Automatic Liquid Filling in Deep Water Culture Hydroponic System Based on Water Level and TDS Meter Value

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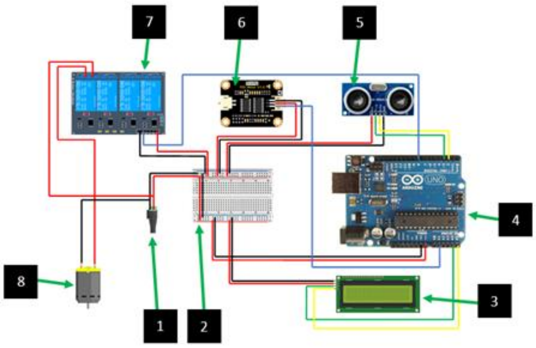
ABSTRACT



Currently, the filling of nutrient fluids for hydroponic systems is still carried out manually or conventionally. In this study, an automatic liquid filling system was made in the DWC hydroponic system based on water level and TDS Meter values. The controlling process uses an Arduino Uno microcontroller. The sensor is used to perform readings of nutrient values using a TDS sensor, for the measurement of water level distances using an ultrasonic sensor HC-SR04. The 16x2 LCD is used to display distance values and TDS values. Meanwhile, to drain nutrient fluids using a 12V pump. The results of this study the system as a whole can carry out the process of filling nutrient fluids automatically when the water level distance is >3.5 cm or the TDS value <700 PPM. Meanwhile, if the water level distance is <3.5 cm and the TDS value is >700 PPM, the pump will turn off. The result of this study was that the ultrasonic sensor HC-SR04 got an average error value of 0.12%. TDS sensors get an average error value of 6.02%.

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1. INTRODUCTION

Agriculture is the livelihood of most residents in Indonesia. Most of their income is generated through farming, because Indonesia is an agricultural country. Farmers usually use the land to plant the vegetation they want to plant. Seeing that there are many untapped courtyards of the house, therefore there is another way to use the place to become agricultural land, namely by hydroponic farming [1]. Hydroponics is a method of growing plants using only water without using soil, that is, by prioritizing compliance with the availability of plant nutrients. The plant is easy to control and does not need a large space [2]. If you use hydroponic techniques, the plants to be produced will be better and of higher quality [3]. But the application of this hydroponic technique requires a high seriousness in terms of plant care because hydroponic plants need to be reviewed at all times especially for the adequacy of plant nutrients [2].

Deep Water Culture (DWC) is a technique in hydroponic systems that is expected to overcome plant nutrient support from root to leaf and overcome canopy pest attacks. Deep Water Culture (DWC) uses the principle of soaking, slicing and floating plants within a certain period of time. When sinking, nourish the crown through the roots and remove pests from the crown. Drying releases oxygen from the air to the crown from the roots and eliminates pests. Then, in the flotation process, it will only provide nutrients to the roots and give oxygen to the header [4].

DWC's hydroponic technique requires very careful consideration of the level of nutrients provided. Lack of nutrition fulfillment over a period will have an effect on plant growth and quality [5]-[10]. If you plant with different types of plants, it will definitely require different doses of nutrients, if the amount of nutrients provided exceeds the needs, then it will be toxic to the plant, and if the nutrients provided are lacking, then the plant cannot grow [5][11].

The most important thing in providing nutrient fluids in a hydroponic system is to regulate the concentration of nutrients, which is expressed by Total Dissolved Solids (TDS) or total dissolved solids with units of Part Per Million (PPM) or parts per million. TDS needs are adjusted to their growth stage. That is, if the plant is still small then the need for TDS will also be low. The older the plant ages, the larger its TDS [12].

The thing that cannot be forgotten and needs to be considered in hydroponic cultivation is the feeding of these plants, which is about providing nutrients or replenishing nutrient fluids. Currently, this process still depends on human effort. This situation can come at the expense of farmers' time as it is required at all times to control the nutritional conditions of the plant [6][13][14]. Currently, there are still farmers who neglect their crops, such as lettuce plants where the leaves often wither due to farmers' negligence in controlling the condition of nutrient water until the volume of nutrient water is reduced or exhausted which makes lettuce plants wither due to no food absorbed for growth. Because hydroponic plant food is nutrient water [1]. Meanwhile, the dose of good nutrition for lettuce plants is in the range of 560 to 840 PPM. So there is a need for developments in the hydroponic crop agricultural sector so that it can help ease the burden of farmers' work and so that crop yields can grow well and be fertile [15][16].

Raising from this problem, the automation system can be a solution to nutrition provision if farmers are forgotten or busy and then do not have time to control the nutritional conditions of plants [1][17][18]. Therefore, a system is designed so that the system runs automatically using the HC-SR04 ultrasonic sensor as an input to measure the distance of the water level in the hydroponic container and the TDS sensor as an input to read the concentration value of the nutrient solution. Arduino Uno microcontrollers are used as sensor input processors to control pump performance. The TDS sensor is set to turn on the pump when the TDS value is <700 PPM then the pump will turn on and the pump will turn off when the TDS value has reached >700 PPM. The ultrasonic sensor HC-SR04 is set when the sensor detects a water distance of >3.5 cm then the pump will turn on and the pump will turn off when the distance is <3.5 cm [12][19][20].

2. METHODS

2.1 System Design

The system design in this study is divided into four parts. The first part is the design of the circuit schematic for the system, the purpose is to know the components to be used and make a difference between each component. The second part is the design of the system flow chart, the goal is to know how the system works. The third part is the design of the system block diagram, the purpose is to know the component parts for input, processing and output in the system. The fourth part is the assembly of the DWC hydroponic system as a whole.

2.1.1 System Circuit Schematic

Schematic design of a series of systems is a process in connecting all existing devices, so that later the system can read the values of the sensors used. The components used are Arduino uno, LCD 16x2, ultrasonic sensor HC-SR04, TDS sensor, Relay, 12V pump and 12V adapter. The red wire is the positive wire. The black wire is the negative cable. Cables with blue, yellow and green colors are output or data cables. The schematic of the system circuit is shown in Figure 1.

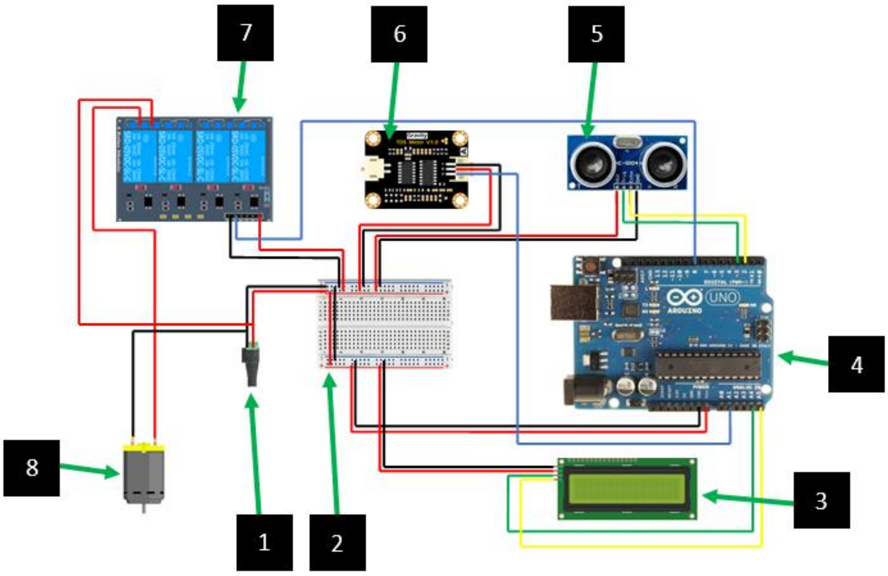

Figure 1. System Circuit Schematic

A description of the usefulness of each component is shown in Table 1.

Table 1. Components and their functions

No	Name	Uses
1	12V Adapter	Used to add voltage to ltraso or to components113
2	Breadboard	Used to connect Arduino with other components
3	16x2 LCD	Used to provide information in the form of data on water level distance values and TDS values
4	Arduino UNO	As a microcontroller for controlling electronic components with the program
5	Ultrasonic sensor HC-SR04	Used to measure the distance of water level in hydroponic containers
6	Sensor TDS	Used to measure nutrient levels that are good for plants
7	Relay	Functions to turn on and off the pump
8	12V Pump	Used as a water suction from a backup nutrient container to a hydroponic plant water container

A description of the input and output pins used in the system circuit is shown in Table 2.

Table 2. Pinout used to a sensor or component

Pin Arduino Uno	Sensors or components
VCC	VCC (Ultrasonic sensor, TDS Sensor, Relay, LCD)
GND	GND (Ultrasonic sensor, TDS Sensor, Relay, LCD)
D2	Echo (Ultrasonic sensor)
D3	Trig (Ultrasonic sensor)
D8	IN1 (Relay)
A1	Out (TDS Sensor)
A4	SDA (I2C LCD)
A5	SCL (LCD I2C)

2.1.2 System Flow Chart

A flow chart is a diagram that reveals the flow of processing in a program and the relationship between processing (instruction) and other processing using certain symbols. In the flow chart for input condition values obtained from experiments when conducting system tests. For input condition values >3.5 cm, the value is obtained from netpot measurements, where at that distance is a safe distance. This means that at that distance the roots of the plant are still submerged in the hydroponic nutrient liquid. For input condition values <700 PPM, where 700 PPM is the middle value of the recommended PPM value for lettuce plants, which is in the range of 560-840 PPM. By installing a 700 PPM setpoint, lettuce plants will always be nourished according to the recommended PPM value. The flow chart of the system is shown in Figure 2.

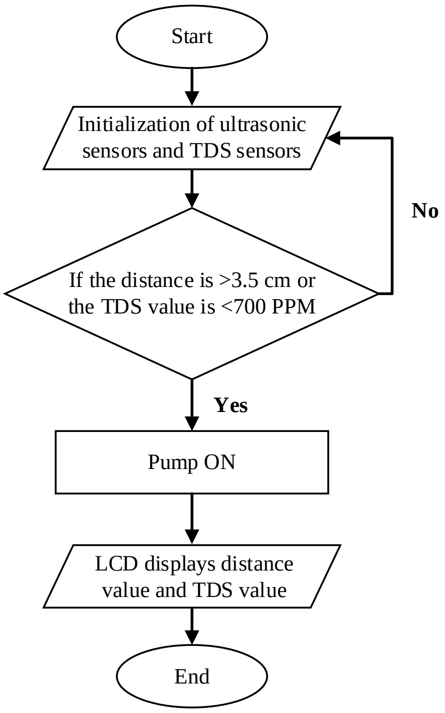

Figure 2. System flow chart

Figure 2 is a system flow chart. The process begins with the initialization of the sensor and then continues with the sensor reading. If the ultrasonic sensor HC-SR04 reads the water level distance <3.5 cm, the pump will turn off and if the sensor reads the water level >3.5 cm, the pump will turn on. Then for the TDS sensor, if the sensor reads the tds value <700 PPM then the pump will turn on and if the sensor reads the tds value >700 PPM then the pump will turn off. The 16x2 LCD will display the distance value of the water level and also the TDS value on the hydroponic nutrient liquid container.

2.1.3 System Block Diagram

Shown in Figure 3 is a system block diagram design. A system block diagram generally consists of three parts, namely input, process and output. The controller uses an Arduino Uno microcontroller that adapts to the input and output needs of the built system. On the other hand, the input and output parts can be described as follows:

a. Arduino input section:
   1. The TDS sensor is used to determine the total dissolved solids in the nutrient liquid prepared in a hydroponic bath.
   2. Ultrasonic sensor HC-SR04, used to read the water level in the hydroponic bath.
   3. The adapter serves to increase voltage or power to the Arduino to turn on other components and also serves to turn on the 12V pump.

b. Arduino output parts:
   1. Relay module, serves for an automatic switch used to turn on and off the 12V pump.
   2. The 12V pump serves as a tool to drain AB Mix nutrient water into a hydroponic container.
   3. The 16x2 LCD serves to display the output values of the HC-SR04 ultrasonic sensor and TDS sensor.

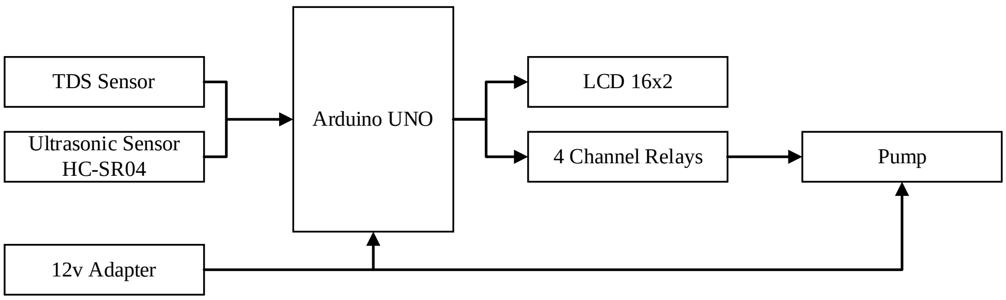

Figure 3. System block diagram

2.1.4 Main Framework of Deep Water Culture (DWC) Hydroponic System

The assembly of the hydroponic system framework uses several materials, namely a transparent plastic container with a size of 50x37x24 which is used as a reservoir for nutrient solutions for hydroponic plants. The selection of a transparent container aims to make the condition of the water visible from the outside. There is a netpot that serves as a place to place plants. The impraboard board is used as a cover and also a place to place the netpot. There is a hose used to drain the nurisi solution from the pump to the hydroponic system container. On the inside of the hydroponic container there is an aerator used to create air bubbles that will produce oxygen in the water. The overall look of the hydroponic system is shown in Figure 4.

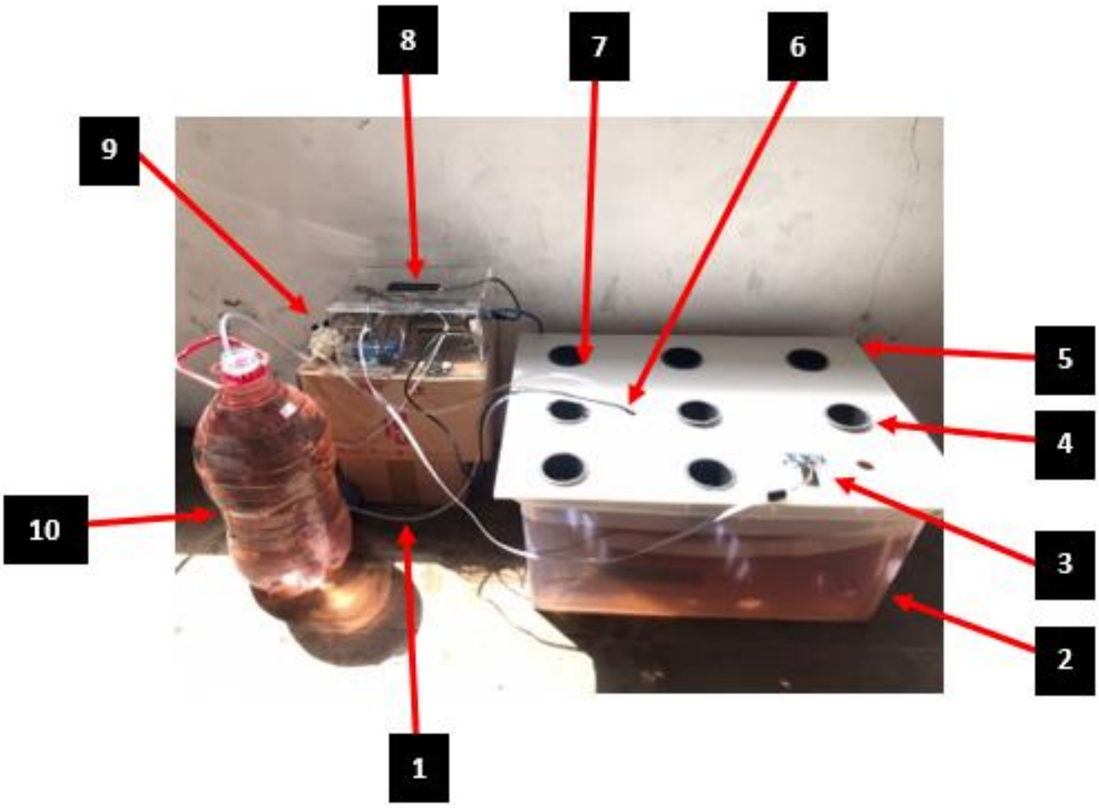

Figure 4. The overall look of the hydroponic system

A description of the usefulness of each material is shown in Table 3.

Table 3. Ingredients and their uses

No	Name	Uses
1	Aerator hose	Create air bubbles that will produce oxygen in the water
2	50x37x24 container container	As a reservoir for nutrient solution for hydroponic plants
3	Ultrasonic sensor HC-SR04	Reading the water level distance
4	Netpot	As a place to put the plant
5	Impraboard board	As a cover and also a place to place the netpot
6	Sensor TDS	Reading TDS values
7	Nutrient solution hose	Draining the nurisi solution from the pump to the hydroponic system container
8	16x2 LCD	Display distance values and TDS values
9	12V Pump	Sucking nutrient fluid from a spare container
10	Spare nutrient solution container	As a place of reserve nutrition

2.2 System Testing

After the hardware and software design is completed, the program is run to test whether each circuit meets the desired requirements. The purpose of this test is whether the sensors and components used have met the specifications and wishes as planned in advance. Testing is performed on parts such as response testing, system coverage, and the overall set of systems. In testing ultrasonic sensors and TDS sensors, error values will be calculated. The error values of these ultrasonic sensors and TDS sensors can be calculated using equation formulas (1) and (2).

$$Difference = |Reference\ Value - Sensor\ Value| \quad (1)$$

$$Percentage\ error = \frac{|Difference|}{|Reference\ Value|} \times 100\% \quad (2)$$

3. RESULTS AND DISCUSSION

System testing is aimed at checking whether this system can operate according to the analysis and plan. The test results are used for the purpose of improving system performance and are used jointly for the purpose of further development of these systems. This test is only focused on testing the sensors used. Tests performed include testing of TDS sensors and HC-SR04 Ultrasonic sensors. In testing TDS sensors and ultrasonic sensors, the error value obtained and compared with standard measuring instruments will be calculated.

3.1 TDS Sensor Testing

TDS sensor testing was performed using 25 solution samples with varying TDS values to obtain varying results. Data retrieval is carried out once. Data collection regarding the TDS value is carried out by dissolving AB Mix liquid into a container and then measuring 25 times with varying TDS values in each test. TDS sensor testing is shown in Table 4.

Result calculation of error values from TDS sensor tests is also shown in Table 4. The error value is obtained from a comparison between readings from the TDS sensor and a standard measuring instrument, namely the digital TDS Meter, and then an error value of 6.02% is obtained. In the TDS sensor test, measurements were carried out from the TDS value range of 259 to 870 PPM where a result was obtained that the TDS sensor had accuracy when measured with a low TDS value. Meanwhile, if the higher the TDS value measured, the higher the error value. Based on the datasheet on the dfrobot website, the TDS sensor used in this study has a measurement accuracy rate of ±10%. When using or applying this TDS sensor, it is not recommended for the sensor probe end to be held close to the wall or edge of the container because it will affect the TDS value obtained compared to if the probe end is placed in the middle of the container, it will get a different value. This TDS sensor has a measurement range from 0 to 1000 PPM.

Table 4. TDS sensor testing

No	TDS Meter (PPM)	TDS sensor (PPM)	Difference	Error (%)
1	259	246	13	5.02
2	276	265	11	3.99
3	301	288	13	4.32
4	326	309	17	5.21
5	348	333	15	4.31
6	369	358	11	2.98
7	382	384	2	0.52
8	398	408	10	2.51
9	424	437	13	3.07
10	448	471	23	5.13
11	477	506	29	6.08
12	501	533	32	6.39
13	533	566	33	6.19
14	566	603	37	6.54
15	598	637	39	6.52
16	633	675	42	6.64
17	662	710	48	7.25
18	683	733	50	7.32
19	711	763	52	7.31
20	738	798	60	8.13
21	765	830	65	8.50
22	788	854	66	8.38
23	807	882	75	9.29
24	836	914	78	9.33
25	870	954	84	9.66
Average error				6.02

A graph of the TDS sensor test results is shown in Figure 5.

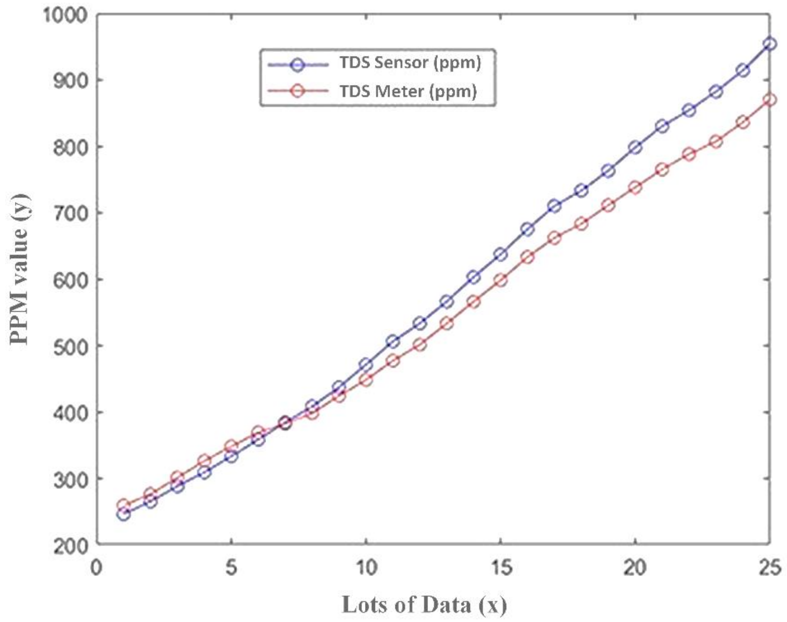

Figure 5. TDS value comparison chart

3.2 HC-SR04 Ultrasonic Sensor Testing

The test was carried out 30 times with different distances in order to get varying results, namely at a distance of 1 cm to 30 cm. Ultrasonic sensor testing is carried out by measuring the distance from the object to the wall and comparing it with the value measured with a ruler. The results of ultrasonic sensor testing are shown in Table 5.

Table 5. Ultrasonic sensor testing HC-SR04

No	Ruler (cm)	Ultrasonic Sensors HC-SR04 (cm)	Difference	Error (%)
1	1	2.38	1.38	138
2	2	1.89	0.11	5.50
3	3	2.3	0.7	23.33
4	4	3.16	0.84	21
5	5	4.64	0.36	7.20
6	6	5.58	0.42	7
7	7	6.12	0.88	12.57
8	8	7.03	0.97	12.13
9	9	8.45	0.55	6.11
10	10	9.31	0.69	6.90
11	11	10.26	0.74	6.73
12	12	11.22	0.78	6.50
13	13	11.75	1.25	9.62
14	14	12.71	1.29	9.21
15	15	14.14	0.86	5.73
16	16	14.74	1.26	7.88
17	17	15.7	1.3	7.65
18	18	17.08	0.92	5.11
19	19	17.61	1.39	7.32
20	20	19.04	0.96	4.80
21	21	20	1	4.76
22	22	20.48	1.52	6.91
23	23	21.98	1.02	4.43
24	24	22.94	1.06	4.42
25	25	23.88	1.12	4.48
26	26	24.85	1.15	4.42
27	27	26.34	0.66	2.44
28	28	26.87	1.13	4.04
29	29	28.21	0.79	2.72
30	30	28.75	1.25	4.17
		Average error		0.12

A graph of the ultrasonic sensor test results is shown in Figure 6.

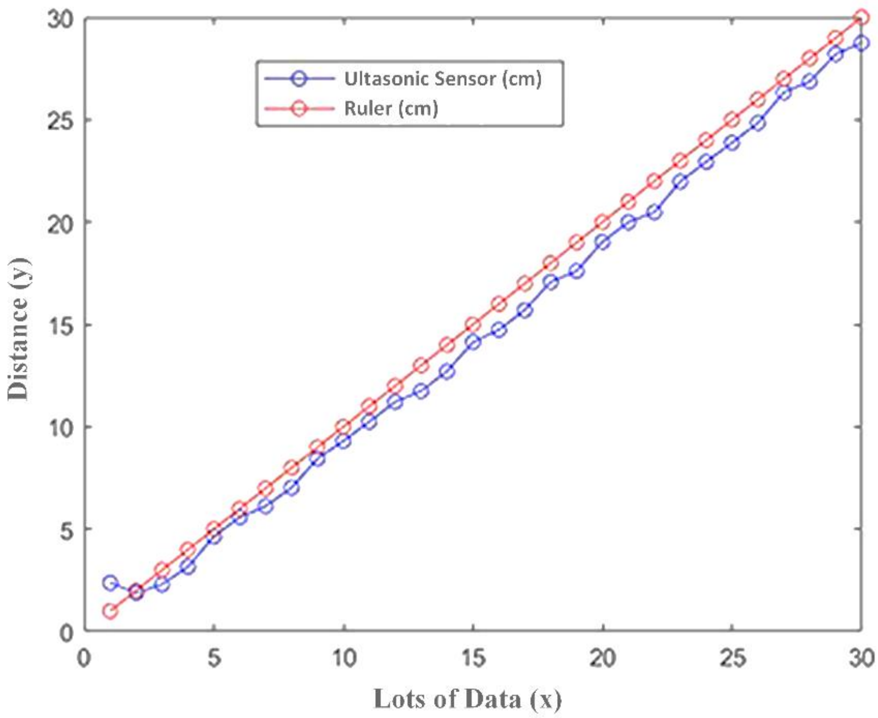

Figure 6. Distance comparison chart

Table 5 is the result of calculating the error value from ultrasonic sensor testing. The error value is obtained from the comparison between readings from ultrasonic sensors with standard measuring instruments, namely rulers and an average error value of 0.12% is obtained. The test results show that the interval of the tool test results is not the same as the interval of the calculation results, with an error rate ranging from 2.44% to 138%. Based on the HC-SR04 ultrasonic sensor datasheet, the distance that can be measured ranges from 2 to 400 cm, therefore when taking measurements below 2 cm, you will get a fairly high error. From the measurement data, there is a fairly large error rate of 138% for a distance of 1 cm, and other measurements leave a normal error rate, indicating that the ultrasonic sensor does not work properly if measured less than 2 cm. This means that the sensor can work at a distance of 2 cm to 400 cm. In general, the greater the distance measured, the smaller the error. The difference in distance between the measuring result and the actual distance is due to noise. Ultrasonic sensors work according to the principle of ultrasonic reflection. These reflections can become aperiodic and make the measurement results incompatible. Ultrasonic sensors use ultrasonic waves to detect the distance of an object in front of it, and after reflecting the object, the ultrasonic waves are received by the receiving sensor. Ultrasonic sensors emit ultrasonic waves if there are trigger pulses from the microcontroller. Also, these pulses are sent from the ultrasonic sensor to the arduino via the echo pin, processed by the arduino and the results will come out on the laptop. Ultrasonic sensors cannot detect objects with surfaces that can absorb sound, for example foam. If the surface of the object moves at a sharp angle, it will also mess up the distance measurement.

3.3 Overall System Test Results

Testing the system as a whole, the measurement results from the sensor and relay status sent by Arduino Uno are processed and will be displayed on the 16x2 LCD. The settings on the Arduino Uno controller hardware system are used to set the maximum limit and the minimum limit of the sensor. The value limit set in this system is that the TDS sensor has a minimum value limit of 700 PPM. Meanwhile, the ultrasonic sensor HC-SR04 has a minimum value limit of 3.5 cm. Table 6 shows the results of TDS and ultrasonic sensor readings and pump conditions. In TDS sensor testing, testing is carried out by providing a reduction in nutrient fluid manually, the goal is to see whether the pump can start and whether the system is running as desired or not. In the first test, the TDS sensor read the initial value of 475 PPM, with this value, the pump condition will turn on and the pump will stop when the sensor reads a value of >700 PPM, when the pump is off, the final TDS value is 721 PPM. With this value, the system can be said to be successful because the pump manages to turn off when the TDS value read is above 700 PPM. For the second test and so on, the pump can run as desired, namely on or off conditions.

Table 6. Overall system test results

No	Nutrition (PPM)			Distance (cm)			AB Mix Pump Conditions
	Min Limit	Readable initial value	Final readable value	Min Limit	Readable initial value	Final readable value	
1	700	475	721	3.5	5.63	3.23	ON
2	700	713	768	3.5	5.12	3.45	ON
3	700	687	712	3.5	4.92	3.42	ON
4	700	702	702	3.5	3.17	3.17	OFF
5	700	738	738	3.5	3.42	3.42	OFF
6	700	718	718	3.5	3.31	3.31	OFF
7	700	637	723	3.5	5.11	3.43	ON
8	700	656	720	3.5	4.89	3.37	ON
9	700	617	712	3.5	5.24	3.44	ON
10	700	723	723	3.5	3.25	3.25	OFF
11	700	708	708	3.5	3.42	3.42	OFF
12	700	678	734	3.5	4.98	3.46	ON
13	700	655	756	3.5	5.02	3.12	ON
14	700	720	720	3.5	3.44	3.44	OFF
15	700	752	752	3.5	3.21	3.21	OFF
16	700	704	731	3.5	3.87	3.38	ON
17	700	541	722	3.5	5.26	3.31	ON
18	700	520	716	3.5	5.38	3.37	ON
19	700	727	727	3.5	3.42	3.42	OFF
20	700	712	712	3.5	3.38	3.38	OFF

A graph of the system test results for the TDS sensor is shown in Figure 7.

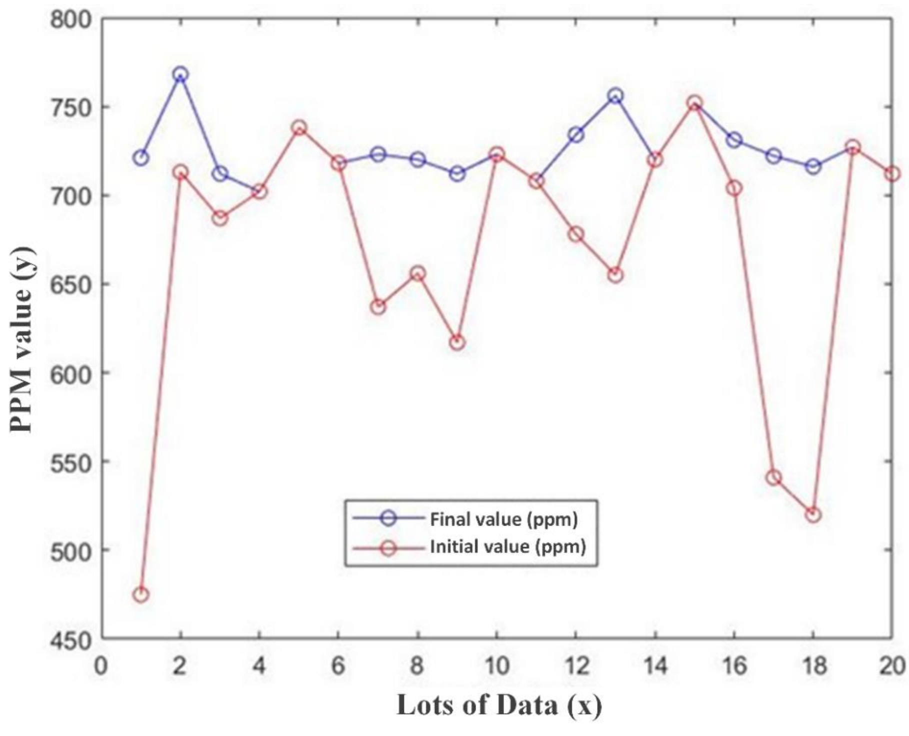

Figure 7. Graph of system test results for TDS sensors

A graph of the system test results for ultrasonic sensors is shown in Figure 8. In ultrasonic sensor testing, testing is carried out by reducing the volume of nutrient liquid so that the distance is farther from the ultrasonic sensor. The reduction in fluid volume is done manually, the goal is to see whether the pump can start and whether the system has run as desired or not. In the first test, the ultrasonic sensor read the initial value of 5.63 cm, with this value, the pump condition will start and the pump will stop when the sensor reads a value of <3.5 cm, when the pump is off, the final value for the distance is 3.23 cm. With this value, the system can be said to be successful because the pump manages to turn off when the read distance value is below 3.5 cm. For the second test and so on, the pump can run as desired, that is, it can be set to on or off.

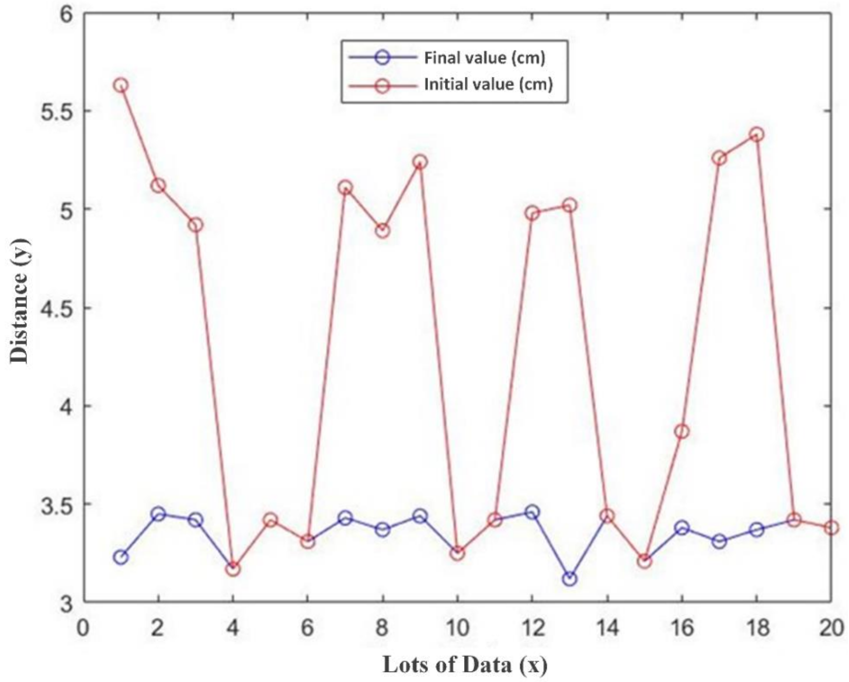

Figure 8. Graph of system test results for ultrasonic sensors

4. CONCLUSION

Based on the test results of the entire system that has been carried out previously through various experiments, it can be concluded that the TDS sensor has measurement accuracy when measured with a low TDS value. Meanwhile, if the higher the TDS value measured, the higher the error value. This is because when calibration is carried out on the serial monitor, only the initial measured value will be used as a calibration benchmark, therefore if there is an additional value, the level of measurement accuracy will decrease. The TDS sensor has a measurement range from 0 to 1000 PPM. The TDS sensor has a maximum measurement error of ±10%. As for the ultrasonic sensor, it can only take measurements accurately when the measurement is above 2 cm, while if you take measurements below 2 cm, you will get a fairly high error value. This is because according to the datasheet on the ultrasonic sensor that the ultrasonic sensor is only able to take measurements in the range of 2 to 400 cm.

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