Sigma X)^2]} \tag{2}$$

Where
n is number of data

3.2.2. a can be find by using:

$$a = \bar{Y} - b\bar{X} \tag{3}$$

Where
$\bar{Y}$ *is mean Y*
$\dot{X}$ *is mean X*

The implementation of linear regression method in this research is by taking sample data to determine the values of a and b, so that the equation can be obtained to be applied in the system.

The sample data collection experiment performed 20 times trial of each A solution and B solution. to determine the increase in TDS value of nutrient solution. This experiment is using pump delay 0.5s, 1s, 1.5s, and 2s, and carried out on a nutrient solution tank with a volume of 30 liters. The result of sample data test for A solution shown through graph in Fig.3.

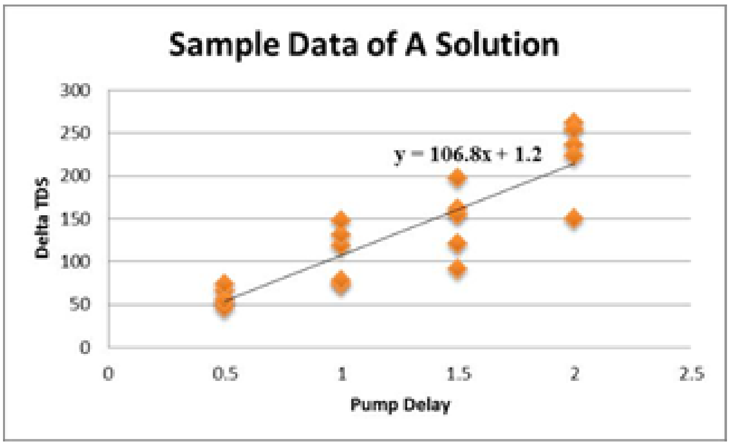

Figure 3. Sample data of A solution's test result.

From data sample collecting experiment of A solution obtained the value of a=1.2 and b=106.8. The equation for nutrient solution A as follow:

$$Y = 1.2 + 106.8\,X \tag{4}$$

The result of sample data test for B solution shown through graph in Fig.4.

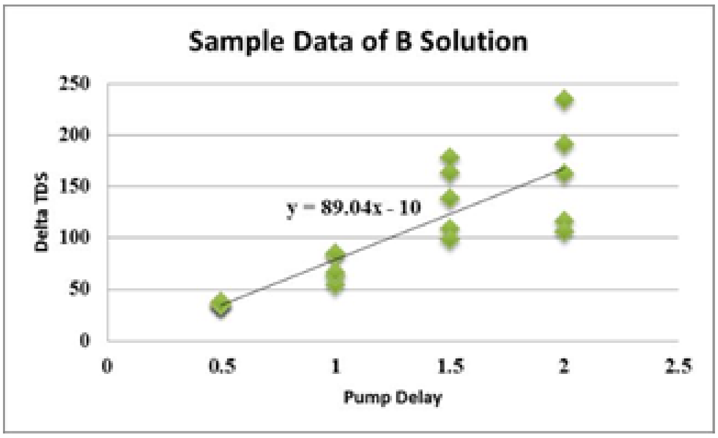

Figure 4. Sample data of B solution's test result.

And from data sample collecting experiment of B solution obtained the value of a=-10 and b=89.04. The equation for nutrient solution B as follow:

$$Y = 89.04X - 10 \tag{5}$$

4. Experimental results and discussion

4.1. Experiment of controlling hydroponic nutrient

Hydroponic nutrient controlling experiment aim to find out system performance using linear regression equation. Threshold is set with delta set point value of 50 ppm, 100 ppm, 200 ppm, 300 ppm, and 400 ppm. The results of experiment are shown in table I – table V:

Table 1. Results data of nutrient controlling with delta set point 50 ppm.

No	Set Point (ppm)	Initial TDS (ppm)	Final TDS (ppm)	Delta set point (ppm)
1	388	338	349	50
2	399	349	378	50
3	428	378	402	50
4	452	402	423	50
5	473	423	454	50
6	504	454	472	50
7	522	472	491	50
8	541	491	510	50
9	560	510	531	50
10	581	531	551	50

Table 2. Results data of nutrient controlling with delta set point 100 ppm.

No	Set Point (ppm)	Initial TDS (ppm)	Final TDS (ppm)	Delta set point (ppm)
1	369	269	329	100
2	429	329	386	100
3	486	386	451	100
4	346	246	302	100
5	402	302	355	100
6	455	355	393	100
7	493	393	431	100
8	697	597	650	100
9	750	650	710	100
10	369	269	329	100

Table 3. Results data of nutrient controlling with delta set point 200 ppm.

No	Set Point (ppm)	Initial TDS (ppm)	Final TDS (ppm)	Delta set point (ppm)
1	457	257	371	200
2	571	371	490	200
3	690	490	621	200
4	821	621	728	200
5	451	251	362	200
6	562	362	493	200
7	693	493	595	200
8	446	246	369	200
9	569	369	477	200
10	677	477	587	200

Table 4. Results data of nutrient controlling with delta set point 300 ppm.

No	Set Point (ppm)	Initial TDS (ppm)	Final TDS (ppm)	Delta set point (ppm)
1	568	268	442	300
2	742	442	653	300
3	953	653	814	300
4	571	271	497	300
5	807	507	704	300
6	537	237	426	300
7	726	426	652	300
8	952	652	851	300
9	687	387	557	300
10	857	557	753	300

Table 5. Results data of nutrient controlling with delta set point 400 ppm.

No	Set Point (ppm)	Initial TDS (ppm)	Final TDS (ppm)	Delta set point (ppm)
1	632	232	444	400
2	844	444	782	400
3	673	273	546	400
4	946	546	856	400
5	647	247	533	400
6	933	533	831	400
7	643	243	521	400
8	921	521	845	400
9	646	246	499	400
10	899	499	825	400

In this experiment, delta set point is results of set point minus initial TDS. The initial TDS is TDS value before the system controls, while the final TDS is TDS value after the system controls.

4.2. Accuracy of nutrient controlling system

Based on the result of nutrient controlling system, calculated accuracy of the controlling system by comparing the value of Final TDS with set point. The calculation of error data and accuracy of nutrient controlling system is given in Table VI – Table X below:

Table 6. The calculation error and accuracy of controlling with delta set point 50 ppm.

No	Set Point (ppm)	Final TDS (ppm)	Error rate (%)	Accuracy (%)
1	632	444	10.05	89.95
2	844	782	5.26	94.74
3	673	546	6.07	93.93
4	946	856	6.42	93.58
5	647	533	4.02	95.98
6	933	831	6.35	93.65
7	643	521	5.94	94.06
8	921	845	5.73	94.27
9	646	499	5.18	94.82
10	899	825	5.16	94.84
	Average (%)		6.02	93.98

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Hydroponic nutrient controlling experiment with delta set point 50 ppm has the biggest accuracy of 95.98%, and an average accuracy of 93.98%.

Table 7. The calculation error and accuracy of controlling with delta set point 100 ppm.

No	Set Point (ppm)	Final TDS (ppm)	Error rate (%)	Accuracy (%)
1	369	329	10.84	89.16
2	429	386	10.022	89.98
3	486	451	7.20	92.80
4	346	302	12.72	87.28
5	402	355	11.69	88.31
6	455	393	13.63	86.37
7	493	431	12.58	87.42
8	697	650	6.74	93.26
9	750	710	5.33	94.67
10	369	329	10.84	89.16
	Average (%)		10.16	89.84

Hydroponic nutrient controlling experiment with delta set point 100 ppm has the biggest accuracy of 94.67%, and an average accuracy of 98.84%.

Table 8. The calculation error and accuracy of controlling with delta set point 200 ppm.

No	Set Point (ppm)	Final TDS (ppm)	Error rate (%)	Accuracy (%)
1	457	371	18.82	81.18
2	571	490	14.19	85.81
3	690	621	10	90.00
4	821	728	11.33	88.67
5	451	362	19.73	80.27
6	562	493	12.28	87.72
7	693	595	14.14	85.86
8	446	369	17.26	82.74
9	569	477	16.17	83.83
10	677	587	13.29	86.71
	Average (%)		14.72	85.28

Hydroponic nutrient controlling experiment with delta set point 200 ppm has the biggest accuracy of 90%, and an average accuracy of 85.28%.

Table 9. The calculation error and accuracy of controlling with delta set point 300 ppm.

No	Set Point (ppm)	Final TDS (ppm)	Error rate (%)	Accuracy (%)
1	568	442	22.2	77.8
2	742	653	12.0	88.0
3	953	814	14.6	85.4
4	571	497	13.0	87.0
5	807	704	12.8	87.2
6	537	426	20.7	79.3
7	726	652	10.2	89.8
8	952	851	10.6	89.4
9	687	557	18.9	81.1
10	857	753	12.1	87.9
	Average (%)		14.7	85.3

Hydroponic nutrient controlling experiment with delta set point 300 ppm has the biggest accuracy of 89.8%, and an average accuracy of 85.3%.

Table 10. The calculation error and accuracy of controlling with delta set point 400 ppm.

No	Set Point (ppm)	Final TDS (ppm)	Error rate (%)	Accuracy (%)
1	632	444	29.7	70.3
2	844	782	7.3	92.7
3	673	546	18.9	81.1
4	946	856	9.5	90.5
5	647	533	17.6	82.4
6	933	831	10.9	89.1
7	643	521	19.0	81.0
8	921	845	8.3	91.7
9	646	499	22.8	77.2
10	899	825	8.2	91.8
	Average (%)		15.2	84.8

Hydroponic nutrient controlling experiment with delta set point 400 ppm has the biggest accuracy of 92.7%, and an average accuracy of 84.8%.

Based on the data on table VI to table X, the nutrient controlling system using linear regression method has the biggest average accuracy of 93.98% on the 50 ppm point set and the smallest average accuracy is 84.8% on the 400 ppm point set. Figure 4 shown the graphic of the accuracy calculation from controlling experiment.

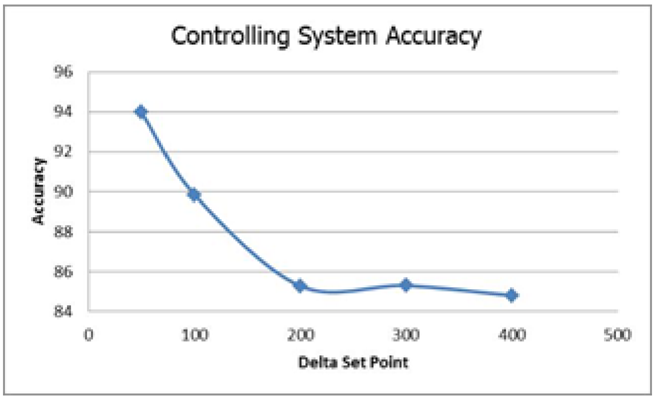

Figure 5. Graphic of controlling system accuracy.

Based on the graph, the bigger differences between set point and final TDS value, the bigger error percentage, and the lower accuracy percentage.

This is due to testing of sample data carried out on 30 liter reservoirs which have not been applied to NFT hydroponics. While the control system testing is done on the NFT hydroponic greenhouse. In NFT hydroponic greenhouse, the volume of nutrient solution is greater because of there is nutrient solution that is flowed to irrigate plant roots. The difference in the amount of water volume of ± 5 liters causes the control of nutrient density solution to be less than optimal.

5. Conclusion and future works

The application of analog TDS sensor can be used as indicator and input of controlling system. Sample data collection using 30 liter tank, with pump delay 0,5s to 2s gets equation results Y= 1.2 + 106.8 X for A solution, and Y=89.04 X – 10 for B solution. Based on the results of the research, controlling system with linear regression method has an average accuracy of 87.84%. The bigger delta set point value, the bigger average of error, and the lower average of accuracy. The use of linear regression method needs to be observed by adding more sample data and using more variables to get the equation in order to make better controlling system.

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