Control System for Pakcoy Hydroponic Cultivation with Nutrient Film Technique based on Internet of Things

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Abstract

When applying the hydroponic method, there are several main factors that need to be looked at, such as nutrition and pH. This research involves the design of a Nutrient and pH Monitoring and Control System for Hydroponic Plants Based on the Internet of Things (IoT) with closed loop control. This system aims to make it easier for farmers to manage their crops in all conditions by monitoring nutritional needs, pH levels and overall plant health from anywhere using a smartphone. Based on research that has been carried out, the Total Dissolved Solid (TDS) sensor shows an accuracy of up to 99.3%, with an error margin of 2.43% and a correction value of 2.43 ppm. The pH sensor has an accuracy of up to 99.35%, with an error of 0.039%, and a correction of 0.039. The JSN-04 ultrasonic sensor has an accuracy of up to 100%, with 0% error, and 0 cm correction. In plants that are cultivated using a control system, the height gain is more significant than plants without a control system.

Keywords: Control system; Hydroponic; Nutrient; pH

1. Introduction

In a time where information and communication technology are growing, everything can be solved in a practical way. Information and communication technology is something that is useful to facilitate all aspects of life . In this case, especially in the agricultural sector, they feel the impact of advanced and rapid technological developments [1], and one tangible form of this impact is smart farming [2]. The data needed on cultivation, settings for watering control, and fertilizer application will be measured and displayed via Smartphone, which aims to facilitate farmer activities [3].

However, sometimes the implementation of smart farming is constrained by inadequate land conditions, especially in urban areas that are quite dense with adjacent houses [4], and many skyscrapers that create a lack of land for cultivation, in this case people who want to cultivate plants must be good at selecting the plants to be cultivated and the methods to be applied [5]. The hydroponic planting method is a solution if you want to have a small garden in the city area. There are several hydroponic cultivation techniques [6], Deep Flow Technique (DFT) which is a cultivation method by submerging plant roots into water mixed with nutrients [7], and containing air that enters through the planting [8], [9] medium, during the cultivation process monitoring of pH, salinity, oxygen, and nutrients is carried out [10]. Next is the Nutrient Flow Technique (NFT), the NFT method has the same concept as DFT, but there are differences in the topology of the shape of the tool [11], there is a slight slope to make it easier for water to mix and distribute nutrients easily [12]. NFT is one of the hydroponic techniques that produces the most significant results . NFT method is very suitable to be applied in urban areas, and quite profitable for farmers. In the use of the NFT method, the water conditions are not easily heated when exposed to the sun so that the water does not evaporate easily and saves on the provision of nutrients, which will affect the results of plant growth [11]. The selection of plants to be cultivated needs to be considered, because not all plants are suitable for this method. One of the plants that is suitable to be grown using this method and can be consumed daily and continuously is pakcoy (Brassica rapa L.) [13]. Mustard plants are in great demand by the public, especially in Indonesia, because mustard has many benefits, and contains vitamins and minerals. The content of vitamins K, A, C, E and folic acid in mustard greens is very high [14]. Other content in mustard plants including vitamins and minerals is also very high [15]. In previous studies, nutritional control and pH monitoring have been carried out [16], [17]. In this study, the authors control the nutrition and pH conditions of plants in real time. To get optimal nutrients and pH conditions that plants need, "Design and Manufacturing a Nutrient and pH Control

System for Pakcoy Hydroponic Cultivation with Nutrient Film Technique based on Internet of Things " with closed loop control. The control system that is manufactured is expected to make it easier for farmers to plant in all conditions, and facilitate the provision of nutrients and pH conditions to be maintained, as well as monitor the condition of plants from anywhere using a Smartphone, so that farmers do not have to worry about the condition of the plants if they are left to do other activities.

2. Method

2.1. Monitor and Control System Design

The system model used in this study is shown in Figure 1. The prototype of this hydroponic control and monitoring system will be based on IoT, which will allow users to adjust the amount of nutrients provided and the pH conditions of the water. In this system Ultrasonic, TDS, and pH sensors function as tools for sensing the quantity to be measured. Then Arduino UNO as the brain or main controller used in managing the whole system, which is supported by the Analog Digital Converter (ADC) [18]. There is an ESP8266 that has embedded WIFI so that it can be connected to the internet and can be displayed on a smartphone and is supported by a Liquid Crystal Display (LCD) [19]. The peristaltic pump functions as an actuator.

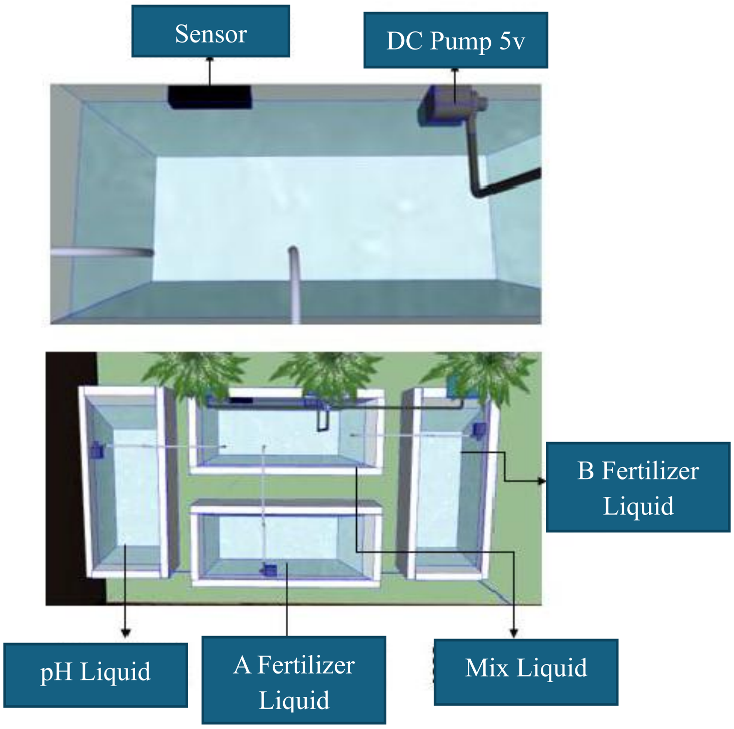

Figure 1. Schematic of NFT hydroponic monitoring and controlling system.

In its application the solution mixing system uses a closed loop control system. In this system, there are three main variables that are changed, water level, solution pH, and nutrient content. The system has a set point setting, namely pH, water level, and nutrient solution. In the control system there are three parts and each has sensors and actuators. After each set point is inputted, the controller will process the data, then the actuator in the form of a peristaltic pump will pump the required solution, and set the value according to the set point that has been determined on the hydroponic plant. The control system has feedback in the form of a sensor, which functions to sense whether the solution value is in accordance with the set point or not. pH sensor for solution pH, TDS sensor for solution nutrition, and Ultrasonic sensor for water level. The sensor will provide feedback to the control by providing data whether the value entered by the controller is appropriate.

In the distribution of the mixed solution, an open loop control system is used. In an open loop system, if the condition of the solution is in accordance with the set point in the previous process, the controller will send a signal to activate the actuator which functions to distribute the predetermined solution. In the NFT hydroponic monitoring and control system, the measured variables are pH, solution nutrients, and water level. Each sensor in the system functions as a sensing element to determine the value that will result in data acquisition. Furthermore, the data will be processed, the data is in the form of a 1- 5 V signal with a current of 4 – 20 mA, then the data will be processed so that it can be displayed on LCD displays and smartphones.

3. Results and Discussion

Good control performance results from the characteristics of good sensor validation results with an accuracy of more than 90% [20]. If the performance is good, it will affect plant growth parameters.

3.1. Sensor Validation Performance

JSN-04 sensor validation regarding water level was carried out using a ruler.

Table 1. JSN-04 water level sensor validation result.

Data	Ruler (cm)	Sensor (cm)	Correction (cm)	Error (%)	Accuracy (%)
0	25	25	0	0	100
1	30	30	0	0	100
2	35	35	0	0	100
3	40	40	0	0	100
4	45	45	0	0	100
5	50	50	0	0	100
6	55	55	0	0	100
7	60	60	0	0	100
8	65	65	0	0	100
9	70	70	0	0	100
10	75	75	0	0	100
Average			0	0	100

The test is carried out by comparing the results of the JSN-04 sensor readings with a standard measuring instrument in the form of a ruler. Validation was carried out with ten variations. Validation begins by preparing tools and materials first, then connecting Arduino with JSN-04. The results obtained are compared with the results of the validator readings. The data from the JSN-04 sensor validation that has been carried out can be seen in Table 1**.**

From the results shown in Table 1, it can be seen that the sensor gets an accuracy of up to 100%, with an error of 0%, and a correction of 0 cm. Based on the results of the data in Table 1 and the graph in Figure 2, it can be concluded that the sensor is feasible to use because the reading result is the same as the value of the ruler as a validator, and the error reaches 0%.

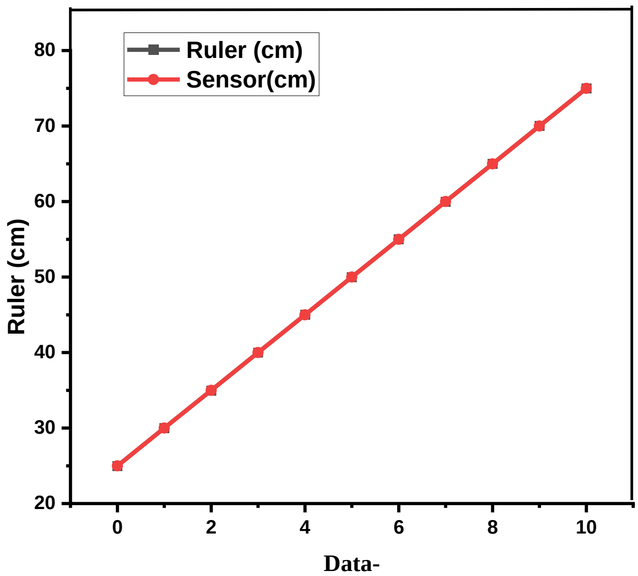

Figure 2. JSN-04 sensor validation graph.

The pH sensor validation using pH Meter, the steps taken in the validation of the pH-4502C sensor are preparing tools and materials, then connecting Arduino to pH-4502C. The next process is to compare the results of sensor and validator readings. The data from the validation of the pH sensor can be seen in Table 2**.**

Table 2. pH sensor validation result.

Data	pH Meter	Sensor (cm)	Correction (cm)	Error (%)	Accuracy (%)
1	2.81	2.79	0.02	0.02	99.288
2	3.14	3.12	0.02	0.02	99.363
3	5.54	5.49	0.05	0.05	99.097
4	6.96	6.91	0.05	0.05	99.281
5	7.78	7.76	0.02	0.02	99.742
6	8.29	8.25	0.04	0.04	99.517
7	9.59	9.55	0.04	0.04	99.583
8	10.06	10.01	0.05	0.05	99.503
9	11.03	11.04	0.01	0.01	100
10	12.5	12.48	0.02	0.02	99.840
Average			0.0372	0.0372	99.3989

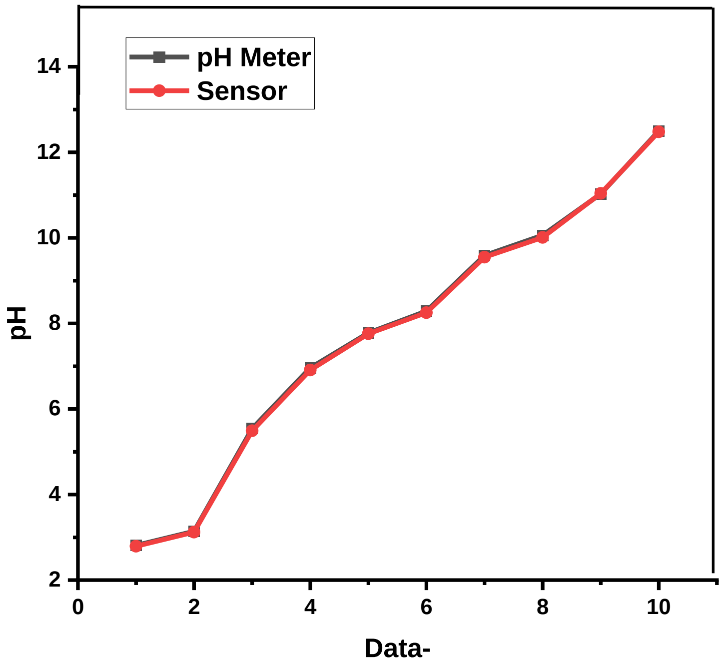

Figure 3. pH-4502C sensor validation graph.

Based on the results shown in Table 2, the sensor has an accuracy of up to 99.35%, with an error of 0.039%, and a correction of 0.039. From the results of the data and graphs shown in Figure 3, the sensor can be used because the readings are very close to the value of the pH meter as a validator, and the error is less than 5%.

TDS Sensor validation using TDS meter, The TDS sensor serves to determine the nutrients needed in hydroponics. The test is carried out by comparing the results of the TDS sensor readings with a standard measuring instrument in the form of a TDS meter. Data collection was carried out with ten variations, in one variation there were three experiments carried out every one minute. The data from the validation of the TDS sensor can be seen in Table 3**.**

Table 3. TDS sensor validation results.

Data	TDS Meter	Sensor (cm)	Correction (cm)	Error (%)	Accuracy (%)
1	121	119.71	1.29	1.29	98.93388
2	167	171.08	4.08	4.08	97.61515
3	255	252.89	2.11	2.11	99.17255

4	343	347.32	4.32	4.32	98.75619
5	397	386.14	10.86	10.86	97.26448
6	466	464.22	1.78	1.78	99.61803
7	550	551.44	1.44	1.44	99.73887
8	676	680.8	4.8	4.8	99.29495
9	891	891.34	0.34	0.34	99.96186
10	930	927.48	2.52	2.52	99.72903
Average			3.354	3.354	99.3989

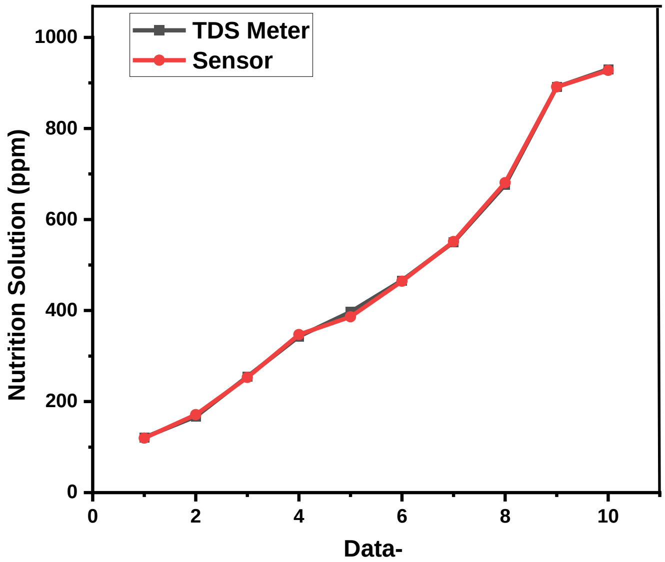

Figure 4. TDS sensor validation graph.

Based on the results shown in Table 3, the sensor has an accuracy of up to 99.3%, with an error of 2.43%, and a correction of 2.43. From the results of the data and graphs shown in Figure 4, the sensor can be used because the readings are very close to the TDS meter value as a validator, and the error is less than 5%.

3.2. *Actuator Performance*

System performance test, in this study, the control system uses an on/off system in its application. Each actuator has a predefined set of points to set it on/off. The actuator used is a 5 V DC pump which will later function to pump the solution needed by the plant.

Table 4. pH actuator test results.

pH Actuator			
No	**pH**	**Response**	
		On	**Off**
1	2.81	v	
2	3.14	v	
3	5.54	v	
4	6.96		v
5	7.78		v
6	8.29		v
7	9.59		v
8	10.06		v
9	11.03		v
10	12.5		v

Based on the results shown in Table 4, it can be seen that the DC 5V pump will be active at a pH above 7, because the set point is set at pH 7. The pump will turn on when the pH reaches the range of 8 - 11. When the pH is in the range of 1-7 the pump will turn off. The pH sensor aims to regulate the distribution of the acid solution to adjust the pH conditions, so that the actuator can work properly.

Table 5. TDS actuator test results.

TDS Actuator			
No	**Nutrition (ppm)**	**Response**	
		On	**Off**
1	167	v	
2	255	v	
3	466	v	
4	550	v	
5	676	v	
6	891	v	
7	930	v	
8	1070		v
9	1230		v
10	1450		v

Based on the results shown in Table 5, it can be seen that the DC 5 V pump will activate when the nutrient value is below 1000 ppm, because the set point has been set at 1000 ppm. The pump will turn on when the nutrients are in the 0 – 1000 ppm range. When the nutrition is above 1000 ppm, the pump will die. The pump will distribute the fertilizer solution A and the fertilizer solution B into a mixed solution.

Table 6. User interface results.

No	**Smartphone**			**LCD Crystal**			
	Water level (cm)	**TDS (ppm)**	**pH**	**Water level (cm)**	**TDS (ppm)**	**pH**	**Delay**
1	26	1156.7	6.34	26	1156.7	6.34	0
2	26	1151.9	6.37	26	1151.9	6.37	0
3	26	1159.1	6.3	26	1151.9	6.37	1
4	26	1152.3	6.33	26	1151.9	6.37	2
5	26	1157.5	6.36	26	1157.5	6.36	0
6	26	1152.7	6.39	26	1157.5	6.36	1
7	26	1157.9	6.32	26	1157.9	6.32	0

User interface test, the following are the results of the smartphone GUI which is used as a system that functions to monitor nutrient solutions, pH conditions, and water levels. With this system, it will be easier to know the nutrient solution, pH conditions, and water level. The test is done by comparing sensor reading data on the LCD and on the Blynk App. The test is carried out when the nutritional conditions match the set points. Blynk can error at any time if internet conditions are not good.

Pakcoy growth data is presented in the form of tables and graphs, data collection was carried out for 14 days on 24 pakcoy plants. Data collection was carried out simultaneously on plants that applied the control system and plants that did not apply the control system. Of the 24 plants, they were divided into 12 plants that applied the control system and 12 plants that did not apply the control system. Pakcoy planting is placed on two different tables, it aims to compare plants directly with the same environmental conditions.

Table 7. Comparison of plant growth.

Day-	Plant Height Average (cm)	
	With control system	Without control system
1	3.8	4.2
2	5.3	4.25
3	6.5	5.2
4	7.1	5.6
5	8.1	5.8
6	9.3	6.1
7	10.5	7.2

During the seven days of observation, comparisons were made between pakcoy plants with a control system and pakcoy without a control system. The results obtained the average difference in plant height growth is significant, so it is concluded that the control system has a good effect on plant growth.

4. Conclusions

The research results demonstrate a very good system performance. The TDS, pH, and ultrasonic sensors achieved high accuracy levels of 99.3%, 99.35%, and 100%, respectively. The actuator successfully performed its function accurately, meeting the required solution pumping needs according to the settings. The user interface also functioned as designed. The implementation of the control system on the plants had a significant positive impact on growth, as evidenced by the increase in average plant height, leaf width, leaf number, and plant weight compared to plants without a control system.

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