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# Analysis of Deep Water Culture (DWC) hydroponic nutrient solution level control systems

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**Abstract**. Hydroponics is the cultivation of plants that use water as a planting medium without using soil. One of the simplest hydroponics is Deep Water Culture (DWC). DWC is a hydroponic technique that allows plant roots to always be submerged in water containing nutrients. The purpose of the application of controlling the level of hydroponic nutrient solution in the type of Deep Water Culture (DWC) in the box is to ensure that the roots of the plant are always submerged in nutrient solution so that the nutrients are still fulfilled. The results obtained from controlling the level of hydroponic nutrient solution in the type of Deep Water Culture (DWC) in the box is when the level of nutrient solution is less than the specified threshold then the 12VDC pump relay will live to drain the source water to the nutrient solution reservoir. The HC-SR04 sensor is used for reading the level of nutrient solution, so it has an effect on determining the pump life time. The HC-SR04 sensor has a reading error of 0.87%. The duration of the pump life is determined based on the linear regression equation. Controlling the level of nutrient solution based on linear regression linear calculation has a good accuracy of 88.6%.

## 1. Introduction

Agriculture is a very important sector for Indonesian people. But along with technological developments, the industrial sector is also increasing. The increase has an impact on the narrowness of agricultural land. To overcome these problems, the solution that can be done is to use a hydroponic farming system. Hydroponics is a method of cultivating plants that use water as a planting medium without using soil, but using water given the nutrient solution needed by plants.

One of the hydroponic techniques used by the community is Deep Water Culture (DWC). DWC is a hydroponic technique that supplies plants with nutrient solutions directly to plant roots. The DWC technique will ensure that the root of the plant is always submerged in a nutrient solution [1]. This Deep Water Culture type hydroponics allows planting indoors or in a box. Planting done in the box can use TL lamps as a substitute for sunlight.

In this DWC hydroponic technique, nutrient solutions need to be aerated to add oxygen dissolved in water because lack of oxygen will interfere with nutrient absorption by plant roots. Plants need a continuous supply of nutrient solutions so that the plants remain nutritionally fulfilled. In hydroponics, nutrition plays an important role in the productivity and quality of lettuce. With balanced absorption of nutrients, it is very important in determining the quality of lettuce products [2]. Sometimes the level of nutrient solution is less than the specified limit which causes the root of the plant not to be submerged in nutrient solution. Likewise, vice versa if the level of nutrient solution exceeds the threshold then the stem of a small plant will also be submerged in nutrient solution, so that the plant will wither even die.

To overcome these problems, a system is needed to control the level of nutrient solution. One method that can be used to adjust the level of nutrient solution is the linear regression method. With this control system, it is expected that the roots of plants can always be submerged in nutrient solutions so that the nutrients remain fulfilled.

## 2. Related works

In the study "Automated system developed to control pH and concentration of nutrient solution evaluated in hydroponic lettuce production" [3] carried out control of pH and the concentration of nutrient solution in lettuce plants. Selenoid valve will automatically drain acid / base solution and drain nutrients when the pH value and nutrient solution density do not match the threshold. But in this study did not control the level of nutrient solution. The level of nutrient solution in the DWC hydroponic plants needs to be controlled so that the plant roots are always submerged in nutrient solution so the plant does not die.

In the study "A Development of an Automatic Microcontroller System for Deep Water Culture (DWC" [1], pH control on DWC hydroponics uses a pH sensor as a reader of the pH value in solution. In addition, in this study also paid attention to the level of nutrient solution by flowing water into and out of the reservoir. In this study, monitoring the level of nutrient solution is important to maintain the level of nutrient solution that is appropriate to the reservoir. But monitoring still uses LCDs and remote monitoring and control cannot be carried out.

In the study "Electrical Conductivity and pH Adjusting System for Hydroponics by using Linear Regression" [4] carried out control of the concentration of nutrient solution and pH using linear regression method on red lettuce and green lettuce. This research was carried out by taking sample data by adding AB solution using a solenoid valve. But this research is still done in a simulation and has not been implemented in the real system.

In this study a new system will be designed to control the level of nutrient solutions in hydroponic plants of the DWC type using linear regression methods. With the level control system of nutrient solutions using this linear regression method, it is expected that there will be no more hydroponic plants from DWC that die because the roots of the plant are not submerged in nutrient solution.

## 3. Proposed methods

### *3.1. Hardware configuration*

In the control system of the level of DWC hydroponic nutrient solution uses two microcontrollers as the program brain, namely NodeMCU and Arduino Nano. NodeMCU in the solution level control system is used to upload the results of monitoring by the sensor to the database server and access the data threshold level of nutrient solution that is regulated via android. The threshold data is then sent to Arduino Nano serially. Monitoring the level of nutrient solution in DWC hydroponics using HC-SR04 ultrasonic sensor to determine the height of the nutrient solution in the reservoir.

The nutrient solution level control system works as a back response to the results of monitoring nutrient levels in the DWC hydroponic plants in the box. The results of monitoring the level of nutrient solution by the HC-SR04 sensor will then be compared with the predetermined threshold. When the monitoring results are not in accordance with the specified threshold, the controller will respond to Arduino Nano to turn on the source water pump relay. To regulate the duration of the active pump linear regression method is used. The pump will be active with time delay according to the linear regression equation. The results of the linear regression equation were obtained from the experimental sample data processed using simple linear regression. Then the pump will pump water from the source reservoir to the nutrient solution reservoir so that the level of nutrient solution is in accordance with the specified measuring limit. Figure 1 shows the architecture of the control system for the level of nutrient solution for hydroponic plants of the DWC type in the box.

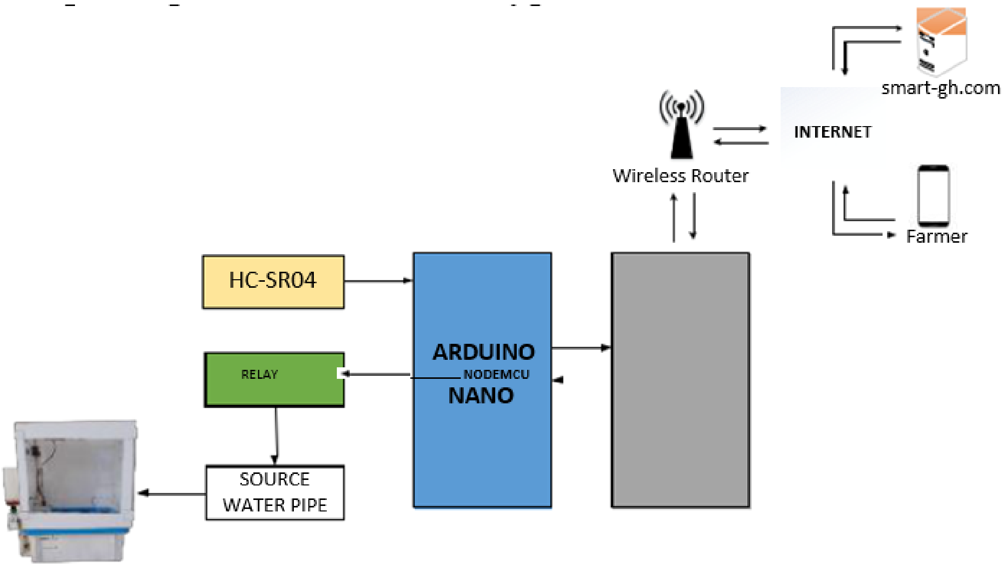


**Figure 1.** DWC hydroponic nutrient solution level control system architecture.

### *3.2. Software configuration*

Designing software in this system includes designing programs on Arduino IDE to run systems and designing Android interfaces for remote control. The design of the software on the Arduino IDE is used to write the program to NodeMCU and Arduino Nano to execute the commands given. While the software design on Android is used for monitoring and controlling the level of nutrient solution remotely. Figure 2 is a flow diagram of the nutrient solution level control programming in the Arduino IDE.

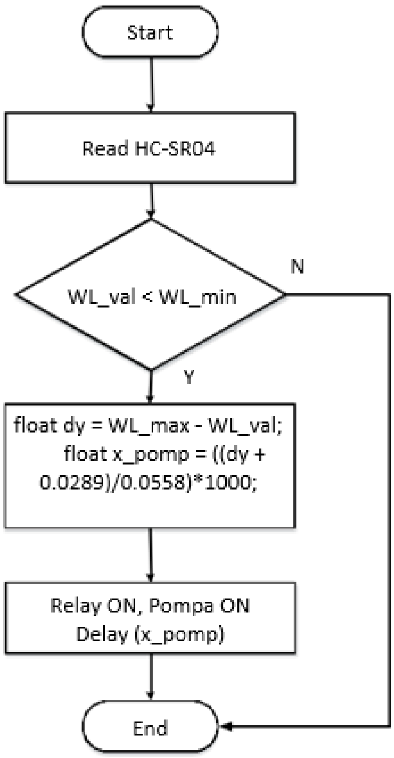


**Figure 2.** Flowchart of the DWC hydroponic nutrient solution level.

### *3.3. HC-SR04 calibration sensor*
The HC-SR04 sensor is used to measure the level of nutrient solution in the reservoir. The HC-SR04 sensor test is done by aligning the position of the HC-SR04 sensor with a ruler measuring instrument in the nutrient solution reservoir to determine the level of nutrient solution. The HC-SR04 sensor calibration is done by comparing the measurement results of the HC-SR04 sensor with the measurement results with a ruler measuring instrument. Figure 3 shows the calibration of the HC-SR04 ultrasonic sensor with a ruler measuring instrument.

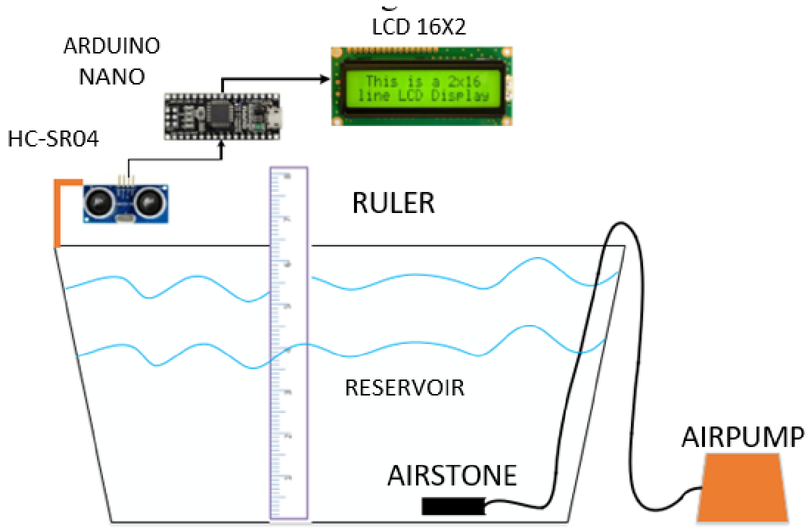


**Figure 3.** Calibration of HC-SR04 sensor using a ruler measuring tool.

### *3.4. Linear regression equations*
Linear regression is an analysis to build a mathematical model that is used to explain the form of the relationship between X variables and Y variables. Y variable is also called the dependent variable or response variable whose values depend on variable X, which is called the independent variable or free variable. Linear regression design as a mathematical calculation of nutrient solution level begins with sample data experiments. The sample data testing aims to get the linear equation level of the nutrient solution by determining the dependent variable X and the independent variable Y. The variable X in the control system of the nutrient solution level is the length of time the pump lives in seconds. While the variable Y is the value of the increase in the level of nutrient solution. In testing the sample data, the addition of the nutrient solution level using a pump is given by giving different pump life times. Equation 1 is a simple linear regression equation.

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

In linear regression testing, sample data was searched. The sample data is then processed using equation (1) so as to obtain the equation for the level of nutrient solution. Then testing the equation is done to get its accuracy.

## 4. Experimental results and discussion

### *4.1. Experiment of HC-SR04 sensor*
The HC-SR04 sensor experiment was carried out by providing water in a reservoir with different water levels. The HC-SR04 sensor is placed together with a ruler measuring instrument in the same time and condition. Table 1 shows the comparison of measurement results using HC-SR04 sensor with a ruler measuring instrument.

**Table 1.** Comparison of HC-SR04 sensor measurement with ruler.

| No | HC-SR04 Sensor (cm) | Ruler (cm) | Difference (Absolut) (cm) | Accuracy (%) |
|---|---|---|---|---|
| 1 | 2 | 2 | 0 | 100 |
| 2 | 2,07 | 2 | 0,07 | 96,5 |
| 3 | 4 | 4 | 0 | 100 |
| 4 | 6,01 | 6 | 0,01 | 99,8 |
| 5 | 6,06 | 6 | 0,06 | 99 |
| 6 | 7,05 | 7 | 0,05 | 99,29 |
| 7 | 8,88 | 9 | 0,12 | 98,67 |
| 8 | 8,98 | 9 | 0,02 | 99,78 |
| Average Accuracy (%) | | | | 99,13 |

From the test results using HC-SR04 sensor and ruler measuring instrument, the measurement results using HC-SR04 sensor have the biggest error of 0.12 cm. Based on sensor specifications, HC-SR04 sensor has an error value of ± 0.3 cm. While the average error of nutrient solution level is 0.041. In this test, the HC-SR04 sensor can work properly because the accuracy value is still in the sensor safe range according to the datasheet. Based on table 1, comparison of measurement results using HC-SR04 sensor with a ruler measuring instrument can be described in graphical form as shown in Figure 4.

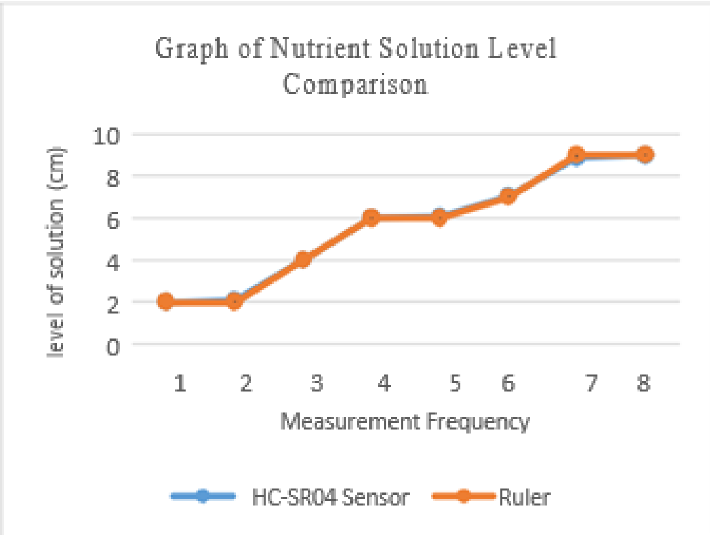


**Figure 4.** Graph of Level Comparison of HC-SR04 sensor solution with Ruler.

*4.2. Results of the Android interface*

The threshold level of nutrient solution can be done remotely using an Android-based cellphone. The monitoring page and threshold level of nutrition solution settings on Android are shown in Figure 5.


**Figure 5.** Monitoring and setting threshold levels of nutrient solutions on Android.

*4.3. Experiment of linear regression equations*

Sample data for the nutrient solution level control system is carried out by giving the pump time to live 1 second, 2 seconds, 3 seconds, 4 seconds, 5 seconds, and 6 seconds. Each t-value was tested for 50 times, so that the sample data collected were 300 sample data. Linear regression equations from the sample data obtained can be calculated by equation 1. Graph data of the hydroponic nutrient solution DWC in the box can be seen in Figure 6 and a graph of the increase in the level of nutrient solution can be seen in Figure 7.

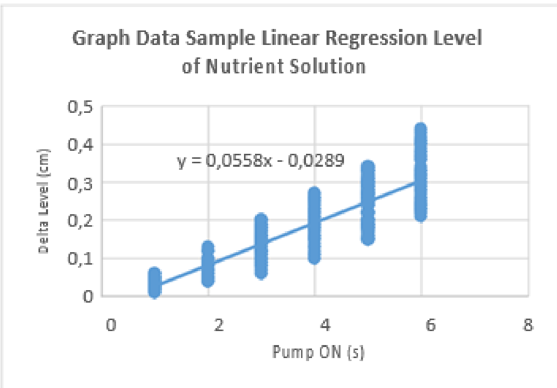


**Figure 6.** Chart of linear regression levels of nutrient solution levels.

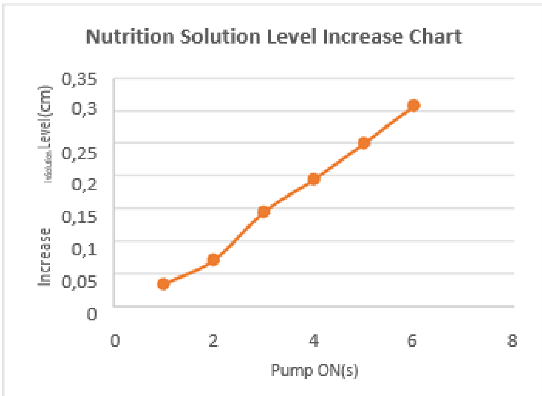


**Figure 7.** Increased nutrient solution level graph.

After the equation for the level of nutrient solution is obtained, then the trial of the equation is carried out. To get a live pump time which is an X variable, the equation used is:

$$X = \frac{Y + 0{,}02895}{0{,}0558} \quad (2)$$

The results of the linear regression accuracy experiments are shown in the following table:

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**Table 2.** Linear regression accuracy data level of nutrient solution Y = 0.5 cm.

| No | Start level (cm) | Set poin t | End level (cm) | Delay (second) | delta level (cm) | delta setpoint (cm) |
|---|---|---|---|---|---|---|
| 1 | 1,88 | 2,38 | 2,41 | 9478.50 | 0,53 | 0,03 |
| 2 | 2,39 | 2,89 | 2,8 | 9478.51 | 0,41 | 0,09 |
| 3 | 2,8 | 3,3 | 3,18 | 9478.52 | 0,38 | 0,12 |
| 4 | 3,18 | 3,68 | 3,57 | 9478.53 | 0,39 | 0,11 |
| 5 | 3,58 | 4,08 | 3,99 | 9478.54 | 0,41 | 0,09 |
| 6 | 3,99 | 4,49 | 4,3 | 9478.55 | 0,31 | 0,19 |
| 7 | 4,4 | 4,9 | 4,76 | 9478.56 | 0,36 | 0,14 |
| 8 | 4,66 | 5,16 | 5,06 | 9478.57 | 0,4 | 0,1 |
| 9 | 5,17 | 5,67 | 5,49 | 9478.58 | 0,32 | 0,18 |
| 10 | 5,57 | 6,07 | 6,18 | 9478.59 | 0,61 | 0,11 |
| Average | | | | | | 0,116 |
| Accuracy Percentage (%) | | | | | | 76,8 |

The results of the experiment with Y = 0.5 cm have an average value of accuracy of the test of 76.8%.

**Table 3.** Linear regression accuracy data level of nutrient solution Y = 1 cm.

| No | Start level (cm) | Set point | End level (cm) | Delay (second) | delta level (cm) | delta setpoint (cm) |
|---|---|---|---|---|---|---|
| 1 | 6,44 | 7,44 | 7,32 | 18439.07 | 0,88 | 0,12 |
| 2 | 7,32 | 8,32 | 8,24 | 18439.07 | 0,92 | 0,08 |
| 3 | 7,94 | 8,94 | 8,8 | 18439.07 | 0,86 | 0,14 |
| 4 | 8,24 | 9,24 | 9,36 | 18439.07 | 1,12 | 0,12 |
| 5 | 9,36 | 10,36 | 10,15 | 18439.07 | 0,79 | 0,21 |
| 6 | 2,26 | 3,26 | 3,2 | 18439.07 | 0,94 | 0,06 |
| 7 | 3,64 | 4,64 | 4,6 | 18439.07 | 0,96 | 0,04 |
| 8 | 5,28 | 6,28 | 6,15 | 18439.07 | 0,87 | 0,13 |
| 9 | 5,62 | 6,62 | 6,56 | 18439.07 | 0,94 | 0,06 |
| 10 | 6,81 | 7,81 | 7,68 | 18439.07 | 0,87 | 0,13 |
| Average | | | | | | 0,109 |
| Accuracy Percentage (%) | | | | | | 89,1 |

The results of the experiment with Y = 1 cm have an average value of accuracy of the test of 89.1%.

**Table 4.** Linear regression accuracy data level of nutrient solution Y = 1.5 cm.

| No | Start level (cm) | Set point | End level (cm) | Delay (second) | delta level (cm) | delta setpoint (cm) |
|---|---|---|---|---|---|---|
| 1 | 7,68 | 9,68 | 9,34 | 36360.21 | 1,66 | 0,34 |
| 2 | 1,63 | 3,63 | 3,65 | 36360.21 | 2,02 | 0,02 |
| 3 | 3,79 | 5,79 | 5,9 | 36360.21 | 2,11 | 0,11 |
| 4 | 6,08 | 8,08 | 8 | 36360.21 | 1,92 | 0,08 |
| 5 | 7,63 | 9,63 | 9,53 | 36360.21 | 1,9 | 0,1 |
| 6 | 2,05 | 4,05 | 4,04 | 36360.21 | 1,99 | 0,01 |
| 7 | 4,3 | 6,3 | 6,34 | 36360.21 | 2,04 | 0,04 |
| 8 | 5,95 | 7,95 | 7,89 | 36360.21 | 1,94 | 0,06 |
| 9 | 7,78 | 9,78 | 9,67 | 36360.21 | 1,89 | 0,11 |
| 10 | 9,21 | 11,21 | 11,09 | 36360.21 | 1,88 | 0,12 |
| Average | | | | | | 0,099 |
| Accuracy Percentage (%) | | | | | | 93,3 |

The results of the experiment with Y = 1.5 cm have an average value of accuracy of the test of 93.3%.

**Table 5.** Linear regression accuracy data level of nutrient solution Y = 02 cm.

| No | Start level (cm) | Set point | End level (cm) | Delay (second) | Delta level (cm) | Delta setpoint (cm) |
|---|---|---|---|---|---|---|
| 1 | 7,68 | 9,68 | 9,34 | 36360.21 | 1,66 | 0,34 |
| 2 | 1,63 | 3,63 | 3,65 | 36360.21 | 2,02 | 0,02 |
| 3 | 3,79 | 5,79 | 5,9 | 36360.21 | 2,11 | 0,11 |
| 4 | 6,08 | 8,08 | 8 | 36360.21 | 1,92 | 0,08 |
| 5 | 7,63 | 9,63 | 9,53 | 36360.21 | 1,9 | 0,1 |
| 6 | 2,05 | 4,05 | 4,04 | 36360.21 | 1,99 | 0,01 |
| 7 | 4,3 | 6,3 | 6,34 | 36360.21 | 2,04 | 0,04 |
| 8 | 5,95 | 7,95 | 7,89 | 36360.21 | 1,94 | 0,06 |
| 9 | 7,78 | 9,78 | 9,67 | 36360.21 | 1,89 | 0,11 |
| 10 | 9,21 | 11,21 | 11,09 | 36360.21 | 1,88 | 0,12 |
| Average | | | | | | 0,099 |
| Accuracy Percentage (%) | | | | | | 95,05 |

The results of the experiment with Y = 2 cm have an average value of accuracy of 95.05%.

From the results of testing the linear regression accuracy of the above nutrient solution level, the average accuracy of testing was 88.6%. From these tests have a high degree of accuracy, meaning that equation (2) can be applied well to the DWC hydroponic nutrient level control system.

In the overall system test, equation (2) is applied to the whole DWC hydroponic system. This test is carried out to determine the performance of the system when combined with other DWC hydroponic systems. Then the results of the overall system testing are compared with accuracy testing without being integrated with other hydroponic systems. In this test 10 tests were carried out. The overall system accuracy results are shown in table 6.

**Table 6.** System trial data overall minimum level = 6.5 cm and maximum level = 9 cm.

| No | Start Level (cm) | End Level (cm) | Y (cm) | Delta Setpoint (cm) | Accuracy (%) |
|---|---|---|---|---|---|
| 1 | 6,15 | 8,46 | 2,85 | 0,54 | 81,05 |
| 2 | 5,85 | 8,41 | 3,15 | 0,59 | 81,27 |
| 3 | 6,1 | 9,23 | 2,9 | 0,23 | 92,07 |
| 4 | 6,46 | 8,41 | 2,54 | 0,59 | 76,77 |
| 5 | 6,2 | 8,34 | 2,8 | 0,66 | 76,43 |
| 6 | 6,08 | 8,87 | 2,92 | 0,13 | 95,55 |
| 7 | 5,9 | 9,11 | 3,1 | 0,11 | 96,45 |
| 8 | 6,13 | 8,75 | 2,87 | 0,25 | 91,29 |
| 9 | 6,3 | 8,64 | 2,7 | 0,36 | 86,67 |
| 10 | 5,79 | 8,97 | 3,21 | 0,03 | 99,07 |
| Average Accuracy Percentage (%) | | | | | 87,66 |

## 5. Conclusion and recommendations

### *5.1. Conclusion*

- Sensor HC-SR04 can be used as an indicator for the process of controlling the level of DWC hydroponic nutrient solution with an average accuracy percentage of 99.13%
- Control of nutrient solution level using linear regression method has an average accuracy of 88.6%.

- The control system for nutrient solution levels combined with the overall system has an accuracy of 87.66%.
- The greater the increase in the level of nutrient solution (variable Y), the better the accuracy of the control with the linear regression method.

### *5.2. Recommendations*

- There needs to be a serial connection test between NodeMCU and Arduino Nano so that the sending and receiving of threshold data is more stable.
- Control methods should use multiple linear regression so that it can be used in different volume volumes.
- Control methods used not only to increase the level of solution, but also reduce the level of solution.

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